Cementing the Case for Collusion under the National Recovery Administration

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Abstract

Macroeconomists have long debated the aggregate effects of the anti-competitive provisions of the "Codes of Fair Conduct" promulgated by the National Recovery Administration. Yet there is only limited evidence documenting any actual effects at the micro level. We use a combination of narrative evidence and a novel plant-level dataset from 1929, 1931, 1933, and 1935 to study the effects of the NRA in the cement industry. We develop a test for collusion specific to this particular industry that is free from the issues surrounding usual tests for collusion such as average profit margin. We find strong evidence that before the NRA, the costs of a plant's nearest neighbor had a positive effect on a plant's own price, suggesting competition. After the NRA, this effect is completely eliminated with no correlation between a plant's own price and a neighbor's cost. We also offer evidence suggesting other provisions of the code regarding labor were followed. We argue that this work provides some of the strongest evidence as of yet for the collusive effects of the NRA.

1 Introduction

For a brief period during the Great Depression, American industrial policy was geared toward actively promoting centralized economic coordination, and arguably toward cartelization of much of the economy. This goal was codified in the National Industrial Recovery Act of 1933 (NRA), which had the stated intention of "eliminat[ing] cut throat competition" and promoting "fair competition." Along with many of his closest advisers, Franklin Roosevelt was convinced that the Great Depression was caused by "cutthroat competition." They argued that ruthless price cutting drove out businesses, led to ruinous deflation, and caused low wages that led to a vicious cycle of under-consumption and further wage cuts. Their solution was greater national planning and coordination

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within industries.[1] This meant that in consultation with government officials, industries drew up codes of conduct to regulate competitive behavior.

As fast as the process of turning the idea into law was, the process of turning the law into reality was even swifter. By the end of 1933, a vast swath of the American economy was operating under a code of fair conduct, including that of the cement industry. In addition, hundreds of other industries were clamoring for approval of codes they had submitted. The codes were supposed to be formulated as a collaborative process between industry, labor, and the consumer. The latter two had explicit representatives appointed by the government while a particular industry was usually represented by its trade association. In reality, the consumer advocate had little effect, and the labor representative was usually satisfied by a collective bargaining provision (Hawley, 1974).

Though the ramifications of this law could have been huge, there is little consensus on its effects at the micro (or macro) level. Bittlingmayer (1995) and Bellush (1975) are some of the strongest proponents that this act served no public purpose and solely increased profits of colluding firms. Alexander (1994) finds that the "critical concentration ratio" falls after the introduction of the NRA, which she takes as evidence that the codes facilitated collusion. Taylor (2007) uses an index of durable good output for a few different industries at a quarterly frequency. He finds that output falls after the codes come into force, which is consistent with a cartelization story. Vickers and Ziebarth (2011) reexamine the macaroni industry with plant-level data from the source employed here and find evidence for collusive activity, in contrast to Alexander (1997).

Others have suggested that these codes had little effect on promoting collusive behavior. Alexander (1997), Krepps (1997), and Alexander and Libecap (2000) all argue that there is little evidence that these codes had much effect. Alexander suggests that the reason for the failure of the codes is due to intra-industry heterogeneity. Low cost plants have a much higher return to cheating on a collusive agreement then high cost plants. This means that small shifts in exogenous circumstances can push low cost firms to exploit their advantage and undercut the agreement. With a more historical gloss, both Hawley (1974) and Brand (1988) make similar arguments regarding the sources of conflict with the added contention that these codes were drawn up to benefit small firms.

[1] At the beginning of the Depression, Hoover actually supported many of these ideas through the strengthening of voluntary trade associations. Ohanian (2009) points to these policies of artificially inflating wages and prices as a major cause of the Depression itself. Rose (2010) does not believe there was actually much of an effect of these policies.

More recent work by Alexander and Libecap (2000) uses some very limited firm-level data to look for heterogeneity in costs. They too argue that because of productivity differences, firms were not able to collude despite being given a ripe opportunity. Responding to Alexander (1994), Krepps (1997) finds no evidence that the critical concentration ratio actually changed once a consistent set of industries are used.

Part of the problem is the level of aggregation at which these studies proceed. Plant or firm level is the natural level of disaggregation at which to study collusion, but all of these works besides Alexander and Libecap (2000) have relied on cross-industry level data. In this paper, we contribute to the literature by examining the cement industry using newly digitized plant-level records from the Census of Manufactures in 1929, 1931, 1933, and 1935. We first provide narrative evidence from trade journals at the time that is suggestive of collusion and close adherence to the code. We then develop a test for collusion motivated by the particular features of the industry. Cement is a local product with almost no physical product differentiation. Because of this geographic segmentation, under competition, the costs of a plant's nearest neighbor play a key role in disciplining the pricing choice of a plant. Under collusion, where plants simply divide up the market, the costs of the nearest neighbor have no effect as the plant simply charges its monopoly price, which depends solely on its own cost. We formalize this logic in a Hotelling framework and then test is using our plant-level data. Our regression results imply before the NRA, in line with the theory, the average price a plant charges is strongly correlated with the costs of its nearest neighbor, controlling for the plant's own costs. After the NRA comes into force, this correlation disappears though own cost still has a strong positive effect, suggesting cooperation over how the market was to be divided. Our test provides strong evidence for the collusive impact of the NRA.

Besides evidence on pricing behavior, we also find evidence that the plants were following other provisions of the code with regards to labor. The codes specified plant behavior beyond pricing to include maximum workweeks and minimum wages. We find that there is a large mass of plants that report a 36 hour workweek, the length of the workweek mentioned in the code. In addition, we find some evidence that the wage distribution in 1935 is being truncated at the minimum wage noted in the code.[2] In the end, while there are reasons to think that cement is an industry particular

[2] Unfortunately, our data does not stretch far enough to consider whether collusion and cooperation continued well after the NRA was struck down in 1935 as suggested by Cole and Ohanian (2004). Given the *Schecter* decision invalidated the NRA in May 1935, the fact that effects are still detectable hints at some persistence. We also highlight

susceptible to collusion,[3] still we think this provides some of the strongest evidence to date that these codes had real effects on competition. In the end, we do not attempt to address the broader question of the aggregate impacts of the law. Cole and Ohanian (2004) have argued that the NRA helps to explain the sluggish recovery from the depths of the Depression. On the other hand, Eggertsson (2011) has suggested that in a liquidity trap, which arguably prevailed at the time, polices that push up inflation expectations like the NRA could serve to break the deflationary spiral and help the economy overall, even at the expense of pushing down output in the cartelized industries. We simply note that the effect at the micro-level is a necessary input into any aggregate model of the NRA's effects.

2 Data

The data used for this paper come from the Census of Manufactures (CoM) collected by the Census Bureau in one form or another since 1810. This was initially done in conjunction with the decennial population census. In the beginning of the 20th century, the census began to be collected quinquennially. Then in 1921, Congress authorized a Census of Manufactures to be taken biannually. This biannual timing, fortunately for us, persisted through 1940 when there was a shift to every 7 years before returning to the current quinquennial enumeration. For reasons unknown, the schedules for 1929, 1931, 1933, and 1935,[4] the first half of the Great Depression, were kept and are housed at the National Archives.[5] Between 1880 and 1929, after tabulations were made, the schedules were either destroyed intentionally by an Act of Congress or through a combination of fire and bureaucratic neglect (1890). The questions on the schedules include revenue, quantity, total wage bill, cost of intermediate goods, and number of wage earners employed at a monthly frequency. There is other information about whether the plant is incorporated and, if unincorporated, who

some narrative evidence that hints at continued collusion even after the Supreme Court's decision in the face of much greater uncertainty about the regulatory environment.

[3]Simply look at the record of anti-trust cases brought against the industry over time starting in 1941 in *Cement Institute v. United States.*

[4]There can be a bit of confusion with the dating of the censuses. The year convention we will use refers to the year the data are meant to cover. The Archives usually employs a convention where the year refers to the year in which the data are collected, which is one year subsequent. For example, the data in the 1929 census cover things that occurred in calendar year 1929, while the data was collected during the calendar year 1930. The Archives is not altogether consistent in how they record the years.

[5]For years 1929 and 1935, the schedules are on microfilm while 1931 and 1933 are on paper. These are in Record Group 29, Entries 307, 307-A, 309, 309-A.

the owner is. This latter piece of information allows us to link plants together into their parent company.

Besides this data from the Census, we obtained data on plant capacities from a court case regarding the legality of base point pricing, *FTC v. Cement Institute* (1948). Capacities were reported in the exhibits that formed a major part of the case.[6] Note that these are *not* production based capacity numbers where capacity is based on the highest output averaged over some period of time. Instead, these are actual physical capacities. We have cross-checked these capacities against the Pit and Quarry Handbook, which among other things contains a directory of all cement plants in any given year and has capacities, though often only at the *firm*-level. For the cases where capacities were reported at the plant level, the correspondence between the directory and the FTC sources is quite good. We have also cross-checked these capacities against the American Cement Directory, another source for capacities. We note that capacities from the court case exhibits are daily rates. To annualize the capacities, we multiply by $.91 \times 365$, which assumes that the plants could not run at their maximum daily capacity for more than 91% of the year.[7] Lastly, the American Cement Directory and the Pit and Quarry Handbook, along with Pit and Quarry Maps were used to obtain information on the production process—wet or dry—used at any given plant, and described in more detail in the next section. We take the market definitions shown in Figure 1 from Chicu (2012).

The plant-level data have been used previously in limited contexts. In Bresnahan and Raff (1991), the authors use data from the motor vehicles industry to examine the evolution of production heterogeneity over the Depression. They find that differences in production technologies predict whether inefficient plants exit the industry. Bertin et al. (1996) study blast furnaces as another case of the impact of heterogeneity on industry behavior. Some recent work using the data, besides the work on the macaroni industry, is Ziebarth (2011a) and Ziebarth (2011b). The first studies the effects of the banking crisis that enveloped Mississippi while the latter work addresses the puzzling decline in productivity over the first 4 years of the Depression.

A worry in working with the schedules is the completeness of the data. Raff (1998) suggested

[6] Stephen Karlson transcribed these capacities and he has graciously shared those data.

[7] This figure is derived from commentary in industry publications which indicates that this is approximately the level at which firms can no longer expand production and shortages occur. Moreover, it corresponds in practice to the average rate at which our daily capacities convert to figures in sources reporting annual capacities.

that the records are more or less complete. In our own experience, we have noted whole states missing for certain industries such as the manufactured ice industry in Texas. Luckily, unlike many other industries, there exist numerous other sources with which we can check the validity of the Census data for cement. First, to check for completeness of the list of firms, the 1929 Census data was compared to the listing of portland cement producers as of Oct 31, 1929 published in the 1928 issue of Minerals Resources.[8] The discrepancies between their listings and our own, which are not large to begin with, can be entirely accounted for by a number of factors. First, there are inclusions in the census of non-portland cement producers, such as producers of masonry cement, or in two cases, grinding plants. There are plants included in the Minerals Resources list which, while still in existence, are idle. In addition, the Minerals Resources list appears to include several plants which, according to other trade sources, are closed down. Second, we have compared our totals from the plant-level data to the totals reported by the Census itself. Coverage seems excellent with very minor differences between our totals and the published ones.

There is a second worry about the quality of the data reported on the forms. This is self-reported and considering the complexity of the form (see Figure 2), it does not seem implausible that data quality could have been quite low. Again the cement industry provides a number of opportunities to independent checks. First, we use the Minerals Yearbook which provides independent estimates of production at a much higher frequency derived separately from the Census. We find very good correspondence between the Minerals Yearbook and our totals. There appears to be no systematic bias between the two sources and the largest divergences are not more than a few percent. Another source for output data is from an FTC court case brought against the Cement Institute in 1941.[9] Here too we find very close agreement at the plant-level between the FTC production numbers and those reported on Census schedules. We have also compared some calculated statistics from our dataset to other published values. For one, the NBER macrohistory database (Series m04076b) has information on cement prices during this time period. We find a relatively stable discount of 17% for our prices relative to the NBER prices. This is not surprising as the NBER prices include any commission to the dealer in addition to the f.o.b. price while our prices only include the latter

[8] Minerals Resources, known as the Minerals Yearbook from 1932 onwards, is the annual publication of the United States government giving summary statistics and annual reviews for a whole range of minerals industries, including cement.

[9] These data were graciously given to us by Stephen Karlson who transcribed them from the court exhibits.

component. Both price series exclude transportation costs.[10]

3 Background on the Portland Cement Industry

Portland cement, often known by its shorthand as 'cement', is a fine powder that is typically mixed with water and sand or gravel ('aggregate') to make concrete. Cement is a very cheap and versatile construction material used in everything from roads and dams to piping. Once dried, portland cement becomes very hard and strongly binds the aggregate together. Because of its strength, it can be used not only as a filler material but also in the construction of load-bearing architectural structures.

The basic inputs to the manufacture of portland cement are limestone, clay, and sand as sources of calcium, aluminum, silicon, and iron. Since limestone is the major input, plants are usually located close to limestone quarries in order to minimize on input transportation costs. Indeed many plants are built on-site. The primary ingredients are ground and combined in precise proportions before being fed into a kiln either dry (for a dry-process kiln) or as part of a slurry (wet-process kiln). Kilns are the heart of a cement plant. They take the form of long, slightly declined rotating tubes, and are the world's largest single piece of moving industrial equipment. Once fed into the kiln, the ingredients slowly tumble down along the interior of the kiln with temperatures progressively increasing up to about 3400° Fahrenheit—one third the temperature on the surface of the sun. The energy requirements to keep the kilns heated to this temperature are significant, with coal and natural gas the typical fuel sources, though fuels as unusual as old tires and napalm have been used. As the initial ingredients approach the hottest part of the kiln, they become partially molten and undergo chemical changes turning them into a material known as 'clinker'—essentially small lumps of portland cement up to an inch in diameter. The clinker is then ground down into a super-fine powder along with small amounts of other elements to control its final properties such as the time it takes to set.

Today the wet-process is typically less efficient than the dry-process since it involves the evaporation of water, which costs energy. Minerals Resources publications around the late 1920s and

[10] The NBER macrohistory database also has wages for the *whole* manufacturing sector for 1929 and 1931 (Series a08050b). In 1929, the NBER reports an average nominal wage of .56 while we have .48 and for 1931, NBER reports .47 compared to .43. We think the correspondence here is rather good given the NBER data covers the whole manufacturing sector and the limitations in the method we employ to calculate the average wage.

early 1930s note that the dry kilns in operation around that time were marginally more efficient on the basis of fuel required per barrel of finished cement. However, for a long time the wet-process was the dominant method because it was technologically simpler and allowed construction of bigger kilns for larger scale of production. In the late 1920s and early 1930s, nearly all new plants were wet-process. Today, however, wet-process kilns are a vanishing minority as technological improvements and greater pressures for fuel efficiency have made dry-process kilns superior.

The portland cement industry is popular in the economics literature because of several key features.[11] First, the product is essentially homogeneous, so that for a buyer the identity of the plant offering the product is of limited relevance. By far the main consideration is the price offered by that plant. Second, there are numerous relatively isolated markets due to geographical segmentation in the industry, providing useful variation in the cross-section. Portland cement is both relatively cheap to produce and particularly heavy: a cubic foot weighs about 100 pounds. For this reason, shipping costs are a nontrivial component of cement prices, and it is uneconomical to ship cement long distances. Thus, for any given plant, its practical market lies within a relatively short distance—commonly cited to be within 200 miles, and often less.[12]

There are some additional features that make the industry particularly attractive to economists. First, markets are relatively concentrated, making them ideal settings to study strategic behavior. Second, the production technology is relatively straightforward, allowing for adequate modeling of the production function itself. Moreover, given the large scale of plants, and the capital-intensive nature of production, fixed costs are high relative to variable costs. Firms therefore have a strong incentive to sell to capacity in order to recover fixed costs. The large capital investments are also largely sunk with no alternative use and low scrap value. Thus, there is potential for ruinous price competition, particularly when firms have excess capacity relative to industry demands.

On the demand side, cement is a key component of many construction activities, though the cost of cement only accounts for on average 2 to 5 per cent of construction costs (Dumez and Jeunemaître, 2000). Because of its essential nature, it has few substitutes, making demand relatively insensitive to price fluctuations. Hence, the overall level of demand is well approximated by the the level of building and highway construction, which in a typical year comprise more than 95% of cement's

[11] Dumez and Jeunemaître (2000) provide a comprehensive overview of the economic characteristics of the portland cement industry. Below we discuss only key features.

[12] See Jans and Rosenbaum (1997) and Ryan (2011) for this figure. See also Dumez and Jeunemaître (2000).

use (Minerals Yearbook).

We now summarize the structure of the industry at the time. Figure 1 displays the spatial distribution of the plants for 1929 with the size of the circle representing the plant's output. Though we do not make active use of market definitions,[13] the bold lines denote our market definitions. These market boundaries better incorporate typical shipping areas for clusters of plants even though they are more aggregated than the markets defined by Minerals Yearbook, which tend to simply divide up the market based on state boundaries taking into consideration the need to preserve individual plant anonymity. Table 1 offers some summary statistics of key variables in our dataset. It is interesting to note that there is a fair amount of turnover at the plant level with around 5% of plants exiting over a two year period and more surprisingly 1% of plants entering.[14] Finally, we offer some summary statistics in Table 2 for the largest firms in the industry. It is important to note that the top 10 firms control around half of the plants in the market, suggesting some scope for coordination on pricing and output decisions.

4 Narrative Evidence

Here we provide a narrative account of collusive activities under the NRA code and an explanation of the mechanisms used to promote cooperation. There were certainly allegations of noncompetitive behavior before the introduction of the code.[15] Nevertheless, there is substantial evidence that the industry became less competitive after the law was introduced. A crucial role in formulating the code as well as enforcing collusion was played by the Cement Institute. Founded in August 1929, its initial function was to support the base point pricing scheme in operation at the time. To facilitate this system, the Institute published freight rate books, which helped standardize the freight charges applied by plants for shipping cement to various locations. This enabled the

[13] Our tests will rely solely on a plant's nearest neighbor that is not part of the same firm.

[14] Exit here means that we were not able to locate a plant in a subsequent census. Similarly, entry means that a plant had no antecedent record. We do not use a master manifest of plants presumably employed by the Census to canvass the plants.

[15] For example, the Chicago municipal government complained bitterly about being overcharged for cement in 1932:

> "Cement was $1.28 a barrel last year," said [Commissioner of Public Works Oscar] Hewitt. "This year it's $2.10 a barrel. I called the companies in and asked them why the identical bids. They told me they had lost money last year on the city business because they fought for it. They admitted they had got together." (*Rock Products*, 1932).

reduction of competition between its member firms who could in principle more easily coordinate on delivered prices of cement. This cooperation was the basis of the allegations in the *FTC v. Cement Institute* case in 1948.

4.1 History of the Code

The Code of Fair Competition for the Cement Industry was approved by the federal government on November 27, 1933, after having first been submitted by the Cement Institute on July 19, 1933. Its first stated aim was to "stabilize the industry and prevent economic disturbances due to price wars." The code included provisions to limit capacity investment, restrict pricing below marginal cost, create guidelines for announcing price changes, prohibit certain competitive practices such as gifts to producers, standardize sales and marketing methods, and stipulate acceptable terms and conditions of sale. A majority of the provisions regarding sales and marketing were suspended soon after the approval of the code because of complaints from industry participants. Nevertheless, much of the code remained intact.

The cement code did not explicitly mandate that prices should be kept at some high level. As the code was first being drafted, the intention was to avoid directly fixing prices and limiting capacity. Industry officials believed that prohibiting sales below cost, together with a unified cost-accounting system, would suffice to limit harmful competition (*Rock Products*, August 1933). However, these principles were later abandoned as the code was being drafted. Feasibly, a market with highly competitive prices could be following the letter of the code. However, the effect of the code was to prevent deviations from the collusive outcome by outlawing the aggressive cutting of prices or deviating by offering, for example, price cuts after an initial price had been set. Thus, the code added to the disincentives from deviating from a collusive outcome.

One code provision was considered by the industry trade publication *Rock Products* to be in some respects "the most radical of any industry's code yet signed by the President" (December 1933). This was the explicit business-sharing provisions seldom seen in other codes. Article VI of the code authorized and required the Board of Trustees of the Cement Institute to institute a plan "for the equitable allocation of available business among all members of the industry" within thirty days of the code being approved. Article VII of the code restricted increases in productive capacity. Specifically, the Cement Institute was tasked to scrutinize proposed new plants or increases in the capacity of increasing plants. If they concluded that more capacity would exacerbate "the problem of over-production and over-capacity," the Institute could petition the President to prohibit the increase. Furthermore, the Institute could study permanent overcapacity and recommend closing less economical plants.

Several principles were articulated in the code which theoretically could have served to protect consumers from anticompetitive activity, but the details of how the protections were to operate were left unclear. The code mandated that the business-sharing plan "shall in no way reduce the total production of all plants below what is necessary amply to supply demand". Of course, at what price level demand was to be satisfied was left unexplained. Moreover, the law states that it was not meant to "promote monopoly or monopolistic practices," although this would seem to conflict with the existence of business sharing plans. These protective clauses were boilerplate restrictions common to many codes and did not indicate a particular concern for maintaining a competitive industry.

The cement industry began to follow much of what later would be put into law even before the codes themselves were ratified, particularly those provisions regarding labor relations. Charles Conn, the president of the Cement Institute, sent a letter to President Roosevelt on July 13, 1933, noting that a minimum wage of 40 cents per hour and a maximum work week of 36 hours was to be in place in the industry by August 1 of that year, supporting the President's Reemployment Agreement (see Taylor, 2011). Numerous organizations objected to the proposed code. The American Federation of Labor wanted a shorter, 30 hour work week. E. M. Tisdale made a statement for the Consumers' Advisory Board of the NRA objecting on behalf of consumers to provisions which allowed the allocation of productive capacity (*Pit and Quarry*, October 1933). However, these complaints did not result in those clauses being modified, and President Roosevelt approved the code for the cement industry on November 27, 1933.[16]

After the Supreme Court invalidated the NRA law in May 1935, various industry groups expressed hope that the code would still be followed by the industry. In one headline, *Rock Products* optimistically suggested that the "Cement Industry's NRA Code Could Be Enforced Without NRA"

[16]Due to some of these complaints, a revised code for the industry became effective on May 21, 1935, although as the law was struck down six days later, the effects of these changes were minimal. Changes made including eliminating provisions regarding the allocation of output, prohibitions on sales below cost, control of increases in capacity and new plant construction, and customer classification (*Concrete*, June 1935).

(June 1935). On June 11, 1935, the board of trustees of the Cement Institute voted unanimously to retain the NRA hours and wages provisions. The trade publication *Concrete* said that "few cement manufacturers have any desire to return to that unbridled and destructive competition" that characterized the industry prior to the introduction of the code. Exactly what mechanism they thought could accomplish this feat is unclear, besides their suggestion of using the NRA as a "code of honor" rather than one of law. In reality, firms began to disregard the labor provisions of the code almost as soon as the law was struck down (*Concrete*, July 1935). Numerous establishments had already reduced wages and increased work hours in the month after the Supreme Court decision. On the other hand, there does not seem to be much evidence that plants ignored the restrictions on price cutting and output controls, which favors an interpretation of continued collusion.

4.2 Enforcement

For the codes to be effective in maintaining collusion, there needed to be mechanisms to enforce agreements. Although membership of the Cement Institute was not necessary for the code to bind on a firm, the organization appears to have played a key role, as evidenced by the large surge in membership as firms presumably wanted input into the drafting of the code and mediation of disputes under the code. At the time that the National Industrial Recovery Act was signed, the membership spiked from 20 firms to 72 firms out of a total of about 80, with several others joining soon after.[17] By 1933, the Cement Institute represented 97 percent of the productive capacity of the industry (*Concrete*, August 1933). What also made the Cement Institute particularly powerful was that it was the sole representative of the industry, unlike other industries that were often represented by multiple trade associations.[18]

There were worries in the industry that the code was not enforceable. *Rock Products* at one point complained that enforcement of codes was useless. For example, the federal government would only interfere with selling below cost when it was done with the express purpose to injure a competitor, because prohibiting it in all cases would be inconsistent with the antitrust laws. Smaller firms were

[17] See *FTC v. Cement Institute* (1948), chart X-B.

[18] The other organization affiliated with the industry was the Portland Cement Association, which at the time was more concerned with the engineering and technical aspects of the cement industry. Today, and following the disbanding of the Cement Institute, the Portland Cement Association assumes both roles.

considered particularly damaging to the effort to maintain higher prices, with one editorial in *Rock Products* referring to them as "the greatest menace to stability and recovery."[19] The Department of Justice and the Federal Trade Commission were tasked with enforcing the codes. Donald R. Richberg, general counsel of the NRA, said that:

> The NIRA does provide that any action complying with the provisions of a code shall be exempt from the provisions of the anti-trust laws. This does not mean two things: First, this does not mean that a code can be written to authorize monopolistic practices. Second, this does not mean that, under the protections of a code, industrial groups can organize and then, without regard to the requirements of the code, proceed to fix prices, or to carry out other operations in restraint of trade, free from the penalties of the anti-trust laws."

The NIRA did not define "monopolistic practices" (*Rock Products*, February 1934). Otto M. Graves, the chairman of the 1934 Code Authority for the crushed stone and slag industries, told a January 28, 1935, meeting of the 1935 Code Authority that code provisions designed to prevent increases in capacity for existing plants could not legally be enforced (*Pit and Quarry*, February 1935).

However, because of the nature of the cement industry, court action was not necessary to enforce cartel decisions. Instead, the government could use its position as a major purchaser of cement to force compliance with the codes. A March 20, 1934, proclamation by President Roosevelt required bidders for federal contracts to sign certificates certifying their compliance with NRA codes (*Rock Products*, April 1934). According to *Rock Products*, the codes were thus being enforced because "nearly all construction today involves the use of [Public Works Administration] money, and the Government can and does refuse contracts to those who fail to comply with codes." Therefore, the lack of criminal prosecutions or civil actions against potential violators is not evidence that the codes were meaningless, and as the cement code provided for specifically allocated production, the likelihood of collusive behavior was high.

The trade publication literature gives some anecdotal evidence for collusion in the cement industry after the introduction of the NRA. One example of alleged collusion came from the federal government. On June 28, 1934, Secretary of War George Dern complained about rigged bids from cement firms working to gain contracts for the construction of the Fort Peck dam in 1934. He alleged that all the bids were at an identical level of $2.70 a barrel regardless of the transport

[19] This is an interesting point of comparison with Alexander (1997) who argues that in the macaroni industry, the largest firms used the code against smaller firms.

distance involved and denounced the collusion. However, he bought the cement at the "outrageous price" because it was needed immediately (*Rock Products*, August 1934). Various groups expressed concern that the cement NRA code was being used to restrict competition. An article in the September 1934 edition of the *Illinois Journal of Commerce*, reprinted in *Rock Products*, suggested that legal price fixing was implicit in the NRA law, with price fixing not forbidden "provided it does not lead to 'monopolies or monopolistic practices'." Also, the Consumers' Advisory Board of the NRA brought complaints against the price control provisions of the cement code. The federal government investigated allegations of collusive behavior in the cement industry. Barton Murray, the deputy NRA administrator, cleared the industry (*Concrete*, August 1934).[20]

The evidence here is certainly not dispositive in settling the issue of whether or not the cement industry became less competitive after the NRA was introduced. On the one hand, the industry was already viewed as collusive even before the law, and it would later be the subject of antitrust legal actions. Despite this, there is at least anecdotal evidence that the industry became even more collusive under the code. Moreover, there were a number of mechanisms by which the code could plausibly have enforced cooperation. Enforcement was especially likely in the cement industry because the federal government was such a major consumer and required firms to follow the code. We thus turn to the plant-level records to provide more evidence of the magnitude of collusion that took place under the code.

5 Theoretical Motivation

In this section, we develop a simple spatial pricing theory to motivate our test for collusion. The model here is a simplified version of a structural model of the cement industry in Chicu (2012). We assume a basic Hotelling setup where we have a market of unit length, with uniform density of consumers N. There are two firms,[21] one located at either end of the market. Suppose that

[20] A separate issue regarding compliance that remains completely unstudied is the degree to which state laws could contribute to enforcing codes. By July 1934, eighteen states had introduced laws allowing the state governments to bring various sanctions against code violators. Pennsylvania, however, a key state with numerous cement producers, never passed one of these laws (*Rock Products*, July 1934). Theoretically, these laws circumvented the constitutional issues involved in the federal governments intensive regulation of commerce in the codes. However, most of them contained clauses rendering the laws operative only so long as the NRA remained in effect. These laws often contained criminal sanctions for NRA code violators. For example, the California law provided for up to six months imprisonment for violations.

[21] We use "firm" here for clarity, but keep in mind the data and tests are done at the plant-level.

each atomistic consumer has valuation v for a unit of cement, where $v \sim F_v$. This effectively defines a demand curve since it dictates the probability a consumer will buy at a given price and location. This distribution of values is important if we want to assume that consumers are not constrained to buy only from one of the firms, but may consider some outside good; that is, not purchasing cement. For ease of exposition, we establish a number of testable implications of the theory under the assumption that F_v is exponential with rate parameter λ, although the results are more general. The proofs for all results and some partial results for a general distribution F_v are collected in Appendices A and B respectively.

There are two dimensions over which firms fight for consumers. First, for any given price level, they fight over the marginal consumers (or the location of the marginal consumer) since they want a bigger slice of the market. Second, for any given slice of the market, the proportion of consumers they capture depends on how high their price is. A higher price means lower probability that any consumer will want to buy, conditional on the firm's price being the lowest net of transportation costs.

We assume that firms can price discriminate between consumers. This is consistent with anecdotal evidence from the industry which suggests that via public and secret discounts, firms have the ability to charge unique prices to individual consumers (see United States Federal Trade Commission, 1966). This is particularly so at times when firms are far from full capacity utilization and do their best to sell to all consumers to whom it is feasible to sell.[22]

5.1 Pricing Strategies under Competition

The choice of an individual i located at x_i is essentially a choice between the outside good, and purchasing a unit of cement from whichever firm $j \in \{1, 2\}$ offers a lower value of $p_j(x_i) + td_{ij}$, where t is the cost of transportation per unit of distance, the 'mill price' $p_j(x_i)$, exclusive of transportation costs, and d_{ij} is the distance of consumer i from firm j. Given our assumptions, $d_{i1} = x_i$ and $d_{i2} = (1 - x_i)$. We assume throughout also that firms have a constant marginal cost c_j motivated by the observation that plant utilization rates are quite low for the time period in question.

[22] The assumption is also theoretically very convenient in that it allows for calculation of competitive prices without recourse to first order conditions, and simplifies the nature of a given firm's dependence on their neighbors' strategies.

A firm targeting a particular consumer has two constraints. The first constraint is imposed by F_v. The distribution of a consumer's (private) valuation dictates the probability that they will buy from the firm given some price plus transportation cost, and implies that there may be some optimal (finite) price for the firm to charge even if there are no other competitors. We denote this the monopoly price, $p_j^m(x_i)$. The second constraint is imposed by the competing firm, and arises from the fact that at any given price above the rival's marginal cost, that rival would be willing to undercut and steal consumers. This competitive environment arises naturally from a setting of price competition with a physically homogeneous good. Thus, while a firm would ideally like to charge the appropriate monopoly price to each consumer in order to maximize profit, they may in some cases be constrained by their rival's willingness to undercut. Accordingly, they will only charge $p_j^m(x_i)$ when it is lower than the maximum price they could charge *without* being undercut by their rival. This intuition forms the basis of the optimal pricing strategies.

We first describe the equilibrium pricing when firms are constrained by their competitors' ability to steal consumers. If for a consumer located at x, $p_1 + tx > c_2 + t(1-x)$, firm 2 can profitably undercut by charging some $p_2 > c_2$ and stealing that consumer. Note that in this case the identity of the consumers at x does not matter, so we drop the indexing by i. This is because if it is profitable to steal the consumer, it is profitable to do so regardless of i. Thus, an equilibrium price is found by setting the undercutting condition to equality. We can perform a similar analysis for firm 2 to reach the equilibrium (Hotelling) prices

$$\begin{aligned} p_1^H(x) &= \max\{t - 2tx + c_2, c_1\}, \text{ and} \\ p_2^H(x) &= \max\{t - 2t(1-x) + c_1, c_2\}. \end{aligned}$$

Firm 1's equilibrium price dictates that the marginal consumer $\tilde{x}$ is given by

$$t - 2tx + c_2 = c_1 \quad (1)$$

$$\Rightarrow \tilde{x} = \frac{1}{2} + \frac{c_2 - c_1}{2t}. \quad (2)$$

The exact same condition holds when calculating the price and marginal consumer for firm 2 as above. Firms' relative market shares are thus, in part, dictated by their marginal costs (competitiveness).

Note that so far the analysis does not make use of the properties of F_v: given that firms cannot charge the monopoly price, it is optimal to charge the highest price feasible that is less than monopoly price, and conditional on being less than monopoly price, the pricing decision does not depend on the consumer's possible outside option.

Now we consider the monopoly pricing problem of firm 1 noting that the problem for firm 2 is completely symmetric. The maximization problem for a consumer located at x is given by

$$\max_{p_x} \pi_1^x = (p_x - c_1)\left(1 - F_v\left(p_x + tx\right)\right),$$

with the first order conditions for optimal pricing

$$\frac{\partial \pi_1^x}{\partial p_x} = -\left(p_x - c_1\right) f_v\left(p_x + tx\right) + \left(1 - F_v\left(p_x + tx\right)\right) = 0. \tag{3}$$

This implicitly defines the optimal monopoly price $p_1^m(x)$. It is useful to rewrite these expressions in terms of the hazard rate associated with f_v. Recall that the hazard rate of a distribution f is defined by

$$h(z) = \frac{f(z)}{1 - F(z)}$$

Therefore, it follows that the monopoly price solves

$$h(p_1^m(x) + tx)(p_1^m(x) - c_1) = 1.$$

This equation has a simple economic intuition. A monopolist who raises its price suffers from the cost of a higher "failure" rate of customers, i.e. a greater rate of consumers not purchasing the goods. To reiterate, we assume the following.

Assumption 1. *F_v is distributed exponentially with rate parameter λ.*

The hazard rate of the exponential distribution is constant and equal to the rate parameter λ. Therefore, the monopoly pricing expression simplifies to

$$p_1^m(x) = \frac{1}{\lambda} + c_1.$$

In this case the monopoly price does not depend on the marginal cost of the other firm. It is clear that in this case $\frac{\partial p_1^m}{\partial c_1} = 1$, so the pass-through of own cost changes into price is complete. In Appendix A, we show that pass-through of own costs is always positive regardless of f_v though under different distributional assumptions pass-through may be less than complete. In general, this will be related to the second derivative at optimum. The second order condition can be compactly written as

$$\frac{\partial \log h}{\partial z} > -h,$$

where both the LHS and RHS are evaluated at $p_1^m(x) + tx$. This puts a bound on how quickly the hazard rate can decline. In particular, this bound rules out the case of the Pareto distribution. In the exponential case, the second order condition is always satisfied because $\frac{\partial \log h}{\partial z} = 0$, and the comparative statics are straightforward.

The optimal pricing strategy in a competitive environment is given by:

$$\begin{aligned} p_1^*(x) &= \min\left\{p_1^H(x), p_1^m(x)\right\}, \\ p_2^*(x) &= \min\left\{p_2^H(x), p_2^m(x)\right\}. \end{aligned}$$

Figure 3 shows how the equilibrium pricing schedules depend on distance. Firms will charge the monopoly price if it is less than the 'competitive' price. This occurs towards where firms are located—where they have more market power over consumers and are less constrained by their opponents willingness to undercut. Once opponents are able to profitably undercut, firms are forced to charge the diagonal constrained price, which they are willing to do until they reach their own marginal cost, which they set for all remaining locations (though do not actively charge as this is after $\tilde{x}$).

With firm strategies outlined, it is useful to state the following result.

Proposition 1. *It is not a competitive equilibrium for both firms to be charging their monopoly price at the marginal consumer $\tilde{x}$, assuming a continuous distribution of valuations, and pricing within the support of those valuations.*

Proof. See Appendix A. □

The implication of this proposition is that for at least some of their consumers, under competition, firms will charge the competitive Hotelling price p_i^H.

5.2 Pricing Strategies under Collusion

We have now fully characterized the pricing strategies under competition. Optimal collusion will be characterized by firm i charging its own monopoly price to each of its customers $p_i^m(x)$. What then has to be decided is how the firms will divide up the market. The joint profit maximizing problem that determines the market split is given by

$$\max_z \pi = \int_0^z \left(p_1^m(x) - c_1\right)\left(1 - F_v\left(p_1^m(x) + tx\right)\right) dx \\ + \int_z^1 \left(p_2^m(x) - c_2\right)\left(1 - F_v\left(p_2^m(x) + t(1-x)\right)\right) dx.$$

where we have already assumed the particular pricing strategy and that firms will want to sell to all customers. Denote the optimal choice of z above by x^*.

Note that this formulation allows for the possibility of side payments between firms. For example, assume that $c_1 + t < c_2$, then it is more efficient for firm 1 to serve all the customers including the ones right next to firm 2. So the joint profit maximizing decision would be for firm 1 to do all of the production charging his monopoly price and then compensating firm 2 for not producing by making a transfer that makes him at least as well off as under competition. The maximization problem in some sense only pins down the efficient split of the market and not exactly how the profits are split between the firms.

Another thing to note is that the cutoff x^* may in principle be different from the competitive cutoff $\tilde{x}$. Assuming the first order condition holds, meaning that there exists $\tilde{x} \in [0,1]$, we can write the first order condition of the above problem as

$$\frac{1 - F_v(p_1^m(x^*) + tx^*)}{1 - F_v(p_2^m(x^*) + t(1-x^*))} = \frac{h(p_1^m(x^*) + tx^*)}{h(p_2^m(x^*) + t(1-x^*))}. \tag{4}$$

In the exponential case, we again use the fact that the hazard rate of the distribution is constant, which implies that $p_1^m(x^*) + tx^* = p_2^m(x^*) + t(1-x^*)$. Substituting the expression for monopoly price and rearranging, we find that

$$x^* = \frac{1}{2} + \frac{c_2 - c_1}{2t}.$$

In this case the market distribution under collusion is the same as in the competitive Hotelling case, but this need not be generically true. Generally, a firm's market share will depend positively on its own cost advantage relative to its competitor.

5.3 Testable Predictions of the Theory

The idea of the test for collusion will be to compare the pass through of a competitor's cost onto own price under collusion and competition. In order to bring the theory closer to the data, it is important to specify how the data we observe maps into our theoretical constructs. In general, the model predicts a different price for each consumer depending on their location. Yet all we observe in our data are average prices, meaning total revenue divided by total output. Total output for firm 1 is given by

$$Q_1(w) = \int_0^w (1 - F_v(p_1(z) + tz))dz$$

where $w, p_1(z)$ denote arbitrary cutoffs and pricing schedules. Also denote total revenue as

$$R_1(w) = \int_0^w p_1(z)\left(1 - F_v\left(p_1(z) + tz\right)\right)dz$$

What we observe in the data for price of the firm 1 is

$$P_1 = \frac{R_1}{Q_1}.$$

This is the unit price calculated as total revenue divided by total output. This in general will not have a closed form expression under competition or collusion. We now state the central proposition.

Proposition 2. *Suppose that firms act competitively. First,*

$$\frac{\partial P_1}{\partial c_1} > 0$$

and under certain conditions,

$$\frac{\partial P_1}{\partial c_2} > 0$$

Proof. See Appendix A. □

What is important here is to show that it is *possible* to yield a stark result about the effect of own and neighbor cost pass-through under a competitive environment. We focus on the cases above since these accord to the most realistic structural parameter values. The heart of the conditions, discussed in the Appendix, is ruling out what we consider a pathological case. The pathology arises because while the firm increases its price for all of its original customers, it may additionally serve a relatively large new pool of low value customers near its new margin. If the mass of this new pool is sufficiently large relative to the mass of consumers receiving the higher prices (some of whom may, in principle, now stop buying), the average price across all consumers may go down. We effectively prevent this by ensuring that market-level demand is sufficiently inelastic that small price changes cannot drastically change the mass of consumers choosing to buy. Both Chicu (2012), as well as Miller and Osborne (2011) in a related model of the cement industry, find such inelastic market-level demand. This is consistent with anecdotal discussion of the cement industry (see Dumez and Jeunemaître, 2000).

Our proof relates only to a subset of cases in which the majority of consumers are charged the Hotelling price. This is highly likely in a majority of cases, given low capacity constraints. The proof will extend in principle to the case where a significant portion of consumers are charged a monopoly price, in the competitive setting. We discuss this issue further in the Appendix.

Proposition 2 forms the basis for our two predictions. First of all, we consider own cost pass through.

Prediction 1. *Firms' average price P_1 is increasing in own marginal cost regardless of whether the regime is competitive or collusive.*

Second, we consider pass-through of a competitor's cost under competition and collusion. We showed that other's pass through $\frac{\partial P_1}{\partial c_2}$ can be positive under competition and reasonable assumptions. What is crucial is that in the exponential case, there is no pass through of other's costs to own price under collusion.[23] To see this, note that since $p_1^m(x^*) = P_1^m$ for the exponential distribution, the derivative with respect to c_2 is 0 implying no effect of other's cost on own average price under collusion. From this theory, we obtain a testable prediction for collusion.

[23] Appendix B considers the general distribution of values case.

Prediction 2. *Under a competitive environment, firms' pricing will depend positively on the marginal cost of their competitor* $\frac{\partial P_1}{\partial c_2} > 0$*. Under a collusive environment, there will be no dependence of price on competitors' marginal cost:* $\frac{\partial P_1^m}{\partial c_2} = 0$.

Figure 4 shows graphically how the price schedule for firm 1 shifts when firm 2's costs increase.

Note that the latter part of Prediction 2 would also be true if firms had decided to split the market without recourse to marginal costs in some sub-optimal though perhaps more practically implementable way: either based on previous marginal costs, or on some other exogenous factor. Lastly, in Appendix C, we show the theoretical implications for the simplification of our model where there is no outside good. In this case, the testable predictions are starkly different, with $\frac{\partial P_1^m}{\partial c_2} < 0$, which we think is an unreasonable prediction. Appendix D discusses some complications from considering more fully the spatial nature of competition.

6 Empirical Specification

Our basic specification estimates the impact of own average variable cost $\log AVC_{it}^O$ and average cost of nearest neighbor not jointly owned by the same parent firm, $\log AVC_{it}^N$, on a plant's average price $\log p_{it}$. We are interested in how the effect of the neighbor's cost changes after the NRA. In particular, we specify

$$\log p_{it} = \alpha_0 + \alpha_1 Dist_{it} + \alpha_2 \log AVC_{it}^O + \alpha_3 \log AVC_{it}^N + \alpha_4 NRA_t \cdot \log AVC_{it}^N + \sum_t \alpha_t Year_t + \epsilon_{it} \quad (5)$$

where $Year_t$ are a full set of time dummies and $Dist_{it}$ is the distance to the nearest neighboring plant that is not owned by the same firm. Because of worries about measurement error in the variables, we choose to trim the 1% tails of $\log AVC^O$. Results are robust to the fraction we trim. We also cluster the standard errors at the plant-level and in some specifications include plant fixed effects.

Following our theory, we do not include market fixed effects, instead treating the relevant variables for summarizing the competitive environment for a particular plant as the distance to nearest neighbor and the neighbor's costs. The distance variable attempts to capture the other crucial implication of our model, which is that distance matters, as it serves to segregate customers from plants (see Appendix D for a more complete discussion). We do experiment with including some market fixed effects where the markets are defined in Figure 1, but find no material difference in outcomes.

A question is whether to treat the data from 1933 as under the NRA or not. The law itself was passed in May 1933 and the code for the cement industry was approved towards the end of the year. There is reason to believe from the narrative evidence that cement plants began operating under the code even before it was approved. Therefore, we treat all of 1933 as an NRA year. While these narrative reports only highlight some of the labor provisions, it is suggestive that there is a sharp increase in the average price-cost margin between 1931 and 1933.

Our test for collusion has two parts: $\alpha_3 > 0$ and $\alpha_3 + \alpha_4 = 0$. The first part asks whether, in the pre-NRA period, plants' pricing decisions were constrained by the costs of their nearest neighbor. A significant finding of $\alpha_3 > 0$ would justify our basic theoretical structure and motivate our test for collusion, which forms the second part of the test. If the second claim cannot be rejected, this implies that under the NRA plants' pricing strategies are no longer constrained by their competitors. Under our model, this is positive evidence of collusion.

A feature of this test is that there is no reason to believe that it is sensitive to external business cycle factors. There is a major worry in simply examining margins before and after the NRA because the period of the NRA coincides with one of the strongest expansions in the history of the American economy. Furthermore, there is extensive evidence that margins and profits are procyclical (Floetotto and Jaimovich, 2008), making inference using those variables very fragile. In fact, our simple theoretical model would predict a similar effect on margins from a rise in demand. But there is no theoretical evidence that external demand factors should increase collusion as measured by our test. Many theoretical models such as Rotemberg and Saloner (1986) actually predict the reverse.

7 Results

7.1 Effect of Neighbor's Cost on Pricing Decisions

Table 3 displays our initial regression results. Our baseline specification in column 1 that only includes year and firm fixed effects shows strong evidence for our theory of how competition operates in the industry and for collusion. Before the NRA, a 1% increase in own average variable cost leads to an increase in the price of 0.2%, while a similar increase in the cost of the nearest neighbor leads to half that increase in own price, still a sizable fraction. What is striking is that after the NRA comes into effect, there is in total no effect of nearest neighbor's cost on own price, both statistically and economically. This conforms closely to our theory that suggests under collusion, there should be no effect. It is interesting to note that this is much less than perfect pass through of costs into prices.[24] This result is robust to other choices of what fixed effects to include, as evidenced by the results in columns (2) and (3), where we add plant fixed effects in one and drop firm fixed effects in the other. The overall significance of the cost terms is decreased in the regression with plant fixed effects.

In column 4, we include an indicator for whether the plant has spare capacity of over 10%. Our model assumed constant marginal cost and, therefore, no capacity constraints. Implicitly, this suggests a situation where marginal costs are infinite once output reaches a certain point (never reached in our setting). However, if plants are sufficiently close to their capacity constraint, it might be unreasonable to assume this pricing structure, and instead allow for an increase in costs as firms approach their constraints. Controlling for this through an indicator to potentially increase costs for 'constrained' firms does not affect the results at all, suggesting our pricing model is sensible.

In columns 5 and 6, we modify the definition of the NRA variable. Column 5 drops the observations from 1933, which allows us to not take a stand on how to treat that year. In column 6, we consider 1933 as a non-NRA year. For both cases, the broad pattern of a strong positive effect of neighbor's price on own price in the pre-NRA years. The only difference is that the negative coefficient for the NRA year (or years) is much stronger. The sum of the coefficients is not statistically significant at standard significance levels in either specification. We take this as evidence that the results are robust to how 1933 is treated though we think that the specification where 1933 is treated as non-NRA simply muddies the picture.

We have also experimented with excluding plants that are effectively monopolies. In particular, we reran the regressions eliminating any plants whose nearest neighbor is more than 200 miles away, which is the maximum distance cement is shipped normally (column 7). This cut of the data does not affect the main results that the NRA dampens competition along this spatial dimension.

[24] Though it makes more sense in the context of a 2-dimensional model.

In addition, it serves as a sort of falsification test. Examining the results for the group of local monopolists in the final column, there is no effect of the NRA on how they set their price. If there had been an effect here, this would have suggested that there was some unobserved trend that was potentially driving the results. The fact that plants who *ex ante* were monopolists continue to exercise their monopoly in a similar way after the NRA is reassuring.

7.2 Other Code Provisions

Of course, there were other provisions to the code besides just price fixing and output sharing. One that we have highlighted is the restriction on hours per week for each wage earner. We can look for evidence that plants obeyed this rule directly since the Census asks a question specifically about how much wage earners are working. Unfortunately, this question is missing for 1933. We make no assumption about whether or not the choice of hours per worker for these plants in 1935 was optimal. Still it is striking that 35% of plants report a work week for 36 hours exactly in 1935. There are cheaters with a number of plants reporting a longer than specified workweek. What is evident though comparing the distribution of workweeks before and after the NRA in Figure 7 is how much more compressed the distribution is after the NRA. While there are focal points in the pre-NRA years around 56 and 48, the distribution stretches from 40 to 84 as compared to 30 to 56 in the pre-NRA period.

The other provision with regards to labor is the minimum wage of \$0.40 per hour. Wage rates are not observed in the data and instead must be inferred from total wage earners, hours per wage earner, and total wage bill. This makes it unlikely that even if plants were following this provision, we would observe much mass right at \$0.40. However, we can formalize a test of this hypothesis taking the measurement error into account.

Consider the following simple model. Suppose that each *observed* wage is a draw z from the distribution of Z, where $Z = W + \varepsilon$. In this setting, ε represents classical measurement error. Let W and ε be the logs of log-normally distributed random variables, where $W \sim N\left(\mu_W, \sigma_W^2\right)$ and $\varepsilon \sim N\left(0, \sigma_\varepsilon^2\right)$, with ε independent of W. Thus, $Z \sim N\left(\mu_W + \mu_\varepsilon, \sigma_W^2 + \sigma_\varepsilon^2\right)$. That is, both the true and observed wage are log-normally distributed, a common assumption.

Impose now that W is truncated at some level τ. Then for F_W the distribution of W, the distribution of the log of the truncated distribution W', $F_{W'}$, is given by the following:

$$F_{W'}(z) = \begin{cases} F_W(\tau) & \text{if } z \leq \tau, \\ F_W(z) & \text{if } z > \tau. \end{cases}$$

That is, it is a point mass at τ, and proceeds with the original distribution thereafter. It follows that the distribution of z' for z' drawn from $Z' = W' + \varepsilon$, is now the sum of a normal and a truncated normal.

In this case, we can derive an MLE estimator for the parameters of the underlying wage and measurement error distributions. This allows us to formulate a specification test where the null is that there is truncation at the wage level specified by the codes. We derive this likelihood under the case where the variances of the wage and measurement error distribution are equal over the two periods though we allow the mean of the wage distribution to differ.[25] Appendix E derives the likelihood as

$$L = L_{pre} + \sum_{i \in post} \log L_{post}(z_i)$$

where the log likelihood for the pre-NRA period is given by

$$L_{pre} = \sum_{i \in pre} \phi\left(\frac{z_i - \mu_W}{\sqrt{\sigma_W^2 + \sigma_\varepsilon^2}}\right) - \frac{N_{pre}}{2}\log(\sigma_W^2 + \sigma_\varepsilon^2)$$

and for the NRA period, the likelihood of a particular observed log wage z_i

$$L_{post}(z_i) = \frac{1}{\sigma_\varepsilon}\phi\left(\frac{z_i - \tau}{\sigma_\varepsilon}\right)\Phi\left(\frac{\tau - \mu_W'}{\sigma_W}\right) + \frac{1}{\sqrt{\sigma_\varepsilon^2 + \sigma_W^2}}\phi\left(\frac{z_i + \mu_W'}{\sqrt{\sigma_\varepsilon^2 + \sigma_W^2}}\right)$$

Then a misspecification that does not reject the model provides some evidence for truncation in 1935. Of course, finding that the model is misspecified does not necessarily imply that no truncation was present. It is a rejection of the joint hypothesis of not only truncation but also normality and equal variances. Therefore, a better test would be semi-parametric in that we assume the same distributions for measurement error in both periods only restricting the mean of the measurement error to be 0. We hope to implement this formal parametric estimation procedure in future work

[25]It may be possible to relax this equal variance assumption.

and develop a semi-parametric test.

Intuitively though, the result of the differences between Z and Z' is that the distribution of Z' will have a fatter right tail: the result of an, on average, larger draw of true wage added to the noise ε, and a slightly thinner/lower left tail, depending on where τ occurs in the distribution of Z. In our setting, $\tau = \log(0.4)$. Figure 8 plots the density of the log of average wages demeaned and scaled by the standard deviation. The change in the shape of the distribution of wages after the NRA is precisely as the model predicts.[26]

8 Conclusion

Macroeconomists have long debated the effect of the NRA on the economy during the early part of the Roosevelt administration. To date, however, there has been little microeconomic evidence about the impact of the law on firm behavior. We have developed new evidence of how the NRA affected competition with a study of the cement industry. Qualitatively, we show substantial anecdotal evidence from the trade literature that the law led to more anti-competitive behavior. We furthermore collect new plant-level evidence from the Census of Manufactures and confirm empirically using a Hotelling framework that collusion increased. Before the NRA, a cement plant's pricing decisions were at least constrained by the pricing behavior of its nearest neighbor. After the NRA, plants were free to choose whatever price they liked.

Admittedly, our industry is perhaps more likely to be collusive than most, especially when it is given an additional push in that direction from the government. The cement industry has a history of complaints about anti-competitive behavior. The narrative evidence suggests that the industry was far from perfectly competitive before the NRA, although it also provides evidence for a further increase in collusion after the NRA. Additionally, the industry at this time was dominated by around ten firms that controlled half the market. For this reason, caution should be exercised in extending these findings to the broader economy. With that said, many large industries in the economy during the 1930s were similarly concentrated.

We remain agnostic on the macroeconomic question of how the NRA affected the recovery in

[26] Unfortunately, a non-parametric Kolmogorov-Smirnov test of the equality of distributions does not have sufficient power to reject the null that the scaled and de-meaned wage distributions are equal in 1931 and 1935. We hope that our parametric test based on our model may have sufficient power to distinguish the two.

the larger economy. Although cartelization is generally considered an unambiguous negative, some have argued that for an economy facing deflationary pressures, the situation may be different. This is surely what FDR and his advisors believed. Specifically, the price support coming from cooperation may be beneficial in stopping a deflationary spiral. Other historians of the era have argued that the law was simply ineffective, and here we disagree. Both anecdotal and econometric evidence suggest that firms did indeed act less competitively under the NRA.

In a slightly broader context, this study provides a relatively rare direct empirical tests of collusion. Much of the empirical industrial organization literature on collusion, largely for the reason that explicit cooperation is generally illegal, has been plagued by a dearth of detailed plant-level data. Given that the Census of Manufactures records are publicly available, the time period seems ripe for further empirical study of collusion. We conclude by suggesting that more case studies of individual industries might be particularly useful not simply for economic historians attempting to gauge the extent of the collusion under the NRA but also for those interested in industrial organization and how collusion actually occurs, tacit or otherwise.

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A Appendix: Proofs

A.1 Own-Cost Pass Through

Here we show that pass through of own costs is positive regardless of F_v. Working in terms of hazard rates, the comparative statics for x can be written in a transparent way

$$\frac{\partial p_1^m(x)}{\partial x} = \frac{-\frac{\partial \log h}{\partial z} t}{\frac{\partial \log h}{\partial z} + h}$$

where h and $\frac{\partial \log h}{\partial z}$ are evaluated at $p_1^m(x) + tx$. From the second order condition, the denominator will always be strictly positive. So whether the monopoly price declines depends solely on whether the (log) hazard rate is increasing, in which case $\frac{\partial \log h}{\partial z} > 0$.

The pass through expression is given by

$$\frac{\partial p_1^m(x)}{\partial c_1} = \frac{1}{1 + \frac{\partial \log h}{\partial z} \frac{1}{h}}$$

With this expression, it is easy to see under which conditions that pass through is incomplete with the monopolist absorbing some of the cost increases. Again the second order condition implies that the monopoly price must increase with cost.

A.2 Proof of Proposition 1

From the first order condition in equation (3), it must be that $p_1^m > c$. If this does not hold, the condition fails by the fact that $f_v > 0$ and $1 - F_v > 0$. Since firms are observed to serve a positive measure of consumers, then there must exist a marginal consumer. If firms charge monopoly price at the marginal consumer, it means that both firms are charging more than marginal cost, and that consumers are indifferent between the two firms. This means that one firm can deviate and profitably steal consumers from the other firm at the margin. As soon as such a deviation is feasible, we do not have an equilibrium.

A.3 Proof of Pass Through Results for P_1 for Exponential Distribution

There are two cases to consider depending on $p_1(0)$. The first case is when $p_1(0) = t + c_2$, which happens when $\frac{1}{2t\lambda} \geq \tilde{x}$. In this case, prices will be the Hotelling prices for all consumers. We focus on this case for the remainder of the proof, and will discuss extensions of the results to the case where some (or all) prices are the monopoly prices. One can calculate in the pure Hotelling case

$$Q_1 = \frac{\exp(-\lambda(t + c_2))}{\lambda t}[\exp(\lambda t \tilde{x}) - 1].$$

Similarly, one can calculate that

$$R_1 = \exp(-\lambda(t + c_2)) \frac{t + c_2}{t\lambda}[\exp(\lambda t \tilde{x}) - 1] - 2t \int_0^{\tilde{x}} x \exp(\lambda t x) dx.$$

Using integration by parts, it is easy to check that

$$f(x) = \int x \exp(\lambda t x) dx = \frac{\exp(\lambda t x)}{\lambda t} \left[x - \frac{1}{\lambda t} \right].$$

Now we have

$$\frac{\partial f(\tilde{x})}{\partial c_i} = \frac{\partial \tilde{x}}{\partial c_i}\tilde{x}\exp(\lambda t\tilde{x}), \text{ and}$$

$$\frac{\partial Q_1(\tilde{x})}{\partial c_1} = t\exp(-\lambda(t+c_2))\frac{\partial \tilde{x}}{\partial c_1}\exp(\lambda t\tilde{x}).$$

Furthermore,

$$\frac{\partial Q_1(\tilde{x})}{\partial c_2} = -[\exp(\lambda t\tilde{x})-1]\exp(-\lambda(t+c_2)) + t\frac{\partial \tilde{x}}{\partial c_2}\exp(\lambda t\tilde{x})\exp(-\lambda(t+c_2)).$$

This derivative can be rewritten as

$$\frac{\partial Q_1(\tilde{x})}{\partial c_2} = \exp(-\lambda(t+c_2))\left[1-\frac{\exp(\lambda t\tilde{x})}{2}\right].$$

Now in general

$$\frac{\partial P_1}{\partial c_i} = -Q_1(\tilde{x})2t\frac{\partial f}{\partial c_i} - R_1\frac{\partial Q_1}{\partial c_i}.$$

We first consider own cost pass through. In this case, $sgn(\frac{\partial f}{\partial c_1}) = sgn(\frac{\partial \tilde{x}}{\partial c_1}) < 0$ and $sgn(\frac{\partial Q_1}{\partial c_1}) = sgn(\frac{\partial \tilde{x}}{\partial c_1}) < 0$. Therefore,

$$\frac{\partial P_1}{\partial c_1} > 0.$$

Intuitively, since we are considering a situation where there are only Hotelling prices, an increase in c_1 has no effect on the prices charged by the plant. All it serves to do is reduce the market served by firm 1 dropping the customers who were receiving the lowest prices.

In the case where there are some consumers charged a monopoly price, the same logic applies for all consumers receive Hotelling prices. Those that are paying the monopoly also see an increase of 1 for 1 when the plant's costs rise. Therefore, assuming that the price sensitivity of those receiving the monopoly price is not too high, the average price across all consumers will increase. Showing this formally remains for future work.

Returning to the calculation of other's cost pass through,

$$P_1(\tilde{x}) = t + c_2 + \frac{2\exp(\lambda(t+c_2))}{\lambda}\left[1-\frac{\lambda t\tilde{x}}{1-\exp(-\lambda t\tilde{x})}\right].$$

To sign the derivative of this expression with respect to c_2, note that $\frac{z}{1-\exp(-z)}$ is increasing in z. So to ensure that pass through is positive, we choose the largest value for $z = \lambda t\tilde{x}$ that is consistent with our maintained assumption of all consumers receiving Hotelling prices, which is

$$\lambda t\tilde{x} = \frac{1}{2}.$$

Substituting this into the expression for $P_1(\tilde{x})$, we find

$$P_1(\tilde{x}) = t + c_2 + \frac{2\exp(\lambda(t+c_2))}{\lambda}\left[1-\frac{1}{2(1-\exp(-.5))}\right].$$

So if

$$\frac{\partial}{\partial c_2}\left(\frac{2\exp(\lambda(t+c_2))}{\lambda t}\left[1-\frac{1}{2(1-\exp(-.5))}\right]\right) > -1$$

then $\frac{\partial P_1(\tilde{x})}{\partial c_2} > 0$. This condition can be re-written as

$$\begin{aligned} \exp(\lambda(t+c_2)) &< \frac{1}{\frac{1}{2(1-\exp(-.5))}-1} \\ \Rightarrow \lambda &< \frac{0.613}{t+c_2}. \end{aligned}$$

Again, the complication here is that when the other firm's costs rise, that allows for the firm to raise its price to its existing customers. It also starts selling to a new lower value group of customers near its margin. The condition above is a condition on how many new customers the firm sells to, and how many existing customers it loses due to higher inframarginal prices. The condition ensures that overall average price rises, and we have our result for the case of all Hotelling prices. In the context of the exponential distribution and the structure of demand in our model, a condition requiring sufficiently low λ amounts to requiring that market-level demand is sufficiently inelastic.

Consider now the case where the firm is charging its monopoly price to some subset of its customers. First, it is easy to check that in the case where a plant is charging the monopoly price to all of its customers, then there will be no effect of a change in c_2 on price. This is then also true for the subset of consumers being charged the monopoly price. However, the analysis for the subset being charged a Hotelling price is analogous to the above. Thus, an analogous condition on demand will be required for the case where the firm sets its monopoly price for a strict subset of its consumers.

B Appendix: Extending the Results to More General Cases

We now consider some results for a general distribution of values F_v. First, we calculate the effect of other's cost on total output under collusion

Proposition 3. *Under collusion,*

$$\frac{\partial Q_1^m}{\partial c_2} = \left[1 - F_v\left(p_1^m(x^*) + tx^*\right)\right] \frac{\partial x^*}{\partial c_2}$$

$$\frac{\partial \log P_1^m}{\partial \log c_2} = \frac{c_2}{Q_1^m} \left[1 - F_v\left(p_1^m(x^*) + tx^*\right)\right] \log\left(\frac{p_1^m(x^*)}{P_1^m}\right) \frac{\partial x^*}{\partial c_2}$$

where we have used the approximation $\frac{p_1^m(x^*) - P_1^m}{P_1^m} = \log\left(\frac{p_1^m(x^*)}{P_1^m}\right)$.

Proof. Apply Leibniz's rule and note that p_1^m does not depend on c_2. We also make use of the fact that

$$\frac{\partial P_1^m}{\partial c_2} = \frac{1}{Q_1^m}\left[\frac{\partial R_1^m}{\partial c_2} - P_1^m \frac{\partial Q_1^m}{\partial c_2}\right]$$

□

The sign of $\frac{\partial \log P_1^m}{\partial \log c_2}$ depends on the sign of $\log(p_1^m(x^*)/P_1^m)$. If p_1^m is strictly increasing for all x, then the sign will be positive since $p_1^m(x^*) > P_1^m$ and vice versa for a strictly decreasing monopoly pricing function. As noted above, the behavior of p_1^m in turn can be characterized in terms of the hazard rate of F_v. For distributions with non-monotonic hazard rates, this formula does not provide a clear implication since the average price may be above or below the monopoly price for the marginal consumer. Finally, at least locally for $c_1 = c_2$, the third term will always be positive as will be shown below. Therefore, the sign of the pass-through rate depends completely on how $p_1^m(x)$ behaves.

This calculation was made simpler by the fact that p_1^m does not depend on c_2. To formulate a test for collusion, we want to compare the above quantities to the competitive analogs. The complication in comparing competition to collusion is the fact that $p_1^*(x)$ does depend on c_2 under competition. Still one can calculate the effect of a change in other's price on own quantity under competition, denoted here for clarity Q_1^H, as

$$\frac{\partial Q_1^H}{\partial c_2} = \frac{1}{t}[1 - F_v(p^*(\hat{x}) + t\hat{x})] - \frac{1}{2t}[1 - F_v(p_1^*(\tilde{x}) + t\tilde{x})]$$

where $\hat{x}$ is defined as

$$p_1^m(\hat{x}) = p_1^H(\hat{x})$$

The key thing to notice is that only in the interval $[\hat{x}, \tilde{x}]$ does the competitive price schedule depend on the other firm's costs. Outside this interval, there is either monopoly pricing or marginal cost pricing where both do not depend on the other firm's cost. Moreover, in this interval, a unit change in marginal cost of the other firm translates into a unit change in own price.

An analogous expression can be derived for total revenue under competition, R_1^H

$$\frac{\partial R_1^H}{\partial c_2} = [1 - F_v(p_1^*(\tilde{x}) + t\tilde{x})]\, p_1^*(\tilde{x})\frac{\partial \tilde{x}}{\partial c_2} + \int_{\hat{x}}^{\tilde{x}} \left[1 - F_v\left(p_1^H(x) + tx\right) - p_1^H(x) f_v\left(p_1^H(x) + tx\right)\right] dx \quad (6)$$

where we have used the fact that $\frac{\partial p_1^H}{\partial c_2} = 1$ for all x. These quantities can be used to construct the marginal effect of costs on price as in the monopoly case.

Now we aim to show that pass through under competition is generically positive. Consider the first order condition for x^* in equation (4).

Proposition 4. *If $c_1 = c_2$, then $x^* = \tilde{x}$.*

Proof. Plug $\tilde{x}$ into the FOC for x^* and note that $p_1^m(x^*) = p_2^m(x^*)$ because x^* is symmetric in $c_2 - c_1$. □

This shows that at least for equal costs, the competitive and collusive outcome are equivalent with regards to the market division. So all that is different is that firms can charge the monopoly price to all their customers instead of being constrained at certain points. We now offer a partial result to show that as a firm becomes less productive, it serves less of the market.

Proposition 5. *For $c_1 = c_2$ and an arbitrary distribution of values F_v, $\frac{\partial x^*}{\partial c_2} > 0$.*

Proof. First, we introduce some notation. Let F_i be F_v evaluated at inclusive price for firm i, similarly for f_v, h and $(\log h') = h'/h$. Also, p_i' denotes $\frac{\partial p_i^m}{\partial x}$ evaluated at inclusive price for firm i. Then differentiating the FOC for x^*, the RHS is given by

$$[1 - F_2]h_1'\left(p_1'\frac{\partial x^*}{\partial c_2} + t\frac{\partial x^*}{\partial c_2}\right) - h_1 f_2\left[p_1'\frac{\partial x^*}{\partial c_2} + \frac{\partial p_2^m}{\partial c_2} - t\frac{\partial x^*}{\partial c_2}\right]$$

And LHS is

$$[1 - F_1]h_2'\left(p_2'\frac{\partial x^*}{\partial c_2} + \frac{\partial p_2^m}{\partial c_2} - t\frac{\partial x^*}{\partial c_2}\right) - f_1 h_2\left[p_1'\frac{\partial x^*}{\partial c_2} + t\frac{\partial x^*}{\partial c_2}\right]$$

The RHS can be reduced to

$$(\log h_1)'(p_1' + t)\frac{\partial x^*}{\partial c_2} - h_2\left[(p_1' - t)\frac{\partial x^*}{\partial c_2} + \frac{\partial p_2^m}{\partial c_2}\right]$$

LHS similarly

$$-h_1(p_1' + t)\frac{\partial x^*}{\partial c_2} + (\log h_2)'\left[(p_2' - t)\frac{\partial x^*}{\partial c_2} + \frac{\partial p_2^m}{\partial c_2}\right]$$

Combining the two sides,

$$\tilde{h}_1(p_1' + t)\frac{\partial x^*}{\partial c_2} = \tilde{h}_2\frac{\partial p_2^m}{\partial c_2} - t\frac{\partial x^*}{\partial c_2}\tilde{h}_2 + \left[(\log h_2)'p_2' + h_2 p_1'\right]\frac{\partial x^*}{\partial c_2}$$

where $\tilde{h} = h + (\log h)' > 0$ by the second order condition. With a bit more algebra, we find

$$\frac{\partial x^*}{\partial c_2} = \frac{\tilde{h}_2\frac{\partial p_2^m}{\partial c_2}}{(\tilde{h}_1 + \tilde{h}_2)t + \tilde{h}_1 p_1' - \tilde{h}_2 p_2' + h_2(p_2' - p_1')}$$

Now if $c_1 = c_2$, it follows that $x^* = 1/2$ and $h_1 = h_2, p_1' = p_2'$. Therefore,

$$\frac{\partial x^*}{\partial c_2} = \frac{\frac{\partial p_2^m}{\partial c_2}}{2t}$$

By continuity, this result will extend for a whole set of c_2 close to c_1. And the result is shown. □

There are a few interesting things to note about this result. First, it does not require any assumptions about the distribution F_v. One may have thought with certain conditions on the hazard ratio, then it might be more efficient from the standpoint of the industry to have the costlier firm to produce if they can charge a higher price. This worry is true in general but we minimize those factors by minimizing the cost differentials.

Proposition 6. *For $c_1 \geq c_2$, $\tilde{x} \geq x^*$ if and only if $\frac{\partial p_m(x^*)}{\partial c} < 1$.*

Proof. We know that when $c_1 = c_2$ that $\tilde{x} = x^*$. Moreover, the ratio of the derivatives is equal to $\frac{\partial p_m}{\partial c}$. So locally the result is shown. □

This proposition implies that whether firm 1 gets more market share under competition versus collusion depends solely on whether pass through is greater than under competition. This comes from the fact that cost differences are second order by assumption and all that matters is what can be charged.

We now consider some propositions regarding the pass through of costs to average price.

Proposition 7. *Assume that $\hat{x}$ is close to 0 meaning Hotelling prices prevail for the vast majority of the consumers, then*

$$\frac{\partial \log P_1^H}{\partial \log c_2} = \frac{c_2}{Q_1^H}\left[\frac{1}{t}\log\left(\frac{p^*(0)}{P_1^H}\right)[1 - F_v(p^*(0))] - \frac{1}{2t}\log\left(\frac{p^*(\tilde{x})}{P_1^H}\right)[1 - F_v(p(\tilde{x}) + t\tilde{x})] - \frac{Q_1^H}{P_1^H}\right]$$

Proof. Rewriting equation 6, we have

$$= \left[1 - F_v\left(p_1^*(\tilde{x}) + t\tilde{x}\right)\right]p_1^*(\tilde{x})\frac{\partial \tilde{x}}{\partial c_2} + Q_1^H - \int_{\hat{x}}^{\tilde{x}} p_1^H(x) f_v\left(p_1^H(x) + tx\right)dx$$

Now we can apply integration by parts to the remaining integral. Let $dv = f_v(p_1^H(x) + tx)dx$ so $v = -\frac{1}{t}F_v(p_1^H(x) + tx)$. The first term comes from the derivative of $p_1^H(x)$. Then $u = p_1^H(x)$ and $du = -2tdx$ under Hotelling. Then we have that

$$-\int_{\hat{x}}^{\tilde{x}} p_1^H(x) f_v\left(p_1^H(x) + tx\right) dx = \frac{1}{t}\left[p_1^H(\tilde{x})F_v(p_1^H(\tilde{x}) + t\tilde{x}) - p_1^H(0)F_v(p_1^H(0))\right] - 2Q_1^H + 2\tilde{x}$$

Combining everything, we find that

$$\frac{\partial R_1^H}{\partial c_2} = -\frac{p^*(\tilde{x})}{2t}[1 - F_v(p_1^*(\tilde{x}) + t\tilde{x})] + 2\tilde{x} - Q_1^H + \frac{1}{t}\left[p^*(\tilde{x}) - p^*(0)\right] + \frac{p^*(0)}{t}\left[1 - F_v(0)\right]$$

where we have used the fact that $\frac{\partial \tilde{x}}{\partial c_2} = \frac{1}{2t}$. A little algebra gives

$$\frac{\partial R_1^H}{\partial c_2} = \frac{p^*(0)}{t}\left[1 - F_v(0)\right] - \frac{p^*(\tilde{x})}{2t}\left[1 - F_v(p(\tilde{x}) + t\tilde{x})\right] - Q_1^H$$

Then we can substitute this expression into the one for $\frac{\partial P_1^H}{\partial c_2}$ to find that

$$\frac{\partial \log P_1^H}{\partial \log c_2} = \frac{c_2}{Q_1^H}\left[\frac{1}{t}\log\left(\frac{p^*(0)}{P_1^H}\right)[1 - F_v(p^*(0))] - \frac{1}{2t}\log\left(\frac{p^*(\tilde{x})}{P_1^H}\right)[1 - F_v(p^*(\tilde{x}) + t\tilde{x})] - \frac{Q_1^H}{P_1^H}\right]$$

where we again have made use of the log approximation. □

To show that pass-through is positive under competition requires further assumptions.

Proposition 8. *If* $\frac{2[1-F(c_2+t)]}{1-F\left(\frac{c_1+c_2+t}{2}\right)} - 1 > 0$*, then pass-through is positive* $\frac{\partial P_1^H}{\partial c_2} > 0$.

Proof. Now we use the bound that $Q_1^H < \tilde{x}[1 - F(p^*(\tilde{x}) + t\tilde{x})]$. Then we have that

$$\frac{1}{t}[c_2 + t - P_1^H][1 - F(c_2 + t)] + \frac{1}{2t}[P_1^H - c_1][1 - F(p^*(\tilde{x}) + t\tilde{x})] - \left(\frac{1}{2} + \frac{c_2 - c_1}{2t}\right)[1 - F(p^*(\tilde{x}) + t\tilde{x})]$$

This is equivalent to

$$(c_2 + t - P_1^H)\left(\frac{2[1 - F(c_2 + t)]}{1 - F\left(\frac{c_1+c_2+t}{2}\right)} - 1\right)$$

Now $c_2 + t - P_1^H > 0$, so if $\frac{2[1-F(c_2+t)]}{1-F\left(\frac{c_1+c_2+t}{2}\right)} - 1 > 0$, then pass through is positive. So the result holds. □

This restriction implies that there is sufficient slope to the 'demand curve' in the region of pricing exercised by firms. In particular, it requires that given the distribution of consumers, there is not too large a difference between the proportion that would buy at the (higher) price charged to the consumer charged to the nearest consumer ($c_2 + t$) and at the price charged to marginal consumer, plus transportation cost ($c_1 + \tilde{x} = \frac{c_1+c_2+t}{2}$). In particular, the former must be at least half as big as the latter. Note that in general, if demand for cement is particularly inelastic (as it is known to be), then this condition will easily be satisfied given the modest regional variations in cement prices empirically observed.

Lastly, whether or not positive pass through under competition contrasts to the collusive outcome depends on the shape of the monopoly price schedule in x. A stronger than necessary condition for weakly decreasing average monopoly price in competitor cost is that monopoly price is weakly decreasing in x. This is a condition satisfied by the exponential distribution, and also by the uniform. In these cases, among others, a test for collusion can be established as earlier.

Now we attempt to show that pass through is greater under competition when pass through is still weakly positive under collusion. Note that this requires that $\frac{\partial \log h}{\partial x} < 0$. Therefore, pass through into monopoly prices for each location is greater than 1, and by our previous results, $\tilde{x} < x^*$. To do this, we attempt to bound the various pieces making up the ratio of the pass through rates.

Proposition 9. $[1 - F_v(p^*(\tilde{x}) + t\tilde{x})] \geq [1 - F_v(p^m(x^*) + tx^*)]$.

Proof. We know that $x^* > \tilde{x}$, therefore the result holds since $p^M(x) \geq p^*(x)$. □

Proposition 10. *There exists* $\alpha > 0$ *such that if* $0 \leq -\frac{\partial \log h}{\partial x} \leq \alpha$, *then* $-\log\left(\frac{p^*(\tilde{x})}{P_1^H}\right) \geq \log\left(\frac{p^m(x^*)}{P_1^m}\right)$

Proof. We have already shown that in the case where $\frac{\partial \log h}{\partial x} = 0$ i.e. exponential values, then the inequality holds strictly since p_1^* is downward sloping. Therefore, by continuity, the result holds. □

This assumption about $\frac{\partial \log h}{\partial x}$ also ensures that pass through is at least weakly positive in the monopoly case. Finally, we need to show that $3Q_1^m > Q_1^H$.

Proposition 11. *(Approximately) If as before* c_1 *close to* c_2*, then* $3Q_1^m > Q_1^H$.

Proof. To be done. □

Corollary 1. *For* c_1 *close to* c_2 *and* $0 \leq \frac{\partial \log h}{\partial x} \leq \alpha$*, pass through of other's cost is greater under competition than collusion.*

Hence, our test for collusion holds generally for a situation where costs are not too different between competitors and demand is sufficiently inelastic.

C Appendix: Model Predictions with No Outside Good

Consider a model identical to that discussed in Section 5, but without an outside option, and the assumption that all consumers have valuation v of the good. In this case, $p_1^*(x) = \min\left(p_1^H, v - tx\right)$ and similarly for p_2^*. Assume $c_i < v$ sufficiently so that some consumers are charged p_i^H. Then the marginal consumer is still given by $\tilde{x}$, and without an outside option, it is trivial that $\partial P_1^H / \partial c_2 > 0$.

Suppose now that the firms collude, and that the market is covered. Then we have that

$$\begin{aligned} p_1^m &= v - tx \\ p_2^m &= v - t(1-x) \end{aligned}$$

and the marginal consumer $\tilde{x}$ is such that

$$\begin{aligned} \tilde{x} &= \arg\max_x \pi(x) \\ &= \arg\max_x \left[(v - tx - c_1)x + (v - t(1-x) - c_2)(1-x)\right]. \end{aligned}$$

This optimization yields $\tilde{x} = 1/2 + (c_2 - c_1)/(4t)$. Consider the perspective of firm 1 (by symmetry the conclusion will hold for firm 2 also). Its average price is given by

$$P_1^m = \frac{\int_0^{\tilde{x}} (v - tx)\, dx}{\tilde{x}}$$

so that

$$\frac{\partial P_1^m}{\partial c_2} = \frac{\frac{\partial \tilde{x}}{\partial c_2} \cdot (v - t\tilde{x}) \cdot \tilde{x} - \frac{\partial \tilde{x}}{\partial c_2} \cdot \int_0^{\tilde{x}} (v - tx)\, dx}{\tilde{x}^2} < 0.$$

The final inequality follows since $v - tx$ is strictly downward sloping in x, and so it must be that $\int_0^{\tilde{x}} (v - tx)\, dx > (v - t\tilde{x}) \cdot \tilde{x}$. Thus, the model without an outside good option unambiguously predicts a decrease in one plant's monopoly price. Intuitively, this is because as plant 2 becomes more inefficient, plant 1 takes over some consumers at the margin to which it must charge a lower price than for any other of its previous consumers, with inframarginal prices remaining unchanged.

D Appendix: Spatial Aspects of the Theory

In this section, we consider some extensions to the basic model by explicitly including spatial data.

D.1 Different distances between competitors

A complication with the basic theory is the assumption of a common distance between competitors. In fact, there is variation in the spatial distribution of plants. These differences are important to consider in conducting the empirical exercises. Suppose per true unit of distance the cost of transportation is τ. Then if we normalize a market of length λ to have length equal to 1, the total cost of traversing the market is $\lambda\tau$. Thus, if λ is normalized to 1, it must be that t, the normalized transportation cost, is such that $t = \lambda\tau$. Thus, firms with competitors further away effectively have a higher t.

Unfortunately, it is harder to say what the effect of changes in t are as conclusively as the effect of changes in marginal costs for a general distribution f_v. Under our assumed exponential distribution for collusion, the average price charged should not depend on t. On the other hand, the model provides significant evidence that under competitive pricing, we might expect the average price to be increasing in t. The first derivative of $p_1^H(x)$ with respect to t is $1 - 2x$. This is positive so long as $x < 0.5$, which will be true for a vast majority of the market if firms have approximately equal marginal costs (recalling equation (2)). Even under competitive pricing, however, firms may charge monopoly price for some subset of consumers, so it is difficult to make a conclusive statement. It can be shown to be true analytically under the exponential distribution.

This provides a different sort of test for collusion

Prediction 3. *Under competitive pricing, price should be increasing in the average distance to the nearest competitor. There is no effect of transportation costs of pricing under collusion.*

We attach less significance to this prediction because our distance measure is somewhat crude, as it is the direct point-to-point distance, which might have very little to do with the actual distance firms must cover.

This spatial aspect is potentially important given one peculiar feature of the market at the time, which is the basing point pricing scheme that was in effect. This allowed firms in a particular area some scope in coordinating on freight rates and consequently makes it easier for firms to collude on mill prices. Since this was in effect well before the NRA, and continued until it was struck down by the Supreme Court as anti-competitive in *FTC v. Cement Institute* (1948), it is in principle feasible that this could eliminate any competitiveness prior to the NRA. There was much debate at the time and more recently on the competitive nature of this pricing strategy. Machlup (1948) offers arguments against the system and Haddock (1982) gives arguments why it might be benign. Karlson (1990) and Karlson (1997) address the phenomenon of base points around the time of our study; the former finds little evidence to suggests that competitive forces determined the location of base points, while the latter finds little effect of base points on prices.

D.2 Dealing with Two Dimensions

The model so far has dealt with competition along a line, but plants are located along 2-dimensions. The intuition outlined readily applies to 2-dimensional plant locations and multiple neighbors: firms pricing, if competitive, depends on distance from, and marginal cost of, its competitor plants—as well as own marginal cost. One simplification of this model is that firms' markets are very clearly demarcated: there is no crosshauling across markets.

Based on market maps from around the time of the Great Depression, this doesn't seem unreasonable as a simplification. Figure 5 shows for a plant located at Greencastle, Indiana, in the inner circular area, the area of freight advantage (where it was cheaper for this plant to ship, compared to any other plant) and in the outer circle the area typically served. This diagram does not make it clear where the bulk of shipment occurred, but if one assumes that it occurred in the inner circle, then our approach, subject to similar marginal costs between firms, closely approximates the area depicted.

Figure 6 gives a depiction of a simulated 2-dimensional version of our model, based on the more general model in Chicu (2012). Here, the independently owned plant locations are denoted by large spots. Consumers offered a competitive price are denoted by spots, while consumers offered a monopoly price are denoted by crosses: as expected, only consumers with the least attractive alternative options are charged monopoly prices. Of course, these consumers may also choose the outside option: the color of the spots denotes which plant consumers *would* buy from if they chose to buy a unit of cement.

The question is how to turn the implications of the more tractable one-dimensional model into a reduced form regression that captures the richness of interactions in two dimensions. To do so necessarily means abstracting from a more fully specified structural model. In our one-dimensional model, what we suggest is that for the two firms in the top right corner of Figure 6, all that matters for pricing decisions is the actions or costs of the other. Obviously this is a simplification: each firm in this figure has an impact on pricing decisions of both of the others, for at least some consumers being targeted. However, the closest firm is the one that has the largest impact: in this figure the highest firm is constrained by the pricing decisions of the firm on the right for over 65% of its consumers, and the rightmost firm is similarly constrained for nearly 70% of its consumers. Thus, we believe it is still useful to take and test the implications of a one-dimensional model despite a necessarily 2-dimensional setting.

E Appendix: A Parametric Test for Truncation

This section develops a parametric test for truncation of the wage distribution in the presence of measurement error. To reiterate, we observe before the NRA the (log) wage Z where

$$Z = W + \varepsilon$$

where both W, ε are distributed normally with unknown variances $\sigma_W^2, \sigma_\varepsilon^2$. We think of W as being the true wage while ε is classical measurement error assumption with a mean of 0. After the NRA under the null that plants follow the minimum wage regulation at wage τ, we observe

$$Z' = \tau + 1[W' - \tau > 0](W' - \tau) + \varepsilon$$

where W' is a normal with unknown mean μ'_W and the same unknown variance as W, σ_W^2. Note that this is a slightly different notation from that used earlier. Now, W' is a new normal distribution for the post-NRA period, as distinct from a truncated version of W. We assume the same structure for measurement error as well. Then it is easy to write down the log likelihood for pre-NRA period as

$$L_{pre} = \sum_{i \in 1929} \phi\left(\frac{z_i - \mu_W}{\sqrt{\sigma_W^2 + \sigma_\varepsilon^2}}\right) - \frac{N_{1929}}{2}\log(\sigma_W^2 + \sigma_\varepsilon^2)$$

where N_{pre} is the number of observations from the pre-NRA period. The likelihood for NRA period is slightly more involved. Let's write

$$\begin{aligned} Pr(Z' < z) &= Pr(\tau + 1[W' - \tau > 0](W' - \tau) + \varepsilon < z) \\ &= Pr(\tau + \varepsilon < z)Pr(W' < \tau) + Pr(\varepsilon + W' < z | W' \geq \tau)Pr(W' \geq \tau) \end{aligned}$$

where we have used the fact that W', ε are independent. To evaluate this probability, fix a value for ε, say y, then we can write

$$Pr(\varepsilon + W' < z | W' \geq \tau)Pr(W' \geq \tau) = \int_{-\infty}^{\infty} Pr(W' < z - y | W' \geq \tau)\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy$$

where we have again used the assumption that W' and ε are independent. Now use Bayes' rule to find

$$Pr(W' < z - y | W' \geq \tau)Pr(W' \geq \tau) = \frac{Pr(\tau \leq W' < z - y)}{Pr(W' \geq \tau)}Pr(W' \geq \tau)$$

Then we can cancel the term $Pr(W' > \tau)$ so that

$$Pr(\varepsilon + W' < z | W' \geq \tau)Pr(W' \geq \tau) = \int_{-\infty}^{\infty} Pr(\tau \leq W' < z - y)\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy$$

Using the assumption of normality, this can be written as

$$= \int_{-\infty}^{\infty} \left[\Phi\left(\frac{z - y - \mu'_W}{\sigma_W}\right) - \Phi\left(\frac{\tau - \mu'_W}{\sigma_W}\right)\right]\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy$$

The second term in square brackets does not depend on y so we can write further

$$\int_{-\infty}^{\infty} \Phi\left(\frac{z - y - \mu'_W}{\sigma_W}\right)\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy - \Phi\left(\frac{\tau - \mu'_W}{\sigma_W}\right)$$

where we have used the fact that $\int_{-\infty}^{\infty} \phi\left(\frac{y}{\sigma_\varepsilon}\right) dy = 1$. The first integral can be written as a double integral

$$\int_{-\infty}^{\infty} \Phi\left(\frac{z - y - \mu'_W}{\sigma_W}\right)\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy = \int_{-\infty}^{\infty}\int_{-\infty}^{z} \phi\left(\frac{\hat{z} - y - \mu'_W}{\sigma_W}\right)\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy d\hat{z}$$

We now reverse the order of integration and attempt to integrate out y first. Focusing on this integral, we need to evaluate

$$\int_{-\infty}^{\infty} \phi\left(\frac{\hat{z} - y - \mu'_W}{\sigma_W}\right)\phi\left(\frac{y}{\sigma_\varepsilon}\right) dy$$

We now combine the two normal pdfs by completing the square and apply some relatively straightforward algebra. Writing out the integrand, we have

$$\frac{1}{\sigma_W \sigma_\varepsilon 2\pi} exp\left(-\frac{1}{2}\left[\frac{(y-\hat{z}-\mu'_W)^2}{\sigma_W^2}+\frac{y^2}{\sigma_\varepsilon^2}\right]\right)$$

Expand the terms in the exponent of the exponential function as

$$-\frac{1}{2}\frac{\sigma_\varepsilon^2 y^2 - 2(\hat{z}+\mu'_W)y\sigma_\varepsilon^2 + (\hat{z}+\mu'_W)^2\sigma_\varepsilon^2 + y^2\sigma_W^2}{\sigma_W^2\sigma_\varepsilon^2}$$

Now let

$$a = \frac{(\hat{z}+\mu'_W)\sigma_\varepsilon^2}{\sigma_W^2+\sigma_\varepsilon^2}$$

$$b^2 = \frac{\sigma_W^2\sigma_\varepsilon^2}{\sigma_W^2+\sigma_\varepsilon^2}$$

then the integrand can be simplified to

$$\frac{1}{\sigma_W \sigma_\varepsilon 2\pi} exp\left(-\frac{1}{2}\left[\frac{\hat{z}+\mu'_W}{\sigma_W}\right]^2\right) exp\left(-\frac{1}{2}\frac{y^2-2ay+a^2-a^2}{b^2}\right)$$

Rearrange to find

$$\frac{b}{\sigma_\varepsilon\sigma_W\sqrt{2\pi}} exp\left(-\frac{1}{2}\left[\frac{\hat{z}+\mu'_W}{\sigma_W}\right]^2-\frac{a^2}{b^2}\right)\frac{1}{b\sqrt{2\pi}} exp\left(-\frac{1}{2}\frac{(y-a)^2}{b^2}\right)$$

Note that integrating the last two terms against y over all the reals evaluates to 1 since it is simply the normal pdf with mean a and standard deviation b. Some further algebra reveals that the remaining terms can be combined into

$$\frac{b}{\sigma_\varepsilon\sigma_W\sqrt{2\pi}} exp\left(-\frac{1}{2}(\hat{z}+\mu'_W)^2\left[\frac{1}{\sigma_W^2}-\frac{\sigma_\varepsilon^4}{b^2}\right]\right)$$

It is easy to check the following two equalities

$$\frac{1}{\sigma_W^2}-\frac{\sigma_\varepsilon^4}{b^2}=\frac{1}{\sigma_\varepsilon^2+\sigma_W^2}$$

$$\frac{b}{\sigma_W\sigma_\varepsilon}=\frac{1}{\sqrt{\sigma_W^2+\sigma_\varepsilon^2}}$$

With all of this in place, the integrand can be reduced to

$$\frac{1}{\sqrt{(\sigma_W^2+\sigma_\varepsilon^2)2\pi}} exp\left[-\frac{1}{2}\left(\frac{\hat{z}+\mu'_W}{\sqrt{(\sigma_W^2+\sigma_\varepsilon^2)}}\right)^2\right]$$

This means that

$$\int_{-\infty}^{\infty}\int_{-\infty}^{z}\phi\left(\frac{\hat{z}-y-\mu'_W}{\sigma_W}\right)\phi\left(\frac{y}{\sigma_\varepsilon}\right)dyd\hat{z}=\Phi\left(\frac{z+\mu'_W}{\sqrt{\sigma_\varepsilon^2+\sigma_W^2}}\right)$$

Putting everything together, we conclude that

$$Pr(Y+W'<z|W'\geq\tau)Pr(W'\geq\tau)=\Phi\left(\frac{z+\mu'_W}{\sqrt{\sigma_\varepsilon^2+\sigma_W^2}}\right)-\Phi\left(\frac{\tau-\mu'_W}{\sigma_W}\right)$$

Returning to equation 7 and using the above proposition, we have

$$Pr(Z'<z)=\Phi\left(\frac{z-\tau}{\sigma_\varepsilon}\right)\Phi\left(\frac{\tau-\mu'_W}{\sigma_W}\right)+\Phi\left(\frac{z+\mu'_W}{\sqrt{\sigma_\varepsilon^2+\sigma_W^2}}\right)-\Phi\left(\frac{\tau-\mu'_W}{\sigma_W}\right)$$

The likelihood for observation z_i is the derivative of the previous expression with respect to z

$$L_{1935}(z_i)=\frac{1}{\sigma_\varepsilon}\phi\left(\frac{z_i-\tau}{\sigma_\varepsilon}\right)\Phi\left(\frac{\tau-\mu'_W}{\sigma_W}\right)+\frac{1}{\sqrt{\sigma_\varepsilon^2+\sigma_W^2}}\phi\left(\frac{z_i+\mu'_W}{\sqrt{\sigma_\varepsilon^2+\sigma_W^2}}\right)$$

Combining everything the log-likelihood can be written as

$$L=L_{1929}+\sum_{i\in 1935}\log L_{1935}(z_i)$$

It is then simple enough to run a specification test to check whether the model is misspecified. If it is not rejected, then it provides some evidence for truncation under the NRA.

F Appendix: Figures and Tables

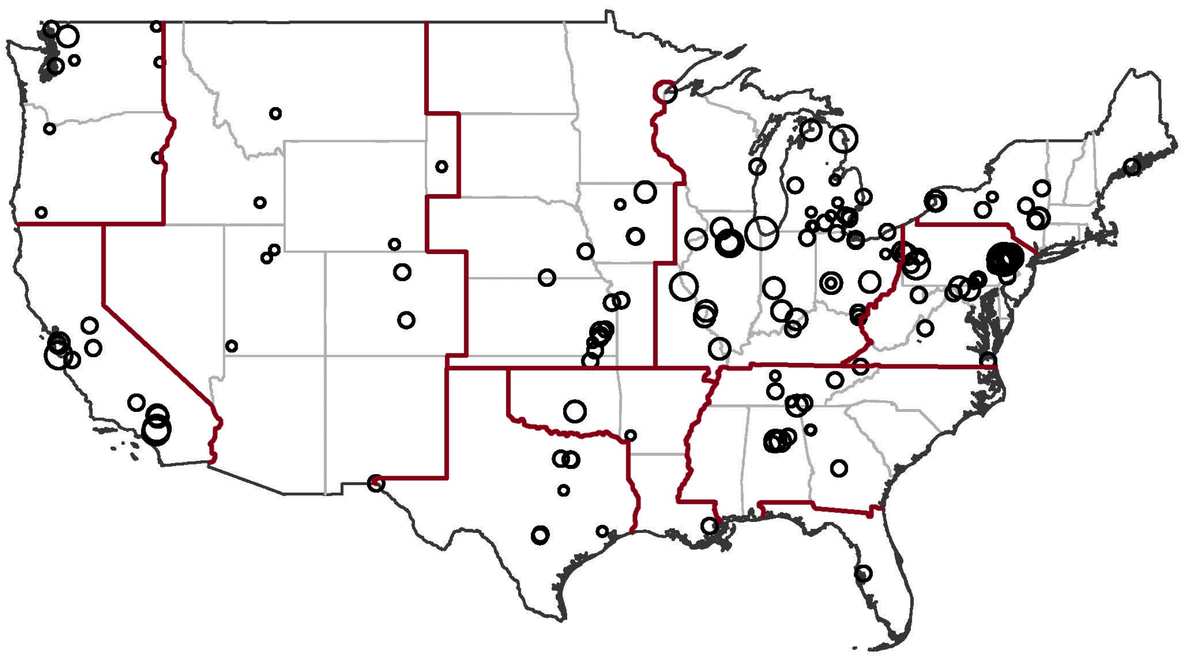


Figure 1: Map showing plant locations for 1929, with circle sizes indicating plant capacity. Markets are distinguished by bold lines.

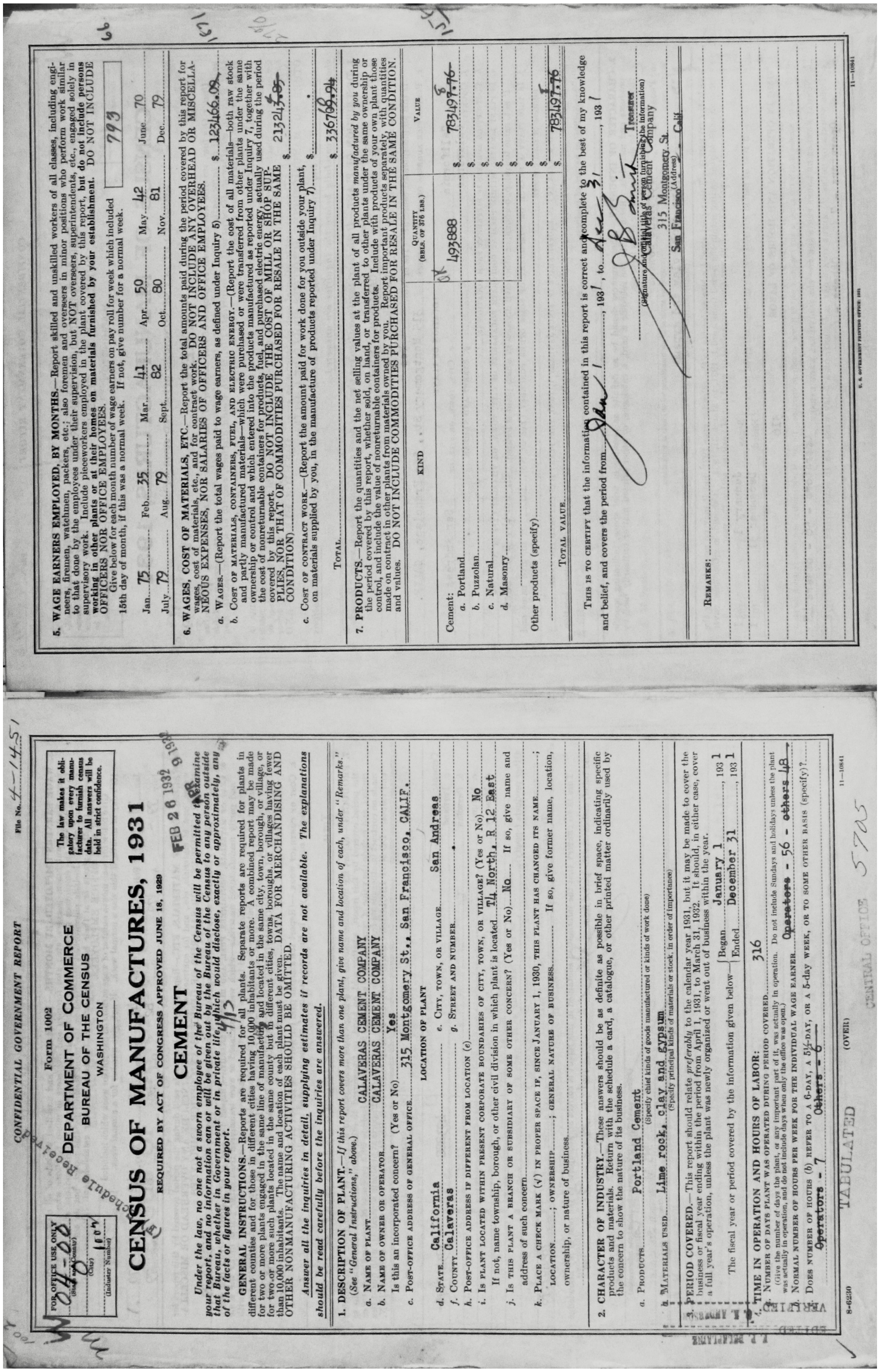


Figure 2: Example of one of the manufacturing schedules for 1931.

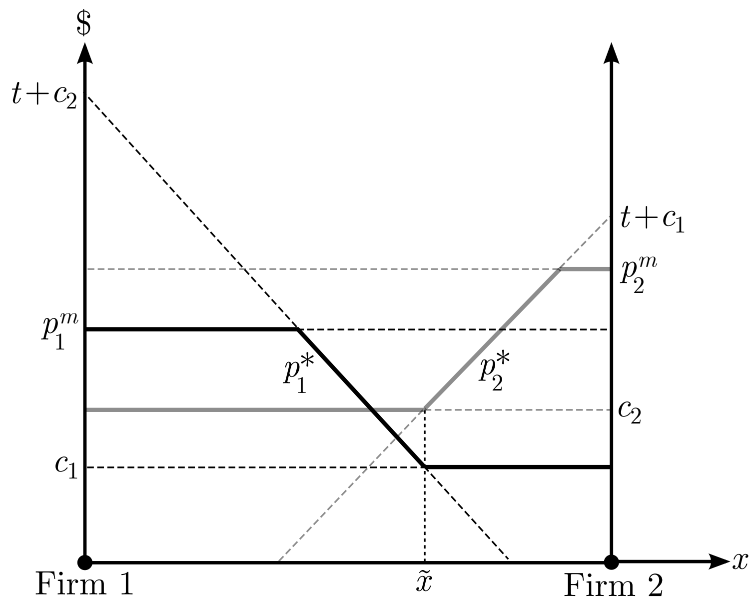


Figure 3: The optimal pricing schedule under the exponential distribution. The pricing functions of firm 1 are shown in black, and those of firm 2 in gray. The bold lines are the prices offered to any given consumer located at x. The diagonal lines are the prices constrained by rival marginal cost ('competitive' prices, $p_1(x)$), and monopoly prices are shown as constant in x, in accordance with an exponential distribution of consumer valuations.

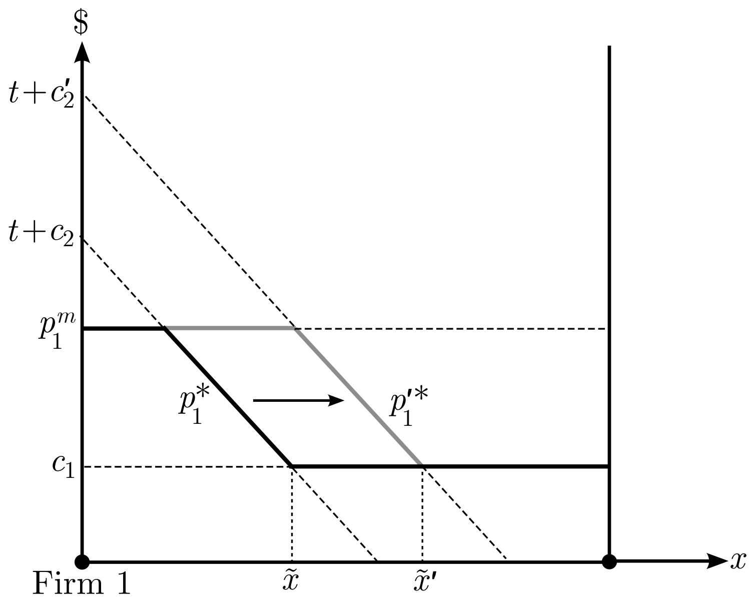


Figure 4: This diagram shows how average price charged by firm 1 can increase if there is an increase in the marginal cost of firm 2, assuming that firms do not collude. When c_2 increases, this shifts outward the line representing 'competitive' prices, $p_1^H(x)$. This means that there is a set of consumers that are now charged a higher price, as the optimal pricing schedule now shifts outwards.

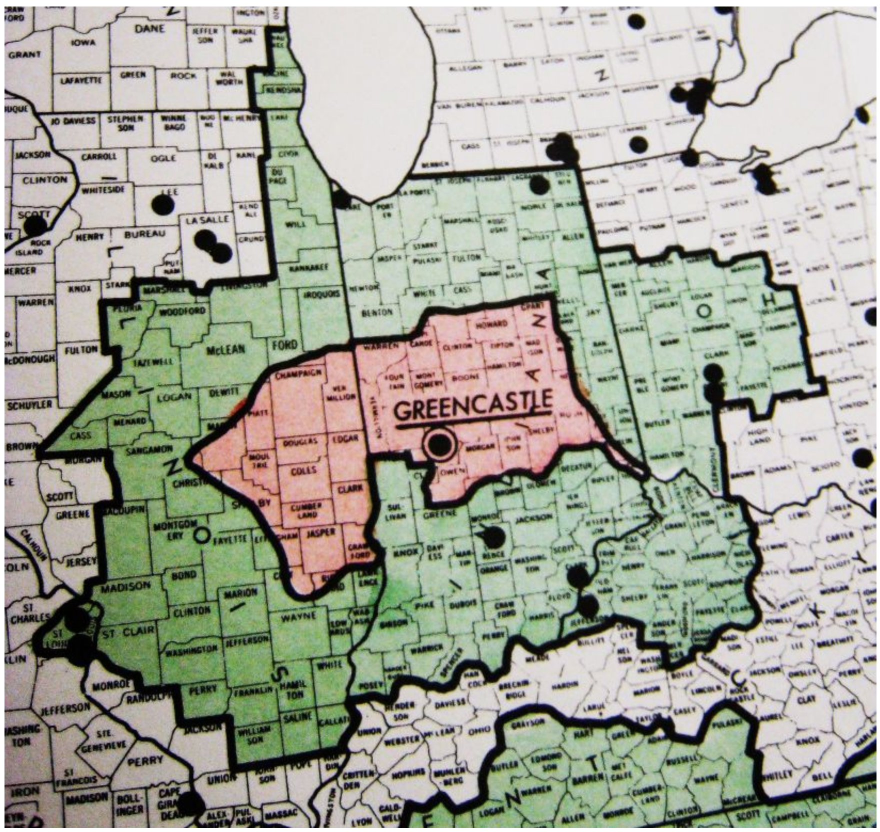


Figure 5: Market area of the Lone Star mill at Greencastle, Indiana. Inner area is area of freight advantage, outer area includes normal sales area, and black dots are competitor mills.

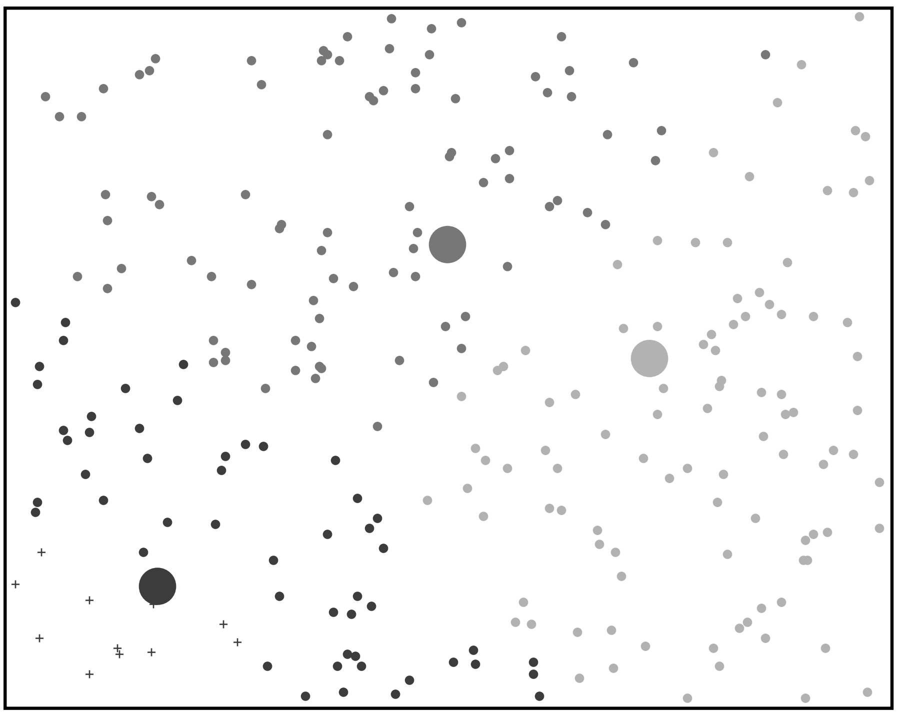
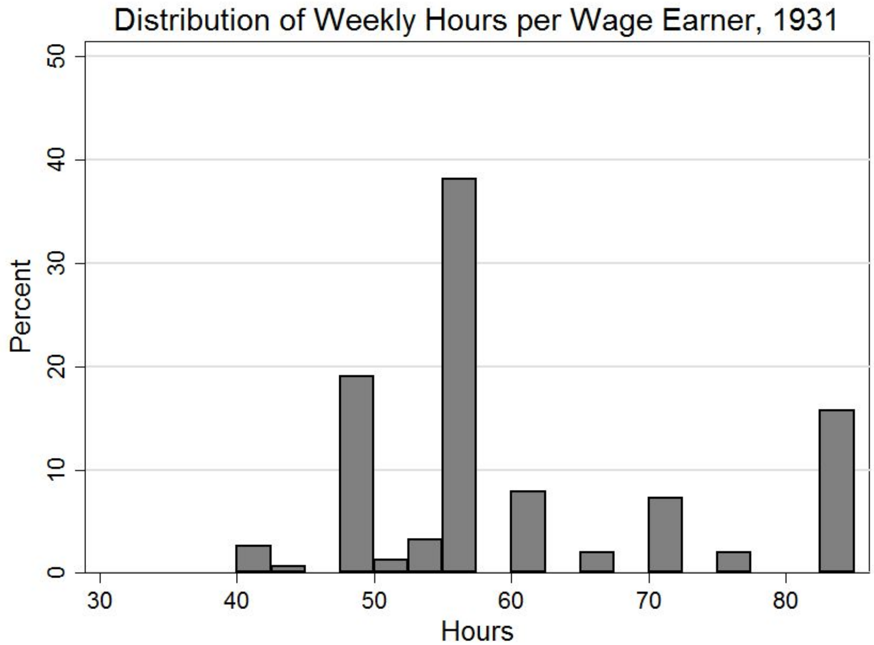


Figure 6: Simulated 2-dimensional market equilibrium. Large spots denote plant locations, small spots denote consumers offered the 'competitive' price, and crosses denote consumers offered the monopoly price. Colors indicate which plant consumers would choose if not the outside option.



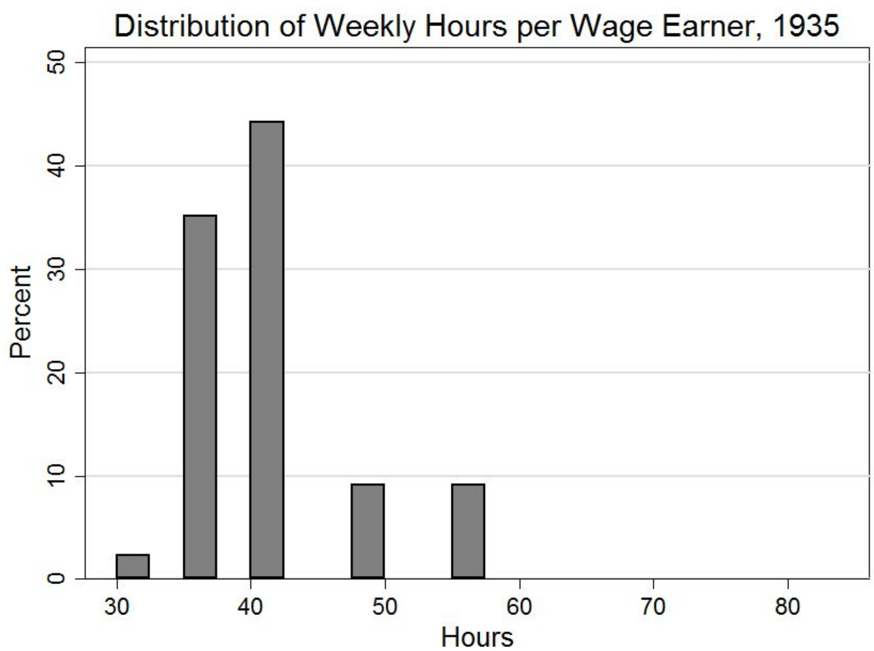


Figure 7: Distribution of hours worked per week for 1931 and 1935.

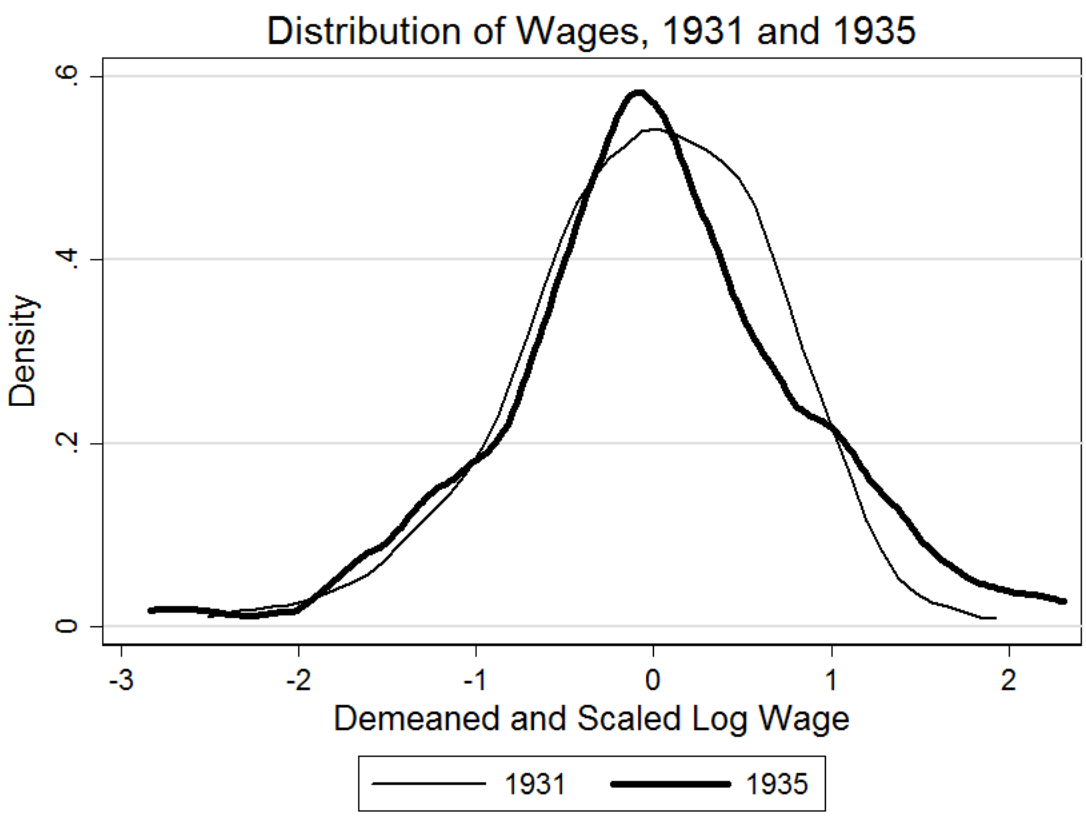


Figure 8: Distribution of log wages for 1931 and 1935. Wages are demeaned by their yearly average and scaled by their standard deviation to ease comparison.

	Price	Quantity	Capacity	Wage	Entry	Exit
Mean	1.46	723086	4819.83	.51	.01	.05
Median	1.44	566659	3516.85	.48	-	-
Std. Dev.	.35	656973	4000	.34	-	-
Min	.75	11970	1000	.05	-	-
Max	4.20	7342167	30000	4.56	-	-
N	598	598	604	451	607	461

Table 1: Summary statistics of various variables over all 4 census years. Prices and quantities are for barrels of cement and prices are in nominal dollars. Wages are not available for 1933. Capacities are daily capacities multiplied by $.91 \times 365$ to give our estimates for annual capacities. Entry and exit are indicators for whether a plant enters the sample or exits.

Firm Name	Avg. Plants	Avg. Mkts	Avg. Plants per Mkt
Lehigh Portland Cement Co.	12.25	10	1.23
Lone Star Cement Co.	9.5	9	1.06
Universal-Atlas Cement Co.	9	9	1
Alpha Portland Cement Co.	8.5	8	1.06
Pennsylvania-Dixie Cement Corp.	7	5	1.4
Medusa Portland Cement Co.	6.75	5.5	1.23
Ideal Cement Co.	6.5	3	2.17
North American Cement Corp.	3	2	1.5
Southwestern Portland Cement Co.	3	3	1
Trinity Portland Cement Co.	3	2	1.5

Table 2: Characteristics of the largest 10 firms in the industry by average plant count. Averages are taken across the four years in which we have data.

	Log Price						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\log AVC$	0.204***	0.159**	0.214***	0.207***	0.223***	0.202***	0.101
	(0.0429)	(0.0623)	(0.0313)	(0.0433)	(0.0521)	(0.0423)	(0.117)
Distance	0.0193***	0.0400	0.0229***	0.0195***	0.0181***	0.0196***	1.530***
	(0.00612)	(0.0319)	(0.00579)	(0.00609)	(0.00645)	(0.00608)	(0.256)
$\log AVC_n$ (a)	0.0934**	0.0650	0.107***	0.0936**	0.0921**	0.0775**	0.175*
	(0.0390)	(0.0410)	(0.0360)	(0.0391)	(0.0384)	(0.0367)	(0.0954)
$\log AVC_n * NRA$ (b)	-0.0953**	-0.100**	-0.0975**	-0.0960**	-0.182***	-0.160***	-0.0229
	(0.0452)	(0.0485)	(0.0493)	(0.0455)	(0.0564)	(0.0535)	(0.0863)
Excess capacity				-0.0508			
				(0.0370)			
Firm fixed effects?	Yes	Yes	No	Yes	Yes	Yes	Yes
Plant fixed effects?	No	Yes	No	No	No	No	No
p-value (a) + (b)	0.970	0.503	0.834	0.961	0.105	0.134	0.152
N	566	566	566	566	445	566	41
R^2	0.575	0.616	0.398	0.577	0.584	0.578	0.698
NRA Definition	1933	1933	1933	1933	Drop 1933	1935	1933
Sample	All	All	All	All	All	All	Monopolies

Table 3: Effect of own and neighbor's cost on log price. Standard errors are clustered at the plant level. Excess capacity is an indicator for whether output is less than 90% of plant's capacity. All regressions include year fixed effects and 1% tails of own and neighbor's AVC are trimmed. The last column restricts attention to plants that are effectively monopolies meaning they have no competitors within 200 miles. $*$ significant at 10%. $**$ significant at 5%. $***$ significant at 1%.