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Does Foreign Competition Spur Productivity? Evidence From Post WWII U.S. Cement Manufacturing*

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ABSTRACT

In the mid 1980s, the U.S. cement industry faced a surge in foreign imports. Whereas imports had amounted to almost nothing for most of the 20th century, imports since the mid 1980s are on the order of 20-30 percent of U.S. production. We show that productivity (measured by TFP) in the industry was falling during the 1960s and 1970s, but that following the import surge, productivity has reversed course and is growing strongly. When foreign competition was weak, then, productivity fell. When it was strong, productivity grew robustly. We explore the reasons for the productivity surge. We argue that a large share of the productivity gains resulted from significant changes in management practices at plants.

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1. Introduction

Does competition spur productivity? And, if so, what are the sources of productivity growth? These are old and important questions. We address them in the context of the post-WWII U.S. cement industry. This industry faced a dramatic surge in competition in the early 1980s. This resulted from a large and unprecedented increase in imports into the United States due, in part, to improvements in technology to transport cement. Whereas imports often amounted to no more than one or two percent of production in the pre-1980 period, in the mid 1980s they rose to 25 percent of production.

In this industry, the answer to the first question above is clear: Increased competition led to a surge in industry productivity. Following the increase in imports, industry TFP grew rapidly. This was in contrast to the previous two decades when TFP was falling. In fact, TFP declined from the late 1950s until the early 1980s, dropping over 10 percent. After the surge in imports in the mid 1980s, TFP grew about 35 percent from the mid 1980s until 1997. When foreign competition was weak, then, productivity fell. When it was strong, productivity grew robustly.

What drove the 1980s productivity gains? The surge in competition led to major investment in new management practices at manufacturing plants in this industry. In particular, the industry went from a situation were management was highly curtailed in how it could run plants before the import surge, to one where management had extensive control over plant decisions. We think these changes in management practices were the major reason for the productivity surge.

The view that changes in management practices are analogous to investment, and can have large productivity consequences, dates to at least Ichionowski and Shaw (1995). Schmitz (2005) shows that changes in management practices in U.S. iron-ore manufacturing, again in response to foreign competition, led to major productivity improvements in that industry. More recently, Bloom and Van Reenen (2007) have found, in a survey across firms and countries, that "poor management practices are more prevalent when product market competition is weak."

Our conclusion that changes in management practices were the major reason for the 1980s productivity surge will rely on two types of evidence. First, we'll provide direct evidence that changes in management practices were important for productivity. Second, we'll provide indirect evidence by showing that other sources of productivity gain seem not to have been as important.

Consider first the direct evidence. Immediately after WWII, nearly all plants in the industry were unionized, and the vast majority of these unionized-plants belonged to the Cement, Lime and Gypsum Workers Union (CLGWU). The CLGWU was a weak union at this point, with very slim contracts (3 or 4 pages). A watershed year was 1957, when the CLGWU called a national strike that idled over half the plants in the country. The union won the strike, and from this point until the early 1980s, the union gradually and significantly expanded its control of the workplace (for a history of the CLGWU see Northrup (1989)). Union dominance had become such that in 1978 the president of the CLGWU could boast that

> "No other industrial workers in the country can point to contracts that impinge on and restrict the rights of management as much as cement contracts do."[1]

While the president could make that boast in 1978, by 1984 the CLGWU had disintegrated (in the words of Northrup). From 1984 on, most cement plants were either non-union, or operated under contracts that put far fewer restriction on the rights of management.

To show that changes in management practices, in particular, changes in the rights of managers to direct plants, were important, we have gathered the contracts over time for a large number of cement plants (90 thus far, and counting). We will show the types of clauses in these contracts, argue they reduce productivity, and then show when the clauses began to appear (and disappear) in the contracts. We'll show that the changes in the contracts over time were closely related to changes in productivity over time.

[1] This quote is from the *Voice*, the main publication of the CLGWU. The date of the issue is October, 1978.

We examine four provisions in CLGWU-contracts. (1) *Seniority rights.* Contracts provided very strong seniority rights. For example, if worker $x's$ job was eliminated because of, say, reduced production, worker x could take the job of *any* less senior person *anywhere* in the plant. Worker x was not even required to be able to perform the job at that time, but only in a reasonable amount of time; (2) *Job protection.* No employee could be terminated as a result of purchases of new equipment or introduction of new production methods; (3) *Jobs "Belong" to Departments.* Contracts gave the rights to specific jobs (say repairing fans) to certain groups of workers. Hence, if a job needed doing, and none of these workers were available, the job would wait. (4) *Contracting Out.* Contracting out protections essentially forbade outside contractors. It was as if there were infinite tariffs at the plant gate.

We'll argue that these clauses reduced productivity, and not only labor productivity, but also capital, materials, and energy productivity. These clauses began appearing in CLGWU-contracts in the early 1960s. For example, the contracting-out clause first appeared in our contracts in 1963, and by 1965 was in all of them. The job-protection clause did not appear until 1965, but then it appeared in nearly all contracts. All four clauses essentially disappeared in the mid 1980s.

We'll then show there was a close connection between the strength of the union and the performance of industry-level productivity. We'll discuss the productivity of a number of inputs, including capital, electricity, fuel and labor. We'll use data from a number of sources, including NBER, Census of Manufactures, Portland Cement Association (PCA), and the United States Geological Society (USGS). For some inputs, then, we'll have multiple sources.

We'll first document that while productivity was growing in all inputs after WWII, partial productivities stopped growing, and even began to fall for some inputs, after the 1957 strike. There was one exception: labor productivity. It continued to grow until 1965, after which it stopped growing. The year 1965 coincided, of course, with the introduction of the job protection clause.

The mid 1970s was, of course, the "initial" energy crisis, and the industry made major investments in new fuel-efficient equipment in response to the crisis. But, luckily for us, we are able to observe the performance of the industry for 15 years from the time of the 1957 union-victory to the energy crisis. As we said, while all partial productivities were growing before 1957, all had stopped growing, and some were falling, for at least a decade prior to the crisis.

With major investments in new fuel-efficient equipment during the crisis, fuel productivity began to grow in the mid 1970s, though it was the only partial productivity to do so.

When imports came in the early 1980s, and contracts were changed, then all partial productivities began to grow. Fuel productivity continued its growth and, interestingly, it grew faster in the 1980s than the 1970s.[2]

The close connection between changes in union strength (as measured by changes in clauses) and changes in industry productivity is evidence for the hypothesis that the 1980s productivity surge was driven by changes in management practices.

How about other possible sources for the surge? With increased competition, and falling prices, one expects very inefficient plants to be driven from the market — the selection effect. Below we'll discuss how important selection may have been in the 1980s increases in each partial productivity.

We first consider labor productivity, and whether the closing of low labor-productivity plants was a major source of gain. We'll show that in the 1982-87 periond of strong labor productivity growth, the "within-plant" plant share amounted to nearly 75 percent of overall growth. Hence, the growth was primarily at the continuing plants, and exit was at most 25 percent of growth. Below we'll discuss the importance of selection for gains in other partial productivities, but at this point our data is not good enough to make strong conclusions.

The increase in competition from imports varied by region. The increase in competition was

[2] We are also able to break the total industry into two sub-industries based on the kiln technology used at plants, wet or dry. We then look at partial productivities in these two sub-industries, and find the same patterns as we did in the total industry.

greater for plants that were located near deep water ports, or were near inland waterways. So, we can ask: Did the regions facing the greatest increase in competition have the greatest productivity gain? and, if so, what were the reasons for differences in productivity gains across regions? While its relatively easy to classify regions by the extent of foreign competition (by, say, the level of imports into relevant ports), its more difficult to develop measures of regional productivity (because of, among other things, disclosure concerns).

We have measures of regional energy productivity from the PCA, though they stop in 1985. While the big and sustained surge in imports only started in the early to mid 1980s, there was an initial surge in 1978 and (especially) 1979. We can use the PCA regional energy data to see if the regions experiencing a surge in imports in this period, like California, had greater energy productivity growth than the nation over 1980-85. And they did. We'll also present some regional labor productivity evidence showing California had greater labor productivity growth than the nation.

Why did productivity growth differ across regions? Were there differences across regions in how extensively management practices were changed? We have not found a contract in a region where imports surged that was not changed significantly. We have found a few contracts that changed little in areas where the threat of imports was not large. But, as we discuss below, most contracts were changed. Management across the country invested in these changes. So, while there may be differences across regions in contract changes, and in the extent of unionization, it will take more work to characterize the differences. In particular, we cannot say at this time that California changed its contracts more than other regions (though it may be true).[3] We do know that California increased it investment in physical capital very significantly following the 1979 import surge.

Another approach to exploring the impact of changes in management practices would be to

[3] There are some states in the East where a few plant contracts changed very little until the middle 1990s. Interestingly, these plants are in regions that faced less increased competition than other plants. Also, interestingly (see below), these plants were not bought by foreign firms.

use panel regressions, asking how differences in contract changes across plants in the 1980s were related to differences in productivity growth. As the above discussion highlighted, it will take more work to characterize differences in contract changes. But there was another major development in the U.S. cement industry during the 1980s and 1990s, which we'll argue was related to managment changes, and might help in constructing panel regressions. During this period, there was a large increase in foreign ownership of domestic cement plants. Foreign ownership was important for two reasons. First, foreign ownership added more pressure for work rule changes as new foreign owners threatened to import cement from their own plants overseas if work rules were not changed. Second, foreign owners likely changed plant managers, making it easier to change work practices. So, foreign ownership and changes in management practices go hand-in-hand, and we may be able to use changes in a plant's foreign ownership status as another proxy for management changes.[4]

Regarding related literature, there are a large number of recent studies examining the impact of unilateral trade liberalization on manufacturing productivity (see references). These studies have found significant "within-plant" productivity gains. An advantage of these studies relative to our analysis is that they analyze a wide set of industries. But there are plusses to our approach as well. By studying a particular industry in detail, we have hope to recover the mechanism that drives the within-plant growth. Uncovering the mechanisms is essential for the development of theory.[5]

The facts we are developing here are somewhat anomalous. Why make new investments in management practices in the 1980s when the domestic industry faced a possible severe shrinkage, and not earlier? One answer is in Holmes, Levine and Schmitz (2008). They argue that firms may face problems integrating new technology or investments, that they may face switchover disruptions. Hence, upon adoption, firms may initially produce below pre-adoption levels. One cost of adoption,

[4] As another way to estimate the impact of management practices, we could try to exploit the differences across plants in the date at which contract changes were introduced in the 1960s. Again, this may be difficult since plants often adopted together.

[5] Another advantage is that we can measure output (and many inputs) in physical units. When real output is calculated using price deflators, serious measurement issues arise.

then, is the opportunity cost of lost profits on these lost sales. These costs are larger the higher is the price. Real cement prices fell nearly 40% over the 1980s (see below), so this dimension of adoption costs fell dramatically.[6]

2. The Surge in Competition and Industry Productivity

In this section we show that there was a dramatic increase in competition in the mid 1980s. We then present evidence on the movements of industry TFP before and after this surge.

A. Competition surges in early 1980s

For most of the 20th century, U.S. cement manufacturers faced very little threat of import competition. In Figure 1, we plot the imports of cement (and cement plus clinker) as a fraction of U.S. cement production from 1918 till 2003.[7] Imports were a very small share of production until the 1970s. The increase in the early 1970s is often attributed to the wage and price controls of that period. The increase in 1979 was (in retrospect) the start of a new era, where imports would come from Australia and Japan (as they did in 1979), and other far-flung nations.

In the 1980s, imports surged to nearly 25 percent of production. There are a number of factors cited for the surge in imports, including new and improved technology to transport cement (see, e.g., Dumez and Jeunemaitre (2000)).[8]

The 1980s surge in imports constituted a significant competitive threat to many U.S. cement producers. Imports were offered for steep discounts relative to domestic cement. As a result, U.S. cement prices fell significantly over the course of the 1980s. The average price of a ton of cement (in 1998 dollars) was $112 in 1980 and only $69 in 1990 (USGS website).[9]

[6] One possible difficulty in adopting new pratices in this industry was, of course, resistance from the union.

[7] Clinker is an intermediate product that is made into cement. More on this below.

[8] The sharp drop in imports in the early 1990s was the result of anti-dumping duties being levied on imports from some countries.

[9] What was the state of domestic competition in the period before the import surge? U.S. antitrust authorities believed that the industry engaged in non-competitive practices. More importantly, its clear that the union had significant power and was a source of non-competitive behavior in the industry.

B. Industry Productivity surges as well

In this section, we begin looking at the relationship between the state of competition in the industry and the industry's productivity. Measures of industry productivity are available from the NBER Manufacturing Data Base (see Bartelsman and Gray (1996) for a description of this data). This data set provides estimates of real output, real energy use, real material use, labor input and capital stock. Bartelsman and Gray also calculate an industry TFP measure based on a gross output production function.

In Figure 2, we plot TFP (1987=1) in the U.S. cement industry over the period 1957-96. From the late 1950s until the mid 1980s, there was a decline in industry TFP. Since the early 1980s, TFP has grown significantly. TFP bounces around a lot, but a conservative statement is that productivity declined about 10 percent in the first period (from roughly .95 to roughly .85), and then grew about 35 percent in the latter period (from roughly .85 to roughly 1.15).

TFP, of course, is an average of the productivities of the individual inputs, of energy, materials, labor and capital. In Figure 3, we plot the productivities for the various inputs (i.e., partial productivities). The partial productivities look very much like TFP, with productivity declines followed by productivity increases beginning in the early 1980s. The only exception is labor productivity, which grows until the mid to late 1960s, and then stops growing.

Another estimate of labor productivity is provided by the Portland Cement Association (PCA). This is given in Figure 4. The PCA series grows between 1960-1965. It shows little growth from 1965 until the early 1980s. At that point, labor productivity begins to grow rapidly. In Figure 4, we also plot the output of the U.S. cement industry (which is a series based on physical output, that is, tons).

The performance of the U.S. cement productivity was not good in the 1960s and 1970s. How did its performance compare to other manufacturing industries? Not well. Aggregate U.S. manufacturing experienced significant TFP growth in the 1960s and 1970s (see, e.g., Gullickson

(1995)). Looking more narrowly, the U.S. ready-mixed concrete industry showed steady TFP growth in the 1960s and 1970s, though it was fairly modest (see, e.g., Syverson (2008)). As for other cement industries, there has been extensive study of the Swedish cement industry over the period 1955-79 (see, e.g., Forsund and Hjalmarsson (1983) and Kumbhakar, Heshmati and Hjalmarsson (1999)). These papers have found strong productivity growth in Swedish cement production over this period. So, the productivity record of the U.S. cement industry in the 1960s and 1970s was dismal compared to overall U.S. manufacturing, ready-mixed concrete and other cement industries.

Both the NBER and PCA data, then, tell the same story: When foreign competition was weak, productivity fell, and when it was strong, productivity grew robustly. The answer to the first question, Does competition spur productivity?, is clear: Increased competition led to a surge in industry productivity. We now turn to examining the sources of the productivity gains.

3. The Production Process

In this section, we present a simple model of the cement production process that we use to study the sources of productivity gains in U.S. cement. In making cement, materials (e.g., limestone) are quarried in mines (the plants are typically located near a quarry). Second, the materials are then crushed in huge machines. Third, the crushed materials are then heated in huge kilns. The material is processed into small pellets, called clinker. Fourth, the pellets are ground, together with gypsum, to form cement. In terms of energy use, large amounts of electricity are used in the crushing of materials, in the cooling of the kilns and in the grinding of clinker. Large amounts of fuel (e.g., coal) are used in heating the kilns.

The cement kilns are of two major types, "wet" kilns and "dry" kilns. The wet and dry refer to how much moisture is in the materials fed into the kiln. If there is a large amount of moisture, then more fuel is needed to burn the material, and hence wet kilns are typically more fuel intensive than dry kilns. Conversely, wet kilns are thought to be less electricity intensive (since there is less processing of raw materials). Overall, dry kilns are typically less energy intensive (considering both fuel and electricity) than wet kilns.

Briefly, here is our model. A major consideration in most manufacturing processes is keeping machines running continuously, that is, avoiding breakdowns and, if they occur, getting machinery back into operating mode as quickly as possible. If machinery is down, output is zero, and productivity suffers (not only capital productivity but labor productivity and energy productivity). In cement manufacturing, where machines operate under extreme conditions, issues of breakdown and repair are paramount. In such circumstances, repair staffs make up a good share of staff, as they did, for example, in U.S. iron ore mining (where in some mines repair staff were 50% of employment in the 1970s).

Our highly stylized model will incorporate break down and repair in the simplest possible way. So, consider the production of cement over a period, say a day. At the beginning of the day, the plant manager finds out if the kiln breaks down or not. With probability $1-q$, the kiln breaks down, and must be repaired. With probability q, the kiln does not break down, and runs the rest of the day. If there is a break down, then time must be spent repairing the kiln. Once repaired, the kiln runs the rest of the day. Let $\widetilde{A}$ denote the fraction of the day the kiln runs (e.g., if it takes one hour to repair the kiln, then $\widetilde{A} = 23/24$).

Assume that the manager must commit to a constant flow of inputs over the day, *before* the realization of the break down. Labor is hired for the day (and really much longer). Kilns burn at extreme temperatures and the heat is not reduced unless a long period of plant shutdown is expected. So, fuel is committed to for a day as well.

To be a bit more formal, let kilns be indexed by i. Kiln characteristics are $z_i = (a_i, \tau_i, k_i)$ where a_i is age of kiln i, $\tau_i \in \{w, d\}$ is kiln-type (where w=wet, d=dry), and k_i is capacity (i.e., maximum daily output). The kiln's variable inputs are (e_i, c_i, m_i, n_i), denoting the constant flow of electricity input, fuel (c=coal) input, material input, and labor input through the day. When the kiln is operating, the instantaneous production function is denoted $y_i = f_i(e_i, c_i, m_i, n_i, z_i)$. When not operating, output is zero.

Expected output for the day is then

$$E(y_i) = [(1-q)\widetilde{A} + q] f_i(e_i, c_i, m_i, n_i, z_i).$$

In order to illustrate our points, we will use a simple parametric form for $f()$. In particular, we assume

$$f() = \begin{cases} \min[B_e(i,z_i)e_i, B_c(i,z_i)c_i, B_m(i,z_i)m_i, k_i] & \text{if } n_i \geq \overline{n} \\ 0 & \text{if } n_i < \overline{n} \end{cases}$$

where $B_e(i,z_i)$, $B_c(i,z_i)$, and $B_m(i,z_i)$ are partial productivity parameters. Note that there is a minimum labor input required to run the kiln, $\overline{n}$. After employment reaches this level, the marginal product of labor is zero.

Suppose that $n_i \geq \overline{n}$, and let $A = [(1-q)\widetilde{A} + q]$, where $A \epsilon [0,1]$. Then expected output over the day is

$$(1) \qquad E(y_i) = A \min[B_e(i,z_i)e_i, B_c(i,z_i)c_i, B_m(i,z_i)m_i, k_i]$$

Lets look at properties of (1) under the assumption that "full-capacity" inputs are chosen over the day, that is, the variable inputs (e_i, c_i, m_i, n_i) satisfy $B_e(i,z_i)e_i = B_c(i,z_i)c_i = B_m(i,z_i)m_i = k$.

If there is no probability of break down ($q = 1$), or if the kiln can be restarted right away ($\widetilde{A} = 1$) given a breakdown, then $A = 1$ and output equals capacity k_i. Otherwise, $A < 1$ and output is less than capacity. Next, consider the partial productivities from (1). For example, fuel productivity is

$$(2) \qquad \frac{y_i}{c_i} = A(i)B_c(i,z_i).$$

where we have dropped the expectations operator. Fuel productivity will differ across kilns since $A(i)$ and $B_c(i,z_i)$ differ. First consider $B_c(i,z_i)$. Newer kilns (those with small a) will likely burn fuel more efficiently and have higher $B_c(i, z_i)$. As another example, there is equipment that monitors the heat rate in kilns, and whose function is to help insure that the rate is even throughout the kiln. Such equipment increases $B_c(i, z_i)$. Dry kilns are thought to have higher $B_c(i, z_i)$ than wet kilns.

Next, consider $A(i) = [(1 - q)\widetilde{A} + q]$ in (2). This increases if the probability of breakdown decreases (i.e. q increases) and if the efficiency of repair increases (i.e., $\widetilde{A}$ increases). Younger kilns may obviously have lower probability of breakdown (i.e., higher q). Also, there are computers that monitor equipment and try to predict machine breakdown before it happens. Such computers lead to increases in q. More efficient organization of repair work increases $\widetilde{A}$.

Unions, too, can influence $\widetilde{A}$. If there are very detailed job classifications in the repair staff, and people are not allowed to work outside their job descriptions, then this tends to keep machines down longer than is necessary, leading to reductions in $\widetilde{A}$.

Recall Figure 3, where energy productivity was falling in the 1960s and 1970s. In the context of our stylized model, this would happen if kilns were getting older or there was a move to wet kilns, for example. This was not happening. Another possibility is that $\widetilde{A}$ was falling.

How does the size of the kiln, k_i, influence productivity (again, under the assumption that full-capacity inputs are chosen)? Labor productivity equals

$$(3) \qquad \frac{y_i}{n_i} = \frac{A(i)k_i}{\overline{n}},$$

so that labor productivity is increasing in the size of the kiln k_i.[10]

Again recall Figure 3, where labor productivity stopped growing in the mid 1960s. Did the size of kilns stop growing at that point? We'll see that the answer is no.

[10] A production function like that above was employed in the Forsund and Hjalmarsson (1983) study of the Swedish cement industry. See also Lau and Tamura's (1972) study of the Japanese petrochemical processing industry who discuss production functions for manufacturing industries that process raw materials.

4. Union and Work Restrictions

In this section, we first briefly review the history of unionization in the industry (Sec. A). Then we discuss various clauses in union contracts and their expected impact on productivity (Sec. B). Lastly, we discuss how the various clauses diffused into the industry (Sec C).

A. History

In 1949, according to the Bureau of Labor Statistics, nearly all cement plants were unionized (only 6 out of 149 were non-union). The CLGWU represented 82 percent of these unionized plants. However, collective bargaining agreements were nearly all negotiated on an individual plant basis. There was no coordinated bargaining across plants, no attempt to have uniform contracts.[11]

Bargaining continued on a plant by plant basis through most of the 1950s. A major milestone in the industry's industrial relations occurred in 1957. In that year, the CLGWU called a national cement strike that idled 79 plants and 17,000 cement workers (Voice, October, 1978, p. 13). The CLGW sought, among other things, to introduce pattern bargaining in the industry. A CLGWU history described the new bargaining as one where "A pattern is set in early negotiations, and locals, through tight discipline, force cement-producing companies to follow this economic blueprint." (Voice, October, 1978, p. 13). The CLGWU strike was successful in that pattern bargaining became a key feature of the industry. As the Wall Street Journal reported, "Some company officials privately concede that results of the strike marked the end of the industry's usual bargaining technique of plant-by-plant negotiations since the union's international headquarters coordinated strike efforts, and laid down basic demands to be followed by individual plant locals."[12]

The union built on this 1957-victory throughout the 1960s and 1970s. Using pattern-bargaining, it was able to introduce new clauses into contracts that were to greatly "impinge on and

[11] These facts are from: Anna Bercowitz, "Labor-Management Relations in the Cement Industry," Monthly Labor Review 72 (January 1951), pp 17-21).

[12] From "Universal Atlas, Cement Workers Agree on Contract; Union Will Seek Similar Pacts With Other Companies," Wall Street Journal, July 29, 1957.

restrict the rights of management." In 1969, commenting on the growth of union power, the executive director of the Cement Employers Association declared "in every respect these negotiations point up the vast economic power imbalance between individual companies and the Union, which has been developing continuously since the last strike in 1957." (Northrup, 1989, p. 349). Below, we will formalize this view, by studying contracts, and showing how contract clauses diffused into the industry over time.[13]

In 1984, with the surge in imports, and with management's decision to attempt to change work practices, the CLGWU disintegrated. In fact, during the summer of 1984, "70 percent of cement workers nationally were without a contract or under company-implemented contracts."[14] In 1984, the CLGWU was merged into the Boilermakers Union (IBB). In 1986, some of the CLGWU locals that were merged into the IBB broke off to form the Independent Workers of North America (IWNA). This union was ultimately merged into the IPIU (International Paperworkers, a Steelworkers affiliate) in 1991. Throughout the 1990s, then, there were two main unions representing cement workers, the IBB and the IPIU. But many cement plants were also non-union.

B. Contract Clauses and Expected Productivity Consequences

In this section, we discuss union work rules and their likely impact on productivity. For information on union rules, our basic source are the contracts between the companies and unions, that is, the Basic Labor Agreements (BLAs). While these contracts can be quite extensive, running to 70 pages and more, there are other documents which further specify rules on how work is to proceed at the plant. We have some of these documents as well. Finally, a lot can be learned about the operations of plants through analysis of arbitration decisions. We use these decisions as well.

We'll discuss four clauses. Some of these clauses are very strong. The reader may wonder whether the firms actually followed the letter of the law on them. So, for each clause we present

[13] Not only was the CLGWU able to greatly extend the restrictiveness of its contracts, it also increased its share of unionized plants, increasing it to about 90 percent in the early 1980s (Northrup, 1989, p. 342).

[14] From United Steelworkers webpage, http://www.uswa.org/usw/program/content/3184.php).

an arbitration decision showing rulings where firms tried to maneuver around the contract but were rebuffed.

Job Seniority Rights and Job Bumping

Union contracts typically have seniority clauses, which give senior workers more rights than junior workers. There are varying degrees of such rights. For example, suppose a worker x loses his job because of a temporary reduction in output. Union contracts sometimes allow worker x to take another worker $y's$ job who has less seniority. Two issues arise: (1) how large is the seniority unit? and (2) does x need to be able to do $y's$ job, or can x learn the job?

Cement contracts provided very significant rights to senior workers. For example, in many contracts, the seniority unit was plant-wide (i.e., the greatest possible right). That is, x could take the job of *any* less senior person in the plant (it was not restricted by department, etc). And the contracts provided that worker x did not initially have to be able to perform job, but only in a reasonable amount of time. A common clause was

> "In the event an employee's job is eliminated because of temporary cessation of his job or the operation, or the reduction in production or forces, or because he has been displaced by another employee, such an employee may apply his seniority by bumping any junior employee in point of seniority in any department, provided he has the skill and ability to perform the job within a reasonable period of time."

Such clauses permit, as is clear from the language, cascading job bumping. I lose my job and bump you, then you bump him, and so on.

There are obvious productivity consequences of such clauses. First, there may be people in jobs that cannot not perform them (at least temporarily). And then the only requirement is that the person be able to do the job, not do it as well. Second, experience is lost as people switch and are bumped from jobs. Third, management loses all rights to assignment. Lastly, how about morale?[15]

Job Protection (No Termination As Result of Increased Efficiency)

Strong seniority rights provided senior workers with good job protection. Contracts contained other provisions that provided job protection to all employees. A clause that began to appear in contracts in 1965 was

> "Employees will not be terminated by the Company as the result of mechanization, automation, change in production methods, the installation of new or larger equipment, the combining or the elimination of jobs."

This is a strong clause. You cannot lose a job because of gains in efficiency at the plant. And, again, its a blanket clause. The productivity consequences are clear. This clause dulls the incentives to find new production methods, etc..

Before 1965, there were agreements that protected jobs from increased efficiency. But these were ad hoc, and we are not sure how extensive. We briefly discuss one example we have found. We found it in an arbitration decision, and the ruling of the arbitrator is instructive.

At one cement plant in New York, there was a four-kiln operation that was run by a crew of six before 1958. Crew size was not set in writing, but in an oral agreement. The four-kiln operation was shut down in 1958 and restarted in 1963. When it was restarted, the company manned the operation with a four man crew on two shifts, and a five man crew on one shift. The union filed a grievance and the arbitrator ruled for the union. The operation was to be run by a crew of six. The arbitrator argued, "Agreements may, in the course of time and technological change, become antiquated or inconvenient, or more costly than anticipated. They do not, by virtue thereof, lose their force."[16] So, even before job protection was formalized into contracts, arbitrators were ruling

[15] Arbitration decisions on job bumping here. Fort Worth chemist example.

[16] The information above is taken from an aribtration decision that was summarized in the Voice, October, 1965, p. 3. The quote is from the aribtrator's decision.

that implicit agreements were strong enough.

Restrictions on How Work is to Proceed

In the BLAs, certain types of work were assigned to different departments. For example, imagine that jobs are indexed by small letters $(a_1, a_2, ..., a_n), (b_1, b_2, ..., b_n), (c_1, c_2, ..., c_n)$ etc, and departments in the plant by large letters A, B, C etc. Contracts gave the "rights" to jobs to different departments, for example, jobs $(a_1, a_2, ..., a_n)$ might belong to department A, while jobs $(b_1, b_2, ..., b_n)$ might belong to department B, and so on. While department B could complete jobs $(a_1, a_2, ..., a_n)$, it was not permitted to do so. We'll give some examples of such job assignments. But lets first discuss their impact on productivity.

First, such restrictions obviously influence staffing levels. If a job in the list $(a_1, a_2, ..., a_n)$ comes up, but department A is already fully engaged, then the job must wait. In trying to minimize such situations, the plant would add more people.

Second, in any case, there will be situations when department A cannot get to a job for a period of time when another department could. Hence, machines will remain in non-operating mode longer than necessary, output will be smaller, and so will productivity, capital productivity, energy productivity, and labor productivity.

Here are some examples from a 1969-contract for a Michigan plant.[17] On pages 64-65, its stated that "The work of balancing fans ..... will be performed by the General Repair Department," and "All dismantling of equipment in an operating department that is not replaced shall also be done the Construction Department." On p. 86, ".. when the Finish Grind Department is completely down for repairs, the Company will not use Repairmen assigned to the Clinker Handling Department on repairs in the Finish Grind Department.", and on p. 87, "Repair work on internal combustion engines will be performed by the Materials Handling Department except for minor repairs or adjustments."

[17] In fact, this plant is not a CLGWU local but a United Stone and Allied Products Workers of America local, Local 135. The contract is very weak compared to a CLGWU local, not having, for example, the job protection clause or a strong contracting out clause (see below).

Sometimes there were provisions so that if a department could not get to a job, other departments could be called. A cash-penalty would be paid by the Company but, very importantly, procedures had to be followed (and time lost) before the provisions were implemented. For example, on p. 86, "In cases where repair work on Mobile equipment (other than structural work or welding) is required at times when Mobile Department Mechanics are not scheduled to work, the Repair Foreman will first attempt to contact the Mobile Mechanics to perform the work on an overtime basis. Should all of the Mobile mechanics refuse the overtime or be otherwise unavailable to report to work, a General Repair crew will be assigned to do the job in conformity with past practices as to the nature of the repair work involved."

Despite these procedures for getting departments involved in the work of other departments, repair work and restarting machines at the plants presented a significant problem for management. For example, one finds these problems discussed in contracts

> "The most efficient and productive method of operating a cement plant is on a continuing process basis. .... However, when major equipment must be shutdown due to operating problems, the present contract severely limits the ability of the Company to make efficient and productive use of its employees and equipment ..."

This discussion is from a Pennsylvania contract in 1996 (p. 52). So, at this plant, work rules were still being fought over in 1996. The union local was perhaps the local that historically had the most restrictive contracts in the country.

Contracting out protections

Another important clause in BLAs concerns contracting out. In the late 1950s, a typical clause was

> "All work customarily performed by the company in its own plants and with its own employees shall continue to be performed by the company, unless in the judgement of

> the company it can be performed more economically and expeditiously otherwise."

This is not a strong clause. In the 1960s, a much stronger clause appeared:

> "All production and maintenance work customarily performed by the Company in its plant and quarry and with its own employees shall continue to be performed by the Company with its own employees."

This obviously is a much stronger clause. Consider the productivity consequences. Having this very strong clause is similar to the plant having a very large (infinite?) tariff on goods and services provided by producers outside the plant's gates. Such protection has been shown to have bad productivity consequences.

A relevant arbitration case involves another Pennsylvania plant. The plant purchased clinker from another firm and planned to grind it at the plant. The Union argued that this violated the contracting out clause (the plant had the second clause above). Purchasing outside clinker obviously violated the agreement, and the arbitrator ruled that the company must compensate the workers for the number of hours it would have taken to produce the clinker (from the Voice).

C. Diffusion of Contract Clauses

To document and characterize the union's growth in power since its 1957-strike, we have collected contracts from 90 cement plants. This list will expand as we find more archives and the like. For some plants we have only one contract, for other plants we have many. Thus far, we have been studying the diffusion of two clauses into the contracts, the job protection clause, and the (strong) contracting out clause.

Table 1, top panel, presents information on the job protection clause. The first row gives the number of plants for which we have at least one contract for the particular period. For example, we have at least one contract dated earlier than 1963 for four plants. We have a contract dated 1963 (i.e. whose beginning date is within 1963) for 36 plants. We have a contract dated in 1965 for 49 plants. We have at least one contract that is dated between 1966 and 1984 (inclusive) for 84 plants, and for dates between 1985 and 1998, 12 plants.

The second row gives the number of plant contracts that contain the job protection clause. As is seen, none of the contracts before 1965 had the clause, and then nearly all had the clause in 1965. It would seem that 1965 was the first year that this clause was in any contract. To check this, we examined the issues of the *Voice* for 1965. In the March issue, on p.1, the CLGWU lists its new agenda for bargaining that year, and this job protection clause was on the new agenda. This is more evidence that 1965 was the first year. After 1984, only a third of the contracts have the clause. Recall that some plants went non-union, so this is an overstatement of the fraction of all plants with the clause.

The contracting out clause is studied in the bottom panel. This appeared in contracts before the job protection clause. Before 1963, none of our contracts have the clause (though we only have four contracts). In 1963, 20 of our 36 contracts have the clause. In 1965, all contracts do. So, two things seem clear: this clause appeared sooner, and diffused more slowly. We still need to learn more about this clause's diffusion into contracts.

5. Union contract changes and productivity: Industry Over Time

In this section, we begin "testing" our hypothesis that changes in management practices was a large reason for the TFP gains in the 1980s. We do this by comparing and contrasting productivity behavior in three periods: Before the union was strong (before the 1957-strike); the period when the union was gaining strength (the 1960s and 1970s); and the period when the union disintegrated (mid 1980s onward). While the NBER manufacturing data base begins only in 1957, we can extend most productivity measures back to WWII.

As we metioned, we find that while productivity was growing in all inputs after WWII, partial productivities stopped growing, and even began to fall for some inputs, after the 1957 strike. Labor productivity stopped growing in 1965. While fuel productivity began growing in the mid 1970s, during the energy crisis, the other partial productivities continued to fall or did not grow again until the early to mid 1980s, when competition had arrived, and the CLGWU-provisions were eliminated from contracts.

A. Electricity Productivity

The United States Geological Survey (USGS) has collected data on the U.S. cement industry going back before WWII. USGS collects electricity consumed by each plant. It publishes the aggregate electricity consumed in the industry in the Minerals Yearbook.[18] Figure 5 plots electricity productivity, that is, cement produced per unit of electricity, for the industry from 1946-97. Electricity productivity was rising after WWII until 1956, and then fell throughout the 1960s and 1970s. It then started to increase in the 1980s when imports surged.

Two things to note about the figure. First, 1956 was actually the peak productivity. Output contracted significantly between 1956 and 1957, falling about 7 percent. Output did not reach its 1956 level until 1959. So, the productivity drop from 1956 to, say, 1959, likely had more to do with output reductions than changes in union contracts. Second, productivity fell more or less continuously through the 1960s and early 1970s. Then it dropped considerably in the mid 1970s. In the mid 1970s, the industry invested heavily in new technology that was fuel-efficient (see the next sub-section) but used electricity intensively. Still, after the surge in imports, the industry was able to increase electricity productivity even with the new electricity-intensive equipment.

B. Fuel Productivity

USGS also collects fuel used by each plant. There are three fuel types: coal, natural gas and oil.[19] USGS publishes the aggregate amount of each fuel consumed in the industry in the Minerals

[18] In particular, USGS collects the amount of electricity purchased by each plant, as well as the amount of electricity self-generated. We define consumption as the sum of purchased and self-generated electricity.

[19] USGS is now collecting information on waste fuels used since they are now a big part of fuel use. But for the period the graphs below are made, waste fuel was not reported to USGS (see more below).

Yearbook.

We define fuel productivity as clinker production divided by a measure of total BTUs in the consumed fuel. To arrive at total BTUs consumed, we first assign a per-unit BTU value to each of the three fuels. We then multiply the total quantity of each fuel used by its per-unit BTU value, arriving at total BTUs per fuel. We then sum BTUs over all three fuel types.

Figure 6 plots fuel productivity for the industry from 1946-90. Productivity was growing in the 1950s, but then slowed to a "crawl" in the 1960s. Productivity began to increase in the mid 1970s. This was the "initial" energy crisis period, and the industry made significant investments in new fuel-efficient equipment. During this period, the industry invested in dry kilns with preheaters, which we'll call preheaters for short. These kilns were more fuel-efficient (but more electricity intensive) than standard dry kilns. Note that fuel-productivity continued to grow in the 1980s when (as we'll show) investment was much smaller.[20] Note that productivity growth in the 1980s was greater than in the 1970s (though this is hard to see in the figure, in part because the figure covers such a long period). For example, from 1974-80, productivity grew 20 percent. From 1980-86, productivity grew 35 percent.

C. Capital Productivity

Again, the NBER does not provide a capital series for the period 1947-1957. We extended the capital stock data from the NBER back to WWII using data from the USGS on clinker capacity. The growth rate in the USGS clinker capacity series was used to extend the NBER series back to 1947. With this imputed capital stock, we present capital productivity in Figure 7. Capital productivity grows after WWII. It begins to fall in 1956, and does not increase until the surge in

[20] The NBER-energy productivity series in Figure 3 was a composite of fuel and electricity productivity. We could construct a USGS-energy productivity series by "aggregating" the USGS-electricity and USGS-fuel productivity series in Figures 5 and 6. Spending on fuel is typically about twice spending on electricity. The aggregated series would look more like the NBER-energy series than the USGS fuel series does.

imports.[21]

We could also estimate the capital stock for recent years from PCA data. The NBER uses investment data, and a constant percentage depreciation rate, to construct capital. PCA has data on kiln sizes, ages and type. It might be possible to construct a better measure of capital from this data. Here we just suggest that this method would likely yield a capital stock that fell in the 1980s relative to the 1970s, and likely would yield a similar pattern for capital productivity as in Figure 7. Bigger kilns are higher quality than smaller ones, and are thought to lead to higher labor productivity. Average kiln and plant size is plotted in Figure 8. Growth in average kiln size was greater in the 1970s than the 1980s. From 1970-83, average kiln and plant size grew .95% and .37% percent per year, respectively. From 1983-96, average kiln and plant size grew .35% and .21% percent per year, respectively.

A younger capital stock is thought to be more productive. Here we examine the average age of capacity, which is defined to be

$$\frac{\sum aK(a)}{K}$$

where $K(a)$ is capacity of age a. In figure 8, we plot the average age of capacity. We plot two series (since at this point we have to estimate average age of capacity). The average age decreases or stays flat in the 1970s, then begins to increase in the 1980s.[22] So, both measures of capital quality show greater growth in the 1970s than the 1980s.

[21] We have yet to make any adjustments to capital because of environmental regulations requiring pollution abatement equipment. Suppose we deducted abatement investment expenditures from total investment. Such expenditures became significant in the 1960s. This would certainly reduce the capital stock in the 1960s relative to the 1950s, so that the decline in capital productivity in the 1960s would not be as large (but almost surely there would be a decline relative to the 1950s). Whether such considerations would change capital productivity comparisons between, say, the 1970s and 1980s is not clear. These are issues we'll explore.

[22] The share of capacity less than 10 years old was falling significantly in the 1980s (since few kilns were opened), as was the share of capacity less than 20 years old (and 30). Again, this contrasts to the 1970s.

D. Labor Productivity

The NBER tracks labor productivity from the late 1950s on. From published Annual Survey of Manufacturers, we can bring the labor productivity series back into the 1940s. In Figure 10, we plot labor productivity in the industry from 1947 to 2006. As is clear, labor productivity was growing prior to 1957. Labor productivity growth continued into the 1960s. This is not surprising. As the union gained strength in the 1960s, plants would try to substitute away from labor. The CLGWU put a stop to this with the No Job Termination Clause in 1965. The effect of the clause is seen in the labor productivity series, where labor productivity shows little growth after 1965 until the increase in imports, whence it begins to grow significantly.

6. Union contract changes and productivity: By Technology Over Time

In this section, we present another "test" of our hypothesis that relaxing of union work rules was a large reason for the TFP gains in the 1980s. We do this by comparing and contrasting the behavior of productivity across technology types for the same three periods: Before the union was strong (before the 1957-strike); the period when the union was gaining strength (the 1960s and 1970s); and the period when the union disintegrated (mid 1980s onward).

A. Electricity Productivity

Figure 11 plots electricity productivity by process from 1946-97. From 1946-71, USGS reported two processes: wet and dry. In 1972, a third process was introduced, "both," that is, establishments using both wet and dry kilns.

The time-series pattern of productivity looks very similar in each process — productivity gains (from 1946-56), followed by losses (1957-early 1980s), and finally gains again. And the drops in productivity were significant. For the wet process, the drop was around 17 percent, if we take peak productivity to be 9, and the bottom to be 7.5. This is a 17 percent drop while there had been a positive trend before! For the dry process, the drop was larger, 21 percent, if we take peak productivity to be 8.25, and the bottom to be 6.5.

Note that the fall in productivity in the wet plants is fairly continuous over the 1960s and 1970s. There is no big drop in the mid 1970s as there was for industry-wide electricity productivity. There is a big mid-1970s drop in the dry plants. That is likely due to the new dry-preheater kilns that were being opened. Finally, during the 1980s, there was productivity growth in all three types of plants, even the drys, which include a large contingent of dry-preheaters. Wet productivity is approaching its previous peaks.

B. Fuel Productivity

Figure 12 plots fuel productivity by process from 1946-90. The same productivity pattern holds in each process. Productivity was growing in the 1950s, but then slowed to a crawl in the 1960s. Productivity began to increase in the late 1970s. When imports came, productivity continued to grow, in fact, just as in total fuel productivity, growth in each type was faster in the 1980s than 1970s.

7. Other Possible Sources of 1980s Productivity Gains

In this section, we begin addressing other potential sources of the productivity surge in the 1980s. In particular, we ask to what extent the partial productivity increases in the 1980s can be explained by selection.

Before we look at partial productivities, lets examine statistics on closure of capacity over the period 1974-1992. Table 2 shows the contributions of the three groups of plants – continuers, entrants and exits – to overall capacity change. The contributions are calculated relative to the base year's capacity and are broken out into two time periods and presented separately for cement and clinker capacity changes.

In the period 1974-82, overall cement capacity increased 11.3 percent. Additions to capacity at continuing plants amounted to 20.9 percent of 1974 capacity. Entrants added another 8.1 percent of capacity. Exiting plants closed capacity that was 17.7 percent of 1974 capacity. The period 1982-92 saw a 6.3 percent decline in capacity. Continuing plant expansions and new entrant capacity contributed little to capacity in this period (4.9 percent and 2.8 percent, respectively). In fact, only 3 new plants came on line in this period. Exiting plants closed capacity that amounted to 14.1 percent of 1982 capacity.

These statistics show that capacity upgrades (both expansions and new entrants) were larger in the 1970s than the 1980s, while closures were smaller.

The bottom of the table shows the results for clinker capacity changes. Results are similar to the above, except that clinker capacity has fallen steadily over time whereas cement capacity saw growth in the 1974-1982 period.

A. Labor Productivity

One potential source of 1980s labor productivity gain is the closing of low labor productivity plants. To examine this, we could use Census plant-level data to produce a labor productivity growth decomposition and ask what share of the growth was due to exiting plants. For disclosure reasons, we can only produce the "within-plant" term in this decomposition. We'll show below that in the 1982-87 periond of strong labor productivity growth, this within-term amounted to nearly 75 percent of overall growth. Hence, the growth was primarily at the continuing plants, and exit was at most 25 percent of growth.

In order to contruct a labor productivity growth decomposition, we use plant-level data from the US Census Bureau for the Census years of 1972, 1977, 1982, 1987, 1992 & 1997. We define the change in industry productivity as the log difference in labor productivity, where aggregate industry labor productivity is real industry production divided by total industry hours. Next, we construct the within-plant productivity term (Ω) as the weighted sum of the differences in the log of labor productivity ($\Delta \ln(y_i/n_i)$) at the plant level between two census years. The weight is the average of the labor input shares ($s_{i,t}$'s) of the plant in the two census years. This is given as

$$\Omega = \sum (\tfrac{1}{2}) \bullet (s_{i,t} + s_{i,t+5}) \bullet (\Delta \ln(y_{i,t}/n_{i,t}))$$

For each plant, $y_{i,t}/n_{i,t}$ is constructed as real plant production divided by the labor input. Real plant production is shipments minus the change in finished goods inventories deflated by state-level price indices from USGS data on unit values. The labor input is constructed using three alternatives – total plant employment; total plant hours where nonproduction workers are assumed to work, on average, same number of hours as production workers; and the Olley-Pakes approach where total salary wages of a plant is divided by the production worker average hourly wage rate. We also use output shares as weights in place of the labor shares to check sensitivity of weighting choice. For the most part, our choice of labor input and weighting method has little effect on the estimate of the within term.

Table 3 presents the overall growth in labor productivity between Census years in column 1 and the within component in column 2. The results presented use employment shares and the Olley-Pakes construction of hours. The growth in aggregate labor productivity is positive in the periods of 1972-1977, 1982-1987 and 1992-1997. Particularly strong labor productivity growth is observed in the 1982-1987 period, where labor productivity grows at a rate of .386. This agrees generally with patterns observed above. The industry experiences negative productivity growth in the 1977-1982 and 1987-1992 periods, though at relative small rates. Overall, productivity growth is relatively flat in the period prior to 1982 and rises sharply thereafter. In both periods of high productivity growth, the within component is relatively large accounting for over 70% of aggregate productivity growth.

Since there was a large productivity surge between 1982-87, it would be nice to have a finer breakout of capacity changes, which we'll construct for the next version.

B. Electricity and Fuel Productivity

We would like to produce a productivity growth decomposition for electricity and fuel, just as we did for labor. We have not done that yet. However, we can still say some things about selection.

Lets consider electricity. And start with the wet sub-industry. Figre 11 shows that wet electricity was falling during the 1970s. Table 2 shows that significant capacity was closed in the 1970s, and most likely this was predominantly wet capacity (we'll produce a version to Table 2 for the wet and dry sub-industries for the next version). So, even though wets were being closed, and likely the low productivity ones, wet electricity productivity fell in the 1970s. This suggests that there were within-plant productivity declines. We present PCA data in the Appendix which supports this view.

In the 1980s, capacity was still being closed, again this was likely predominantly in wet. But, of course, the percentage reduction in wet may now have been bigger, given the 1970s closures reduced the "base." Selection may have played a large role in the wet electricity gains in the 1980s.

Consider next electricity productivity in dry plants. Lets focus on the 1980s, where productivity was increasing. There was likely very little dry expansion, or closure, in the period, say, 1983-87. One way to see this is in Figure 13. This gives the dry plant and the "both" plant share of production. From the data we have, the dry plus both-plant share of production seems reasonably close to dry capacity share. In both-plants, it is likely that older, small wet kilns operated along side larger drys (until the wets were retired). The dry plus both-plant share increased a small amount between 1983-87, but this may well have been driven by closures of wets. This train of logic leads us to the tentative conclusion that within plant productivity growth was important in the dry electricity productivity gains. As we update our information on capacity by year, and by type of kiln, these arguments can be made more tightly.

Consider next fuel productivity, and dry gains in the 1980s. The same train of logic as in electricity applies here, and within gains may have been important.

As suggested above, we have plant level PCA data than shed some light on these issues. We look at this in the Appendix.

8. Regional Productivty

The increase in competition was not uniform throughout the country. It would be nice to see how changes in contracts were related to changes in competition. While our analysis of union contracts across regions is still in progress, there are some states in the East where a few plant contracts changed very little until the middle 1990s. Interestingly, these plants are in regions that faced less increased competition than other plants. Also, interestingly, these plants were not bought by foreign firms. This is something we'll pursue in the next version.

As mentiond, we have measures of regional energy productivity from the PCA, though they stop in 1985. While the big and sustained surge in imports only started in the early to mid 1980s, there was an initial surge in 1978 and (especially) 1979. We can use the PCA regional energy data to see if the regions experiencing a surge in imports in this period, like California, had greater energy productivity growth than the nation over 1980-85.

Figure 14 shows energy productivity by states from the PCA. Southern California faced a surge in imports in 1978 and especially 1979 (imports likely exceeded 20 percent of local production). Texas also had imports in 1979 that were unusually large. Most ports on the East coast had very few imports in the late 1970s and early 1980s. New York City had some, but nothing greater than in years prior to 1978-79. New York City imports picked up in 1984. California's energy productivity increases significantly relative to the national average. California made significant investments in new equipment in 1981.[23] States on the East coast had relative productivity declines.

In Figure 15 we plot California's labor productivity relative the national average. One series uses Census numbers in both the numerator and denominator. The other series uses International

[23] It seems that only a small portion of this investment was announced before the import surge into California.

Trade Commission data (from dumping cases) in the numerator and PCA data for the denominator.

The ITC data for California is likely very high quality, in that plants provided tons produced and hours worked. This data shows a bear doubling of productivity between 1980 and 1987. We plot that relative to the PCA national average will also shows very strong growth. Census national average growth is less than PCAs.

9. Appendix on PCA Plant Level Data

The PCA plant level data has two measures of energy productivity: tons of cement per kilowatt hours and equivalent tons produced per total BTU's. An equivalent ton represents 92% share of clinker produced and an 8% share of cement at the plant. Plant reports are anonymous but a plant identifier number allows us to link plants over time. The sample of plants does not represent the full universe of cement plants. In the early years, coverage is close to 100% of plants, while in the mid 1980's coverage is closer to 85 to 90 percent of cement plants. We also know information about the technology used at the plant – the 1970's distinguish between wet- and dry-kilns, whereas the later data also distinguish among plants that have adopted the pre-heater technology.

The PCA has two major drawbacks for our purposes. First, there is no plant level output, so we cannot construct standard productivity decompositions. The data set provides two ratios (tons divided by BTUs and tons divided by KWH) but no "size" measure. Second, the data runs from 1972 to 1985. The changes in management practices began in earnest in the middle of 1984, so we really do not have much of a look at the impact of the changes. Another drawback is that when a plant leaves the sample we don't know if it closed, or simply stopped reporting. Similar issues occur when a plant "enters" the sample.

Table 1 looks at the change in the (unweighted) average plant-level energy productivity for the time period 1972-1985 and two sub periods: 1972-1980 and 1980-1985. The first line of the table presents data on equivalent tons per MBTU and the second line presents the tons per KWh. In the case of overall Tons per BTU, energy productivity improved by 30 percent from 1972-1985. The relative changes are quite similar across the two sub-periods (14 percent and 13 percent) indicating the (unweighted) average energy productivity has improved steadily over the time period.

If we looked at the fuel productivity growth from USGS (Figure 6), which is a similar productivity measure, we see that from 1972-80 productivity growth is 26 percent (so, is almost twice as high), and from 1980-85 productivity growth is 27 percent.[24]

Electricity productivity shows a markedly different pattern. Average plant electricity productivity fell from 1972 to 1985 with all of the fall occurring in 1972-1980 period. In the 1980-1985 period, electricity productivity improves slightly.

To look more closely at the patterns, we estimate simple regression models with the log of energy productivity as the dependent variable and just a set of time dummies. In this analysis, we use a balanced panel, that is, we use only the plants with records over the full period. Our focus is to look at how the plant average changes over time and across technologies. We define technology here based on the ending technology of the plant in 1985. Looking at Log of Tons per MBTU in Table 2, the first column pools across technologies, putting in controls for pre-heater and wet technologies. The omitted group is dry plants. Plants with pre-heater technologies have about 10% higher energy productivity than dry plants while plants using Wet technologies have roughly 10% lower productivity. The omitted time dummy is 1972 and no data are available for 1973. Overall, energy productivity rises in a monotonic fashion over time, with about half the rise in productivity occurring after 1979. The patterns differ by technology (columns 2 through 4). The rise in energy productivity in dry plants (with no pre-heaters) and wet plants is considerably more muted than pre-heater plants – 10.5% to 13.8% growth, respectively. Note also that plants identified using pre-heaters in 1985 likely adopted the technology through the installation of new kilns during

[24] Recall that above we presented the following numbers for USGS grrowth: 1974-80, productivity grew 20 percent; 1980-86, productivity grew 35 percent. USGS growth picked up after 1985.

the period under study. Plants with pre-heaters in 1985 experienced substantial improvements in energy productivity over the 1972-1985 period, growing by 40%, on average.

Table 3 reports electricity productivity results. Our data differ here from Table 2 in that we have information only for 1972 and 1978-1985. Electricity productivity was not broken out in the earlier reports. Overall, electricity productivity declined through 1983 and then began to rebound in 1984 [a rebound, that at the industry-level (see Figure 5), continued into the 1990's.] The sample that is pooled across technologies shows that wet plants have higher electricity productivity than dry plants and pre-heater plants but that there is little difference, on average, between dry and pre-heater plants. Examining the specific technology regressions, the time series patterns for dry (no pre-heater) and wet plants are similar with productivities declining over the 1970's until 1983. Pre-heater plants show the sharpest drop in electricity productivity, which is not too surprising since pre-heater technologies substitute toward electricity using devices. However, beginning in 1981 there is an improvement in electricity productivity which continues through 1985. Note that most of the pre-heater kiln installations would have been done prior 1983, as there were few pre-heater adoptions in the 1983 to 1985 period.

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Figure 1.
U.S. Cement Imports
(Relative to U.S. Production)

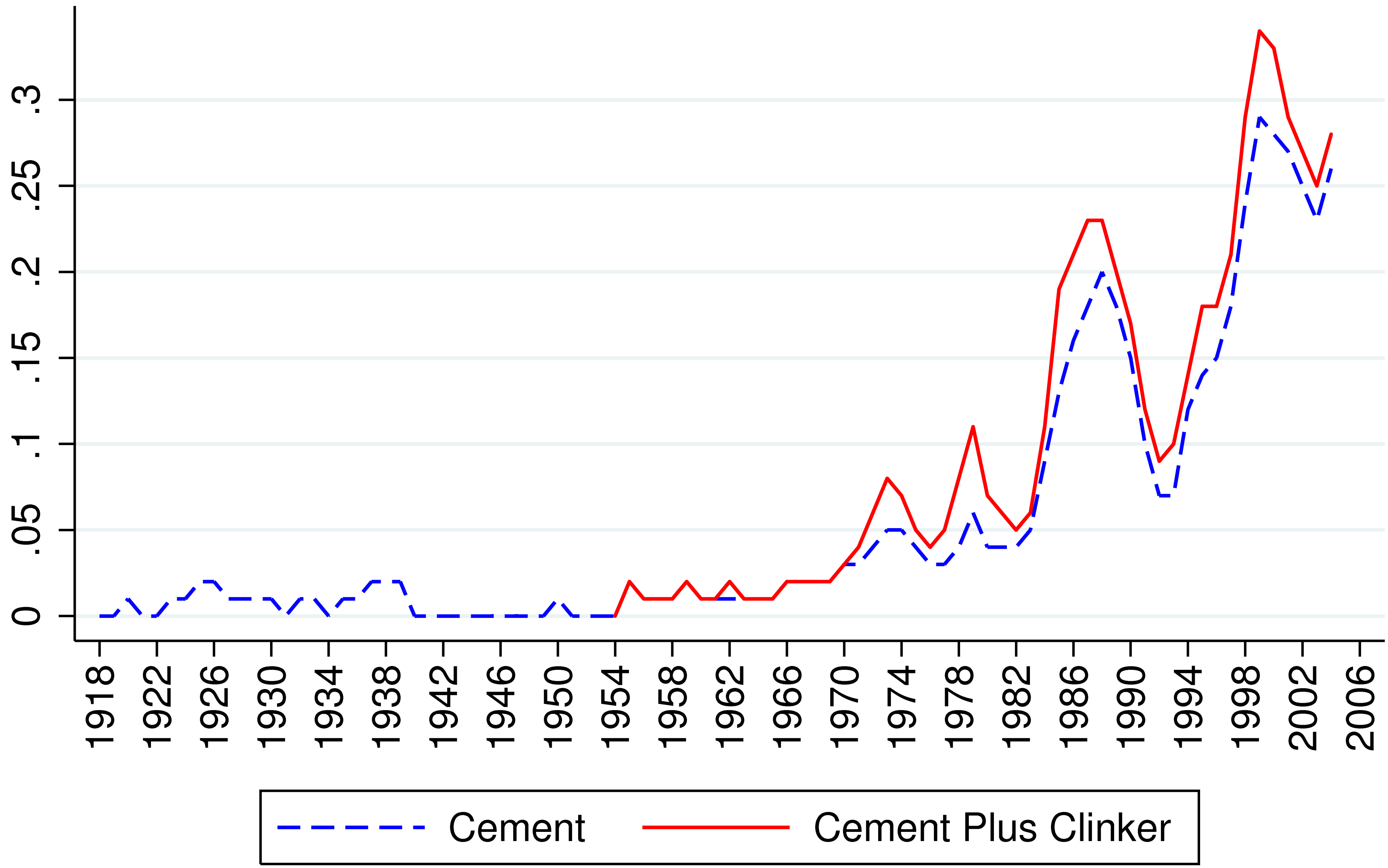
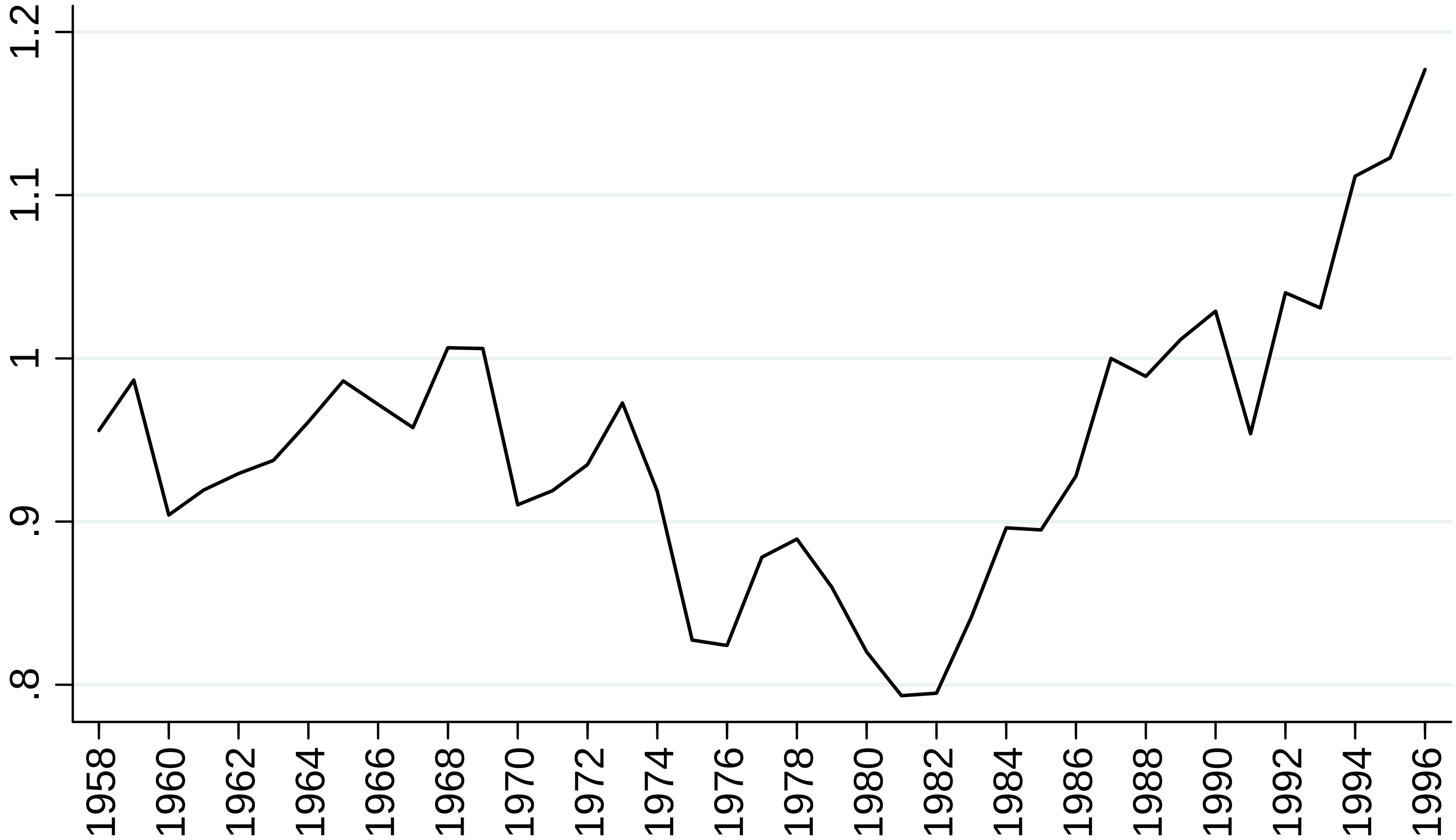


Figure 2.
Total Factor Productivity
U.S. Cement Industry

(NBER Manufacturing Database, 1987=1)



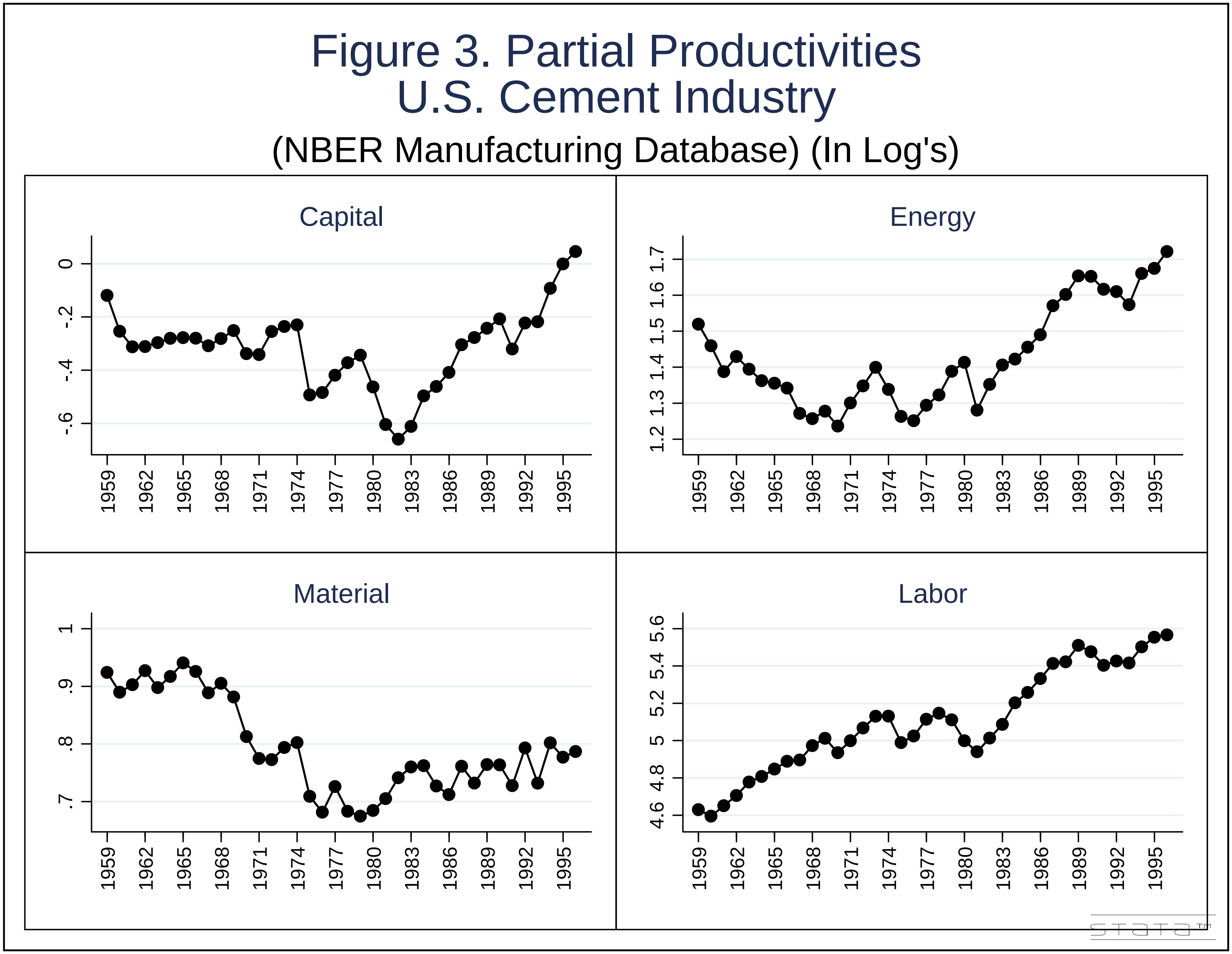


Figure 3. Partial Productivities
U.S. Cement Industry
(NBER Manufacturing Database) (In Log's)
Capital
Energy
Material
Labor
0
-.2
-.4
-.6
1.7
1.6
1.5
1.4
1.3
1.2
1
.9
.8
.7
5.6
5.4
5.2
5
4.8
4.6
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995

Figure 4. Production vs. Labor Productivity
Portland Cement Association
U.S. Cement Industry

(1980=1.00)

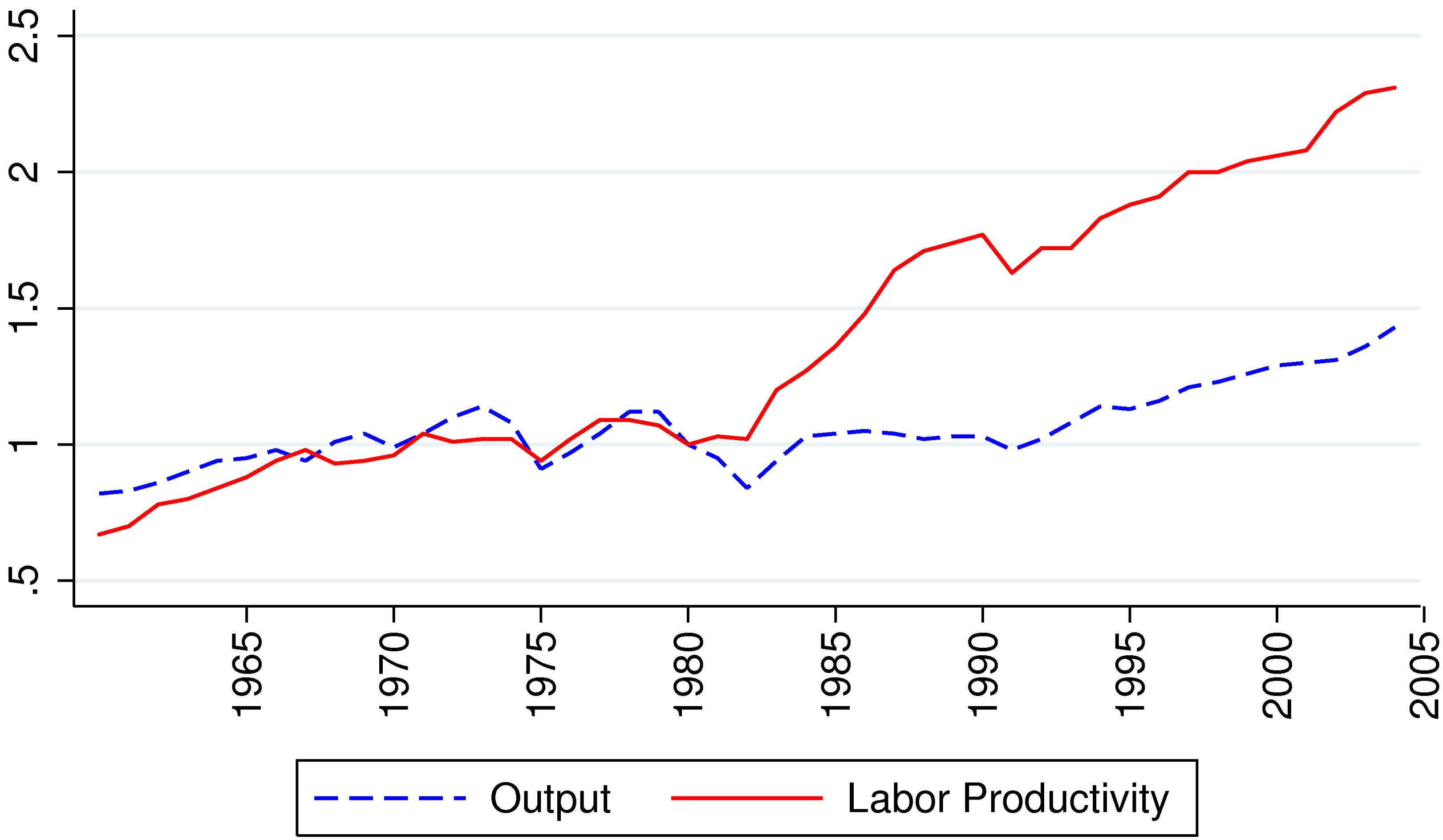


Figure 5. Electricity Productivity
U.S. Cement Production Per Unit of Electricity

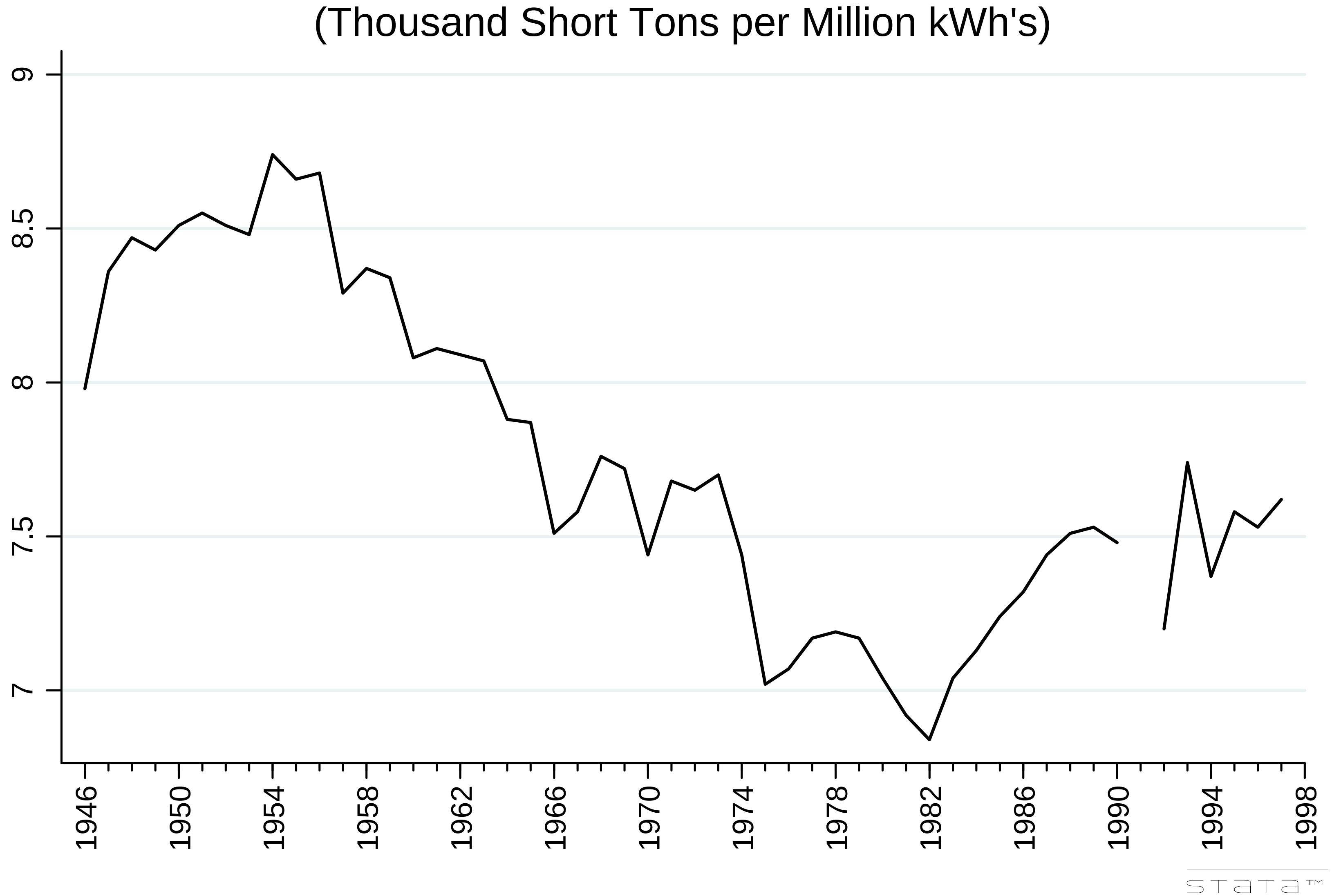


Figure 6. Fuel Productivity
U.S. Clinker Production per Unit of Fuel

(Log of Thousand Short Tons per Million BTU's)

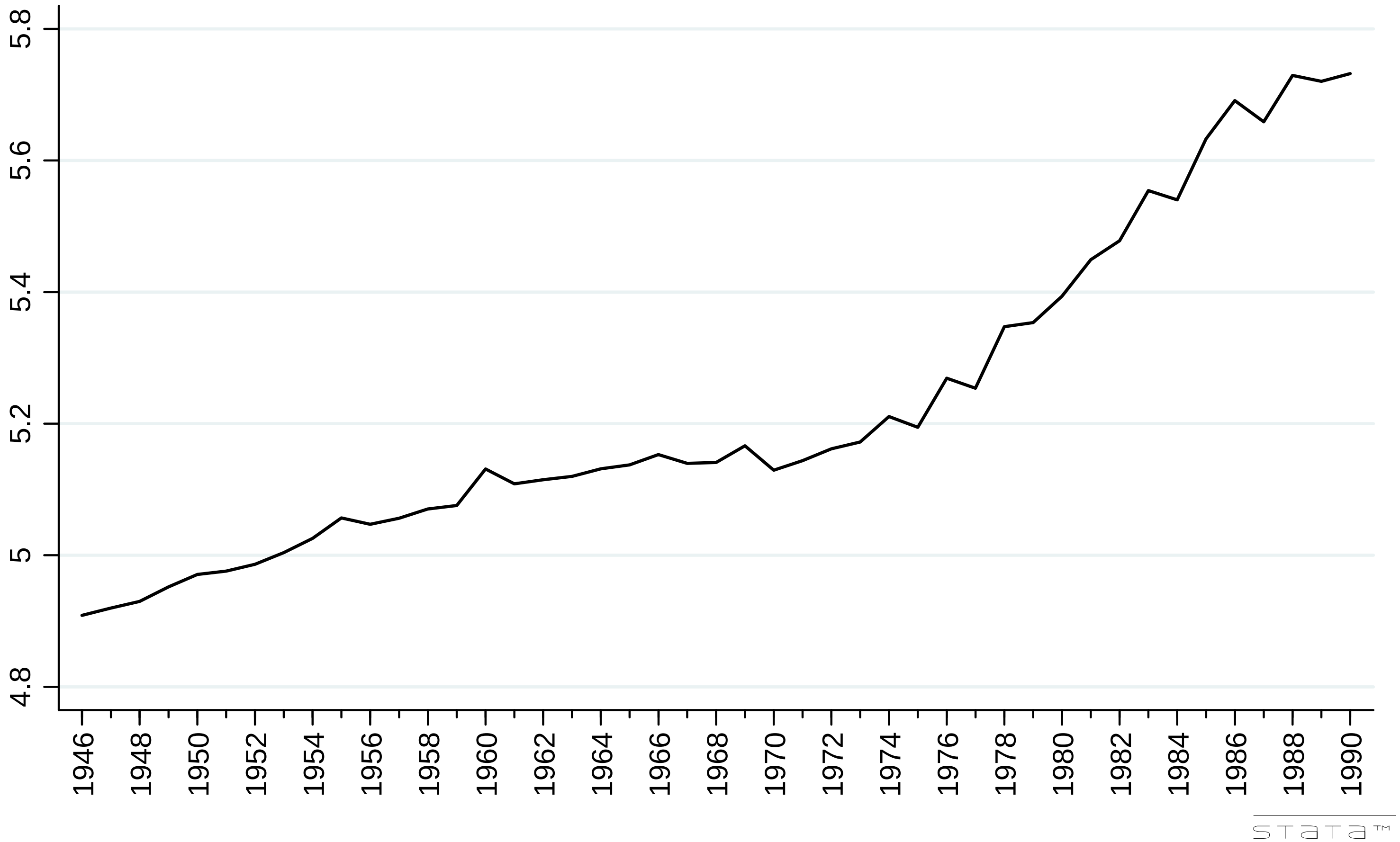


Figure 7.
Capital Productivity
U.S. Cement Industy

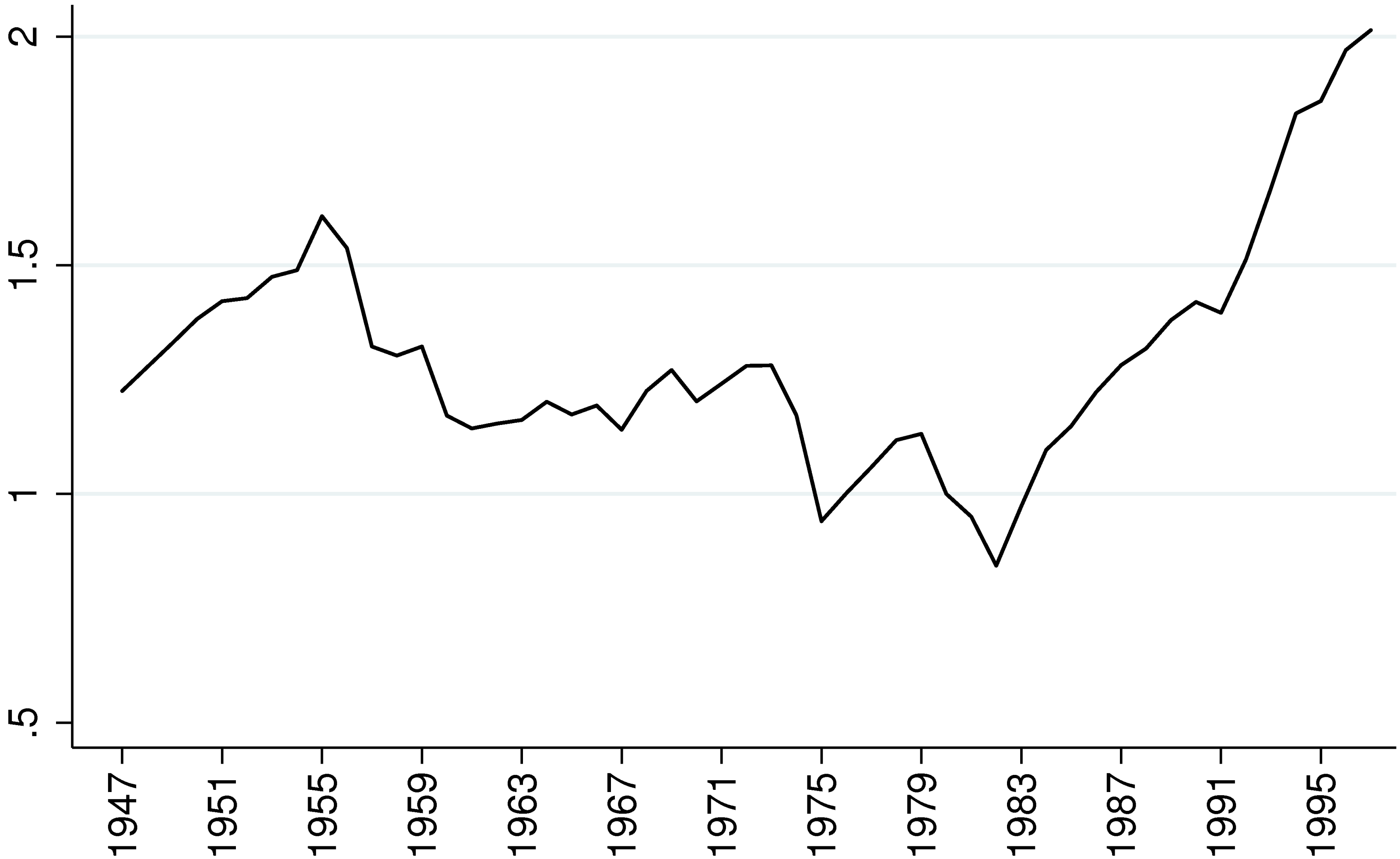


Figure 8.
Average Kiln Size and Average Plant Size
U.S. Cement Industry

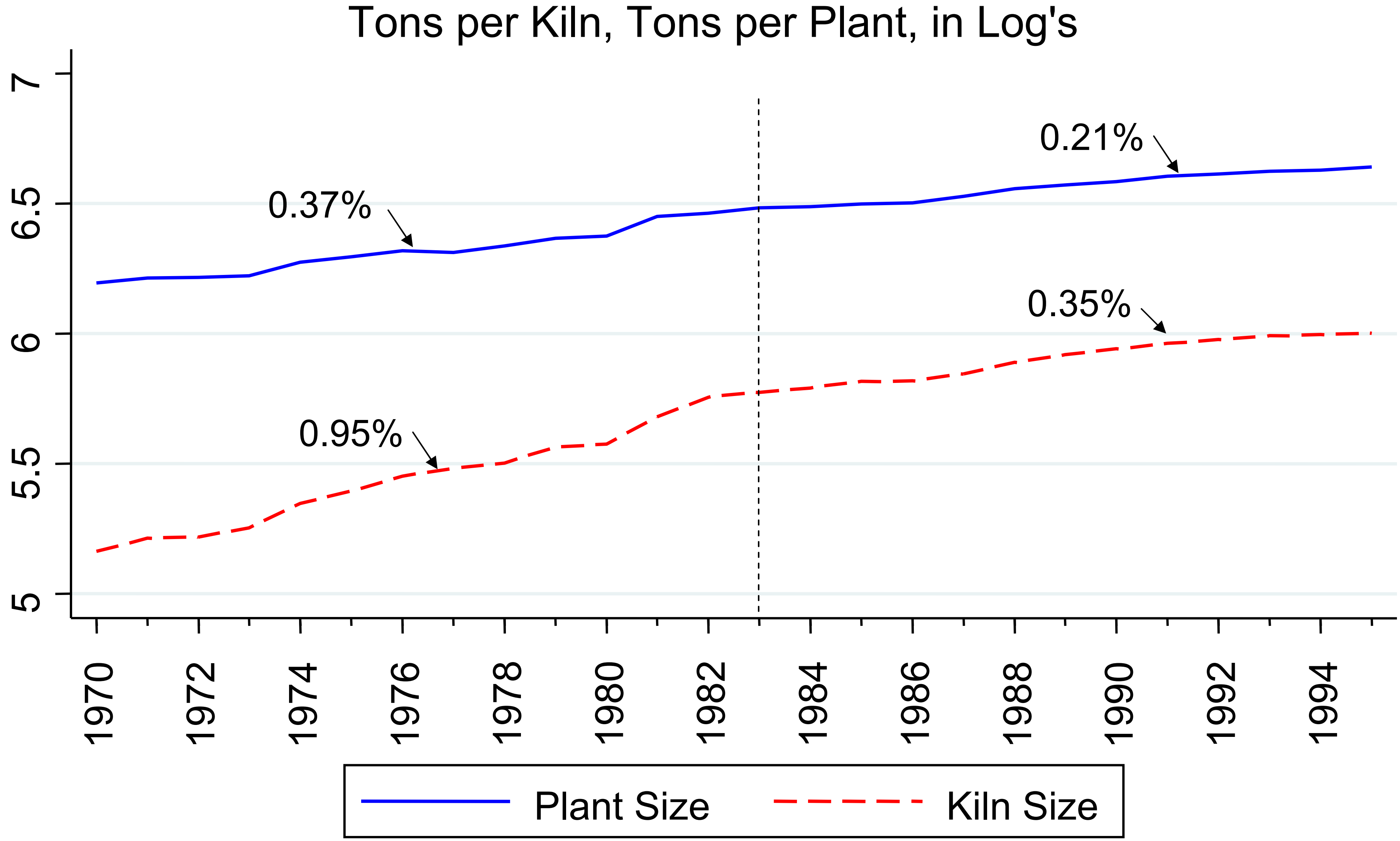


Figure 9. Average Age of Kiln Capacity
(Two Methods of Calculation)
U.S. Cement Industy

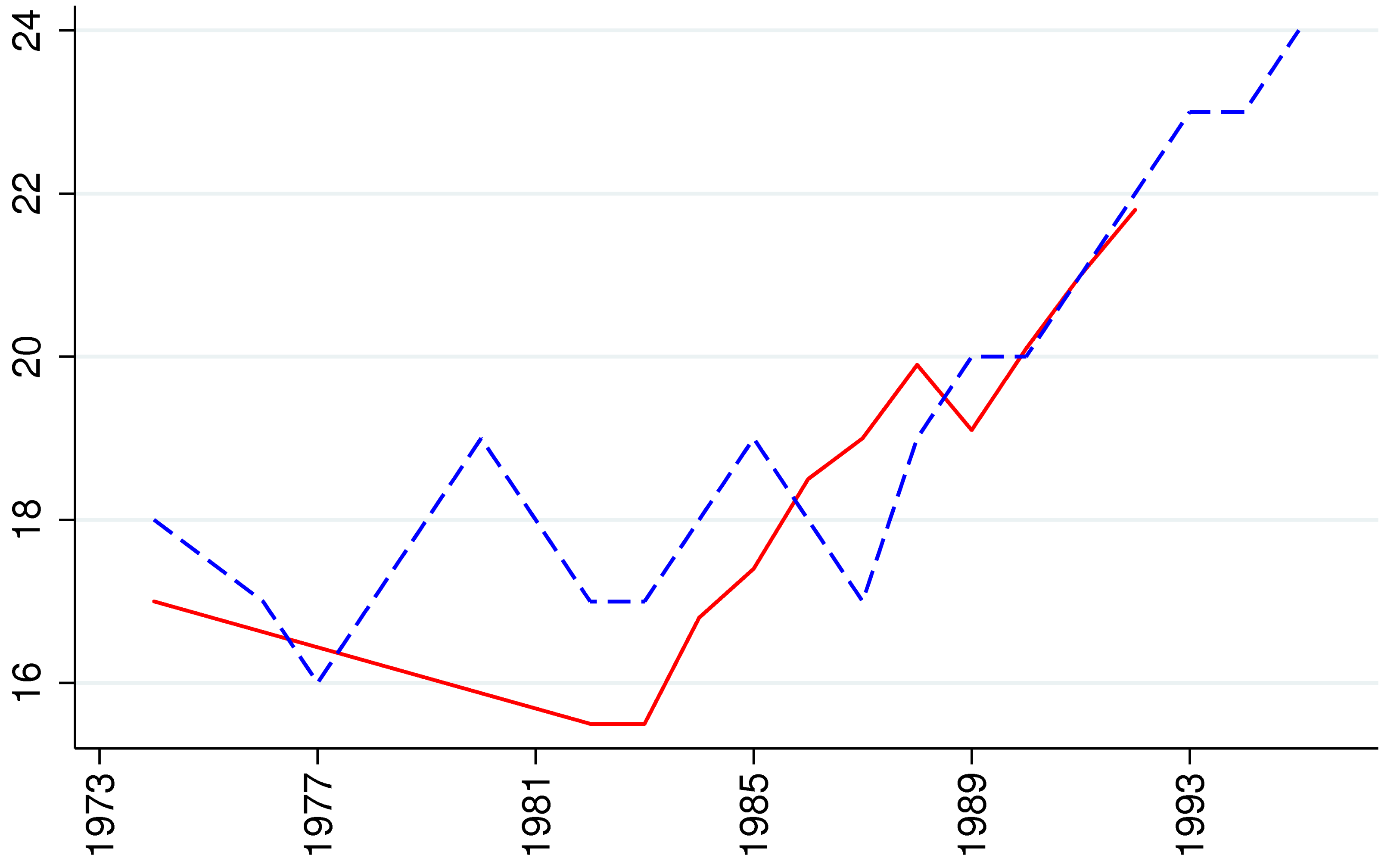


Figure 10.
Labor Productivity & Production 1947–2006
(1980=1.00)

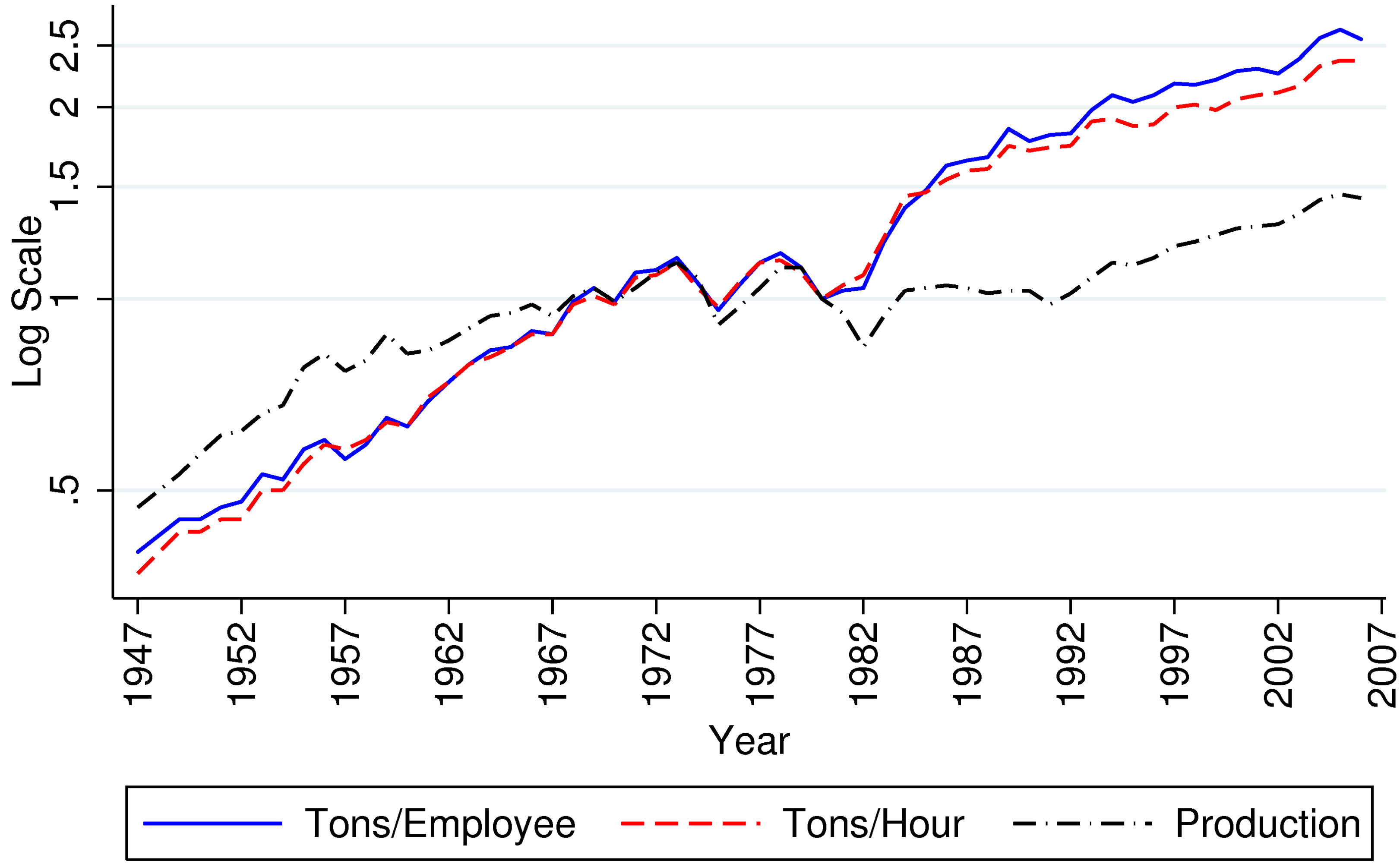


Figure 11. Electricity Productivity
U.S. Cement Production Per Unit of Electricity
(Thousand Short Tons per Million kWh's)
By Process

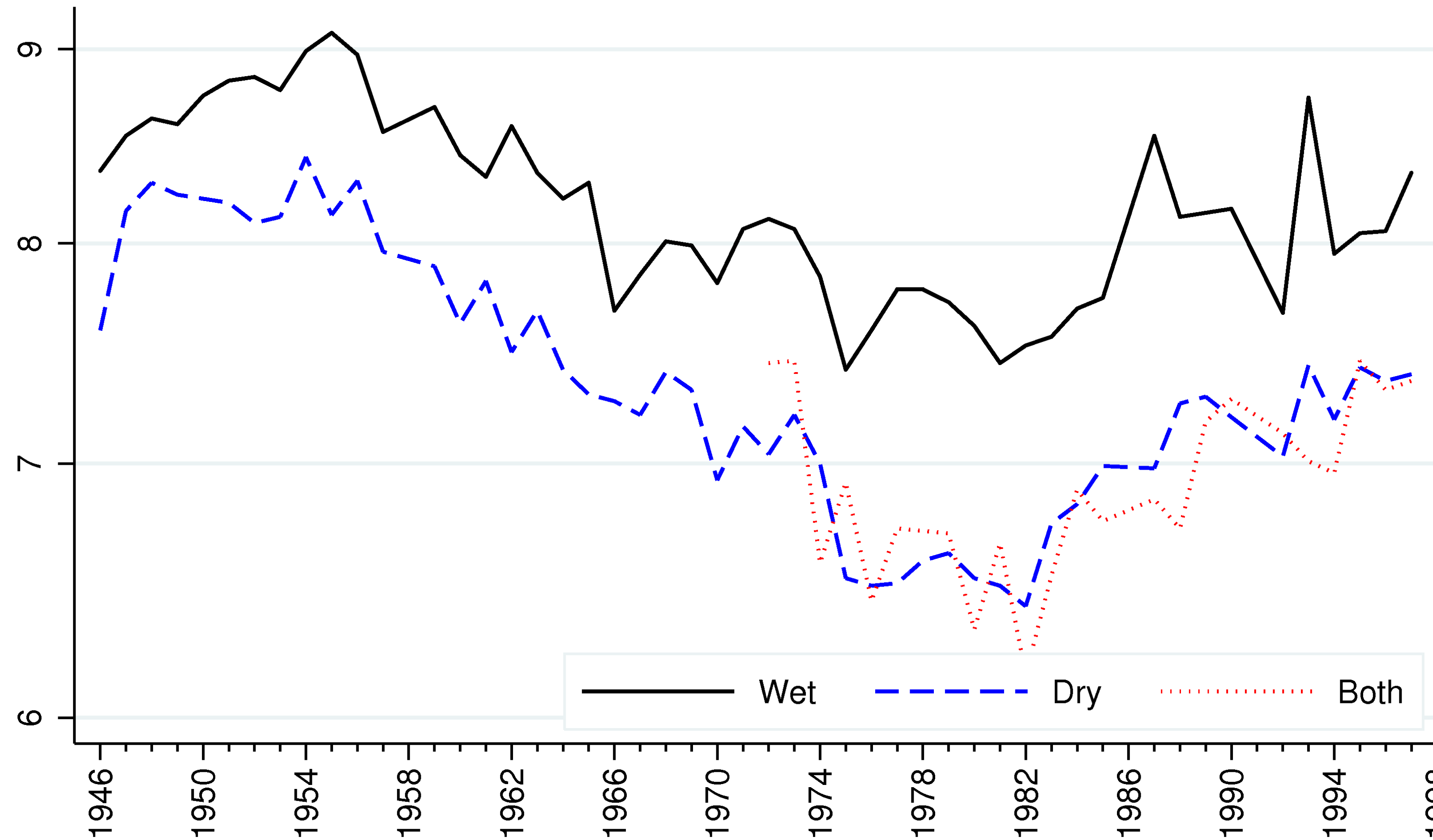


Figure 12. Fuel Productivity
U.S. Clinker Production per Unit of Fuel

(Log of Thousand Short Tons per Million BTU's)
By Process

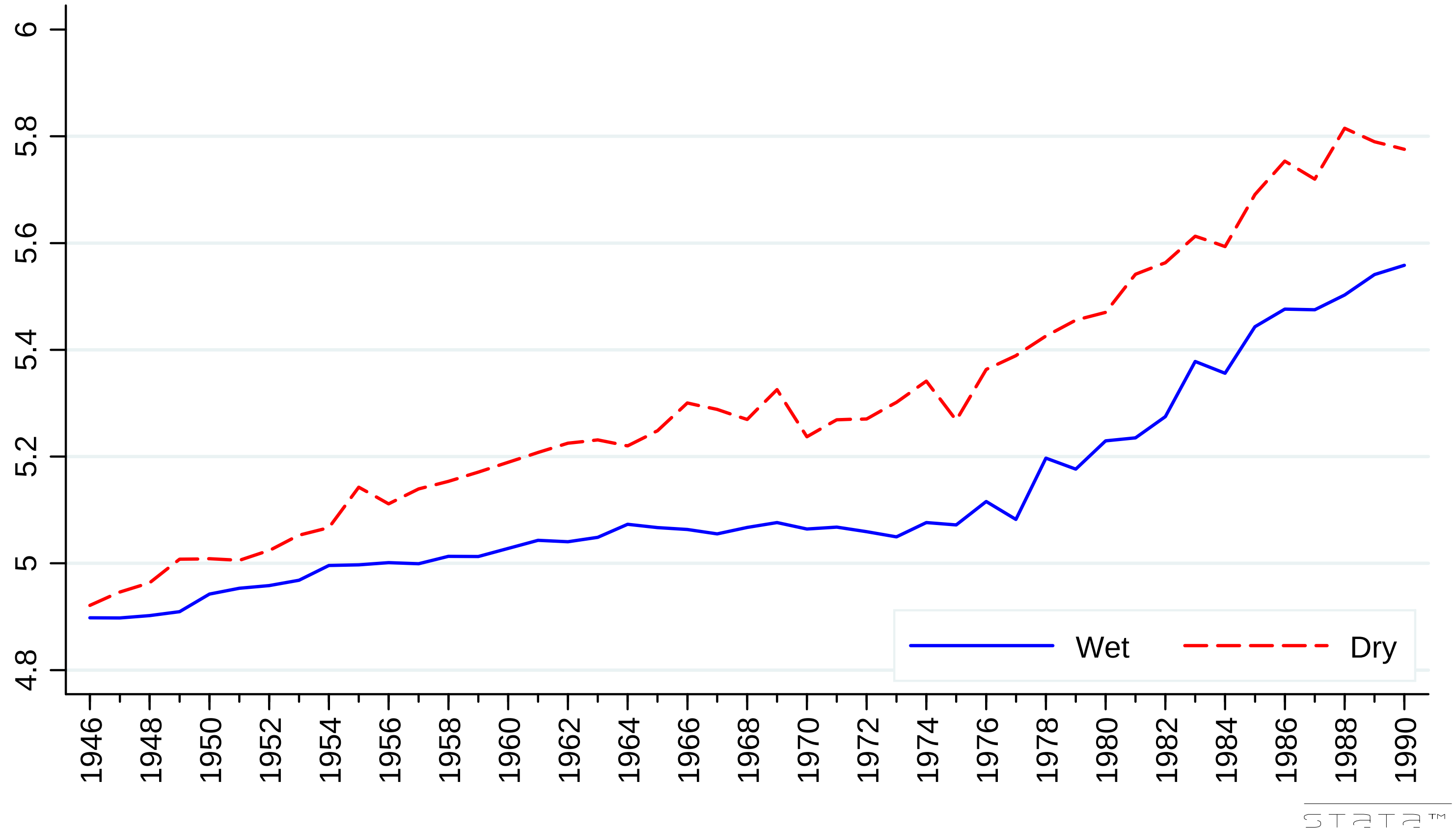
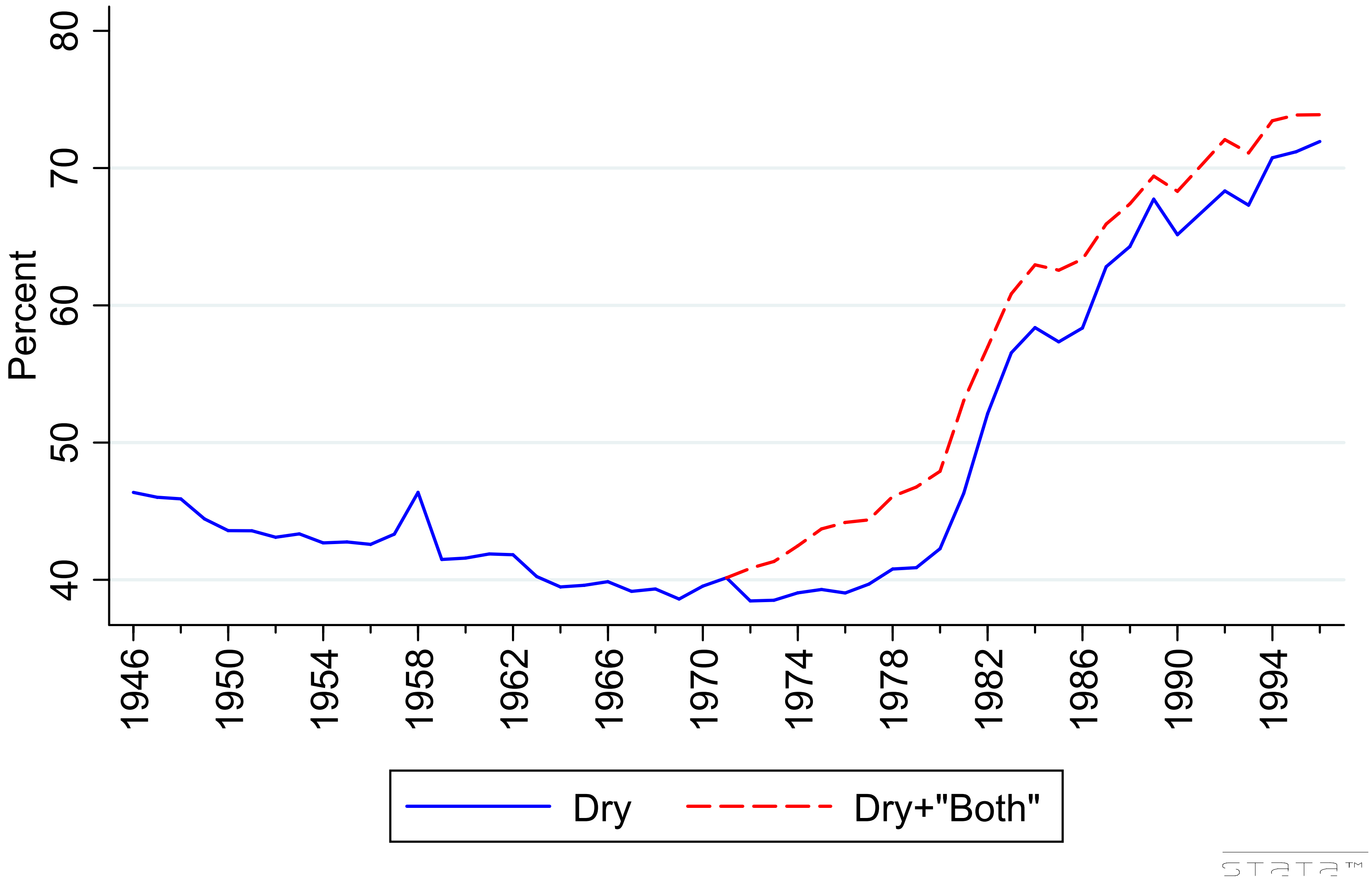


Figure 13.
Dry Plant Share of Production
U.S. Cement Industry



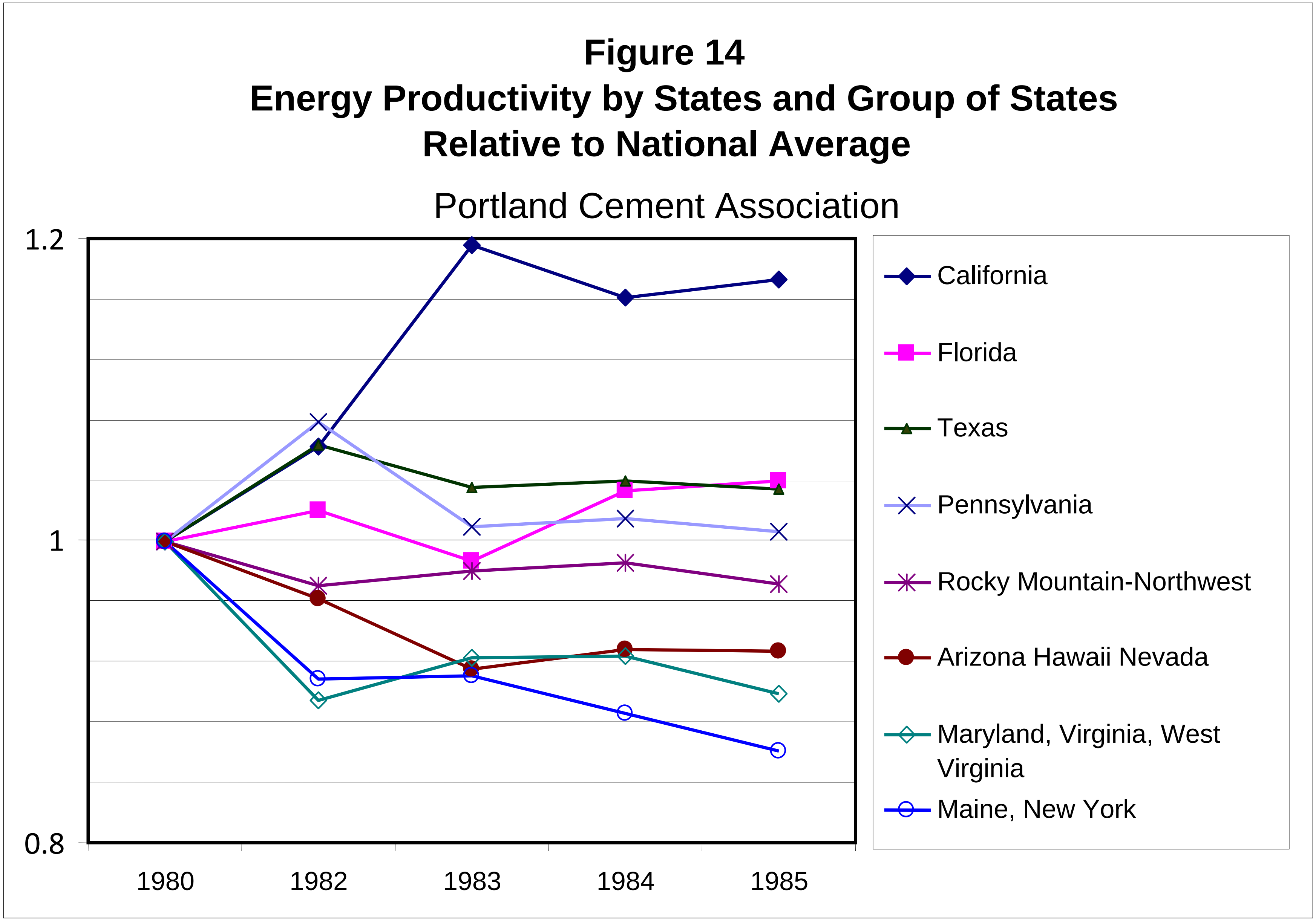


Figure 14
Energy Productivity by States and Group of States
Relative to National Average
Portland Cement Association
1.2
1
0.8
1980
1982
1983
1984
1985
California
Florida
Texas
Pennsylvania
Rocky Mountain-Northwest
Arizona Hawaii Nevada
Maryland, Virginia, West Virginia
Maine, New York

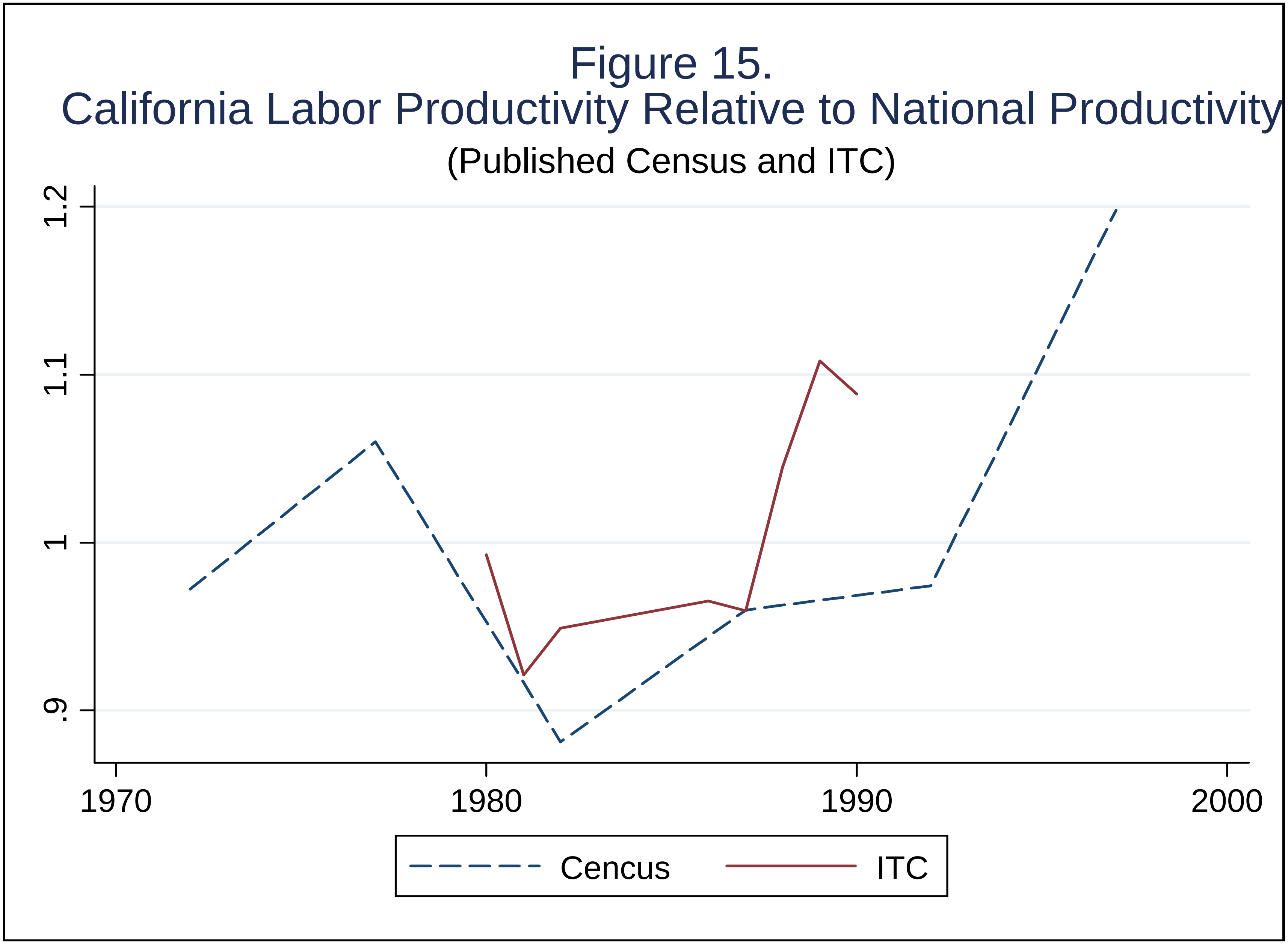


Figure 15.
California Labor Productivity Relative to National Productivity
(Published Census and ITC)
1.2
1.1
1
.9
1970
1980
1990
2000
Cencus
ITC

Table 1

Union Contract Provisions

US Cement Industry

	Job Protection Clause				
	Before 1963	1963	1965	1966-1984	1985-1998
Number of Locals(plants) for which we have contracts	4	36	49	84	12
Number of Locals which have clause	0	0	47	81	3
	Strong Contracting Out Clause				
	Before 1963	1963	1965	1966-1984	1985-1998
Number of Locals(plants) for which we have contracts	4	36	49	84	12
Number of Locals which have clause	0	20	49	83	0

Note: Total Number of Locals = 90

Table 2

Cement and Clinker Capacity Changes: 1974-1992.

	Cement Capacity			
	Total % Change	% of Capacity Gained due to Plant Expansion	% of Capacity Gained due to Entry	% of Capacity Lost due to Closings
1974-1982	11.3	20.9	8.1	-17.7
1982-1992	-6.3	4.9	2.8	-14.1
	Clinker Capacity			
	Total % Change	% of Capacity Gained due to Plant Expansion	% of Capacity Gained due to Entry	% of Capacity Lost due to Closings
1974-1982	-2.5	8.4	6.3	-17.3
1982-1992	-5.6	5.4	2.6	-13.5

Table 3

Labor Productivity Growth Decomposition

Census Years	Aggregate Productivity Growth	Within Component	Within Share
1972-1977	0.055	0.019	
1977-1982	-0.028	-0.058	
1982-1987	0.386	0.280	72.5%
1987-1992	-0.012	-0.035	
1992-1997	0.164	0.125	76.2%

Appendix Table 1.

Relative Plant-level Energy Productivity: 1972-1985

	1972-1985	1972-1980	1980-1985
Equivalent Tons per Million BTU (number of plants)	1.30 (n=96)	1.14 (n=113)	1.13 (n=102)
Tons per Kilowatt Hours (number of plants)	.92 (n=94)	.91 (n=112)	1.03 (n=101)

*Each cell contains the ratio of end period energy productivity to beginning period productivity.

Appendix Table 2.

Plant-level Energy Productivity: Log of Tons per MBTU

	All Continuing Plants	Dry in 1985	Wet in 1985	Dry/Pre-Heater in 1985
Constant	-1.88 (.023)	-1.818 (.043)	-1.960 (.027)	-1.858 (.037)
Pre-Heater	.108 (.014)			
Wet	-.122 (.013)			
1974	.023 (.029)	.035 (.053)	.005 (.039)	.039 (.051)
1975	.044 (.028)	.023 (.054)	.022 (.038)	.081 (.050)
1976	.082 (.028)	.063 (.056)	.050 (.038)	.127 (.050)
1977	.091 (.027)	.069 (.056)	.057 (.037)	.142 (.046)
1978	.108 (.028)	.074 (.057)	.070 (.037)	.167 (.050)
1979	.112 (.026)	.044 (.059)	.079 (.036)	.185 (.046)
1980	.128 (.027)	.042 (.059)	.095 (.037)	.209 (.046)
1981	.151 (.027)	.044 (.062)	.094 (.035)	.270 (.048)
1982	.185 (.026)	.078 (.058)	.118 (.036)	.315 (.044)
1983	.215 (.036)	.098 (.059)	.139 (.035)	.359 (.044)
1984	.203 (.027)	.059 (.058)	.118 (.038)	.370 (.044)
1985	.230 (.027)	.105 (.060)	.138 (.037)	.400 (.044)
N	1167	221	504	442
R^2	.361	.031	.081	.344

Appendix Table 3.

Plant-level Electricity Productivity: Log of Tons per KWH

	All Continuing Plants	Dry in 1985	Wet in 1985	Dry/Pre-Heater in 1985
Constants	-4.868	-4.897	-4.753	-4.862
	(.018)	(.045)	(.034)	(.030)
Pre-heater	-.024			
	(.078)			
Wet	.131			
	(.018)			
1978	-.056	.021	-.049	-.097
	(.026)	(.069)	(.042)	(.038)
1979	-.075	-.006	-.051	-.131
	(.029)	(.069)	(.046)	(.042)
1980	-.119	-.040	-.094	-.182
	(.027)	(.064)	(.042)	(.039)
1981	-.118	-.061	-.089	-.175
	(.027)	(.078)	(.042)	(.036)
1982	-.134	-.104	-.117	-.165
	(.026)	(.075)	(.042)	(.036)
1983	-.134	-.152	-.112	-.148
	(.026)	(.065)	(.043)	(.036)
1984	-.106	-.109	-.099	-.111
	(.025)	(.051)	(.044)	(.035)
1985	-.105	-.124	-.092	-.110
	(.026)	(.054)	(.045)	(.037)
N	812	147	350	315
R^2	.209	.087	.041	.126