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COMPETITION AND THE NATURE OF COSTS: THE CAST IRON PIPE INDUSTRY, 1890-1910, AND THE CASE OF *ADDYSTON PIPE*

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Chapter 1

Introduction

The aim of this study in industrial organization is threefold. First, it presents some theoretical results that are pertinent to the study of industry behavior and antitrust policy. The focus will be placed on a detailed model of markets that emphasizes the stringent conditions necessary for the existence of a competitive equilibrium. Although the central results can be expressed in more familiar terms, the roundabout method used here has the virtue that it makes explicit our assumptions about markets and competition. This theory is also introduced because it holds out the promise that it can resolve the problems it calls to our attention. The most important issue taken up is the incompatibility of increasing returns and competition. Increasing returns are of course a prevalent feature of economic life, and this is often recognized in economic models. It turns out, however, that no competitive equilibrium exists in the most familiar case embodying increasing returns, namely an industry composed of plants with identical U-shaped average cost curves. Furthermore, no competitive equilibrium is possible in the case of industries that operate under a variety of related and empirically important cost conditions.

The second aim of this study is to present a detailed analysis of an industry that figures prominently in the development of antitrust policy, and in particular in the development of the *per se* rule against price fixing. It is argued here that the events on which *Addyston Pipe* is based are best explained by a theory that does not take the existence of a competitive equilibrium for granted. Evidence that has previously not been used in discussions of *Addyston*, some of it from court documents, some from the trade journals, supports the view that a competitive equilibrium could not have been attained in the cast-iron pipe industry in the period 1890-1910. The fundamental reason for this is that plants in the industry had declining average costs over a considerable range of output.

The third aim will be to explore more thoroughly the cost conditions in this industry. The monthly figures on costs, output, sales and many other relevant measures are available for eleven cast iron pipe plants for one year. These data also indicate declining average costs, and, what is more, suggest that firms typically operated over the portion of their cost functions for which average <u>variable</u> cost was constant or decreasing. These empirical results are consistent with what researchers have found in other industries. In the case treated here they raise serious doubts about the ability of marginal cost pricing to cover costs and provide additional support for the view that industry cost conditions were incompatible with competition.

1.1 The Monopoly Explanation and Addyston Pipe

Students of American industrial history have for the most part convinced themselves that the last one hundred years were marked by the accumulation and exercise of substantial monopoly power. At the very least, the evidence appears to indicate that such monopoly power was actively sought. Throughout this period, but particularly during the last twenty years of the nineteenth century, producers in numerous manufacturing industries entered into price fixing agreements. In what has usually been taken to be a related development, a substantial fraction of U.S. industrial capacity merged during the six year period beginning with 1897. This merger wave occurred at the same time that the courts developed a more or less consistent interpretation of the Sherman Antitrust Act of 1890. This interpretation became discernably hostile to agreements among producers, and as it happens, the first years of the merger wave coincided with the emergence of the <u>per se</u> illegality rule of price fixing, the rule that price fixing could not be sanctioned because its only conceivable purpose is economic extortion. A common interpretation of the mergers is that they were substitutes for the illegal price fixing agreements.[1] Finally, there was the development of the basing point pricing system in which buyers at all points paid the price prevailing at a certain location plus freight charges. This system led to a number of seemingly perverse economic distortions. Although it was often defended by the representatives of various industries as a fundamentally competitive and spontaneous arrangement, it seems in fact to have been collusively operated in at least some cases.[2]

While the most commonly cited industry in which this pattern of collusion, merger and basing point pricing occurred is steel, this pattern also conforms to the events in the cast iron pipe industry, the focus of this study. The cartelization of cast iron pipe producers during the 1890's is well established, since key documents in the case were copied and supplied to the government by the cartel's stenographer. The cartel was composed of six manufacturers of cast iron pressure pipe located between Cincinnati, Ohio and Bessemer, Alabama. In 1898 the Sixth Circuit Court of Appeals found these six to have been in violation of the Sherman Antitrust Act, but only months after this decision was handed down, four of the six firms merged. Justice appeared doubly thwarted when the two remaining firms and five previously unassociated producers joined the four merged firms even before the Supreme Court affirmed the lower court's view. Antitrust policy, insofar as it had any effect, appeared to have driven the firms to more effective collusion. Moreover, the newly reorganized industry engaged in basing point pricing within a few years of this merger, probably beginning in 1902, if not earlier.

This episode of collusion and merger in the cast iron pipe industry has usually been taken as an indication that producers sought monopoly returns, as have similar arrangements in other industries. The standard empirical tests for monopoly in this instance are inconclusive. Some evidence suggests that the colluding firms got a higher price in 1896 at the factory gate for orders going to nearby communities than for those going to other parts of the country. The fact that prices in the South, where the colluding firms were located, were generally lower than in the North might be explained by a limit pricing argument and the threat of entry. Other evidence, particularly that concerning entry, does not support the monopoly view. New plants were established in the period following the merger, some near the southern plants that were charged with price fixing, others in Ohio and Pennsylvania. Entry by itself might suggest that other firms were attracted by the higher profits in a newly monopolized industry, but this entry took place at the same time as the business booms of the early 1900's. New firms, in particular those at locations west of the Appalachians, where cities were growing rapidly, would have been expected to appear anyway. More important than this, entry was relatively easy. Plants that manufactured cast iron pressure pipe were very much like other cast iron foundries. Knowledge of the production process was widely diffused, the amount of capital relatively small, and non-specialized plants could and did produce pressure pipe on a makeshift basis. It was also the case that other types of plants could be readily converted to cast iron pressure pipe production, as several were in the period 1900-1903. The prices of pig iron and pipe were widely quoted in the trade journals, and producers and purchasers made it a point to know what bids were in various parts of the country on municipal contracts. An ordinary monopoly would have been hard to conceal, and once discovered, difficult to protect.

What then might be advanced as an alternative? In particular, is there a unified theory that can link cartelization, apparent "merger for monopoly," and basing point pricing in the cast iron pipe industry and perhaps in other industries as well? All three practices seem to indicate a failure of competition. On the view presented here, competition as it is ordinarily thought of in economics may be impossible in industries characterized by quite plausible cost conditions. Although an explicit treatment of the alternatives to unrestrained competition will not be taken up, the aim will be to demonstrate that some alternative was very likely necessary.

1.2 Economic Theory and Competition

We can summarize the analytical method used here as follows. It is possible to define in a precise manner what competition is and to show whether particular cost and demand conditions are compatible with it. Specifically, it must be the case that some group of agents (one or more) cannot disrupt a proposed reallocation of goods in a market by allocating the goods over which it has control in a manner that leaves each agent better off. Such an allocation, if it exists, is called the core and is defined for a set of allocations that contains the usual competitive equilibrium. More importantly, if this set is empty, then there is no competitive equilibrium.[3]

Although the results in core theory suggest that we may often have a situation in which an unrestricted competitive equilibrium is not possible, it should not be supposed that the application of this theory to industrial organization implies conclusions that are fundamentally different from those arrived at by means of more familiar economic reasoning. J. M. Clark came to similar conclusions in his Studies in the Economics of Overhead Costs and in "Toward a Concept of Workable Competition." This view is substantially less critical of agreements or tacit understandings among producers than that prevailing more often among economists. Alfred Marshall, in writing Book V ("General Relations of Demand, Supply and Value") of his Principles, was in part concerned with the same problems and took the opportunity to emphasize that his concept of competitive equilibrium applied only to long-run tendencies. The common thread in these approaches is the attention paid to the influence of fixed costs.

The idea that complete freedom of contract is economically untractable, or at least inefficient, is by no means novel. It has long been recognized that restrictions on transactions promote efficient outcomes in certain situations. For example, copyrights, patents, resale price maintenance, franchise arrangements, and covenants not to compete prohibit certain forms of "competition." The generally accepted argument is that such restrictions allow certain types of (socially beneficial) expenses to be covered. In core theory it is a well established result that an equilibrium can emerge in certain situations when restrictions are placed on agents (Telser, 1978, pp. 81-85). The surprising result is that similar restrictions may be necessary in the case of the production of standard industrial goods such as steel, cement, and cast iron pipe. Viewed in this light, the significance of the events surrounding Addyston may very well be that they provide an instance in which a competitive equilibrium could not be sustained, and in which restrictions promoted the production of a good by allowing firms to cover their costs.

Some pieces of evidence from Addyston and its aftermath are consistent with such an explanation. A particular result which emerges from core theory is that a stable equilibrium can be achieved in certain cases if either all supply or all demand is placed under single control. The collusion of firms and the geographic restrictions that were part of their agreement may have provided such solutions. Moreover, events in the early 1890's and again in

1899 provide additional support for the view that a naive theory of competition is inadequate here. In 1899 the margin between the price per ton of pig iron and the price per ton of cast iron pipe fell to levels not reached in the entire period from 1890 to 1910. Trade journal reports characterized this as a struggle in which the newly formed consolidation sought to punish the other firms which it had unsuccessfully tried to include in the merger. A similar period of cutthroat competition existed in the early 1890s among the independent firms. These episodes are hard to square with the smoothly functioning textbook equilibrium in which firms simply shut down or start up as shifts in demand take place, or if the number of active firms does not change, prices simply slide up and down upward-sloping marginal cost curves.

1.3 The Nature of Plant Costs

An important empirical point, as this discussion suggests, is the sort of cost conditions prevailing at the plant level. The specific form of the cost function will determine whether a competitive equilibrium is possible, and if not, how far we are from it. In particular, we are interested to know whether the plants in an industry have the familiar U-shaped average cost curves, that is, whether there are increasing and then decreasing returns.

There are a number of interesting questions that arise if plants do have such cost curves. Will a plant shut down or merely curtail operations in the face of transitory declines in demand? For otherwise identical cost curves the answer depends on the relative magnitudes of fixed costs that are inescapable over the short term and avoidable costs that are also largely independent of plant output but that are avoided if plant output is brought to zero. The existence of U-shaped average cost curves also has important implications for the behavior of inventories in a market characterized by cyclical or stochastic variations in demand. Finally, industries in which increasing and then decreasing returns characterize plant costs may not achieve a competitive equilibrium. Roughly speaking, conditions that thwart competition arise if a) each plant's capacity constitutes a substantial fraction of total market capacity, b) inventories are costly to hold, and c) certain costs are not associated with incremental units of output.

To bring into focus the importance of cost conditions for the matter at hand, think of the two following problems. First, we ask plant managers who are given control over a plant of fixed capacity for some period of time to organize a plan of production and inventory holdings that will satisfy a certain path of plant sales at least cost. Second, given an industry's collection of plants, these plants possessing various capacities and various fixed and avoidable costs, as well as differing variable costs, how shall we assign sales paths to plant managers in order to satisfy a given path of industry demand (with marginal cost equal to marginal benefit) at least total cost? Although still short of the situation we do find in actual markets, this second exercise will provide some notion of what an industry supply curve looks like and suggest as well how far the industry may be from satisfying the assumptions necessary for a competitive equilibrium.

It should be stressed that the answer to the first problem will depend on our assumptions about plant costs and the cost of holding inventories. In particular, the most plausible alternative to U-shaped average cost, constant marginal and average cost, implies no output inventories and, consequently, pari passu changes in output and sales. Such cost conditions also imply that plants will not shut down, except when demand for the product collapses completely. Perhaps it might be more accurate to say that the extent of production cutbacks is arbitrary across plants.

As an empirical matter, we do observe cyclical swings in inventories, divergences between sales and output, and plant shutdowns. These are consequences of the failure of plant cost curves to satisfy the assumption of constant returns , and an item-by-item examination of plant costs suggests that there are many factors that cannot be varied by equal percentages with changes in output. Fixed costs of substantial magnitude arise because of the nature of capital outlays, inventory costs, depreciation expenses, taxes, insurance, and terms of employment for some workers, particularly those with special skills and those whose wages fall in the general category of overhead expense. Although some of these expenses are not incurred if a plant shuts down, the requirements of a particular plant that is in place are such that these factors result in declining average costs.

While all these influences contribute to the creation of a range of output over which average cost falls, the amount of capital at a plant also determines the range over which it rises, abstracting from span of control questions. Equally important, technological considerations dictate how sharp the increases in marginal and average costs, past the point of minimum average cost, will be. Production processes that rely on the continuous application of heat, such as those utilizing blast furnaces and kilns, for example, often cannot be brought to a faster pace at a particular plant except at great expense. This feature of cost curves also implies that if plant output must be varied at all, the optimal average output should be less than the rate of output corresponding to minimum average cost, so that firms will typically be operating over the range for which average cost falls.[4]

The assumption of constant returns it should be noted, also fails to hold in the long run. When we examine the cost of operation in an industry for plants of various sizes, we find that the long-run average cost curve has an initial portion over which average cost falls. There is first of all some minimum efficient scale of operation due to the combined influence of an array of immutable physical constants (including their effect on the size of human beings). While it might be possible to construct a plant that produces only four pounds of pig iron per day we should not consider it a realistic possibility. This has the consequence that with a given set of plants, industry supply will exhibit a saw-tooth pattern for finite rates of output. In the long, long-run we could of course always operate one plant to meet a given, constant demand if long-run average cost for a plant never rises over the relevant range. If demand varies however, the presence of fixed and avoidable costs at the plant level calls for the use of some comparatively small plants whose minimum average cost may be higher than that which prevails for plants of greater capacity.[5] Moreover, changes in demand will be met most efficiently not by proportionate decreases in production at all plants, but rather by a combination of decreases in production at some, shutdowns at others, and no change at all in production for yet a third class. It should be noted that analytical solutions to this sort of problem are difficult for cases in which all plants are located at a single point, and substantially more complex in those cases where plants and consumers are geographically dispersed. What should be uppermost in our minds, however, is that we have no assurance that the short-run supply curve in either case is as smooth as we would like.

For our purposes the significance of these observations is that certain aspects of firm behavior in the cast iron pipe industry reveal the nature of plant costs; we can be fairly confident about the general nature of plant costs without looking at cost data. We know, for example, that the cast iron pipe industry faced seasonal and cyclical swings in demand and that this variation was accommodated by holdings of inventory and by variations in output. We also know that the size distribution of firms did not reach below a certain minimum. These facts suggest declining average costs at the plant level and increasing returns to scale over some range. Finally, certain plants were shut down during the winter or during downturns in demand, which indicates that a significant source of declining average costs were costs that could be avoided in the short run.

Chapter 2

The Existence of a Competitive Equilibrium

Should we ever doubt that the participants in a market can arrive at a competitive solution to the problem of who gets what? There are two reasons why we might raise this issue. First, various theoretical approaches suggest that only certain types of markets are likely to achieve thoroughly competitive solutions to the problem of market allocation. The particular apparatus employed is not crucial to this result. For example, economists who used less formal analyses, among them Alfred Marshall and J. M. Clark, recognized the point. Formal models other than the one invoked here will also do, as modern economists who have looked at this issue have shown.[1]

The second reason for calling the assumption of competition into question is that collusion has been a demonstrable phenomenon in industry, and perhaps equally important, has been viewed differently in foreign countries than in the U.S. It is also the case that certain industries are more often among those that are linked with collusion, whether the collusion is of their own making or regulated by government. Firms in transportation industries and in steel, cement, and heavy construction, for example, are thought to be reluctant competitors. Might it be possible, after the issue is examined, that collusion in certain industries is necessary or inevitable? We can suggest the nature of the problem by noting, as Marshall did, that the "plants" in such industries appear generally to be operating with slack capacity, where marginal cost is less than average cost. Yet marginal cost pricing, which is what competition implies, will not in general recover all plant costs.

The question of competition is illuminated here using the theory of the core. This theory deserves the attention of economists because it is based on the notion of recontracting. The idea of a market clearing price, for example, emerges from the possibility of recontracting, as does the concept of competitive equilibrium. The core is defined as those allocations that the procedure of recontracting could not, from the point of view of some set of participants, improve upon. It is important to note that it contains the usual competitive equilibrium. In many cases, however, no point exists such that voluntary reallocation of money and goods among some participants would not leave them better off. The usefulness of the theoretical structure in such cases is that the feasible contracts or coalitions that block such allocations can be identified.

2.1 An Introduction to Core Theory

Suppose buyers and sellers are assembled at a single site. Each is willing to exchange one or more units of a good for some set of prices. Furthermore, each agent is free to enter provisional contracts with others that may be broken unilaterally if he can find a contract that offers him better terms. Will there necessarily be some final set of contracts such that no single agent or group of agents can do better? Surprisingly, no. To see why it will be useful to examine the following situations.

A Simple Game. Imagine a game with n players denoted by $A_1, A_2, \ldots, A_n$. Each player can assure himself of a return $a_i \geq 0$ and two or more players can assure themselves as a group of at least as large a return as they can obtain if split up into non-intersecting subgroups. This situation is represented by the von Neumann-Morgenstern characteristic function where $V(A)_i = a_i$ is the security value of player A_i and for which it is true that $V(A_i,A_j) \geq V(A_i) + V(A_j)$ for all $i \neq j$. More generally, for any two subsets of players S_1 and S_2 such that $S_1 \cap S_2 = \emptyset$, we have $V(S_1,S_2) \geq V(S_1) + V(S_2)$.

Denote the returns we propose for any player A_i by x_i. Then for any coalition S contained in N, it must be the case that

$$\sum_S x_i \geq V(S) \qquad (2.1.1)$$

that is, the proposed returns to members of the coalition must sum to an amount greater than the amount it can assure itself. It must also be true, however, for the all-player coalition, denoted by N, that

$$\sum_N x_i \leq V(N) \qquad (2.1.2)$$

i.e., the proposed returns cannot exceed what the coalition of all agents can assure itself.

Denote a proposed solution by $\underline{x}$. Such a vector is said to be in the core if it satisfies (2.1.1) and (2.1.2). The core itself consists of all possible vectors satisfying these conditions. It may happen, however, that no proposed vector can provide every coalition with more than it can assure itself without at the same time breaking the resource constraint. If that is the case it is said that the core is empty.

Consider the following simple game with three players. Each player can assure himself of one dollar, any group of two can assure itself a return of three dollars, and the group as a whole can have four dollars. One may think of this as a case in which there is first increasing and then decreasing returns to scale. Formally,

$$V(A_1) = V(A_2) = V(A_3) = 1$$

$$V(A_1,A_2) = V(A_1,A_3) = V(A_2,A_3) = 3$$

$$V(A_1,A_2,A_3) = 4$$

Is there a set of returns, x_1, x_2 and x_3 that can satisfy the following inequalities?

$$x_1 \geqslant 1 \qquad x_2 \geqslant 1 \qquad x_3 \geqslant 1 \tag{2.1.3}$$

(the amount the players can assure themselves alone),

$$x_1 + x_2 \geqslant 3 \qquad x_1 + x_2 \geqslant 3 \qquad x_2 + x_3 \geqslant 3 \tag{2.1.4}$$

(the amount any two can assure themselves jointly), and

$$x_1 + x_2 + x_3 \leqslant 4 \tag{2.1.5}$$

(the feasibility constraint).

Note that (2.1.4) implies

$$x_1 + x_2 + x_3 \geqslant 4.5$$

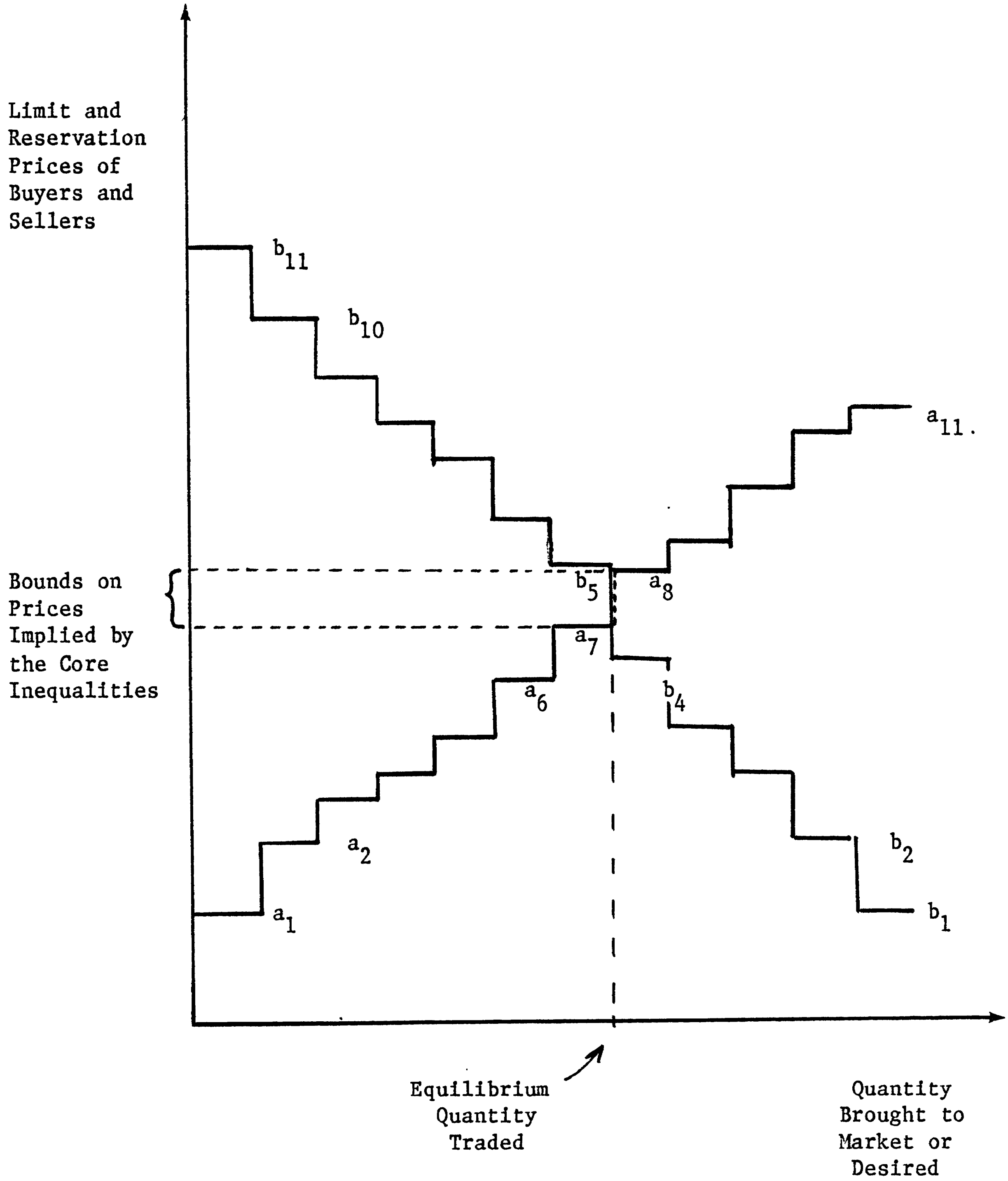
But this contradicts the feasibility constraint in this case, so that the core is empty. It may be noted in passing that this example illustrates in a simple fashion the problem frequently encountered in economic applications, namely the power of coalitions of intermediate size to demand a higher average return than is available for the coalition of all players.

Market Trade. An example of market exchange analyzed by Telser (1972) should help to illustrate the usefulness of this approach and its relation to what is usually meant by competition. Imagine a market with n buyers and m sellers, each willing to exchange one unit of the good but having different limit prices. Buyers will not pay more than a given price, and sellers will not accept less than a given price. Let these limit prices be represented by $b_1 \leqslant b_2 \leqslant \ldots \leqslant b_n$ for the buyers and $a_1 \leqslant a_2 \leqslant \ldots \leqslant a_m$ for the potential sellers. This situation is represented for the case where m = n = 11 in Figure 2.1. The number of inequalities that have to be satisfied are numerous, representing the returns that all possible coalitions could assure themselves. In fact there are $2^{n+m} - 1$ or 2,047 constraints in this case. It is sufficient, however, if we focus on what each participant can assure himself and on what all possible pairs of buyers and sellers can assure themselves.

Figure 2.1

REPRESENTATION OF EQUILIBRIUM

IN A MARKET WITH SINGLE UNIT TRADE



Individual sellers can always keep their units of the good so that we have $V(A_i) = a_i$ for $i = 1, \ldots, m$. Potential buyers, on the other hand, do not have any units of the good, so that the best they can do by themselves is $V(B_j) = 0$ for $j = 1, \ldots, n$. Together with the pairwise security values $V(A_i,B_j) = \max(a_i,b_j)$, for all i and j, which indicates that these coalitions can always award a unit of the good to the participant valuing it the most, these determine the minimum necessary returns to buyers and sellers. Let x_i denote the return to seller i and y_j the return to buyer j. Then the inequalities $x_i \geq V(A_i) = a_i$, $y_j \geq V(B_j) = 0$ and $x_i + y_j \geq V(A_i,B_j) = \max(a_i,b_j)$ together with the feasibility constraint defined for all i and j

$$\sum x_i + \sum y_j \leq V(N) \tag{2.1.6}$$

determine the core allocations. V(N) has the interpretation of the maximum return possible to the participants in the market, and in terms of Figure 2.1 we see that returns are maximized if we transfer units of the good from the potential sellers who value them least and to buyers who value them most until we reach the seller who values the good more than the most eager unsatisfied buyer. If we let these transactions be voluntary, the exact price charged per unit can be indeterminate over a range, but it falls between bounds whose lower limit is established by the least eager seller who does trade or the most eager buyer who does not, whichever is higher, and whose upper limit is established by the least eager buyer who does trade or the most eager seller who does not, whichever is lower. It can be seen that as the number of buyers increases, and under reasonable assumptions about the distribution of limit prices, this interval is forced to a single point. In such a case the imputations or returns in the core are those that emerge from a traditional supply and demand analysis. An important result in core theory, however, is that when traders participate in multi-unit trade, it may no longer be true that there is a set of market clearing prices.

2.2 Competition in Industries with U-shaped Cost Curves

Although most industries to which economics pays attention are located across space, it is of considerable interest first to abstract from the spatial aspects of industry equilibrium. This is so even in the case of the industry under consideration here since most of the plants in it were located close together in one of several major producing areas. With geographically concentrated production, a reasonable way to proceed is to view consumer demand net of transportation costs.

The Status of the Core. The main result that follows in this section is that there is in general no competitive equilibrium in an industry composed of firms with identical U-shaped cost curves and some arbitrary rate of demand. This has been demonstrated by Telser (1978, Chapter 3) using a more sophisticated structure that is integrated with his concept of a "kind" characteristic function. The analysis that follows here is based on his demonstration of similar propositions for an analysis of the status of the core in a set of location problems.

Imagine an industry in which there are z identical buyers each having a demand function $p = b(q)$ with $b'(q) < 0$ where p is to be interpreted as the valuation placed on the q-th unit. We can describe the total benefit to a buyer of the continuous quantity q as

$$B(q) = \int_0^q b(s)ds \tag{2.2.1}$$

Also assume that a plant producing for this industry has costs equal to $c > 0$ that do not vary with output, and that variable costs are $G(Q)$ where Q represents plant output. We require that $G(0) = 0$, $G'(Q) > 0$, and $G''(Q) > 0$ and that $(G(Q) + c)/Q$ have a minimum at some finite, positive value of Q. The expression for total plant costs, $G(Q) + c$ is of course the cost curve that provides the familiar U-shaped average cost function. Note also that the formulation is fairly general and that by an appropriate choice of c and G(Q) we can represent a wide variety of plant cost functions having fixed costs, positive marginal cost and some capacity constraint.[2]

The analysis will proceed by considering the returns that coalitions of buyers and plants can assure themselves. The arrangement may be thought of as a contract among the buyers and the plant owner, the task being to find the optimal contract terms. One may also think of groups of buyers operating plants for their mutual benefit. Although there may be a temptation to assume that this results in the same output decision as occurs if we follow the rule that demand should cross summed industry marginal cost, this is not always so. Any "club" operating a plant always has an incentive to include more members or reform, thereby expelling some, until it manages to operate its plant at minimum average cost. It is this basic conflict between groups of buyers and the market as a whole that thwarts an equilibrium.

Let m be the number of buyers in a coalition operating a single plant and define the net benefit function to such a coalition as

$$\gamma(m,q) = m \cdot B(q) - G[Q(m,q)] - c \qquad (2.2.2)$$

with $Q(m,q) = m \cdot q$, by which is implied that the total amount is allocated equally to the m buyers who belong to the coalition. The equal distribution is a natural result of the identical, downward sloping demand curves. What are the properties of this function? First note that the net benefit to the coalition of an extra player is equal to his gross benefit from a given quantity of output less the marginal cost of producing that quantity:

$$\frac{d\gamma}{dm} = B(q) - \frac{dG}{dQ}\cdot q \tag{2.2.3}$$

Furthermore, note that the extra net benefit decreases as the number of players is increased, so that

$$\frac{d^2\gamma}{dm^2} = - \frac{d^2G}{dQ^2}\cdot q^2 < 0 \tag{2.2.4}$$

This implies that the net benefit increases more slowly with large coalitions because of rising marginal cost.

It is also necessary to look at the average net benefit to a buyer in a coalition. Define

$$A(m,q) = \frac{\gamma(m,q)}{m} = B(q) - \frac{G[Q(m,q)] + c}{m} \tag{2.2.5}$$

The first-order condition for a maximum average benefit is

$$\frac{\partial A}{\partial m} = \frac{G[Q(m,q)] + c - \frac{dG\partial Q}{dQ\partial m}\cdot m}{m^2} = 0 \tag{2.2.6}$$

This in turn implies $G\ (Q(m,q)) + c = \frac{dG}{dQ}\cdot Q$, total cost equals marginal cost times plant output. The highest average benefit therefore occurs where average cost is at a minimum. Similarly, since

$$\frac{\partial A}{\partial q} = b(q) - \frac{dG\partial Q}{dQ\partial q}/m = 0 \tag{2.2.7}$$

we have the result that marginal cost equals marginal benefit. So we have the point of maximum average benefit identical with the point at which the demand of all buyers in a coalition crosses the intersection of average and marginal cost, which by our assumption above we know exists.

A summary of the analysis above can be gleaned from Figure 2.2. The function $\gamma(m,q)^*$ in the upper part of Figure 2.1 traces maximum net benefit as a function of the number of buyers. This function is constructed with simultaneous optimal adjustments to quantity made. It is negative for small coalitions because of the influence of fixed costs, and increases at a decreasing rate due to the increasing marginal costs of production. For any given number of buyers there is also an optimal output rate for the plant, represented in the lower part of Figure 2.2.

How do we determine the status of the core for an industry with two or more such plants? It is useful to extend the results portrayed in Figure 2.2 to cases where coalitions operate more than one plant. That such larger coalitions are desirable is evident, since the average benefit to a coalition declines after some number of buyers is reached. Imagine a series of benefit functions

$$\gamma_n(m,q) = m \cdot B(q) - n \cdot G(Q(m,q)) - n \cdot c \qquad (2.2.8)$$

where the integer n refers to the number of plants operated by a coalition. Figure 2.3 shows what the net benefit functions with $n = 1$, 2 and 3 look like. The key feature of the diagram is that each coalition can obtain the maximum average net benefit, but only at the point where the number of buyers it has is the appropriate integer multiple of m^*, the number of buyers necessary to obtain the maximum average return in a single plant coalition. At all other points, the net joint return per buyer could be increased.

In order to determine the status of the core define the maximum average return to a coalition as $\gamma(m^*)/m^*$. For an arbitrary number of buyers, z, we know that $\gamma(z)/z \leq \gamma(m^*)/m^*$, that is, the average gain to the coalition of all z buyers is less than or equal to the maximum possible for some subset.

Figure 2.2

NET BENEFIT FUNCTIONS FOR COALITIONS

OF ONE PLANT AND ARBITRARY NUMBERS OF BUYERS

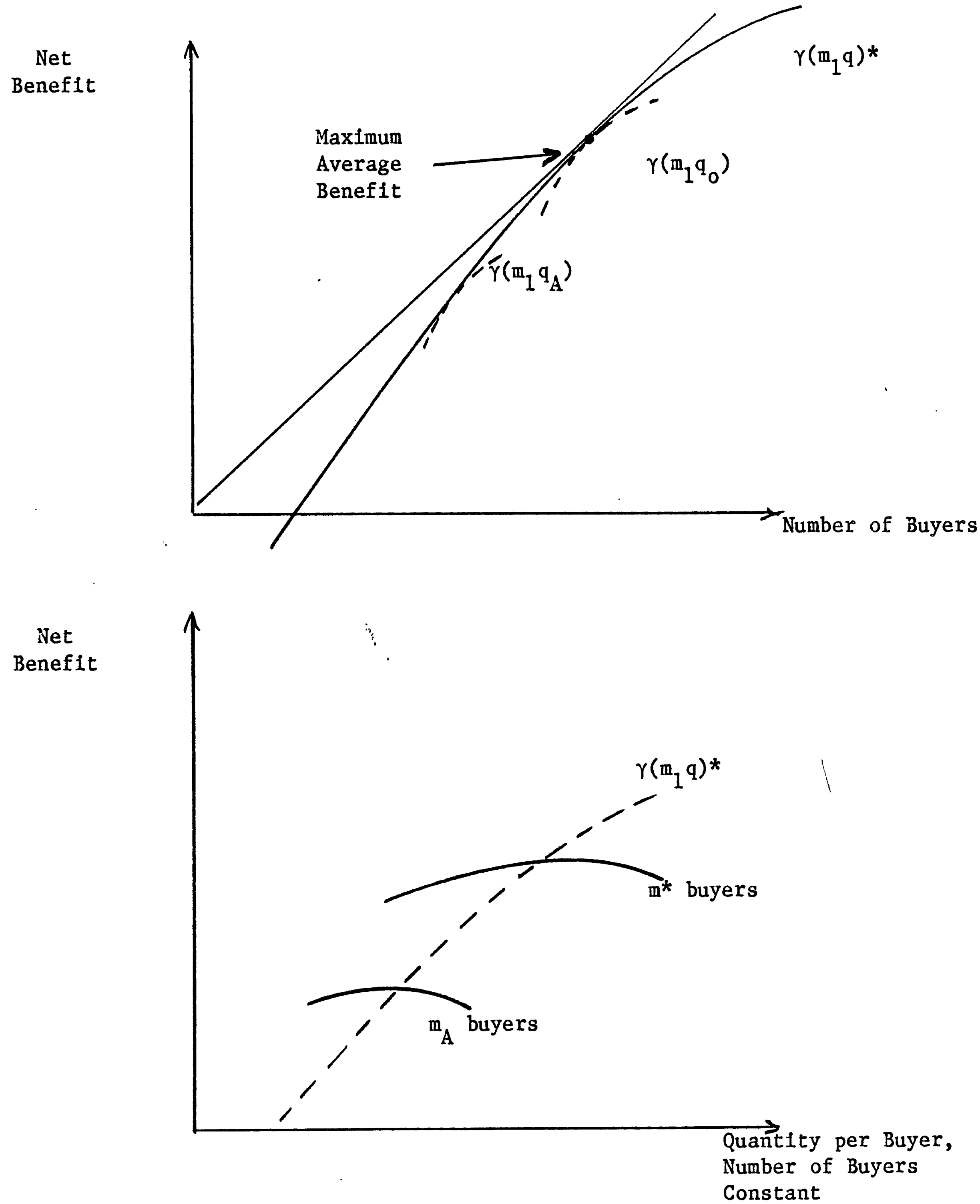
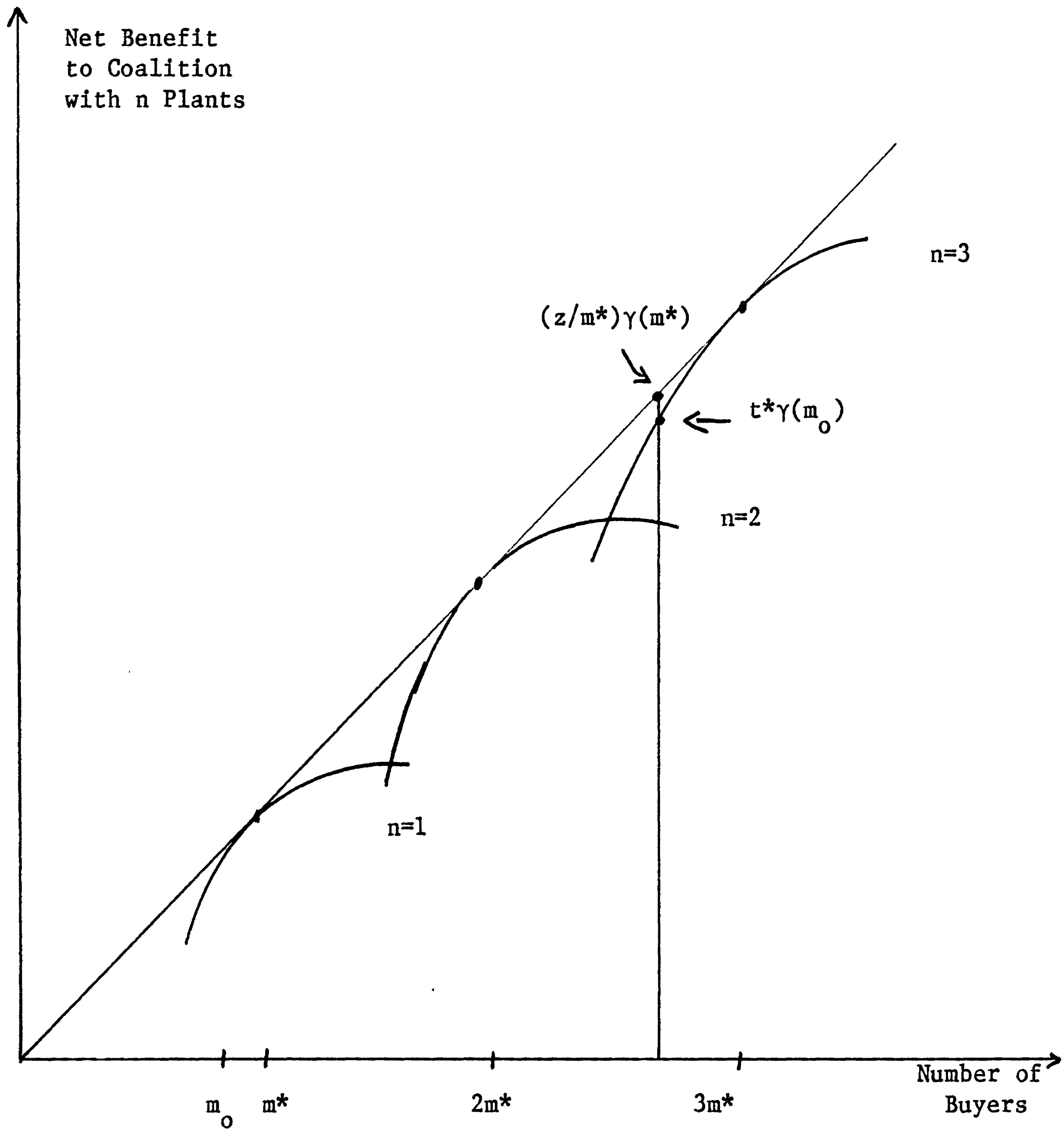


Figure 2.3

NET BENEFIT FUNCTIONS

FOR COALITIONS WITH 1, 2 AND 3 PLANTS



Let $m_o = z/t^*$ be the number of buyers in the optimal feasible coalition with one plant, where t^* is an integer so that $t^*\gamma(m_o)$ is as close as possible to $(z/m^*)\cdot\gamma(m^*)$, the maximum possible if plants could be built in fractional sizes. In Figure 2.3, t^* takes on a value of 3 since z buyers are better served by three than by two plants. We then have $V(z) = t^*\gamma(m_o)$ as the value of the characteristic function for the all player coalition. Two situations may arise. In one z is an integer multiple of m^*. The more common case is where $t^*\gamma(m_o) < (z/m^*)\gamma(m^*)$. Let x be the return to a buyer and $X(m^*) = \gamma(m^*)$ be the value of the characteristic function for coalitions with m^* buyers. The following core constraints exist:

$$m^*x \geq X(m^*) = \gamma(m^*) \tag{2.2.9}$$

$$zx \leq t^*\gamma(m_o) < (z/m^*)\cdot\gamma(m^*) \tag{2.2.10}$$

Multiply (2.2.9) by z and divide by m^* so that

$$zx \geq (z/m^*)\gamma(m^*)$$

Clearly this violates (2.2.10) so the core is empty.

A Graphical Representation. It may be useful to cast this argument in a more familiar form. Figure 2.4 illustrates in terms of demand and marginal cost curves the situation represented by the net benefit functions in Figure 2.3. The intersection of the demand curve D' and the sum of three firms' marginal cost curves at the point where summed marginal cost equals average cost corresponds to the case in which $3m^*$ buyers are in the market. At this point maximum consumer benefit is obtained for that rate of demand, and economic profit to the firms is zero. Moreover, the competitive price implied by that point has the property that, in the language of core theory, no feasible and mutually beneficial set of contracts can prevent it.

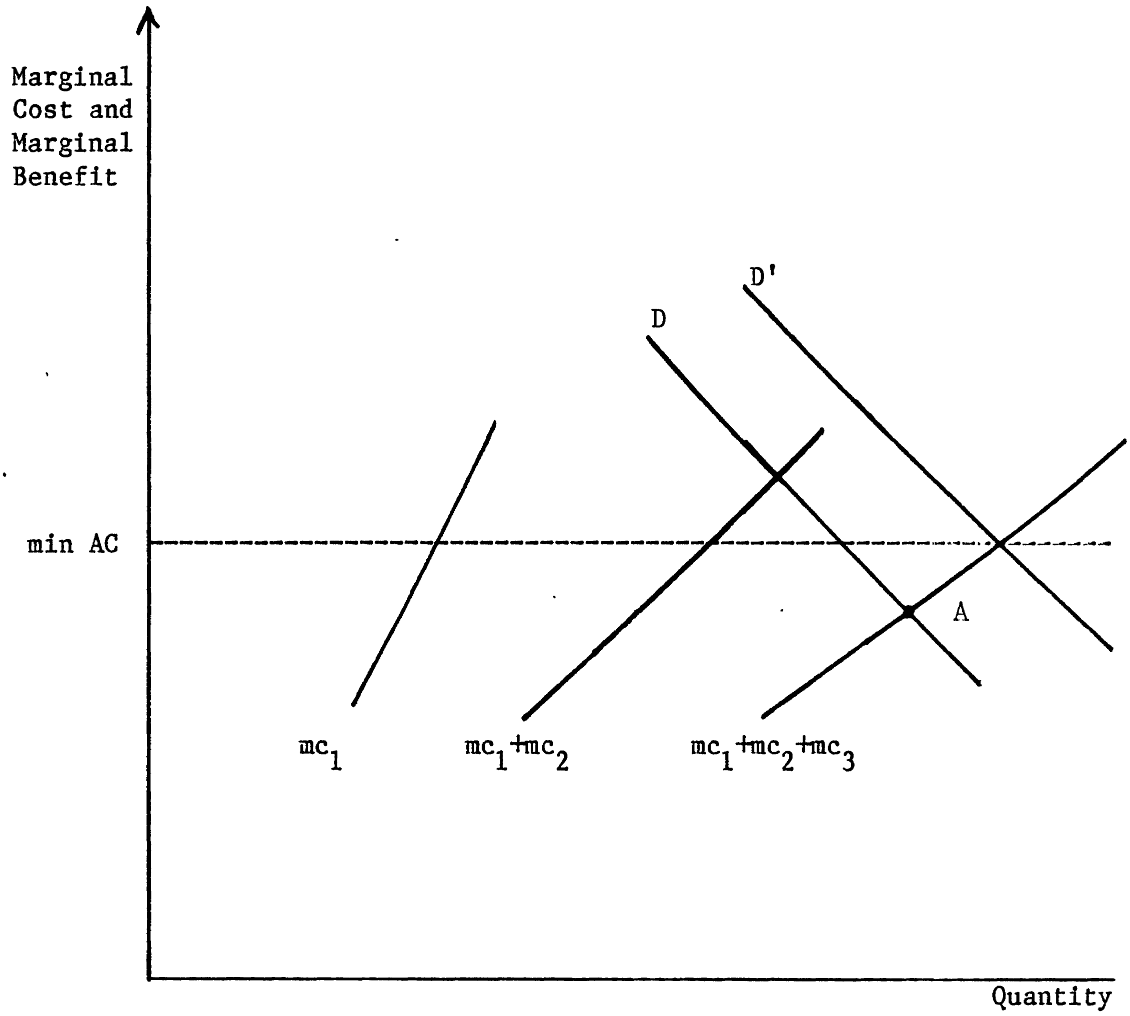
This is not so, however, for almost every other rate of demand. Consider what happens if instead the rate of demand is represented by D. The optimal

Figure 2.4

SUPPLY AND DEMAND REPRESENTATION OF EQUILIBRIUM

AND NO EQUILIBRIUM IN A MARKET

WITH THREE PLANTS



solution will call for the three plants to be operated at a locally inefficient point. Suppose we do operate all the plants at an output rate and with prices implied by point A. There are, strangely enough, arbitrage opportunities in such a situation, opportunities that cannot be realized, however. If we assume the freedom to contract, for example, the plants and some group of buyers, larger than any of three sets now buying from any one plant, may merge. The joint interest of the plant's new owners will not be served, however, by operating at the old output point. They would in fact prefer to operate it at the point of minimum average cost, pulling in more buyer-stockholders if necessary.

The more familiar economic story that goes with this is that if only two firms exist in such an industry, a new firm might enter, either because it does not know that it will drive profits down or because it expects one of the other firms to leave if it enters. Either way, we can no longer talk about price takers, nor can we use the concept of a supply curve to derive equilibrium quantities and prices.[3]

An Historical Note. An early and more or less formal treatment of the topics raised here is that of George Johnson Cady, who in 1942 published Entrepreneural [sic] Costs and Price. One of his major criticisms concerning price theory as it was then expounded was that it devoted too little attention to the behavior of marginal and average costs near the vertical axis and to "the device and implications of the enveloping curve." [Cady (1942), p. vii] He was particularly concerned with the analysis of markets in which atomistic competition was unlikely because of fixed costs and begins his chapter on "Perfect Competition" with an analysis of a market in which demand can support only two plants. He proposes a situation in which demand is such that a price equal to marginal cost generates profits if only one plant is active, but losses if two are active. From a graphical analysis of this situation (based on a diagram similar to Figure 2.4 here) he concludes that this is an unstable equilibrium:

> We have a singular situation; if the second remains aloof the price is high enough to draw him in, if he comes into the industry the price falls below his, as well in this case as his competitor's minimum opportunity average cost. This will undoubtedly be the case even after full account is taken of the effects of the specialization of his factoral equipment. This tends to drive him back out. In such a situation any one of several things may happen.... What is more probable is that the two will eventually agree to follow a live-and-let-live policy, involving, at least, a tacit understanding that their prices will be about the same and that production will be consciously controlled. [Cady (1942), p. 41]

Cady takes this analysis further, showing the potential disequilibrium in the case of several plants, and then takes his analysis to the case of atomistic competition. This, so far as I know, is the first formal, analytic treatment of the issue that this section treats.

Jacob Viner, who developed the analysis of industries with U-shaped average cost curves, was not unaware of this problem. In his classic expository article, "Cost Curves and Supply Curves," Viner considers the case in which there are constant industry costs because all existing firms and an indefinite number of potential entrants face the same long-run average cost curve (which has a minimum). "Here...actual long-run price and output for the industry would oscillate above and below stable points of equilibrium price output." [Viner (1931), p. 212] Judging by this comment and an elaboration of the same point in the next paragraph, Viner appears to be addressing the same issue. This passage in Viner is discussed in Telser (1978, p. 387).

2.3 The Role of Fixed Costs and Uncertainty

The results in the previous section are clear and straightforward. No competitive equilibrium exists for almost any rate of demand in an industry whose firms have identical U-shaped average cost curves. More difficult problems arise when we want to employ a theoretical structure that bears some semblance to the facts we actually encounter. Specifically, we would like to be able to analyze the (combined) influence of uncertainty and increasing returns. For our purposes we will take uncertainty to apply only to demand because this approach illuminates the problem without needless complications. Increasing returns over some range are also a necessary ingredient in our analysis, and indeed it would be foolhardy to deny the practical importance of increasing returns. It does not seem at all plausible that a typical industry would not find production more expensive if its plants were one-half, one-quarter or one-eighth as large as they are today. There will be some fraction small enough to make the total cost of providing a given output go up. But attached to this empirical fact is an important observation; a size distribution of plants covering an appreciable range is consistent with increasing returns over that range. The optimal use of resources under uncertainty will imply the use of large, efficient plants as well as small, inefficient ones. Whether we will in fact see such an optimal distribution emerge in an industry is another matter, although the evidence indicates that something like it does emerge.

The results which are presented below are from Sharkey (1973) and Telser (1978, Chapter 2), and the interested reader is directed there for a fuller treatment. Our concern here will be to provide a summary of those theoretical results that provide insight into the apparent failure of competition in the industry under consideration. Specifically, it turns out that if plants have avoidable costs related to capacity and if there are fixed costs to having plants, then competitive solutions are not possible in the short-run (the period for which the decision to shut down is made). A related finding is that increasing returns, in the strict sense of decreasing long-run average costs, will prevent firms from recovering their costs under the optimal output paths if firms are restricted to use only short-run marginal cost pricing.

Some Results on Industry Structure and Equilibrium. The following model due to Sharkey (1973) embodies the essential characteristics of our case. There are m buyers each willing to buy one unit at limit prices $b_1, \ldots, b_m$. There are also n sellers with avoidable costs $h_1, \ldots, h_n$ and capacities $q_1, \ldots, q_n$. The h_i are lump sum costs incurred if the plant is operated at all. The buyers' limit prices are considered to be net of marginal costs.

While the results concerning the existence of a competitive equilibrium do not depend on it, the optimal structure of the industry is also of interest. Assume that there are fixed costs of the form f + gq, where f and g are constants and q is plant capacity, and also assume that the lump sum avoidable costs are a linear homogeneous function of capacity. For simplicity assume that all buyers have the same limit price and that the number of buyers is a random variable uniformly distributed on the interval [0, R]. It then turns out that the optimal number and sizes of plants will be such that each plant has twice the capacity of the next smallest. While an analysis based on more general assumptions seems desirable, the technical difficulties are substantial. See Telser (1978, Section 2.5) for an idea of the problems one encounters. In general, however, we can expect that existing plants will not be able to meet a particular rate of demand without excess capacity at active plants or excess (unsatisfied) demand under the optimal assignment.

Note that fixed costs are crucial for the result that some finite number of plants will be employed. In addition, as these fixed costs increase, the optimal solution calls for a smaller number of plants. It is this consideration in fact that underlies the observation that firms typically operate at less than minimum average cost. If there were no fixed costs, an infinite number of plants of different sizes would be costlessly available so that any particular level of demand could be met with one active plant operating at full capacity (minimum average cost).

The central result for our purposes is that when there is a collection of plants, each of which incurs lump-sum avoidable costs, the core is empty for almost all rates of demand that call for two or more active plants. Observations of a similar character concerning a related model are provided in Telser (1978, Section 2.3). It should be noted, however, that the core is not empty if all supply or all demand is placed under the control of one agent. This restriction prevents one group composed of some plant owners and some buyers from undermining other arrangements that cover costs. This suggests that a variety of business practices which appear anticompetitive can be interpreted as an attempt to achieve stabilization in a market. In an industry with seasonal fluctuations, for example, a firm may ask its buyers to commit themselves to buy all of a year's requirements from that firm. This was the case in the cast iron pipe industry. Under other circumstances it can lead to state control of the enterprises or to state-sanctioned collusion. Of course there may also be private-sector collusion taking the form of price fixing or geographic restrictions on dealings.

Will Marginal Cost Pricing Sustain the Industry? The results just cited indicate that in the absence of restrictions on interplant rivalry the core is often empty for a given set of plants if avoidable plant costs depend on capacity and not solely on output. This is basically a short-run analysis but it is crucial to the question of whether a competitive market can arise in an industry; once plants in an industry exist, will competition allow them to operate harmoniously? A related problem is whether firms can be induced to enter an industry with competitive pricing.

Obviously if there is no short run equilibrium that allows firms to cover discretionary costs they will not enter. We can make this second question meaningful by supposing that a short run competitive equilibrium does exist or by using an essentially negative answer to reinforce our earlier answer for the short run. It is necessary, however, to restrict the question in another way.

As we have already indicated, a solution to the problem of finding the optimal collection of firms is difficult. It should also be noted that without an answer to the question of how industry decisions are made in the absence of a competitive equilibrium we appear to give up our ability to discover the sort of size distribution of plants that does emerge. It might be argued that if there is a unique optimal distribution, the actual possible market arrangements, whether competitive or not, may not be compatible with it. While it would be nice to have a theory that gives both the actual industry structure (optimal or not) and the nature of the ultimate equilibrium, that is not the aim here. But a completely arbitrary solution of plants won't do either. It might be possible to find some collection of plants with suitable cost conditions that could sustain itself by competition or come arbitrarily close to a competitive situation. (We could require that iron be made only in independently owned backyard furnaces, for example.) But such collections of plants will very likely be costly to operate. To eliminate the problems that arise from these considerations it seems sensible to proceed by suppressing the question of the size distribution of plants and to look at the problem from the point of view of the industry, focusing on the nature of the optimal industry response. One might argue that this is the right approach since some cooperative approximation to the optimum solution will be found if competitive approaches are not feasible.

Consider the analysis due to Telser (1978, Section 3.6). Specify p = b(Q, u) as the demand function for the market each period, where Q is the quantity produced and consumed and u is a random variable whose realizations are independently and identically distributed. Let total industry cost be represented by $a = H(Q, Q_0)$ where Q_0 is the permanent rate of output corresponding to the optimal capital stock for this distribution of demand. (Q_0 is the output rate at which average cost is a minimum for this capital stock.) Depending on which of several assumptions we use to restrict the form of the total cost function, a regime of marginal cost pricing may not enable us to cover costs. In particular, if we merely ask that short-run marginal cost rise with increases in output, expected receipts can fall short of expected total costs. This is related to well-known results from the natural monopoly literature. [See, for example, Mohring (1970).]

A simple example will illustrate this point. Take an industry in which two states of the world can occur with probabilities p and p - 1. If state 1 occurs the total market benefit of quantity q is $B_1 = a_1q - \frac{1}{2}bq^2$ and if state 2 occurs it is $B_2 = a_2q - \frac{1}{2}bq^2$ where $a_1 \neq a_2$. The cost conditions for this industry are

$$TC = k + k^{-\beta}cq^2$$

where k is the fixed expense each period and $k^{-\beta}cq^2$ is the variable expense that depends on capacity. Note that for $\beta = 1$ this function is homogeneous of degree 1 in k and q.

Let q_1 = the quantity we choose in state 1 and q_2 the quantity in state 2 and look at the expected net benefit

$$ENB = p[a_1q_1 - \frac{1}{2}bq_1^2 - k - k^{-\beta}cq_1^2] + (1-p)[a_2q_2 - \frac{1}{2}bq_2^2 - k - k^{-\beta}cq_2^2]$$

First-order conditions call for us to choose a fixed cost k to satisfy

$$\frac{\partial ENB}{\partial k} = -1 + \beta p k^{-\beta-1} c q_1^{\,2} + \beta(1-p)k^{-\beta-1} c q_2^{\,2} = 0$$

This in turn implies

$$p k^{-\beta} c q_1^{\,2} + (1-p)k^{-\beta} c q_2^{\,2} = k/\beta$$

We must also choose the appropriate quantity for each state of the world:

$$\frac{\partial ENB}{\partial q_1} = (p)[a_1 - bq_1 - 2k^{-\beta} c q_1] = 0$$

$$\frac{\partial ENB}{\partial q_2} = (1-p)[a_2 - bq_1 - 2k^{-\beta} c q_2] = 0$$

This is the familiar result that marginal cost should be equal to marginal benefit. What is total expected revenue from this rule under a regime of marginal cost pricing?

$$TER = p2k^{-\beta} c q_1^{\,2} + (1-p)2k^{-\beta} c q_2^{\,2}$$

Similarly, total expected cost is

$$TEC = k + p k^{-\beta} c q_1^{\,2} + (1-p)k^{-\beta} c q_2^{\,2}$$

Will expected costs be greater than expected revenues? We know that

$$TER - TEC = p k^{-\beta} c q_1^{\,2} + (1-p)k^{-\beta} c q_2^{\,2} - k$$

We also know from above that the first two terms on the right are equal to k/β. So we see that we get expected profits or losses in this industry as $k/\beta - k \gtrless 0$. Obviously this expression equals zero only if $\beta = 1$, i.e. if there are constant returns. If $\beta > 1$ there will be losses. It is easy to demonstrate that this implies increasing returns. Doubling of fixed costs and output will result in costs that are less than twice as great. By this we have illustrated how the existence of increasing returns makes it impossible to sustain the optimal industry output by means of marginal cost pricing.

2.4 Economists and Competition

The difficulty that the existence of overhead expense poses for a competitive equilibrium was recognized by Marshall, J. M. Clark and Frank Knight, among others. The basic problem they saw was that costs could not be covered by a regime of marginal cost pricing in an industry in which firms typically operated at an output rate at which average cost exceeded marginal cost.

Marshall. A quick reading of Book V of Alfred Marshall's Principles of Economics provides ample support for the view that firms do not generally practice short-run marginal cost pricing. A more careful reading suggests that Marshall was aware of the logical difficulties posed by the assertion that a competitive, "supply-and-demand" equilibrium could exist in industries with fixed costs. In fact, Marshall was not eager to push the concept very hard, as he indicates early on when introducing the notion of "equilibrium."

> This term is in common use and may be used for the present without special explanation. But there are many difficulties connected with it, which can only be handled gradually. [Marshall (1949), p. 269]

Is the concept ever unambiguous? Clearest is the case of the boy picking blackberries. "Equilibrium is reached when at last his eagerness to play and his disinclination for the work of picking counterbalance the desire for eating." [Marshall (1949), p. 276]

Once the notion of fixed costs is introduced into more complex economic situations, Marshall saw that one sort of equilibrium, a competitive equilibrium, would in fact lead to marginal cost pricing, provided everyone's attention is focused on the short run only.

> The immediate effect of the expectation of a low price is to throw many appliances for production out of work, and to slacken the work of others: and if the

> producers had no fear of spoiling their markets, it would be worth their while to produce <u>for a time</u> for any price that covered the prime costs of production and rewarded them for their own trouble. [Marshall (1949), p. 311, emphasis added]

But he goes on to note that "they generally hold out for a higher price" for fear of satiating the market for their goods at an unremunerative price (thinking of the long run) or because of pressure from competitors. He asserts that the price producers do receive is nearly always above the "prime" or marginal cost of production so that general expenses may be covered.

> In a trade which uses very expensive plant, the prime cost of goods is but a small part of their total cost; and an order at much less than their normal price may leave a large surplus above their prime cost. But if producers accept such orders in their anxiety to prevent their plant from being idle, they glut the market and tend to prevent prices from reviving. In fact, however, they seldom pursue this policy constantly and without moderation.... [G]eneral opinion is not altogether hostile to that code of trade morality which condemns the action of anyone who "spoils the market" by being too ready to accept a price that does little more than cover the prime cost of his goods, and allows but little on account of his general expenses. [Marshall (1949), pp. 311-312]

Nor was Marshall's concern over the problem of "spoiling the market" a mere digression or ancillary point. In the six-and-a-half page summary of the general theory of equilibrium covered by "the great fifth book" he devotes yet another full paragraph to this question. Earlier, in his discussion of the related topic of increasing returns, he takes pains to point out that

> [t]he theory of stable equilibrium of normal demand and supply helps indeed to give definiteness to our ideas; and in its elementary stages does not diverge from the actual facts of life,.... But when pushed to its more remote and intricate logical consequences, it slips from the conditions of real life. [Marshall, (1949), pp. 381-382]

Marshall was always eager to keep his analysis practical and we should not be surprised that he offers no substantial explanation of why businesses might find themselves operating short of minimum average cost a great deal of the time, or what the "more remote and intricate logical consequences" might be. These are, as it turns out, difficult and often abstract problems which Marshall, who had men of affairs in mind when he wrote, decided not to take on.

J. M. Clark. The topic of "general expenses" in relation to competition also became the focus of some of J. M. Clark's work, in particular his Studies in the Economics of Overhead Costs and his well-known article "Toward a Concept of Workable Competition." His main point was that marginal-cost pricing will not in general lead to the recovery of costs.

> In theory, the same argument which is used to show how competition brings prices down to cost...can be used to prove conclusively that competition tends to force prices down to the level of differential [marginal] cost, if existing productive capacity will supply the demand at that price. And as industry is in a chronic state of partly idle capacity, to insist that producers shall compete unchecked appears to amount to inviting competition, and private enterprise with it, to commit suicide. [Clark (1923), p. 435]

Clark also dwelled on this point in The Social Control of Business, where he noted that "perfect" or "pure" competition is characterized by marginal cost pricing. But when marginal cost is less than average cost, "such a price spells cut-throat competition and is itself a rather serious imperfection." [Clark (1939), p. 135]

In his article, "Toward a Concept of Workable Competition" Clark pointed out, as our analysis also shows, that

> perfect competition requires operation at full capacity, which is sometimes defined as the point of minimum cost, or as the point where marginal and average cost are equal. Actual competition has to make terms with the fact that, when demand fluctuates, industry must inevitably be operating short of full capacity much of the time. [Clark (1940), p. 250]

In those cases where there is substantial product differentiation, where small price increases do not imply enormous losses of business, the firms in an industry are in a somewhat better position.

> Prices will tend to be above added cost of added output, affording some protection against the danger of cut-throat competition, but are not likely to be above total cost for the industry as a whole on the average of good and bad times ("cost" including the minimum necessary return to capital). [Clark (1939), p. 378]

Two other comments by Clark should be borne in mind when considering the facts in Addyston. First, he cited among the reasons firms join in combinations "defense against cut-throat competition and economic instability." [Clark (1939), p. 378] Second, it was his judgment that

> the general effect of the policy of the American states has been to drive combinations from the looser and open forms, like pools and cartels, into the closer forms like corporate consolidations, or else into those very informal and secret forms, of which proof is difficult or impossible to establish. [Clark (1939), p. 381]

The hypothesis proposed here to explain the events in Addyston is therefore J. M. Clark's. Supporting evidence would include declining average cost over some range and operation at rates of output that typically fell in that range.

Knight. In his insightful exposition, "Cost of Production and Price," Frank Knight argued that the only cost conditions at the firm level that are compatible with competition are increasing and constant unit costs. He also explicitly pointed out the difficulties that fixed costs raise for the notion of competitive equilibrium if firms operate short of full capacity. He was, however, inclined to question the empirical relevance of fixed costs in disrupting competition by arguing that most industries typically face increasing demand and that their capital stocks are mobile. "In our rapidly growing society," he wrote, "contractions in demand are a relatively short-period phenomenon." [Knight (1935), p. 211] During those short periods, however, competition would lead to costs not being covered.[4]

> When from any temporary cause an industry is working below correct capacity of the fixed equipment, there is a tendency toward decreasing costs with their concomitant of cut-throat competition. Here the fixed costs represent either contractural renumerations not subject to quick re-adjustment or the physical immobility of the intermediate forms in which ultimately mobile ultimate resources are temporarily embodied. [Knight (1935), pp. 211-212]

Knight, agreeing with the analysis laid out by Marshall, also pointed to the reluctance of businessmen to "spoil the market" by pricing just above prime cost.

> When an industry is in a depressed state, working below the capacity of equipment not transferable within the period in which reduced demand operates, a feeling of community interest tends to prevent that reduction of prices to the level of prime costs which would follow from perfect competition. [Knight (1935), p. 213]

Hicks. Concerned as John Hicks was in Value and Capital with the development of a theory that explained general economic equilibrium, his development of market equilibrium in Value and Capital deliberately ignores the more difficult questions that a thorough look raises. His dynamic analysis of pricing in Chapter 4 is based on Marshall's Book V. Although we have shown that Marshall was concerned with the topic we raise here, Hicks does not mention it in his parallel treatment. Earlier, in his chapter on the equilibrium of the firm, he explains why. A competitive firm that operates at a point where average cost exceeds marginal cost must sell at a loss. While we could assume instead that such firms continue in existence because they face less than perfectly elastic demand curves, that would constitute a "monopoly."

> It has to be recognized that a general abandonment of the assumption of perfect competition, a universal adoption of the assumption of monopoly, must have very destructive consequences for economic theory. [Hicks (1939), p. 83]

Economic analysis could only be saved from such consequences, according to Hicks, if it can be assumed that the markets in which most firms operate "do not differ very greatly from perfectly competitive markets.... At least, this get-away seems well worth trying." [Hicks (1939), pp. 84-85] In a footnote to this passage Hicks justifies the assumption of perfect competition as "an immensely simplifying approximation to the facts," to which he might have added, "if one is interested in developing a theory of value."

Several years after Hicks' work appeared the Committee on Price Determination of the National Bureau of Economic Research published a volume called Cost Behavior and Price Policy. This book bore the strong imprint of J. M. Clark, who together with Joel Dean, Theodore Yntema and several other economists formed the committee. In particular they explicitly rejected Hicks' method of attacking the problem and welcomed an "increasing emphasis on the operation of the individual firm under various assumed demand and cost conditions." [NBER (1943), p. 3] This appears to be a reference to the work on imperfect competition. They then go on to add:

> While some theorists are of the opinion that this trend has gone too far and that approximately accurate and useful results can be obtained only so long as firms can be grouped into markets or industries which are treated as substantially competitive [a footnote occurs here quoting Hicks from the same passage as we do], it seems safe to say that with respect to most industrial market situations the competitive assumption involves serious distortion. [NBER (1943), pp. 3-4]

2.5 Conclusion

Two points have been made in this chapter. First, it is very easy to derive plausible conditions under which a competitive equilibrium is unlikely. Industries in which there are identical U-shaped average cost curves, for example, do not in general have a competitive equilibrium and this was shown. A number of related cost conditions also lead to the same result, as work by Telser (1972 and 1978) and Sharkey (1973) demonstrates. In general, some combination of fluctuating demand, fixed costs and long-run average cost that declines over an initial range will result in an empty core. A related long-run result is that short-run marginal cost pricing will not cover the cost of providing the optimal output if the industry operates under increasing returns.

Second, the character of the problem can be illuminated to some extent by other, less formal techniques. In particular, Alfred Marshall was aware of the difficulty posed by "general expenses," as were other economists. Although their insights are useful in their own right, the chief reason for citing Marshall, Clark and Knight (the list could probably be expanded quite easily) is to help us remind ourselves that the problem of fixed costs is fundamental to the analysis of market behavior.

Chapter 3

The Events in Addyston Pipe

Students of antitrust policy are nearly unanimous in their praise of Judge William Howard Taft's opinion in Addyston Pipe. Robert Bork suggests that "given the time at which it was written, Addyston must rank as one of the greatest, if not the greatest, antitrust opinions in the history of law." [Bork (1978), p. 26] The major contribution to antitrust law with which Taft is credited is the per se rule against price fixing, the rule that bars agreements among competitors when the primary apparent purpose is the establishment of a monopoly price.

Important as it is, the events in the case have not been examined at any length. This is perhaps not surprising considering what we find after only a brief look. Six firms form a cartel, a detailed account of their agreements is part of the court record, and the six merge after they lose their case in circuit court. Most commentaries on the case are in fact based only on the circuit decision itself, which of course does not mention the merger.

Although sparse treatment of the facts in the case is typical, there are two exceptions, the studies by Whitney (1958) and Phillips (1962). While they do provide additional material on the case and its aftermath (it is probably from these studies that it has become generally known that the firms merged), Whitney and Phillips provide little in the way of a theoretical structure. Whitney does suggest that "product homogeneity, high fixed costs, fluctuating demand, small numbers of producers and high freight cost" [Whitney (1958), p. 7] were factors that contributed to collusion, but does not say why. Whitney and Phillips both suggest that one possible beneficial effect of a price agreement is that it saves from bankruptcy firms which ought to survive temporary slumps. Whitney goes on to note, however, that

> the dangers of a pool are so great...and the impossibility of having the court rule separately on each pool so clear, as to justify their general condemnation by the law. [Whitney (1958), p. 8]

The aim of this chapter is to present a history of the cast iron pipe industry and of the events in Addyston that remedies the neglect these topics have suffered, and to carry out this discussion with those points in mind that were developed in the second chapter. Two sources, readily available but generally ignored, deserve special mention. The Transcript of Record provides a record of cartel activity, data on industry structure, and perhaps most surprising, numerous affidavits in support of the defendents from precisely those buyers one would expect to object to the cartel the most. Various issues of The Iron Age, the industry's trade journal, are also useful in establishing a record of events and provide much information concerning prices, industry practices, and the identity of buyers and sellers.

3.1 The Industry to 1896

Technology. The cast iron pipe industry of this period is well suited to an economic analysis. The fundamental technology remained unchanged from the middle of the 19th century until the 1920's when centrifugal casting was adopted. Pig iron was melted and poured into vertical sand-lined molds, and the cast pipe was dipped in a hot coal-pitch bath. The process required considerable amounts of fuel. Coke was used for melting the iron, coke and coal were used to dry the sand molds, and the cast pipes had to be heated to 300 degrees before being dipped in the coal-pitch. Minor changes in this technique did occur, but at any one time several variations of the same basic process were used.

The maximum possible rate of output at a firm appears to have been governed by certain technical features. The cupolas in which the pig iron was melted had to be cooled off, cleaned and repaired once a day after a maximum of twelve to sixteen hours of operation. It was the practice at some foundries, not necessarily pipe foundries, to melt pig iron in a particular cupola every other day and use the day in between to work on it. In other cases the cupola was cooled down, emptied and worked on at the end of the day. Melting capacity at foundries were determined by the sizes and capacities of the cupolas, and this in turn put a limit on the amount of pig iron that could be turned into pipe each day as did the number of pits in which the molds could be placed while the iron solidified. Another operation that had some bearing on capacity was the drying of molds and cores (the two parts of the form into which the molten iron was poured). The amount of these that could be handled was limited by the sizes and capacities of drying ovens. Molds that were prepared one day were dried overnight and used the next.

There are certain other technical considerations in such operations that also deserve our attention. Data presented in the next chapter suggest that large foundries enjoyed economies of scale. From what do these economies arise? A brief discussion of the cupola will illustrate the sorts of savings that are possible.

A cupola is fundamentally a cylindrical furnace into which layers of pig iron and coke are placed. It is very efficient from a technical standpoint because the fuel is in direct contact with the metal. The layers are melted progressively from the bottom to the top, and the molten pig iron that collects at the bottom is tapped to a laddle. As molten iron is run off, new layers of iron and coke are placed on top of the old from an opening halfway up the side of the cupola.

By this brief description it is clear that at least several workers were required for the continuous operation of a furnace. For units with daily capacities of only 60 to 100 tons, which we shall see is near the minimum efficient size, six men with separate duties attended a single cupola. One man controlled the tapping hole and blast of air at the bottom, two men charged the furnace, two men broke pigs into smaller pieces and brought them to the furnace door, and one had as his duty miscellaneous trouble-shooting and fixing up [Sharp (1900), p. 146]. By this description it does not seem plausible that doubling the cupola diameter will more than double the number of men required to service it. In fact, one would expect a less than proportional increase. Yet doubling the diameter from 30 to 60 inches, resulted in a three-to-four fold increase in the average melting rate [Stimpson and Gray (1944), pp. 136-137]. Another way of stating this is that the melting capacity depends on the surface area of the floor of the cupola and this increases according to πr^2. On the other hand, to the degree that cleaning and relining costs, and radiation heat loss depend on the surface area of the sides, these costs only go up in direct proportion to the diameter. If we let h be the height of the cupola, then the surface area is only directly proportional to the radius and equals $2\pi rh$. We see that there are good reasons why it might be cheaper per ton to melt 200 tons of pig iron each day rather than only 100 tons. Moreover, there are clear inefficiencies involved if we melt only 100 tons per day in a 200 ton furnace. Substantially the same crew will have to be used, although for a shorter period, since considerable waste resulted if a cupola of specific capacity was run at an <u>hourly</u> rate different from what it was designed for. Slag build-up, and waste of fuel were problems that arose in such circumstances. It was also the case that the start-up procedures and clean up were largely unaffected by the size of the daily run. Thus, although only half the iron of a full-capacity run was melted, it is not all likely that only half the labor and fuel costs were incurred. By these observations we should not be surprised if we find that there are economies in the application of variable factors. We see then that a mere technical summary of cupola operations already provides a reason for both short- and long-run economies. These economies arise partly from physical laws and partly from the economies that a division of labor provides. A cupola three feet in diameter was considered small and melted 4 to 6 tons per hour, and with a ten hour working day had a daily capacity of 40 to 60 tons. An additional shift might be able to operate it for a few more hours, but as we noted, after 16 hours it had to be shut down and cleaned. The engineering literature indicates that at least 17 to 24 tons per hour was a feasible rate at larger furnaces [Stimpson and Gray (1944), p. 137]. Some of the pipe plants we shall look at had capacities larger than this, and these may have operated two cupolas. If they did, it is still not likely that all long-run economies at the plant were exhausted. Inventories are a well-known source of economies, for example.[1]

Although the technology was relatively simple, municipalities imposed stringent requirements on manufacturers, especially in the case of large contracts. Pipes had to conform to certain specifications concerning size, weight and how well the joints fit. Test bars coming from the same iron from which the pipe was cast had to be able to withstand prescribed amounts of stress, and and each finished pipe was tested under several hundred pounds pressure while being struck with a proving hammer [Transcript of Record, pp. 249-251]. Purchasers frequently went to the effort of sending a representative to be present for such tests [Transcript of Record, p. 42]. Another requirement called for the pig iron to be remelted as we have described. Why was it not used directly from the blast furnace? Iron gains strength from remelting and cooling and it was often stipulated for cast iron water pipes both in the U.S. and Britian, that the iron be remelted. Some European founders were able to obtain satisfactory results by using iron directly from the blast furnace. On these points see Sharp (1900, pp. 53-57) and J.B. Nau (1905). A plant constructed during the 1905-1906 building boom at Sheffield, Alabama attempted to cast pipe directly from the blast furnance, but this attempt failed and the plant was closed in 1908 [Moore (1939), pp. 27-28].

Plant Location and Costs. Another virtue of this market is that the price of the main input, pig iron, was widely quoted, and the price of finished pipe is available from a number of sources, in particular the bids submitted at public auctions and the prices quoted for the New York tidewater market. Prices for both pig iron and the finished pipe were quoted in tons, and the cost of pig iron usually amounted to between 50 and 80 percent of the f.o.b. price of the finished pipe, which ranged from $15 to $30 per ton. The other major expense was rail freight, which ranged from $2 to $6 per ton, depending on the route and distance shipped. This amount was included in the bids. A large part of output was not sold by means of public auctions but through negotiated contracts, particularly when the buyers were private firms. Municipalities also made such contracts, often committing themselves to buying a "year's supply" at a particular price per ton. Many firms also sold a large fraction of their output overseas. One New Jersey firm, for example, sold 40 percent of its output abroad in 1897 [Noble (1939), p. 62].

The structure of the industry in 1890 is easily determined because the U.S. Census Office chose to make a special study of it for the census of that year. Thirty-six establishments were reported as primarily engaged in the manufacture of cast iron pipe. Of these, two were not in operation the year of the census. The largest grouping of firms was in New Jersey and Pennsylvania. Together these two states had twelve of the thirty-six firms. This area had been the center of pipe production in the early years of the industry and still accounted for 43 percent of U.S. production in 1890. Eleven of the fourteen plants in operation west and south of Ohio were constructed after 1880. Nationwide 20 of the 36 plants were built in that decade. A curious situation regarding the construction between 1880 and 1890 was that the new southern mills tended to be of large capacity, while the new mills in Pennsylvania and New Jersey were of small capacity. This and the somewhat lower pig iron prices that the southern firms faced led them to be considered the low-cost producers. The mill at Anniston, Alabama was built in 1889 and, according to one authority, was "the largest pipe and foundry in the world at the time of its building." [Noble (1940), p. 74]

Tables 3.1 and 3.2 summarize some of the information from the special study in the 1890 census report. The New Jersey firms were apparently the largest, which can be explained by the fact that several had multiplant operations. They seem also to have produced a lower fraction of non-pipe output, probably because there were foundries in the Northeast that specialized in the production of these items, which consisted mainly of pipe fittings, gates, valves, and related products. The firms in Ohio and the South were remarkably similar in size and in composition of output, while the Pennsylvania plants, although they had the same product mix, were about half as large.

How did costs compare across areas? The measure of capital stock is most likely based on book value. Since the southern and western plants were newer, changes in the price level and biases resulting from depreciation schedules will import some biases to book value capital. The amount of capital employed per ton of pig iron used was higher in the South, where plants were newer, and in New Jersey, where firms were larger. The differences are slight, however. Wage costs also varied only slightly across regions, as did the cost of pig iron, fuel, and miscellaneous expenses. The figures understate the variability that did occur, however, because the figures for the South include Texas,

Table 3.1

CHARACTERISTICS OF FIRMS IN MAJOR PRODUCING AREAS, 1890

	New Jersey	Pennsylvania	Southern States a/	Ohio
Number of firms	6	6	8	4
Tons of pipe per firm	30,918	8,143	16,031	18,434
Percentage of non-pipe outputs in value terms	5%	14%	14%	16%
Capital per firm	$757,201	$220,068	$445,145	$487,578
Employees per firm	380	118	245	267

Source: U.S. Census Office, pp. 487-490.

a/ Composed of plants in Alabama (1), Kentucky (2), Tennessee (2), Texas (1), and Virginia (2).

Table 3.2

EXPENSES PER TON OF PIG IRON USED AND MARGINS PER TON OF PIPE

	New Jersey	Pennsylvania	Southern States	Ohio
Capital per ton	23.88	22.93	24.35	21.48
Wages per ton	6.40	5.98	6.38	6.04
Cost of Materials Used Per Ton[a]/	16.30	17.10	15.43	15.48
Cost of pig iron per ton	14.07	14.78	13.13	12.74
Cost of fuel per ton	1.01	.95	1.07	1.35
Miscellaneous Expenses per ton[b]/	1.04	.99	1.10	.93
Value of non-pipe products per ton of pipe	.89	3.20	2.34	1.93
Total non-capital cost per ton of pipe[c]/	22.85	20.87	20.57	20.51
Price of pipe per ton	25.88	25.08	24.78	24.81
Margin (Price of pipe less non-capital costs)	3.03	4.21	4.21	4.30
Gross Margin (Price of pipe less price of pig iron)	11.81	10.30	11.65	12.07

Source: Same as Table 3.1.

a/ Includes, in addition to pig iron and fuel, mill supplies and "other materials."

b/ Includes rent, taxes, insurance, repairs, interest paid on cash, and sundries.

c/ The sum of wages, materials and miscellaneous expenses per ton of pig iron less the value of non-pipe castings (net of the pig iron price) and the value of other products all on the basis of per ton of pipe. The intention here, as explained in the text, is to attribute as much as possible of materials and miscellaneous expense to non-pipe production in order to get a lower limit on the expense incurred in making pipe.

Virginia, and Kentucky, which did not have costs that were as low as Alabama and Tennessee. Chapter 4 contains plant data that demonstrate this.

What we would like from these figures is a measure of the total cost attributable to pipe production. To do this we can add all costs, expressed on the basis of how much was spent per ton of pig iron used. This will be an over-estimate of costs per ton of pipe because we will be including the costs of producing other, more complicated castings ("specials" in trade jargon), as well as the cost of producing things that were not made of cast iron. Our fuel cost per ton of iron, it should be noted, is an accurate measure of fuel costs per ton of pipe because almost all fuel was used either to melt iron or to dry the molds, and costs for this would be the same whether it was melted for pipe or specials. We can be less sure of this for other costs. To correct for this, we calculate the average value of these other items per ton of pipe produced. This will be too generous, but a partial correction is possible by subtracting the value of pig iron used for casting specials. We see that between $1 and $3 worth of these other items were produced for each ton of pipe. So if we subtract this from the sum of all costs per ton of pig iron used, we will have a lower bound on the cost of producing pipe. This implies that there are no capital costs attributable to these other items. After we have computed the total non-capital cost of pipe this way, we arrive at figures that fall only $3 to $4 short of the price of pipe per ton. This is what was, at most, left over to pay capital. Note that wages, materials (excluding iron) and miscellaneous expense amounted to about $7 to $9 per ton of pipe. Figures from individual plants compiled sixteen years later show almost precisely the same situation. (See Table 4.3 in the next chapter.) Wages, fuel, repair and replacement, and a variety of other explicit expenses amounted to between $5.72 and $9.25 per ton of pipe (ignoring one very small and costly plant).

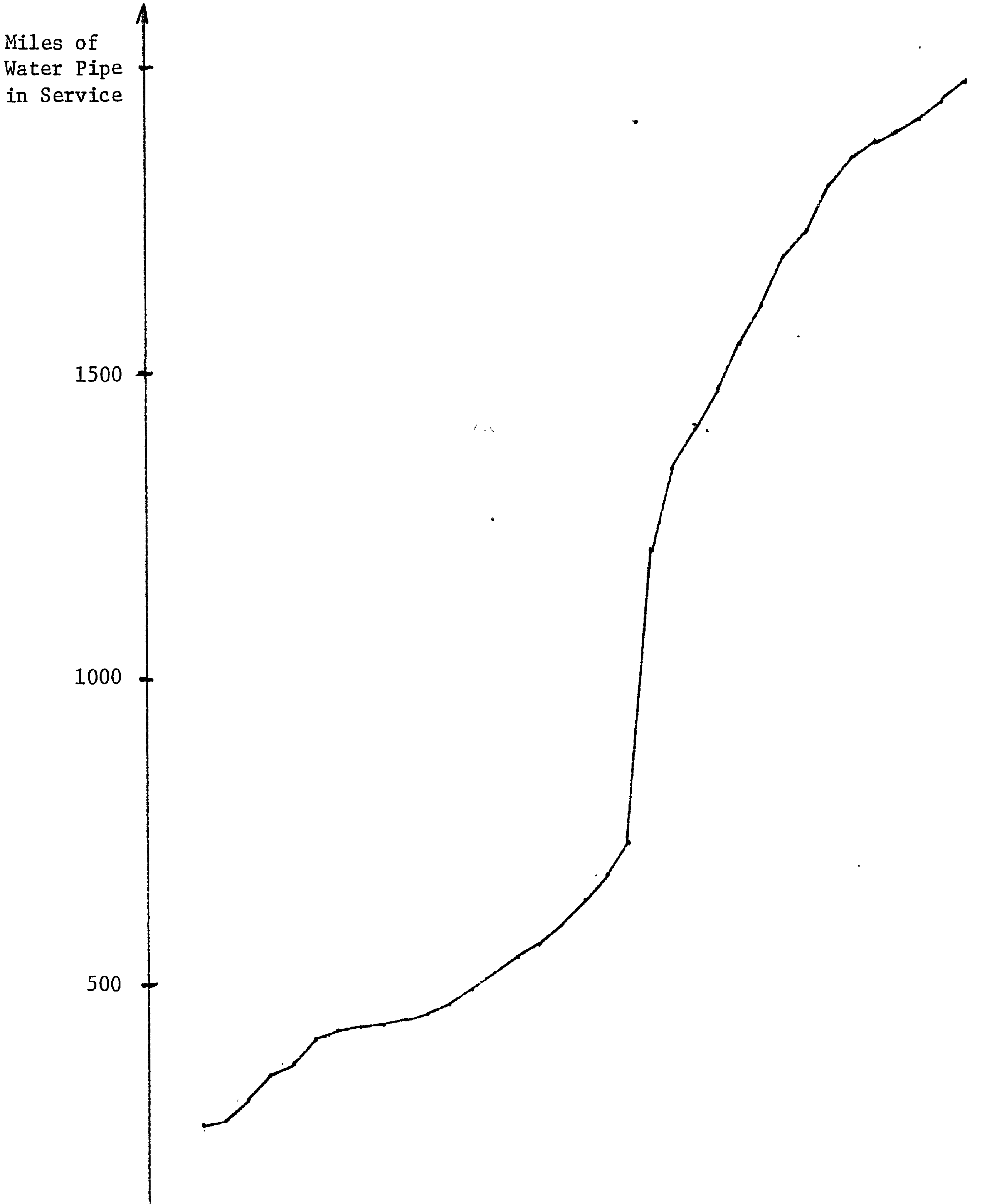
The greater range comes about because plants of different sizes and in different locations had different costs. Since wholesale prices moved up only by 10.0 percent, and average hourly earnings in foundries moved up only slightly, from 18.5 to 21.3 cents an hour, [Historical Statistics (1975), series E40 and D874], these are consistent measures of the costs of pipe founding.

Boom and Bust. The extent of the increase in demand that resulted in new plant construction in the 1880's can only be guessed at since figures on total industry output are hard to come by. The amount of new water pipe laid down during the late 1880's in Chicago must have been considerable, however, to provide the astounding increase in pipe-in-use (measured by miles of pipe in service) recorded for the year 1890 in Figure 3.1. This increase in demand was not confined to Chicago, but occurred over the whole eastern half of the United States. Although we have only fragmentary data, the overall magnitude of the boom is nevertheless well established by evidence on new plant construction in the two industry histories, Moore (1939) and Noble (1940), and the 1890 census. This evidence is summarized in Table 3.7 and Figure 3.3 below.

By the early 1890's, however, the boom in water pipe was over. In February of 1892 The Iron Age reported that "the manufacturers of cast-iron pipe are just now passing through the vale of adversity." [Iron Age, February 25, 1892, p. 353] By the end of the year trade reports began to circulate that predicted a consolidation of firms in the business. In December it was rumored that two groups were formed, one in the East, the other in the "West," i.e. Ohio and the South, "the ultimate object being to fuse the two groups into one large concern, which is to manufacture and distribute the product for the whole country." [Iron Age, December 22, 1892, p. 1235] Two weeks later this intelligence was changed. The eastern shops had not proceeded very far in their plans. The western shops denied the merger, but Iron Age stuck to its

Figure 3.1

MILES OF WATER PIPE IN CHICAGO, 1870-1904



Source: Fifty-fifth Annual Report of the Chicago Department of Public Works, 1930, p. 74.

story, and backed it up with the details concerning the identity of the negotiating parties (nine firms including all six of the Addyston defendants) and the news that the new firm would offer stock to the public. It also added that the western producers met with eastern producers to discuss the prices on some large upcoming contracts [Iron Age, January 12, 1892, p. 83].

The Associated Pipe Works Agreement. This merger attempt failed and little is known concerning what devices the various firms were compelled to resort to. From the court record we know that the four southern shops locate in Tennessee and Alabama operated a cartel in 1894, although it may have been formed earlier. In December of that year the Southern Associated Pipe Works allowed the two Ohio River firms (Louisville and Addyston) to join them, and modified rules for the association were drawn up. Certain cities were reserved for each shop, usually but not always cities close by (Table 3.3 has the details), and a schedule of "bonuses" was established which indicated how much was to be paid into the common fund for every ton of pipe shipped to various points in "pay territory." The schedule seemed designed to conform to a limit-pricing notion. Water transportation being cheaper than rail, North Carolina, South Carolina, Florida, and coastal points in Georgia and Texas had only $1.00 bonuses per ton. Wisconsin, Kansas, Montana, Minnesota, Illinois, Indiana, Iowa, and the interior of Georgia had $2.00 bonuses. Nebraska, Oklahoma, and Louisiana had $3.00 bonuses. The higher bonus for Louisiana than for Kansas and Wisconsin was probably due to the influence of competitors in northern Ohio. Ohio itself had a $1.50 bonus. Pennsylvania, Virginia, and states in the Northeast, called "free territory," had no bonuses, while reserved cities had bonuses of $2.

How was the bonus fund divided? It was explicitly set forth in the agreement that this fund would be divided on the basis of plant capacity. The

Table 3.3

RESERVED CITIES FOR MEMBERS OF THE CARTEL

Firm Location	Reserved Cities
Addyston, Ohio	Cincinnati, Ohio Covington, Kentucky Newport, Kentucky
Louisville, Kentucky	Louisville, Kentucky Jeffersonville, Indiana New Albany, Indiana
Anniston, Alabama	Anniston, Alabama Atlanta, Georgia
Chattanooga, Tennessee	Chattanooga, Tennessee New Orleans, Louisana
Bessemer, Alabama	Bessemer, Alabama Birmingham, Alabama St. Louis, Missouri
South Pittsburg, Tennessee	Omaha, Nebraska

Source: Transcript of Record, p. 66.

Note: The plants are referred to by the name of the city in which they were located, following the practice of the successor firm, United States Cast Iron Pipe and Foundry. Addyston is near Cincinnati.

bonuses on the first 90,000 tons shipped to any territory were divided six ways; the bonuses on the next 75,000 tons five ways, with the smallest plant (South Pittsburgh) dropped; those on the next 40,000 tons four ways, with the two smallest plants (South Pittsburg and Anniston) dropped; and finally the next 15,000 tons were divided among the three largest plants only (Chattanooga now added to the dropped firms). If tonnage was in excess of 220,000 tons the "reserve fund" beyond that amount was allocated to the plants according to the proportion of excess tonnage that each firm had shipped to pay or free territory. There was a settlement on this basis twice each month, which implies that the small plants were paid off during the first part of each year.

The agreement also contained explicit reporting requirements. All orders, whether from pay or free territory, were to be reported daily, and summary reports of shipments were to be made twice each month. Carbon copies of all reports received were to be sent to all members of the cartel, together with a statement showing net bonus payments due from one firm to another. All existing orders at the time of the agreement were to be filed with the organization, and only these orders would be exempt from the bonus payment. Furthermore, existing quotations were to be withdrawn unless firms were willing to pay the bonuses on these amounts. The agreement also required that an auditor check firms' books each month, and stipulated that each firm's representative at a public auction was to send to the auditor a list of bids and bidders. In addition, any information about work undertaken by firms outside the association was to be submitted to the auditor [Transcript of Record, pp. 64-69].

Apparently this system did not work well. Only five months later, on May 16, 1895, the members met and considered the following resolution affecting work awarded through public auctions.

> Whereas, the system now in operation in this association of having a "fixed bonus on the several states" has not in its operation resulted in the advancement in the prices of pipe anticipated, except in the "reserved cities" and some further action is imperatively necessary in order to accomplish the ends for which this association was formed. Therefore, be it resolved. That from and after the first day of June that all competition on the pipe lettings shall take place among the various shops prior to the said letting. To accomplish this purpose it is proposed that the six competitive shops have a "representative board" located at some central city to whom all enquiries for pipe shall be referred, and said board shall fix the price at which said pipe shall be sold, and bids taken from the respective shops for the privilege of handling the order, and the party securing the order shall have the protection of all the other shops. [Transcript of Record, p. 70]

The "protection" referred to was the submission of false bids above the price that the highest bidder in the association's internal auction was committed to charging. Eleven days later a new meeting was held at which this resolution was adopted and provision was made for sales not made through public auctions. In the case of "special customers" the price and bonus would be established by the committee of six representatives to reflect prices and bonuses generally prevailing at that time. On other work the minutes simply state that "bonuses shall be fixed by the committee." Again, existing quotations were recalled and new prices and bonuses on such work were established by the committee [Transcript of Record, p. 71].

The new system of internal first round auctions proposed in May 1895 and apparently aimed at remedying the problem of low prices was in fact implemented. The bonuses collected on the first 220,000 tons shipped were still allocated on the basis of capacity, although on December 20, 1895 the agreement was changed so that the first 220,000 tons shipped to pay territory -- which included all states west of Pennsylvania, south of Virginia and east of the Rockies -- and not shipments to any destination formed the basis for the allocation [Transcript of Record, p. 72-73]. This was proposed by the firm located in Bessemer, Alabama and may have been the response to, or anticipation of, member firms along the Ohio River taking work outside pay territory. Depending on how much work was done there, the bonus fund on the first 220,000 tons would have been watered down. All firms but Addyston, which was "not prepared to vote," supported the resolution.[2]

It is not clear how much of the work of the six firms was taken by the reserved cities. A good deal of work went abroad, to the Northeast, or to the Plains States and Far West. One-half of the cartel's output went to Illinois [Transcript of Record, p. 73]. The 1890 census figures provide data on the number of people in each state living in cities with 25,000 or more inhabitants. Using these figures it turns out that the reserved cities accounted for 47.7 percent of the total inhabitants in their respective states. In Louisiana, only New Orleans had a population over 25,000, while in Indiana inhabitants of the reserved cities accounted for less than 10 percent of the urban population. Towns smaller than 25,000 did have water works, and at least half of firm output went to states without reserved cities, so we can be sure that reserved cities accounted for less than one-quarter of total cartel output.

Something of the method used by the cartel to allocate its gains can be learned from Table 3.4, which presents the net settlements between firms during the first three-and-one-half months of the year. The striking feature in these settlements is that some firms, namely Bessemer and Louisville were very big net lossers, at least as far as the bonus fund goes, while Chattanooga, South Pittsburgh and Anniston were net winners. The fact that these small plants appear to be net winners is not surprising, however, because the system called for small plants to be reimbursed early in the year. (For the first 90,000 tons, the bonus was split evenly six ways and so on as related above.) Other factors also played a role, although it is difficult

Table 3.4

NET BONUS SETTLEMENTS BETWEEN PLANTS, EARLY 1896

	January		February		March		April	January 1 to April 15	Cartel Assigned Capacity[a]
	1/1 to 1/15	1/16 to 1/31	2/1 to 2/15	2/16 to 2/29	3/1 to 3/15	3/16 to 3/31	4/1 to 4/15		
Addyston	+1,159	+312	+2,392	+2,708	+1,387	+589	-2,662	+5,925	45,000
Anniston	+1,173	+1,475	+1,818	+2,150	+589	+181	+715	+8,101	30,000
Bessemer	-882	-2,685	-6,295	-8,534	-1,773	-3,958	-4,261	-28,388	45,000
Chattanooga	-2,016	+213	+2,265	+3,147	+1,635	+3,188	+4,630	+13,062	40,000
Louisville	-52	+41	-1,627	-1,218	-1,721	-1,554	-1,126	-7,257	45,000
S. Pittsburg	+619	+645	+1,449	+1,747	+1,061	+850	+2,663	+9,034	15,000

Source: Transcript of Record, pp. 98-99, and p. 65.

Note: A "+" means a net positive settlement or gain that month, a "-" means a loss.

a/ "Cartel assigned Capacity" formed the basis for the bonus fund settlements.

to say what weights we should give them. What we can say is that a firm that got a large (positive) net settlement in the first part of the year did so because 1) it did relatively little work, 2) it did relatively little work in pay territory, or 3) the jobs it bid on had low bonuses. Small plants would have negative net settlements if they took work in pay territory once a certain aggregate tonnage was reached. The Addyston plant, located in the Northeast and close to non-member plants, was better situated to take low bonus work in Ohio and Pennsylvania. Yet its share of the fund was not affected so that it got a positive bonus settlement. Shops located closer to the heart of pay territory payed out more than they earned in the way of bonuses. Louisville, a few hundred miles down river from Cincinnati was a small net loser. Bessemer, even farther south, was the big net loser.

An additional factor seems to have been plant cost conditions; firms with low marginal cost probably should be expected to bid more to obtain a contract and contributed more than their share of the bonus. The Chattanooga management was very happy in fact to let the Bessemer plant take work in early 1896 that, after bonus and freight were paid, netted only $12 per ton. In a letter to its cartel representative in Cincinnati it instructed him to accept no work that would not provide at least $14.25 for the smaller and $13.00 for the larger sizes at the shop gate after bonus was paid. Chattanooga's share of the bonus was secure in any event, and it looked to work in free territory to provide some extra return [Transcript of Record, p. 94]. In fact, it seems to have been able to get at least $13 in free territory. (See Table 3.15.) This policy may very well account for its large net settlement. More concrete evidence concerning marginal costs across plants is presented in Chapter 4 and supports this conjecture that Chattanooga had higher marginal costs. It may be objected that there is no good reason why Chattanooga and not Bessemer should get work in free territory at a higher net price. It is quite likely, however, that variations in output were more expensive at the larger plant and that overhead costs were a larger fraction of costs. If work in free territory was more sporadic, there is no necessary inconsistency.

It should also be noted that the curious method of dividing the bonus fund had a predictable effect. By the rules of the agreement if there was a bad year, say only 90,000 tons shipped to pay territory, then all six firms, large and small, each got only one-sixth of the bonus fund. Clearly the large firms might be unhappy with this arrangement if business conditions turned sour. It comes as no surprise then to learn that the Addyston plant, the largest of the six plants, sought a readjustment in December of 1895. It predicted that in 1896 total cartel tonnage would be only 195,000, in part because bonuses were now calculated on the basis of shipments to pay territory and not shipments to any territory. Accordingly, it suggested a decrease from 220,000 to 200,000 in the tonnage forming the basis for the division of the bonuses, the relative allocations to remain unchanged [Transcript of Record, pp. 90-92]. No evidence exists that this suggestion was adopted. Recall that five out of six firms had to support motions for changes in the agreement for those motions to pass.

Discovery of the Agreement. The system of internal auctions and reserved cities was the one in effect in February of 1896 when the Anniston, Alabama works submitted a bid of $24.00 per ton to the city of Atlanta, its reserved city on a small order of only 375 tons. This bid was duly protected by other members, but was underbid by a New Jersey firm whose representative was in town. "In reply will say," wrote the vice-president of Anniston to one of the other firms, "we believe we made a mistake in trying to get $24.00 for pipe and 2-1/2 cents for specials, but there would have been no difficulty in this respect had we not run up against R. D. Wood & Co.'s man there putting in his bid for hydrants, and he also put in a bid for the pipe and specials at the last minute." [Transcript of Record, p. 84]

Nor can it be doubted that the price was high. The January 30, 1896 issue of The Iron Age reported that Anniston had bid $21.50 per ton in Jacksonville, Florida for 4,100 tons of pipe. The Bessemer shop, which had protected Anniston in Atlanta with a higher bogus bid, won that contract at $19.20. Since the freight rate from Anniston to Atlanta was only $1.60 per ton [Transcript of Record, p. 76], the Anniston shop bid more per ton, net of freight, at Atlanta than it did in Jacksonville. A curious detail about this bid was that the Chattanooga management thought it was too low.

> It is useless to argue that Howard-Harrison Iron Co., Cincinnati and other shops, who have been bidding bonuses of six and eight dollars per ton, can come out and make any money if they continue to bid such bonus. In the case of the Howard-Harrison Co., people on Jacksonville, Florida. The truth of the business is they are losing money at the prices they bid for this work. [Transcript of Record, p. 93][3]

Work in the Northeast at that time was being let at $17 to $20 per ton even on small lots. The Anniston and Chattanooga plants themselves bid $20.00 and $20.62 for work in Boston during the early part of 1896 [Iron Age, March 12, 1896, p. 663]. Since freight was at least $5, the price at the factory gate was at most $15. Later that year on a contract at Lawrence, Massachusetts a "southern shop" bid $21.12 per gross ton ($18.86 per net ton). Iron Age [June 4, 1896, p. 1,324] speculated that the southern firms must have had some cheap sources of pig iron since freight charges left only $12.15 at the shop.

Other evidence that their prices were discriminatory, charging more to people close by, comes to light in a letter to a contractor (it seems) in New Orleans. The South Pittsburgh works had quoted a much lower price f.o.b. New Orleans on an inquiry for a lot of pipe that was to go to South America than on an identical lot going to New Orleans itself. Anxious to avoid any misunderstanding, South Pittsburgh sent off a letter dated May 10, 1895 which included the following.

> We cannot furnish this pipe for New Orleans consumption. It's true that the transaction looks all right on the face of it, but we could never explain it satisfactorily and it would result in breaking up an arrangement, which is bringing to us as well as others considerable more profit than we would reap if this arrangement should be broken. The parties that I refer to, as your Mr. Marrion well knows, will watch every movement made in New Orleans so far as the purchase of pipe is concerned, and for this reason we would greatly prefer not to run any chances. [Transcript of Record, p. 41]

The suspicion in Atlanta that there was a cartel among the four southern shops had some interesting consequences. The Chattanooga works complained that the system of reserved cities was undesirable since the fact that only one firm wound up with a city's orders was proof to the city that a combination existed. They also appear to suggest that this system had inefficiencies insofar as they were denied work, sometimes of considerable magnitude, that often fell into their hands before the combination existed (or at least before "reserved cities" existed--we don't know how long or in what form the southern shops had been operating their cartel). Chattanooga also suggested that a "proper talk with R.D. Wood & Co. would result in a better understanding between us." [Transcript of Record, p. 87]

The water commissioners of the City of Atlanta threatened that if they discovered a combination, none of the southern shops would get another order, but in the meantime they rejected all bids and asked for new ones from the same local firms accused of price fixing. Writing to Chattanooga, they asked "if it is not possible for a lower bid to be made from those who are so near this point, you might say, right at our door." [Transcript of Record, p. 84]

The Atlanta board of water commissioners did initiate an investigation into the question of whether any legal action should be taken. J. E. McClure, who had been the cartel's stenographer during 1895 and 1896, began in March of

1896 to contact various municipalities in pay territory with the aim of receiving some compensation for his efforts. He had assiduously and secretly copied dozens of letters, telegrams and cartel minutes and promised to provide his copies to the cities he contacted, among them Boonville, Indiana and Omaha, Nebraska, if they split any damages with him. McClure also contacted the Atlanta officals, who reviewed his evidence, but declined to press charges. In doing so, they argued for the importance of the following points:

1. The outcome of the sugar case, E.C. Knight, indicated that a suit filed against the pipe companies was not likely to succeed.

2. The common law on cases such as this was ambiguous.

3. Georgia law only granted relief if purchasers made an effort to award their trade to other parties; i.e., Atlanta had not made an effort to shop outside the combination.

4. The references in Chattanooga upon whom McClure had relied to provide letters of recommendation repudiated him once they found out what he was up to. The testimony and evidence of their chief witness was therefore likely to be questionable.

The unanimous opinion of the water commissioners was not to bring suit, although their lawyers had argued the contrary course [Transcript of Record, pp. 169-174].

In additon to contacting the various city officials, McClure also seems to have attempted blackmailing the cartel. In their demurrer the defendants claimed that they had "persistently refused to be blackmailed by all parties claiming to have secured copies of private letters and agreements alleged to have been stolen from them." [Transcript of Record, p. 35] Although McClure is not mentioned, he appears to be a likely candiate.

The city of St. Louis also refused to prosecute, although for slightly different reasons. The City Counselor, although he declined to submit an affidavit on behalf of the defendants, did express a willingness to supply testimony on their behalf "at any time it may be desired, and sought in the regular legal methods." In a letter to the vice-president of the Bessemer firm, who had solicited an affidivat, he indicated that he too was suspicious of McClure and that the city had been reluctant to become involved with him. McClure had written to the mayor of St. Louis in March of 1896 and visted that city in May. The second reason, besides McClure's character, that purportedly led the city to decline involvement in the matter was that it could and did reject bids that were too high.

> We have competent engineers who keep posted as to market values, and whenever bids do not come within the amount estimated by them for the doing of public work...the board rejects the bids and readvertises...we do not feel that the city has been or can be defrauded by any combinations that may be made between manufacturers, for whenever any such attempts are made the city protects itself by refusing to agree to pay the prices bid, and by continuing to readvertise for bids until the prices come within the estimated cost of the work. [Transcript of Record, p. 256]

It is also interesting that the firms were accused by the government of maintaining their conspiracy. See the restraining orders issued between December 15, 1896 and January 9, 1897 [Transcript of Record, pp. 14-19]. An odd detail that also emerges at this point is that by February of next year the city of Atlanta had again solicited bids. Although Atlanta bought pipe from the Anniston plant in April of 1896, none of the defendants had wanted, or perhaps none was permitted, to provide pipe the following February. The firms that did participate in the bidding were located in Lynchburg, Va. (the low bidder), Florence, N.J., Berwick, Pa., and Columbus, Ohio [Engineering-News Record, February 18, 1897]. This is surprising when we remember that there are at least four plants, all four of them defendants in the case, who were located much closer. Two years later, however, in February of 1899, the low bidder on an Atlanta contract was American Pipe and Foundry, the firm formed by the merger of those same four plants [Engineering News, February 9, 1899].

Cartelization in Related Industries and Sources of Supply. It should be noted that cast iron pipe manufacturers were not the only producers of iron and steel products to be involved in price fixing arrangements at this time. The southern pig iron producers also had an agreement and this was well-known. For example, the trade press reported in December of 1895 that a large southern producer had sold 10,000 tons to "pipe works in Tennessee" (the Chattanooga or South Pittsburgh shops are the only ones we know of) at 50 cents below quoted prices, or so it was charged. "Other claim that 'full' prices were obtained. Since the placing of this order, however, the information comes that the largest Southern furnaces have reached an understanding by which prices will hereafter be maintained." [Iron Age, December 12, 1895, p. 1,231] One month later trade reports indicated some suspicion among these pig iron producers. One firm had committed itself to a contract at a price below prevailing prices, claiming that a mistake in the telegrams had resulted in that low price. Unfortunately, the buyer, a large northern pipe producer, accepted before it could be withdrawn. "Whether this explanation is correct or not seems to make little difference. It has resulted in unsettling confidence and subsequent sales have been made on a lower basis, at least 25¢ per ton under the level recognized by the furnaces, and in some instances even lower." [Iron Age, January 23, 1896, p. 262]

Other industries which had pooling agreements at this time included manufacturers of steel rails, steel billets, wire nails, and anthracite coal. See Burns (1936) and Seager and Gullick (1929) for brief treatments of these and many other turn-of-the-century cartels.

Given that the producers of pig iron were operating a cartel, what can we say about the way the pipe works purchased their pig iron and the prices they paid? Very little can be known *a priori*. As large consumers, they had a substantial incentive to induce their suppliers to shade prices, and the relative stability and size of their requirements might lead us to expect that they got lower than "prevailing" or openly quoted prices. On the other hand, it is probably more difficult to hide from other cartel members such large orders made at reduced prices. Furthermore, if the cartel of pig iron producers had the same causes as those we propose for the cast iron pipe cartel, then the pipe producers, who numbered among the furnace owners' steady and sizable consumers, would not have eagerly sought to initiate and sustain cutthroat competition among their suppliers. Considering their interests as a group and over time, it was to their benefit if prices enabled producers to cover costs. At the risk of belaboring our theme, these prices were not necessarily marginal costs.

Speculation aside, we can establish that the pipe plants contracted for large lots of pipe at a time, and received these contracted amounts in sizable shipments, sometimes dividing the whole contracted amount into two or three shipments several months apart. This much is clear from the trade reports as well as the monthly plant data on which our results in Chapter 4 are based. Orders of 5,000 to 10,000 tons were common, which would have provided for one to three months' operation of a plant [Iron Age, November 7, 1895, p. 956, and December 12, 1895, p. 1,231].

The tonnage of these contracts depended on expectations concerning prices. In January of 1896, many observers predicted that prices had bottomed out. This turned out to be false; prices fell near two dollars more very soon. Regardless, the Bessemer cast iron pipe plant took delivery at prevailing prices of 18,000 tons that month, attributed in the trade press to these expectations [Iron Age, January 23, 1896, p. 263]. The next week, the "various interests at Anniston" also bought a large order on the belief that prices could go no lower [Iron Age, February 6, 1896, p. 379]. The "various interests" turned out to be "one Pipe concern." (We quote from the next issue, Iron Age, February 13, 1896, p. 432--this journal often went to considerable lengths to conceal the identities of the parties to a transaction.) The total amount was purchased in three lots by the Anniston plant from three separate furnaces in Birmingham. For all six plants in the Associated Pipe Works cartel, the main sources of supply were the plants located in northern Alabama, primarily Birmingham. The foundries at Louisville, for example, got about 95 percent of their supplies from the southern pig iron producers [Iron Age, January 2, 1896, p. 71].

3.2 Consolidation, Rivalry and Prosperity

The defendants won their first trial on charges that they had violated the Sherman Act. This decision was appealed to the Sixth Circuit Court where the opinion written by Judge Taft held that the attempts by the defendants to establish the reasonableness of the prices they agreed to charge was not at issue.[4] Rather, the agreement on prices, regardless of how high or low they may have been, was a violation and indicated intent to monopolize. This decision was again appealed, the Supreme Court affirming Taft's decision in 1899.[5]

The Round of Mergers. Already in May of 1898, however, four of the six defendants merged. In the month following the initial consolidation Iron Age (June 2, 1896, p. 28) reported that an attempt was also under way to consolidate all the shops "west of the Alleghanies, north of the Ohio and east of the Rocky Mountains." The following February [Iron Age, February 2, 1899, p. 35] it was reported that "no marked progress has been made in the effort to consolidate the Cast Iron Pipe business. The options on some of the plants expire on February 15, while in the case of some concerns no options have been secured." This issue also predicted better prices and expanded business for the upcoming season. A week later (February 9, 1899) Iron Age reported that the consolidation had taken in more members. At this point USCIP&F consisted of all six defendants and five outside firms. (See Table 3.5 and Figure 3.2 for the capacities and locations of the specialized producers at this time.)

One issue was clearly on people's minds at this point, and that was whether there would be rivalry between the consolidation and the remaining independent firms.

> As yet no opportunities have presented themselves to test the attitude of the consolidation of [toward?] the outside interests in the matter of competition for business nor will the Brooklyn order for about 3,000 tons, to be let tomorrow, throw any light on the situation because the contractors will do the bidding. [Iron Age, March 28, 1899, p. 33]

The situation in the cast iron pipe industry at this point was analyzed in early April by P. D. Wanner in an address to the Foundrymen's Association (published in Iron Age, April 13, 1899, p. 8). Wanner chronicled the history of the industry, noting that although business had been good in the 1880's, the boom had resulted in over-expansion. He also recalled that producers had responded in 1879 to poor business conditions by attempting to form a pool. Participants to that attempt had agreed that their pool should have four aims:

1. To devise some method to secure more remunerative prices.
2. To divide the work or assets realized for the letting of the work on a basis equitable to all.
3. To prepare uniform specifications under which we shall all pledge ourselves to bid at public auctions.
4. To prevent the expansion of present shops or the building of new ones.

This attempt failed, he noted, because one firm, the Warren Foundry, refused to take part. Pressing his point, he added that a similar effort failed in 1892 because a few concerns opposed the effort or failed to join.

Viewed against this record of plans gone awry, Wanner welcomed the move to consolidation. Since cast iron pipe was expensive to transport, he thought it

Table 3.5

MAJOR CAST IRON PIPE PLANTS
1900

Firm and Plant			Daily Melting Capacity (in tons) 1900	1896
U.S. Cast Iron Pipe and Foundry	2,625			
Defendants in Addyston		1,500		
Addyston: Cincinnati, Ohio			350	
Dennis Long: Louisville, Kentucky			250	
Chattanooga: Chattanooga, Tennessee			150	
South Pittsburgh: South Pittsburgh, Tennessee			100	
Howard-Harrison: Bessemer, Alabama[a]			300	
Anniston: Anniston, Alabama			350	
Included in USCIP&F, 1899-1901		1,185		
Lake Shore Foundry: Cleveland, Ohio			300	200
McNeal: Burlington, New Jersey			200	225
National Foundry: Scottdale, Pennsylvania			300	200
Buffalo: Buffalo, New York			150	100
Ohio: Columbus, Ohio			175	150
West Superior: West Superior, Wisconsin			60	75
Major Outside Firms	1,270			
Warren: Phillipsburg, New Jersey			275	200
Wood: Florence, New Jersey			300	400
Donaldson: Emmaus, Pennsylvania			100	
Utica: Utica, New York			80	50
Reading: Reading, Pennsylvania			140	125
Clow: Newcomerstown, Ohio			125	75
Penninsular Car: Detroit, Michigan[b]			100	
Jackson and Woodin: Berwick, Pennsylvania			75	75
Radford: Radford, Virginia[c]			75	
Glamorgan: Lynchburg, Virginia				75
Shickle, Harrison & Howard: St. Louis, Mo.				75

Sources: Directory to the Iron and Steel Works of the United States, various issues, Transcript of Record, pp. 36-37, and Noble (1940). Three small foundries in Texas, Colorado and Oregon are omitted.

a/ Closed temporarily in 1900.
b/ Joined in Southern Car and Foundry, Directory, 1901, pp. 143-144.
c/ Owned by Virginia Iron, Coal and Coke and leased to Glamorgan Pipe and Foundry of Lynchburg, Virginia, Directory, 1904, p. 177.

Figure 3.2

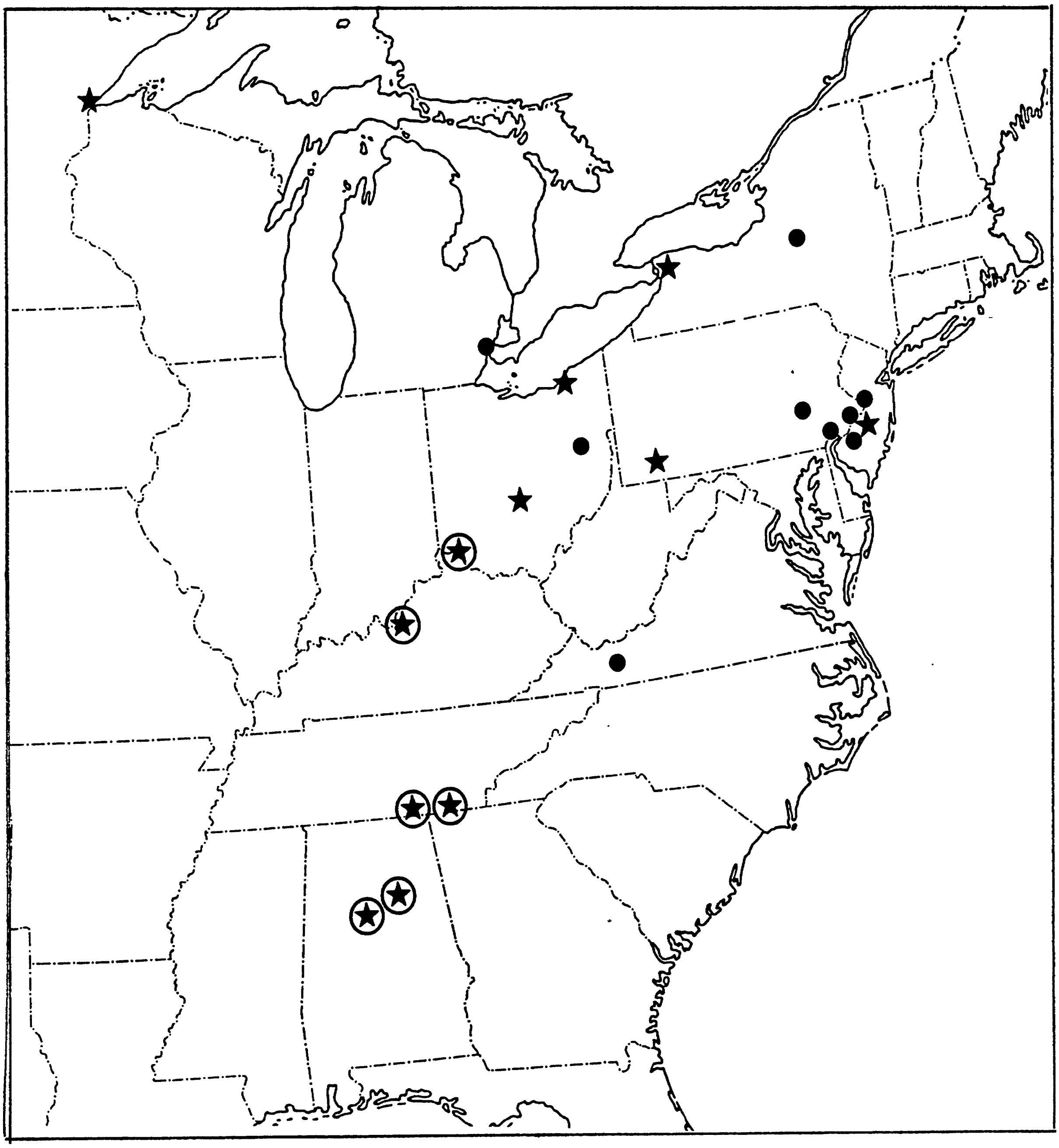
LOCATIONS OF MAJOR PIPE PLANTS

1900

⊛ Plants belonging to defendants in <u>Addyston</u>

★ Plants included in United States Cast Iron Pipe & Foundry in 1900

● Plants of major independent producers



sufficient that there be only regional consolidations. What the aim of such mergers would be was clear to Wanner.

> This [consolidation] and all governments were created and upheld by necessity. It will be so with both all trade or manufacturing interests in the future. It has been truly said that business is war, and to make it a success warlike methods will have to be restored [sic] to, and success will be on the side of those who have the largest guns or aggregation of capital; in other words, a combination of the greater part of the trade will be able to dictate prices and a line of behavior to those outside, or crush them. It is no longer the survival of the fittest, but of which can hold out best and longest.

The next report of activity occurs one month later, when it was noted that "efforts are being made to reach an agreement with the outside shops in the East." [Iron Age, May 25, 1899, p. 38] Comment on this topic unfortunately remains sparse. During the same period the price of pig iron moved up to very high levels and business slacked off as a result. One southern town even considered using wooden pipes, which was the standard practice in some parts of the West [Iron Age, November 8, 1899]. In early 1900 it was reported that "there are indications of a struggle between the Eastern independent shops and the consolidation." [Iron Age, January 11, 1900, p. 30] Business for the Midwest and southern shops picked up over the next few months but competition between this group and the eastern shops was considered to be sharp [Iron Age, April 26, 1900, p. 29]. By June of 1900 business was so bad that at least six foundries closed down in the middle of what was normally the peak season [Iron Age, June 14, 1900, p. 38].

Two months later competition was still keen between USCIP&F and the independents and it was reported that "invasion of territory is general. Eastern shops have taken good orders in the Central West and in the Northwest. The result is that the market is very irregular." [Iron Age, August 9, 1900] Data on prices supporting the view that this was a period of unusually low pipe prices, taking into account the price of iron, are presented in the next section.

Addyston and the Merger Wave. To what extent can the mergers in this industry be attributed to the antitrust action? This is by no means as clear an issue as it seems at first. There is a remarkable confluence of events in the late 1890's that makes this a difficult issue. This was the period during which merger activity reached epic proportions. In industry after industry, mergers of firms placed sizable portions, sometimes nearly all of the plants under one corporate roof. The statistics of this period have been ably compiled by Nelson (1959). Discussions of these mergers appear in National Industrial Conference Board (1929), Jones (1921) and Stigler (1950). By any measure, whether we look at the number of consolidations, the number of firm disappearances, or merger capitalizations, the merger movement reached a sharp peak in 1899, the year Addyston reached the Supreme Court. Table 3.6 shows this clearly and reveals also that however strong these tendencies were in 1898, they were much stronger, by a factor of four or five, in 1899 and that they subsided just as rapidly. Stigler has remarked that "the effectiveness of the Sherman Law in dealing with conspiracies was not clear until 1899, when the Addyston Pipe case was decided." [Stigler (1950), p. 102] Although there were two earlier cases in 1897 and 1898, Trans-Missouri and Joint Traffic, these involved railroads and were carried by slim majorities. Railroading had become the focus of considerable public controversey and, in 1888, became subject to ICC regulation. This industry may very reasonably have been considered sui generis so far as its legal status was concerned. Addyston, and this point bears emphasis, was the first significant case not involving a railroad and struck at the heart of the widespread, explicit and well-publicized cartelization of this period. The Supreme Court heard arguments in the case in May of 1899 and this was reported and extensively covered in the trade press. "The case has attracted an unusual amount of attention for the reason that it is the first of its kind to reach the Supreme Court, and the decision of the

Table 3.6

STATISTICS OF THE MERGER MOVEMENT

1895-1904

Year	Number of Consolidations	Firm Disapperances by Merger	Merger Capitalizations (millions of dollars)
1895	5	43	40.8
1896	5	26	24.7
1897	10	69	119.7
1898	26	303	650.6
1899	106	1,208	2,262.7
1900	42	340	442.4
1901	53	424	2,052.9
1902	48	379	910.8
1903	15	142	297.6
1904	9	79	110.5

Source: Nelson (1959), p. 24 and p. 37.

tribunal will have an important bearing upon trade combinations and agreements thoughout the country." [Iron Age, May 4, 1899, p. 13] A decision was expected before the summer recess.

By a curious coincidence, the firms in a related industry, cast iron soil pipe manufacture, were among those firms that merged in 1899. Soil pipe is used to carry off waste or to conduct water not under pressure. Although it does not have to meet the same standards as water pressure pipe, it was manufactured the same way. In July of 1899 the firms of this industry merged and formed the Central Foundry Company. The expectation was that the promoters "would have a free and undisputed field in which they could control the market for Cast Iron Soil Pipe and Fittings.... It was explained that with the control of all the plants new prices would be announced and new regulations as regards shipments and freight allowances would be made, which would leave considerable profit to the interested parties." [Iron Age, December 13, 1900, p. 47] New firms entered almost immediately, however. The response of Central Foundry was not to lower prices, but rather to maintain its original prices and to refuse to sell to jobbers who did not buy all their soil pipe from it. This policy failed, and the new firms were soon able to provide complete service to the jobbers. The response of the Central Foundry Company at this late point was warfare; it now reduced its prices with the idea, it was claimed, of driving the newcomers out of the business. Whether this was necessarily the aim is open to question; the result was that in December of 1900 the consolidated firm and its new rivals formed a pool.

The details of the soil pipe agreement were remarkably similar to those we saw in the case of water pipe. A percentage of receipts would be paid into a pool, and the pool was to be divided among the firms. The plants were located primarily in Alabama, in the New York-Philadelphia area, and Indiana and Ohio, much as in the case of water pipe. All firms in the country were party to the agreement [Iron Age, December 13, 1900, p. 50]. We see then here a simultaneous merger in a closely related industry, a similar struggle between the major firm and the rest of the industry, and in addition the resolution of this struggle by means of a cartel arrangement. This agreement was initiated more than a year after Addyston reached the Supreme Court and yet was publicized in the trade press.

Plant Closings and New Construction. Among the curious acquisitions of the cast iron pressure pipe consolidation at this point were the small plant at West Superior, Wisconsin and an idle unit located at Metropolis, Illinois. The plant in Illinois was built at the very end of the 1880's water pipe boom and was closed shortly afterwards. According to one source, it was bought by the consolidation in 1899 but never operated [Noble (1940), p. 68]. Exactly why this was done is unclear. The firm also announced in early 1899 that it was going to build a new plant at Bessemer, Alabama, but this plant appears never to have been built [Commerical and Financial Chronicle, January 28, 1899, p. 185]. H. C. Frick, who later consolidated nearly all the coke ovens near Connellsville, Pennsylvania, the country's major coke producing area then, had in June of 1898 announced plans to build a plant in Chicago [Iron Age, June 9, 1898, p. 28]. These plans were apparently also never carried out.

Two operations were started up in 1900, however. One of these was erected in Massillon, Ohio. The other, more important plant was constructed by J. K. Dimmick at Birmingham, Alabama. Dimmick had been owner of the Anniston plant and one of the chief architects of the cartel. In 1898 he assumed the position of General Manager with U.S. Cast Iron Pipe and Foundry before quitting to start his own firm. Several other operations were established in the next few years. A new plant was built at Lynchburg, Virginia in 1902, and a soil pipe plant built in 1899 at Bessmer was converted to pressure pipe in 1903 [Noble (1940), pp. 79-82].

The acquisition by USCIP&F of an idle plant, although it smacks of capacity restriction, may be interpretable as a mistake if we keep these developments in view. Both the consolidation and H. C. Frick may have thought that industry capacity should be expanded in Illinois, but these plants were rendered unprofitable by the establishment of new producers elsewhere, or perhaps by some more general economic turn of events such as changes in pig iron prices across regions.

It will also prove useful at this point to pause and look at the changes in industry structure that occurred over the two decades that are being examined. Table 3.7 presents the number of major new cast iron pipe plants constructed and plants converted to cast iron pipe production for five-year periods beginning with 1870. These figures indicate that there was a rather large increase in capacity between 1880 and 1895, twenty-four new plants. During the five years which cover the period of collusion among the six firms only two new plants were constructed, one in Ohio to replace a plant destroyed by fire, and one in Tennessee to accommodate equipment from a dismantled branch plant of one of the defendants in Addyston. The second building boom occurred after 1900. It was during this period that Alabama became the major cast iron pipe producing state. In all, seven new plants were put into operation in that state by 1915.

The figures for the period after 1900 take on more significance when we inquire into the ownership of plants. Of the original twelve plants owned by USCIP&F in 1899, ten were in operation in 1910, but only six by 1915. During this time the firm had acquired only one new plant, that of J. K. Dimmick, its former General Manager who in 1900 had set up his own firm. Figure 3.5

Table 3.7

MAJOR NEW PLANTS AND ENTRY, 1870-1920

Period	Major New Plants North	South	Total	Major Plant Sites a/ Total	b/ USCIP&F
1870-74	3	0	3	11	--
1875-79	0	1	1	12	--
1880-84	3	2	5	15	--
1885-89	9	5	14	22	--
1890-94	3	2	5	25	--
1895-99	1	1	2	23	12
1900-04	2	3	5	25	10
1905-09	2	5	7	29	11
1910-14	1	5	6	28	11
1915-1920	0	0	0	23	6

Source: Noble (1940) and Moore (1939), derived from text. "Major new plants" includes all plants mentioned as specialized producers of cast iron pipe or converted to specialized production. General foundries which were in the business for a short period are not included. New units appear sometimes to have been built alongside existing ones which were then torn down at some later date. "Major Plant Sites" counts such arrangements as one unit.

a/ No exact date was given for some of the plants shut down in the period 1905-1920, only that they were out of operation by some date.

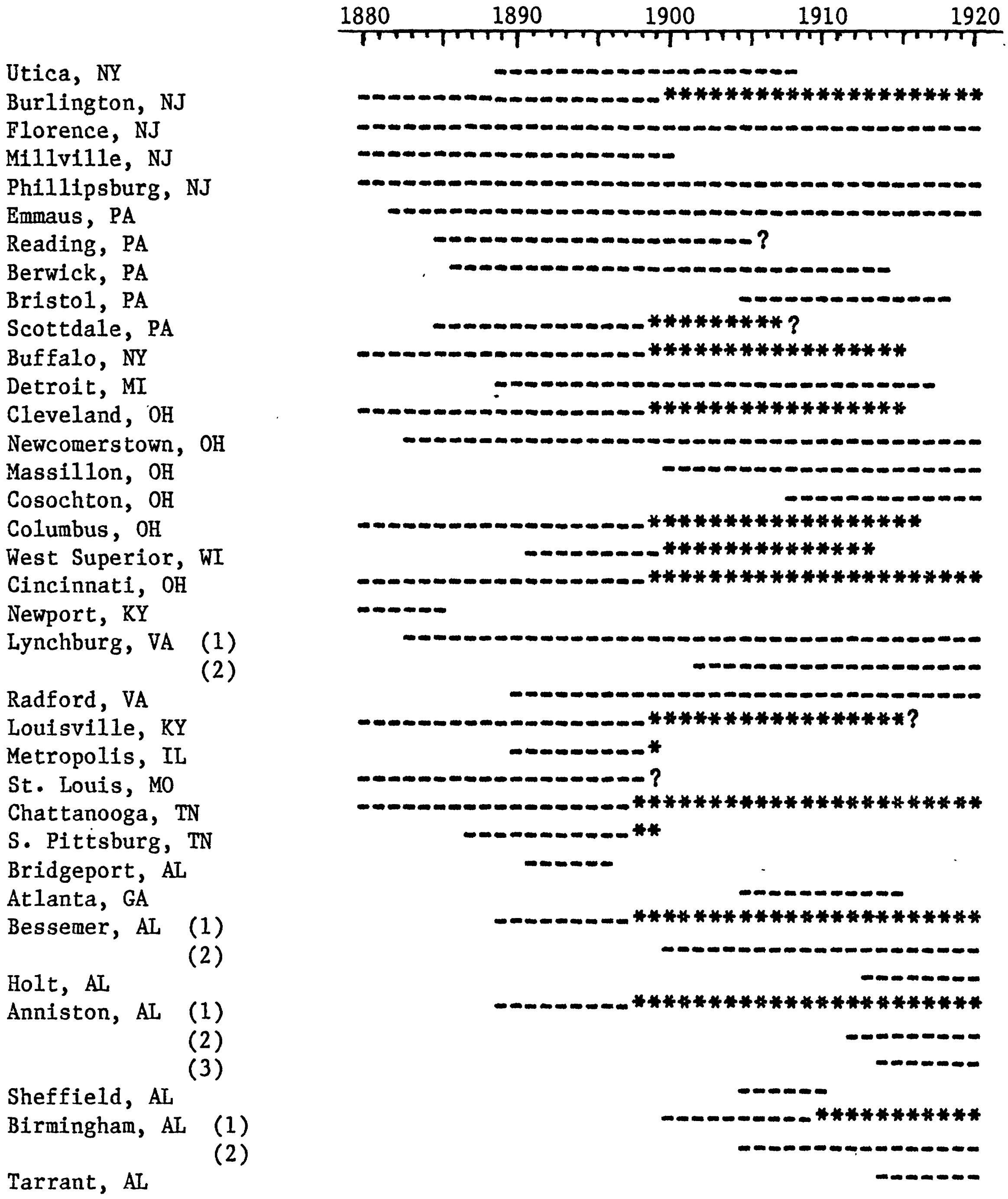
b/ The 1890 census counted thirty-six plants. The discrepancy may be partially accounted for by noting that the figures here do not include the three small plants in Texas, Colorado and Utah, and also do not include the two plants which were idle that year. The census report did not reveal where the idle plants were located. The next point for which we have an independent record is 1914. The December 31, 1914 issue of Iron Age reports 34 plants, including one each in the states of Massachusetts, Maryland, Colorado and Oregon, which we ignore here.

provides a summary of the changing structure of the industry for the period 1870-1920. An attempt has been made to give the firms a north-south ordering in order to reveal the geographical shift of the industry. While complete figures on capacity are not available, it would appear that USCIP&F's share declined over this period. It is not clear, however, to what we should attribute this decline. There were several other smaller multiplant operations at this time. By the late 1930s USCIP&F still had only six plants. Clow operated two plants directly and one through a subsidiary. The remaining thirteen firms were either one or two site operations [Noble (1940)].

Who constructed and operated the new plants? For the most part it seems to have been the foreman, clerical workers and managers of existing firms. The careers of two of these are summarized here. In May of 1906 the American Cast Iron Pipe Company began operations at its newly constructed plant. This firm was founded by Charlotte Blair and her brother. Miss Blair had started in the cast iron pipe business as a stenographer with the Radford Pipe Co. of Virginia. She later worked at the Anniston Works while it was owned by J. K. Dimmick and she became the first Alabama woman to serve on the directorate of a corporation. The plant's manager, Edwin Linthicum, began with Dimmick also as Anniston's telegrapher, and rose by rapid steps to become that plant's manager in 1898. In 1905 he took up his position with newly formed American Cast Iron Pipe Co. He resigned in 1908, and in 1913, when business began to pick up again, organized the National Cast Iron Pipe Co. and served as its Vice-President and General Manager. The lesson in this brief history of two careers is that it was an easy matter to find qualified managerial personnel for industry expansion. Summaries of many other similar careers can be found in Moore (1939).

Figure 3.3

LOCATIONS OF MAJOR CAST IRON PIPE PLANTS, 1875-1920



Source: Noble (1939) and Moore (1940).

Note: The symbol * indicates that the plant was owned by USCIP&F that year. A question mark indicates that the sources above say a plant was out of operation by that date (or perhaps earlier).

Although the information we have about plant openings over time is detailed and seemingly complete, it does not solve the riddle of competition and monopoly. Another significant factor is transportation cost. There is substantial clustering of firms in certain areas: Pennsylvania-New Jersey, Ohio, and in the southern iron-producing area. With high transportation costs the major plants in these areas would each have contributed a substantial portion of the output in the relevant market. At the time of the agreement among the Associated Pipe Works, for example, only four plants were located in the states of Alabama and Tennessee. Their immediate "natural" market included these states as well as Georgia and Louisiana. As demand there changed, it would have been unlikely that the optimal solution called for a rate of output such that all operating plants produced at minimum average cost. If this assertion is accepted then the usual evidence concerning ease of entry, for example, has no direct bearing on what the purpose of collusion in this industry might have been. In this case it only suggests a classical joint monopoly was an unlikely aim.

Prices and Cutthroat Competition. The major factor influencing the price of cast iron pipe was the price of pig iron. By subtracting one from the other we obtain a gross margin, which could in principle be used to determine whether firms were charging more than their costs. This is not the same thing as determining whether they fixed prices. Unfortunately, the one long series we have for prices at a single location is not for the South but rather for the Delaware Valley. Although trade reports suggest that cartel activity in the western states had an effect in the East, we wouldn't be on safe ground if we attempted to find evidence of it in an overly generous margin in the Northeast. It would be difficult to deduce when, and how vigorously, monopoly was pursued in the South and West. Our fragmentary evidence from the court documents indicates that the cartel did charge high prices in certain instances, but buyers could and often did seek more favorable terms. While we cannot provide a complete account of the returns in this market, a single price series and some fragmentary evidence concerning prices on particular contracts can be used to answer the question whether there was cutthroat competition. For our purposes cutthroat competition will be taken to mean pricing at marginal cost in an industry where marginal cost pricing won't sustain its operation.

Figure 3.4 presents the price of pig iron and the price of pipe from which our gross margin is calculated. The longer price of pipe series represents prices at the Delaware River foundries in New Jersey and eastern Pennsylvania. These prices are usually greater than the prices (at the factory gate) quoted on large municipal contracts, but are less than the spot prices for small orders. Monthly data from which this series is compiled are available beginning with 1902 and these monthly figures ($23.25, $25.00, $25.00, $24.75, etc. for the first four months of 1902) suggest that the basing point system or some other quotation method was used for part of this period. Actual delivered prices on municipal contracts tend to be consistent with this series, however. These contract prices are about two to four dollars higher, which is easily explained by the freight rates.

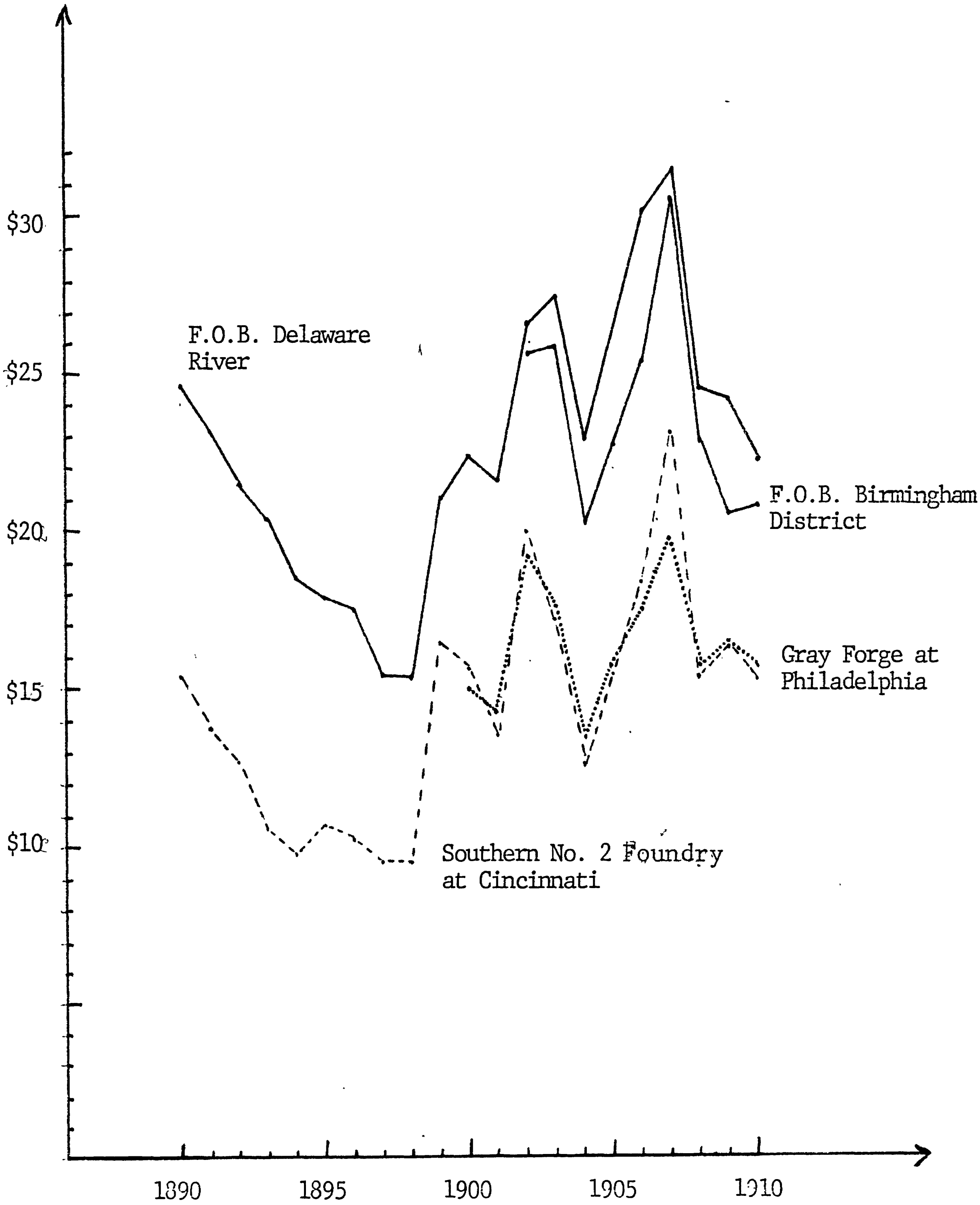
Two pig iron series are used in Figure 3.4 because the price of gray pig iron at Philadelphia is available only from January 1900. We see, however, that the figures for Southern No. 2 foundry at Cincinnati closely match this series, being only slightly higher in some years and slightly lower in others. Since the Cincinnati series has more variability (higher highs and lower lows) it might in fact be a better measure of transactions prices, although other explanations are possible. On average, however, these figures turn out to be

Figure 3.4

F.O.B. PRICES OF CAST IRON PIPE, DELAWARE RIVER AND

BIRMINGHAM, AND THE PRICE OF PIG IRON

1890-1910



Sources: Southern No. 2 Foundry Pig Iron at Cincinnati; Iron Age, March 30, 1912, p. 1351.

Gray forge at Philadelphia; Iron Age, January 2, 1913, p. 49.

F.O.B. Delaware and Birmingham pipe prices; United States Pipe & Foundry Co., Price History & Price Index of Cast Iron Pipe (no date). All figures are averages of monthly data.

very accurate. We know this because we can check them against USCIP&F's own ledger for June 1905 to May 1906. The average cost of iron for these twelve months for the Burlington, New Jersey plant was $14.51; Philadelphia gray forge for those same twelve months had an average price of $14.32 per net ton. Similarly, the Addyston plant paid $14.26 per ton for its pig iron, and Cincinnati No. 2 foundry iron had an average price of $14.10 per net ton for that period. (The sources are the same as for Figure 3.4.)

Our calculations of the gross margin per ton of 2,000 pounds are presented in Table 3.8 using both current dollars and 1906 dollars. The most striking feature of these figures is that the difference between the price of pipe and the price of pig iron hovered roughly between nine and thirteen dollars, good times and bad. There is one exception however at the end of the 1890s. In 1899 the margin was only half of what it was in better periods. How is this explained? Recall that industry reports characterized the end of 1899 as a period of struggle between the consolidation and the rest of the industry.

What constitutes a remunerative gross margin? Our detailed plant cost figures for 1905-1906, a relatively good period, indicate that labor, fuel, and repair and replacement costs (together called "direct and indirect" expense) amounted to between $6 and $8 for large northern plants. (Earlier we saw that in 1890 about $7 to $9 per ton went to these items.) Another $5 to $7 was left in the majority of years to provide a return to capital, to cover selling expense and to cover inventory cost. In the lean years, 1897 to 1900, say, the gross margin was not very far above the figures for direct and indirect expense, however, leaving very little for the other items mentioned.

Data from individual contracts presented in Tables 3.9 to 3.11 provide substantially the same result. Data from the years 1899-1902 indicate that the gross margin plus transportation costs was $7.61 in early 1899 and that it

Table 3.8

GROSS MARGIN FOR F.O.B. DELAWARE RIVER PRICES PER TON OF 2000 POUNDS

Year	Gross Margin in Current Dollars		Gross Margin in 1906 Dollars	
	Using Cincinnati Iron Prices	Using Philadelphia Iron Prices	Using Cinicinnati Iron Prices	Using Philadelphia Iron Prices
1890	11.16		12.36	
1891	10.74		11.93	
1892	10.05		11.96	
1893	11.10		12.92	
1894	9.60		12.44	
1895	8.25		10.48	
1896	8.45		11.31	
1897	7.07		9.43	
1898	7.03		9.00	
1899	6.37		7.58	
1900	8.45	8.94	9.36	9.90
1901	9.48	8.87	10.64	9.96
1902	8.77	9.18	9.23	9.66
1903	12.31	11.97	12.83	12.48
1904	11.55	10.56	12.00	10.97
1905	12.64	12.46	13.05	12.86
1906	13.73	14.46	13.73	14.46
1907	10.89	13.92	10.37	13.26
1908	10.81	10.56	10.67	10.43
1909	9.68	9.64	8.88	8.84
1910	9.45	8.95	8.31	7.87

Sources: Same as Figure 3.3

Note: The wholesale price index is used to obtain the margins in terms of 1906 dollars.

rose to $11.63 by the early part of 1902. Freight constituted between $1.50 and $3.00 of these amounts. Even the shortest hauls of 50 or 100 miles had freight rates of one or two dollars. The average gross margin plus transportation cost for all of 1899 was $8.76. This would imply a margin of $5.76 to, at best, $7.26 in 1899. (Compare this to $6.37 which was estimated from the yearly data.)

Several details concerning these numbers have to be mentioned. For 1899 an effort has been made to obtain pig iron prices that are comparable to the gray forge prices we do not have. Standard mill iron was the cheapest of various grades, and its prices are related in other years to those for gray iron, also a low-cost iron. Data from only the first half of later years is presented because we are primarily interested in watching how the gross margin changed from year to year and in checking the yearly figures from which the entries in Table 3.8 are calculated. It is also true that large orders were cheaper per ton than small orders, and orders involving large pipe were cheaper per ton than those involving small diameter pipe. Since quantities and diameter weren't provided in all cases, it seems best to present the data we do have and hope that the mix of orders is substantially the same from year to year.

Were the margins in 1899 and 1900 low? Certainly the yearly data in Table 3.8 say they were, as does our contract data for 1899 to 1902. Were they unremuneratively low? On the basis of our cost data, which covers only a portion of all costs, we can say that the gross margin would have barely covered direct and indirect expenses in some years, regardless of which data we use to estimate costs (the 1890 census numbers or the figures from plants in 1905-1906).

Were the prices equal to marginal cost? On the one hand indirect and direct expense probably contained some fixed element so that their average values would not reflect their contribution to marginal costs. On the other

Table 3.9

SAMPLE OF CONTRACTS FOR 1899

Date	Destination	Location of Winning Firm	Delivered Price	Tonnage	Pipe Diameter	Price of Standard Mill Iron at Philadelphia[a]	Gross Margin (per net ton)
January 12, 1899	Binghampton, NY	-	16.55	320	8	10.75	6.95
February 2, 1899	Boston	Phillipsburg	16.70	5,500	-	10.75	7.10
February 2, 1899	Baltimore	Camden, NJ	18.64*	1,098	16	10.75	7.04
February 16, 1899	Malden, MA	Florence, NJ	20.20*	21	8	11.25	7.99
March 16, 1899	Windsor, NY	-	18.40	351	8	13.75	6.12
March 16, 1899	Pittsfield, MA	-	21.80*	225	-	13.75	7.19
April 6, 1899	Reading, PA	Reading, PA	24.42*	950	8	15.00	8.41
April 6, 1899	McKeesport, VA	Scottdale, PA	21.60	-	-	15.00	8.21
April 13, 1899	Yonkers, NY	Florence, NJ	23.75	-	6-8	15.00	10.36
April 27, 1899	Lowell, MA	-	22.41*	700	-	15.00	6.62
May 4, 1899	Frederick, MD	-	21.65	655	12	15.00	8.26
May 18, 1899	Newark	Camden, NJ	23.20*	790	-	15.00	7.32
May 25, 1899	Pittsburg	Scottsdale, PA	21.20	-	10-40	15.50	7.36
						mean =	7.61
July 6, 1899	Allentown, PA	Emmaus	26.40*	-	-	17.25	8.17
July 13, 1899	Syracuse	Camden	24.40	345	-	18.00	8.33
July 15, 1899 (ER)	Baltimore	Scottsdale, PA	24.87	2,200	-	18.00	8.80
July 20, 1899	Lansingburg, NY	Utica, NY	28.56*	-	14	18.00	9.43
July 20, 1899	Philadelphia	Burlington, NJ	24.87[b]	2,000	-	18.00	8.80
August 10, 1899	Baltimore	Burlington, NJ	24.87[b]	2,000	-	18.00	8.80
August 24, 1899	Buffalo	Buffalo	29.00	-	-	18.00	12.93
September 16, 1899 (ER)	Jersey City	-	28.40	700	8	18.00	12.33
October 7, 1899 (ER)	Livonia, NY	Phillipsburg, NY	27.90	343	-	19.50	10.49
October 26, 1899	Wilmington, DE	Wood	29.00	75	8-12	19.75	11.37
November 4, 1899 (ER)	Berea, OH	-	28.00	169	8	20.00	10.14
December 30, 1899 (ER)	Hamilton, Ont.	Buffalo	28.50	-	-	20.25	10.42
						mean =	10.04

Source: These figures are taken from various issues of Engineering News or, where the symbol ER is used, issues of Engineering Record. The date in the first column indicates which issue.

* Indicates gross ton (2,240 pounds).

a/ Standard Mill Iron was the cheapest grade and is used here because gray iron prices were not quoted. Prices are per gross ton.

b/ The identical prices and quantities for these two locations and dates have been double-checked at their source.

Table 3.10

SAMPLE OF CONTRACTS FOR 1900

Date	Destination	Location of Winning Firm	Delivered Price	Tonnage	Pipe Diameter	Price of Gray Forge Iron at Philadelphia[a]/	Gross Margin (per net ton)
January 11, 1900	New York	Phillipsburg, NJ	25.90	1,495	-	20.375	7.71
February 1, 1900	Nyack, NY	Phillipsburg, NJ	27.00	148	2-12	20.25	8.92
February 1, 1900	Boston	Phillipsburg, NJ	26.00	2,280	4-30	20.25	7.92
February 8, 1900	Middletown, CT	Florence, NJ	27.50	-	4-8	20.25	9.42
February 15, 1900	Perth Amboy, NJ	-	25.00	-	8	20.25	6.92
March 1, 1900	Auburn, ME	-	28.00	100	10-24	19.25	10.81
March 15, 1900	Hoboken, NJ	Florence, NJ	26.40	-	6	19.25	9.21
March 22, 1900	Reading, PA	Reading, PA	29.79*	180	-	19.25	9.41
April 5, 1900	Lebanon, PA	Emmaus	24.20	-	20	18.75	7.46
April 5, 1900	Worcester, MA	Florence, NJ	25.30	2,400	-	18.75	8.56
April 26, 1900	New Britain, CT	Florence, NJ	27.33	-	-	18.75	10.59
May 3, 1900	Newark, NJ	-	28.00*	344	-	18.00	8.93
May 10, 1900	New York	Burlington, NJ	24.70	430	-	18.00	8.63
May 10, 1900	Lancaster, PA	Florence, NJ	26.45	-	-	18.00	10.38
May 24, 1900	Lansingburg, NY	Utica, NY	26.25	-	8	18.00	10.18
June 21, 1900	Allegheny, PA	Scottdale, PA	24.50	550	4-30	16.50	9.77
						mean =	9.00
July 12, 1900	Holyoke, MA	Phillipsbugh, NJ	25.90	750	-	14.50	12.95
August 16, 1900	Boston	Burlington	20.90	900	-	14.50	7.95
August 30, 1900	Odensburg, NY	Utica, NY	22.50	750	14	14.50	9.55
September 20, 1900	Smyrna, NY	Phillipsburg, NJ	23.45	-	-	14.00	10.95
September 20, 1900	Holyoke, MA	Florence, NJ	22.80	-	-	14.00	10.30
September 20, 1900	Smithfield, VA	Lynchburg, VA	21.95	-	-	14.00	9.45
October 4, 1900	Laurel, MD	Phillipsburg, NJ	22.85	-	-	13.50	10.80
October 11, 1900	Hoboken, NJ	Burlington, NJ	20.90	35	10	13.50	8.84
October 11, 1900	Washington, DC	Burlington, NJ	23.40	800	6	13.50	11.35
						mean =	10.24

Source: Same as Table 3.9, except for the iron series which comes from Iron Age, January 2, 1913, p. 49.

* Indicates gross ton.

a/ Prices are per gross ton.

Table 3.11

SAMPLE OF CONTRACTS FOR 1901 AND 1902

Date	Destination	Location of Winning Firm	Delivered Price	Tonnage	Diameter of Pipe	Price of Gray Forge Iron at Philadelphia[a]/	Gross Margin (per net ton)
January 24, 1901	Middletown, NY	Utica, NY	20.90	2,460	20	14.50	7.95
February 21, 1901	New York	Burlington, NJ	20.40	700	-	14.50	7.45
March 7, 1901	Brockton, MA	-	21.60	285	8	14.00	9.10
March 21, 1901	Quincy, MA	Burlington, NJ	23.50	400	-	14.00	11.00
March 21, 1901	Schenectody, NY	Utica, NY	20.65	2,500	6	14.00	8.15
April 11, 1901	Everett, MA	-	24.25	-	-	14.375	11.41
April 18, 1901	Hudson, NJ	-	24.80	30	-	14.375	11.96
April 18, 1901	Yonkers, NY	Burlington, NJ	23.70	150	6	14.375	10.99
April 18, 1901	Richmond, VA	-	20.30	120	8	14.375	7.46
April 25, 1901	Reading, PA	Camden, NJ	25.00	780	12	14.375	12.16
May 16, 1901	Melrose, MA	Burlington, NJ	24.40	300	8	14.375	11.56
May 30, 1901	Cohoes, NY	-	21.85	180	6	14.375	9.01
						mean =	9.85
February 27, 1902	Washington, DC	-	26.90	540	-	15.75	12.84
February 27, 1902	Boston	Camden, NJ	26.40	2,375	-	15.75	12.34
March 20, 1902	Reading, PA	Camden, NJ	28.80*	2,100	12	17.50	10.10
April 10, 1902	Lawrence, MA	Burlington, NJ	27.20	175	6	18.25	10.90
May 8, 1902	Yonkers, NY	-	29.40	23	6	19.00	12.43
June 5, 1902	Caldwell, NJ	Burlington, NJ	28.40	254	12	19.25	11.21
June 12, 1902	Newark, NJ	Burlington, NJ	31.45*	700	8	19.25	10.89
June 19, 1902	Melrose, NJ	-	33.00*	233	10	19.25	12.28
						mean =	11.63

Source: Same as Table 3.10.

* Indicates gross ton.

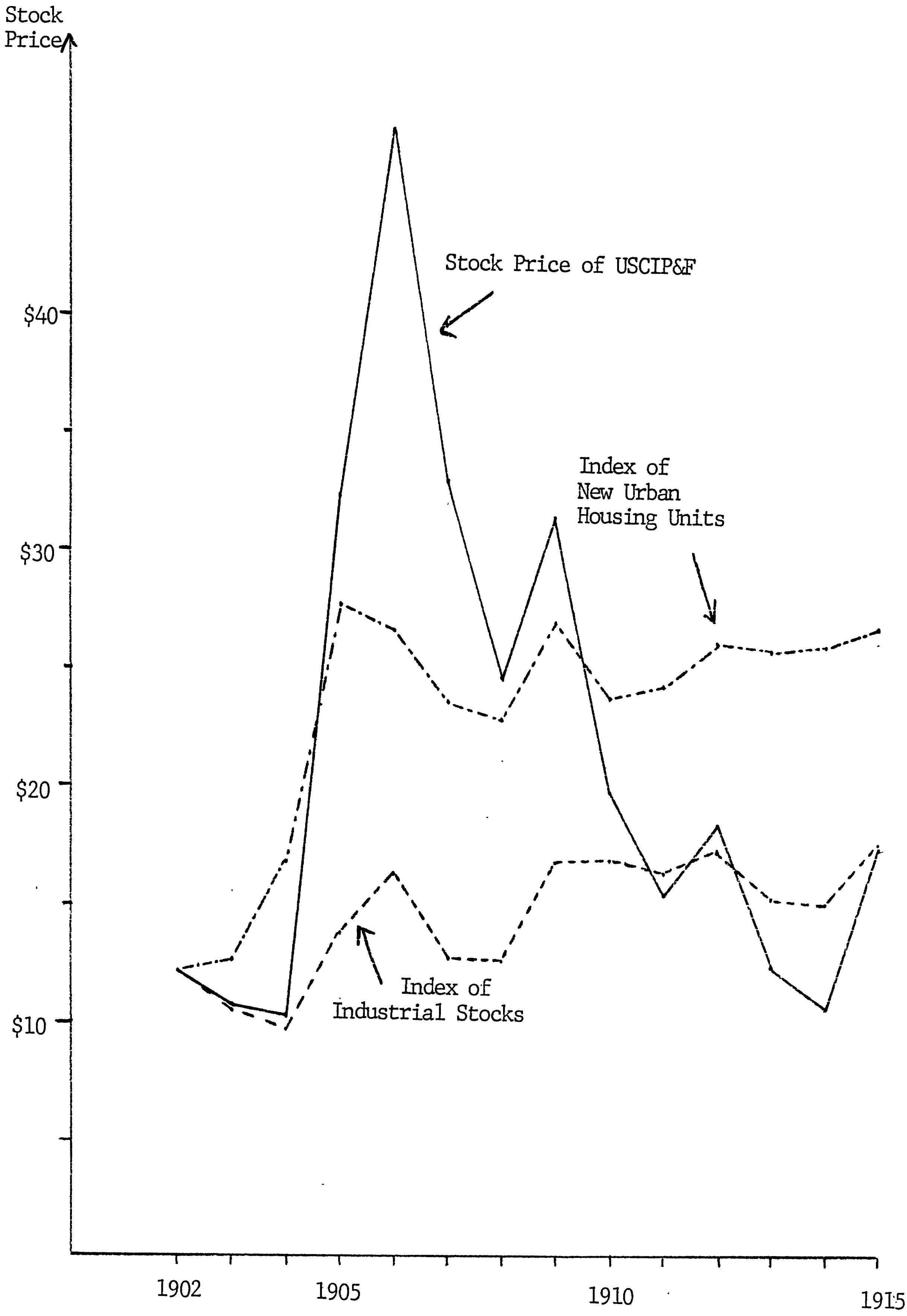
a/ Prices are per gross ton.

hand, some items that are also a marginal expense are not included in the measures of direct and indirect cost. What this means is that our estimates of marginal cost derived from direct cost items capture only part of marginal cost. These estimates range from two-and-one half to seven dollars per ton, with a fairly solid tendency for the higher figures to be associated with the smaller plants (See Table 4.12). For some plants then it seems that prices were at marginal cost.

Performance of USCIP&F. The consolidated firm turned in only a mediocre performance during the first fifteen years of its existence. U.S. Cast Iron Pipe and Foundry made three successive quarterly dividend payments on preferred stock beginning December 1899, but passed payment in September of 1900. Payment on preferred stock was resumed in 1902. Later that decade, between 1904 and 1908, the stock's value rose and payment of dividends on common stock was briefly resumed. In fact the firm surprised some observers by being able to maintain its dividends (on preferred stock) during the 1903-1904 slump at a time when firms in related industries were doing poorly [Iron Age, November 16, 1905, p. 1,304]. It was also noted that the 8 percent payment in 1905 on preferred stock was the highest allowed by USCIP&F's charter. But the firm's fall from this position was fairly rapid, as Figure 3.5 shows. Certainly when contrasted to the fortunes of an index of stocks of industrial firms, the consolidation's success, relative to its position in 1902, was fleeting. By 1910 its value had dropped to the point where one would have done no better by investing in USCIP&F in 1902 than in the basket of industrial stocks. Other indications of the firm's financial health are consistent with this picture. In 1915, for example, its bonds had Aa ratings and its preferred and common stock were rated Caa and D. See Moody's Industrials (1915, p. 1,297), Gibson's Manual (1909, p. 333) and the Manual of Statistics (1915, p. 835). Certainly

Figure 3.5

COMMON STOCK OF USCIP&F AND INDEX OF INDUSTRIAL STOCKS



Source: National Industrial Conference Board (1929), p. 62, and U.S. Historical Statistics, Colonial Times to 1970, Series X496, p. 1004, and Series N162, p. 640.

the merger seems not to have resulted in a successful long-term monopoly, if that indeed was its aim. The extraordinary record of entry and geographical movement would have made long-term monopoly unlikely; already by 1902 circumstances in the industry had changed considerably.

But suppose there was monopoly in 1902. It would be hard to tease evidence of it from the data we have. The value of the stock in 1902 should incorporate any expected monopoly gain. Deviations of the price of the stock from the market average could be due to the quality of management of a competitive enterprise, luck, or to whether the firm happened to reap a large or small part of any expected monopoly gains. The value of the firm did rise relative to the industrial stock index during the period of 1904-1906. As it happens, four new plants, three of them in Alabama, were constructed in 1905, suggesting that rents to industry capacity during a business boom and not monopoly determined changes in the value of USCIP&F stock. New competitors would mean declining, not rising, monopoly returns. This explanation gains support from the data on new urban housing, which is also included in Figure 3.5. Notice the remarkable burst in this series in 1904 and 1905. This measure provides a good indication of the state of economy-wide investment in urban housingrelated capital, and what is more, probably gives us a good idea of the demand for water pipe during this period. Once demand reached its new higher level, entry or a revision of expectations could easily have caused the drop in value. For the years 1898 to 1902 we have only to look at the gross margin figures to see that the situation was even worse than in the years 1902 to 1910, when USCIP&F's stock price only stayed even with the market average. These figures then, as stock prices often do, say little on the question of monopoly or competition, but do reveal the industry's sensitivity to demand conditions.

This sensitivity showed itself most strongly in the months October through March during the years 1902 to 1908. Table 3.12 summarizes the evidence on yearly highs and lows for common and preferred stock, and indicates that fully twelve out of twenty-eight highs or lows (twenty-six if we neglect the lows at the stocks' introduction to the exchange) occurred in the months of December and January. Why was this? These were the months during which cities made their plans for expansion in the coming year, and as commitments were made the value of the stock price changed to reflect this news, i.e. movements were most likely during these months. Note that one alternative explanation cannot be supported by the data. It might be argued that a rising price level over this period or other trend-related factors caused the stock price to peak systematically at the end of the year and bottom out at the beginning. It happens, however, that the first and last three months each have roughly as many highs as lows. Might it be possible that this regularity will show itself in other similar data?

While we can satisfy our curiosity about prices, the behavior of stock values and industry entry and structure, any regularities there are not consequential for our hypothesis, which addresses itself to a more fundamental question. Over the long term, looking at good times and bad, this industry doesn't seem to have offered extraordinary profitability. It is true that there is a record of collusion, not only among the southern firms, but also in the East. After the consolidations of 1898 and 1899 this industry appears also to have been one of the many that adopted a basing point system, with Birmingham and the Delaware River foundries serving as the two basing points. How do we reconcile the evidence of easy entry and substantial turnover of firms with the evidence of collusion? Our explanation is that the two strands of evidence are not incompatible under plausible cost conditions. Even if we

Table 3.12

FREQUENCY OF YEARLY HIGHS AND LOWS OF COMMON AND PREFERRED

STOCK BY MONTH, USCIP&F, 1902-1908

	Preferred		Common		Total Yearly Highs and Lows
Month	Highs	Lows	Highs	Lows	
January	2	2	2	1	7
February	1				1
March		1	1	1	3
April	1				1
May a/		1(0)		3(2)	4(2)
June					0
July					0
August	1				1
September	1			1	2
October		1	1	1	3
November		1			1
December	1	1	3		5

Source: Gibson's Manual (1909), p. 333.

a/ A bias is introduced for May because these shares were introduced to the stock exchange in May 1902 and had their yearly lows then. Corrected figures are in parentheses.

have collusion it will not necessarily be true that firms are primarily motivated in this collusion by the desire for classical monopoly gains.

3.4 Costs and the Purpose of Collusion

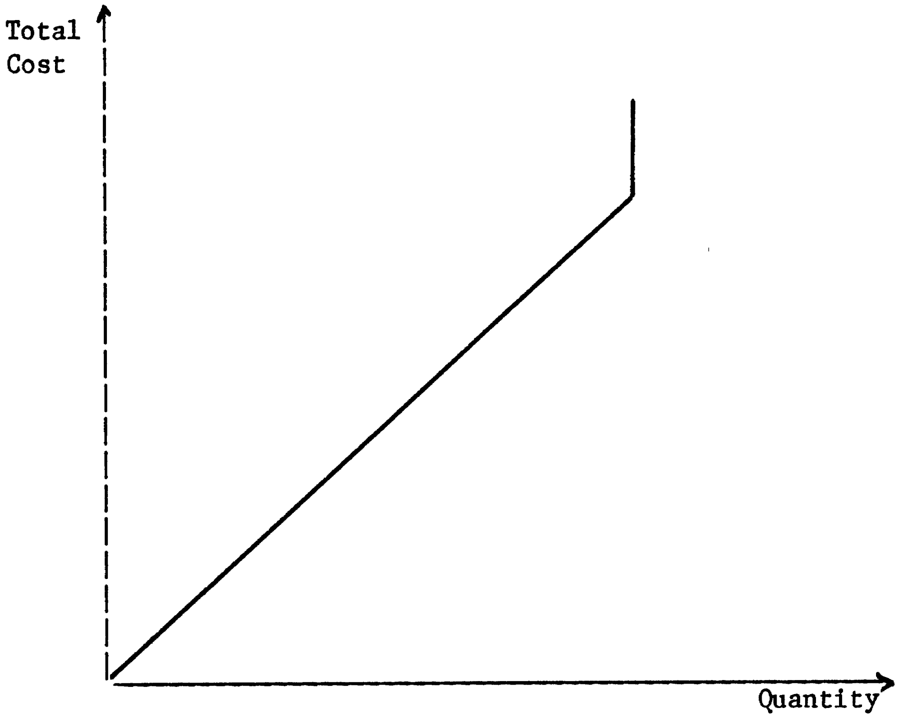
What Do the Numbers Show? The major empirical question, as we have tried to show, is the shape of the total cost curve. Figure 3.6 represents two stylized possibilities. The top graph represents a firm with constant marginal and average cost up to some capacity. If firms in an industry typically operate under these conditions, then the argument in this paper is hard to sustain.[6] In our example here marginal cost equals average cost up to some capacity constraint, and any level of demand can be satisfied by some collection of firms operating short of full capacity at no loss in efficiency. In fact, it would imply no loss of efficiency for each buyer to operate his own plant.

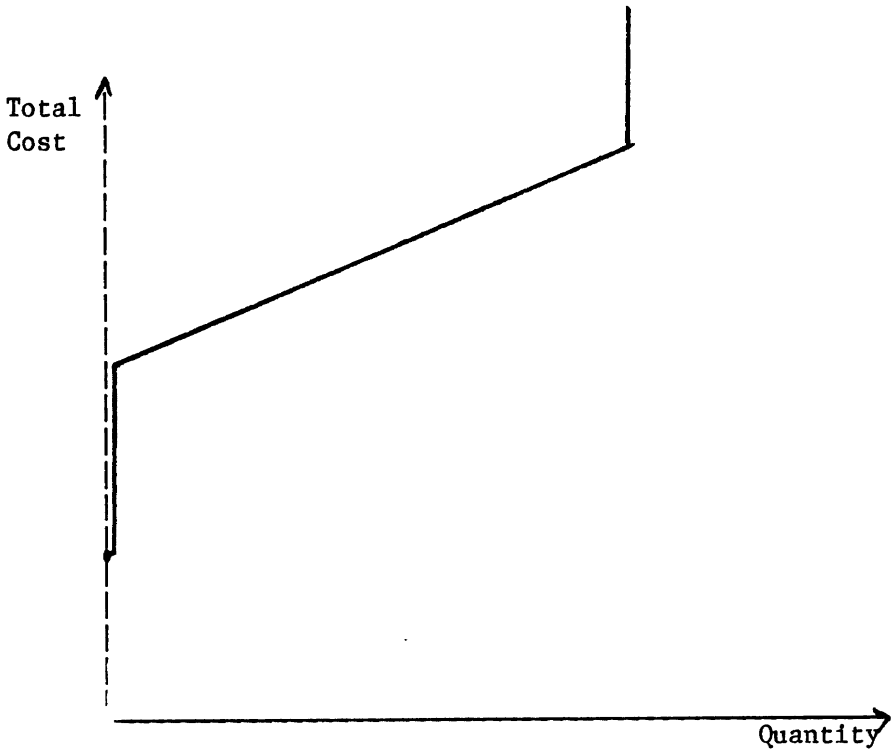
The lower graph represents the cost curve for a plant that implies an empty core for arbitrary rates of demand in an industry composed of such plants. This cost curve is such that there is some minimum average cost and that marginal cost lies below it up to that point. This exaggerated form of the general U-shaped cost curve has been chosen in part because the 1890 census data for the cast iron pipe industry and certain calculations derived from the court record do not permit a determination of much more than the size of capacity, the amount of costs at or near capacity, and the value of marginal cost over a restricted interval. In part also, however, this cost curve is chosen because there is evidence that the capacity constraint was sharp.

Although we are fortunate to have a special census study of the industry for the year 1890, the figures presented there are for a single point, and it requires some judgment to extract a cost curve. (Chapter 4 provides more

Figure 3.6

STYLIZED POSSIBILITIES FOR PLANT COST CURVES





detailed estimates based on monthly plant data. The results there are in close agreement with what our estimates here suggest.) Table 3.13 presents the costs of operation for 1890 broken down by various categories of cost. The year 1890 was a rather good one for the industry, the 1880s having seen the substantial expansion of U.S. water works capacity and the construction of many new pipe plants. This is reflected in the fact that total value of products, $15.2 million, exceeded total non-capital cost by about $1.3 million, and that this amount together with an assessed capital stock of $14.2 million implies a rate of return of 9.3 percent.

Further evidence for the view that 1890 was a good year for the industry comes from independent estimates of industry capacity. An article appearing in The Iron Age (December 22, 1892, p. 1,235) reported that industry capacity was "not very far from 600,000 gross tons per annum," or 672,000 net tons. Acccording to the 1890 census report, the firms in the industry, exclusive of non-specialized producers, used 573,226 tons of pig iron to produce 513,250 tons of pipe, plus some amount of "specials." The industry would seem to have been operating on average at least at 85 percent of capacity judging by these figures. In the spring and summer this figure was probably higher.

What were the fixed costs of operation? The average commerical paper rate for 1890 was 6.91 percent [Historical Statistics (1975), Series X445]. A reasonable lower bound on the fixed capital cost to the industry is therefore $979,820, the commerical paper rate times the industry capital stock. Other items such as rent, certain taxes and some amount of wages were also unavoidable in the event of a plant shutdown. Suppose these amount to 5 percent of wages and 10 percent of miscellaneous expenses. Our chief aim now will be to calculate the amount of avoidable fixed cost, cost that would be incurred at positive levels of output but that does not vary with output.

Table 3.13

STATISTICS ON THE CAST IRON PIPE INDUSTRY, 1890

Category of Cost	Amount	
Materials	$9,453,652	
Pig Iron		7,926,104
Fuel		652,495
Mill Supplies		65,751
All Other		809,302
Wages	3,792,557	
Officers and firm members		187,465
Clerks		94,546
Skilled		1,575,780
Unskilled		1,785,812
Pieceworkers		148,954
Miscellaneous Expenses	622,614	
Rent		12,365
Taxes		41,164
Insurance		32,017
Repairs to machinery		189,906
Interest on cash used in business		150,283
Sundries		196,879
Total Non-capital Costs	$13,868,823	

Other Statistics	Amount
Capital	$14,179,733
Value of Products	15,182,652
Value of pipe	13,091,209
Value of other castings	1,657,529
Tons of pig iron used	573,226
Tons of pipe produced	513,250

Source: U.S. Census Office, pp. 487-490.

One way to do this is to derive estimates of marginal cost, but where do we find them? There are two ready sources for the year 1896, six years following this census. It is necessary first, however, to summarize certain aspects of the agreement among the defendants in Addyston Pipe. On any order placed with the firms outside certain reserved cities but in pay territory (areas to the south of Virginia and west of Pennsylvannia), the price was fixed by a committee representing the six producers. The work went to the member who bid the most on it in an internal auction. The difference or "bonus" was placed in a fund that was divided among the six firms on the basis of plant capacity. Although the price to buyers was not the marginal cost, we can expect that in this bidding the net price to the firm would be driven down to marginal cost. The net price was not exactly equal to marginal cost since a firm could expect to get back one-sixth of the bonus if its capacity was one-sixth of the total cartel capacity, provided that the cumulative tonnage had not reached 220,000.

In passing it may be noted how nicely this system provides support for the hypothesis that firms could not cover all costs with marginal-cost pricing The problem of an empty core arises when certain costs are largely associated with a plant's capacity and not with its level of output. Both kinds of cost must be covered, but to do so we must prevent the formation of destabilizing coalitions. In more familiar terms a destabilizing coalition is the arrangement between a firm that cuts prices and its new customers. The reason it is destabilizing is that it takes revenue from other firms that makes it possible for those firms to cover overhead costs. The impulse of the firms that lose customers to respond in kind has the unfortunate result that eventually revenues will not cover all costs if the firms are operating over the range for which average costs decline.

The agreement had an efficiency enhancing aspect as well. Not only was price cutting prohibited, but it was prohibited in a way that allowed those firms wanting work the most an opportunity to get it. While a simple scheme of geographic division could have established substanially the same protection against cutthroat competition, it would also have led to inefficiencies since the demand across areas is not perfectly correlated. The system by which the cities awarded contracts, namely sealed bidding, also influenced the form of the agreement. Vickery (1961) has shown that a sealed bid auction is less likely to result in optimal allocations in a market than a standard auction. The cartel's procedure removed this source of inefficiency.

Table 3.14 presents calculations of the net price to southern firms for several large pipe contracts. This price represents delivered price less freight and bonus. It cannot be determined from the minutes of the meeting which shops filled these orders, but this is of no great importance. First, most of the orders were for buyers in Chicago or St. Louis, and the freight rates from the shops would not have differed by more than one or two dollars. Freight costs per mile decrease with distance. Second, the price of pig iron at Louisville and Cincinnati, where the two northernmost shops were located was governed by the price of pig iron prevailing in Birmingham, Alabama, the difference being the freight rate for pig iron between the two points. The southern shops did often fill orders to the north and west of Louisville and Cincinnati and the use of the Chattanooga freight rates probably introduces no sizable error even if the orders were filled by the two Ohio River plants. Using the average value, we have an estimate of the net gate price, our first measure of marginal cost, of $13.61 for February 1896.

We gain confidence in this estimate by looking at the calculations made by the Chattanooga firm on the net gate price it and the nearby South Pittsburgh plant received (Table 3.15). These were calculations of net price on orders going to free territory, areas in which the pricing agreement did not

Table 3.14

ESTIMATES OF NET PRICE TO THE SOUTHERN SHOPS,
VARIOUS DESTINATIONS, FEBRUARY 1896

Buyer	Delivered Price	Bonus	Amount (tons)	pipe dia.	Freight a/	Net Price
Chicago Gas Co.	$22.00	$5.00	7,000	6"-8"	$3.60	$13.40
Chicago Gas Co.	21.50	5.00	10,000	"larger"	3.60	12.90
Calumet Gas Co.	23.50	5.00	1,500	4"	3.60	14.90
Calumet Gas Co.	22.50	5.00		6"-8"	3.60	13.90
Calumet Gas Co.	21.50	5.00		"larger"	3.60	12.90
Louisville Water Co.	22.50*	6.50	NA	4"-8"	2.25	14.25
LaClede Gas (St. Louis)	25.00**	5.65	3,248	4"	3.25	16.10
LaClede Gas (St. Louis)	24.00**	5.65		6"-12"	3.25	15.10
LaClede Gas (St. Louis)	22.75**	5.65		16"-20"	3.25	13.80
St. Louis Water	24.00#	6.50	2,800	3"-12"	3.25	14.25
CRL&PRR (Chicago)	22.35	7.50	##	NA	3.60	11.25
CB&Q (Chicago)	22.35	7.50	##	NA	3.60	10.95
Indianapolis Water Co.	20.70	4.20	1,000	NA	3.25	13.25
					mean =	13.61

Source: Transcript of Record, p. 75. All figures are for February 1896 deliveries

a/ Freight rates for pig iron from Chattanooga, Iron Age, May 18, 1893, p. 1,130.

*Drayage of 35 cents included.
**Drayage of $1.00. This contract was taken by the Bessemer, Alabama shop.
#Drayage of 40 cents included.
##Indicates "year's" supply."

Table 3.15

CHATTANOOGA'S ESTIMATES OF NET PRICE AT SHOP
FOR ORDERS CHATTANOOGA AND SOUTH PITTSBURGH
SHOPS TOOK, MARCH-APRIL, 1896

Destination of order	Net Price at Shop
Peabody, Massachusetts	$13.75
Lockhaven, Pennsylvania	13.45
Clifton Springs, New York	12.57
Wytheville, Virginia	13.50
Troy, New York	14.00
Allegheny, Pennsylvania	13.25
Syracuse, New York	13.50
Malden, Massachusetts	14.40
	Mean = $13.55

Source: Transcript of Record, pp. 88-89.

apply and which were excluded from the bonus scheme. The average for these figures was $13.55, or six cents lower than our estimate of marginal cost for work in pay territory for orders taken one and two months earlier. Both of these estimates are for early 1896 and for substantial orders.

Armed with an estimate of the slope of the total cost curve, two things remain to be done. First, we have to correct the 1896 estimate of marginal cost for changes in the price of pig iron, this being by far the largest component and subject to fairly wide price fluctuations. We could use an index of a basket of various types of pig iron, called "composite" pig iron, which was widely followed in the industry. This dropped in price from $17.00 to $11.14 per ton from 1890 to 1896, a difference of $5.86 [Metal Statistics, 1915, p. 12]. By this measure we would have to increase the 1896 estimate of marginal cost by $5.86 to correct for the drop in pig iron prices, obtaining an estimate for 1890 of $19.41 as the marginal cost for some range of output. This is likely to be an inaccurate correction, however. Our estimates of marginal cost are for early 1896 when pig iron prices were higher than in the rest of the year. The correct comparison is for all of 1890, since the census is for that year, and the first three or four months of 1896. One continuous series of monthly data is available, that for Southern No. 2 Foundry pig iron at Cincinnati [Iron Age, March 30, 1912, p. 1,351]. The average price for 1890 was $15.11 (which is itself misleadingly high because of high January price -- the median price was $14.53), while the average for January to April of 1896 was $10.84. Judging by this series, we should only correct for a price change of $4.27, and so obtain a marginal cost in terms of 1890 prices equal to $17.82. A correction for movements in other prices will not be attempted. As the census figures show, wages were probably the other major variable cost. It's difficult to tell what happened to manufacturing wages over this period;

different sources indicate either a slight rise or a slight fall in manufacturing wages. Average hourly earnings in foundry and machine shops fell slightly from 10.10¢ to 10.03¢ between 1890 and 1896 [Historical Statistics (1975), Series D874].

The second question is, to what range of output does this estimate of marginal cost apply? Firms rarely operated below 50 percent of capacity -- so the question can be restricted somewhat. As a preliminary step, we may ask whether marginal cost pricing would have covered costs. To do so, we have to make certain assumptions about how the costs of non-pipe production were allocated. There was about $2.1 million worth of non-pipe output, of which $1.7 million was composed of cast iron specials. Their higher cost per ton was due to the extra labor required. It seems safe then to subtract the total value of items not made of cast iron pipe ($433,914) and the value of specials above and beyond what the same amount of iron would have been worth as pipe [$1,657,529 - (573,226 - 513,250) X ($13,091,209/513,250) = $1,657,529 - $1,529,778 = $127,751] from total non-capital cost to arrive at a measure of what fraction of these costs were attributable to pipe and to "specials considered as pipe." This amount is $13,307,158.

Could marginal-cost pricing have covered these costs? Since $17.82 times 573,226 equals only $10,214,887, we see that total receipts would fall short of total non-capital costs. Thus, even under conservative assumptions regarding the fraction of costs attributable to pipe production, marginal-cost pricing would not have covered out-of-pocket expenses. Even at the upward biased estimate of $19.41, receipts would have amounted to only about $11 million, still short of $13 million. In fact, the average non-capital cost was about $23.21 per ton, and the average total cost in excess of $26 per ton. Obviously these two measures of average cost both turn out to be greater than what we believe marginal cost to have been for some range. The cost curve must therefore have had the familiar reverse-S shape, and the one that gives us an empty core.

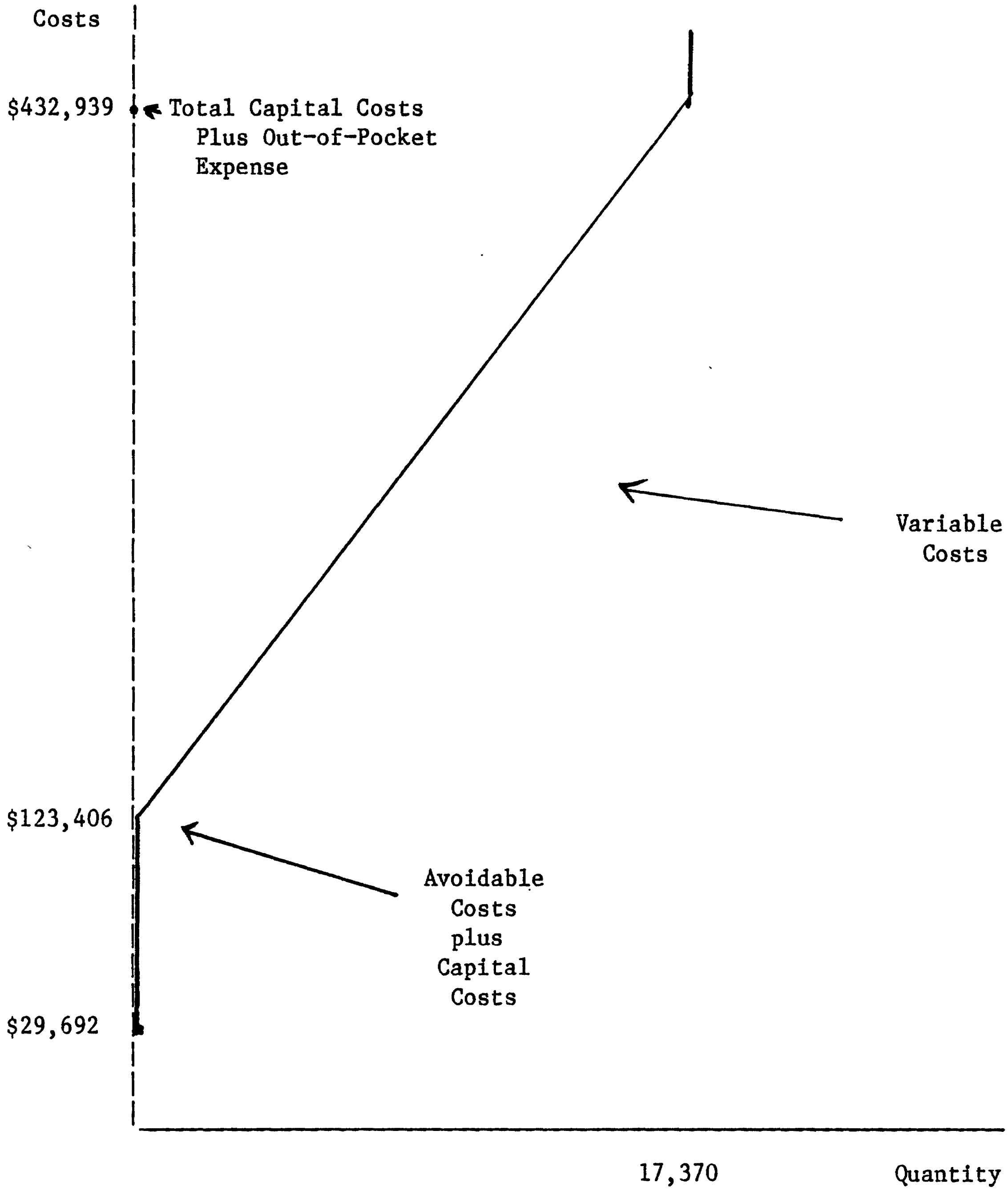
The suggested interpretation is presented in Figure 3.7. The census data have been divided by 33, the number of plants in operation in 1890, to arrive at the figures for a "typical" plant. Since average output per plant was about 17,370 and marginal cost is estimated to have been $17.82 on this amount, total variable cost is $309,533 per plant. The key question is where shall the "wedge" of variable cost be put? Using the average commercial paper rate of 6.91 percent, capital costs were $29,692 per plant. We also have average out-of-pocket expenses attributable to pipe and "specials considered as pipe "of $403,247. Since this includes different kinds of costs that we wouldn't expect to vary with output, it seems reasonable that these were what we call "avoidable costs." We have also already established that the plants were operating at 85 percent of "capacity" -- a point we would expect to be <u>below</u> minimum average cost. If we make the amount of avoidable cost very small, it should be noted, we are saying in effect that plants were operated very inefficiently, and that demand of 1890 was met on a makeshift basis.

If we assume that $432,939 represents total cost at the point of minimum average cost, we see that avoidable and fixed costs may have been as large as $123,406 per plant. How reasonable is this figure? If we divide total per plant output into this figure, we obtain $7.10 per ton, an amount that is rather close to the typical bonus prevailing in the cartel run by the Associated Pipe Works.

Another way of answering this question is to find out how close to capacity plants were when the estimates of marginal costs apply, namely in early 1896. A representative of the Chattanooga works wrote the following on January 2, 1896.

Figure 3.7

ESTIMATE OF TYPICAL PLANT COST CURVE, 1890



Source: Calculations in text.

> We find there was sold and shipped into pay territory from January 1, 1895, to date, including the 40,000 tons of old business that did not pay a bonus, about 188,000 tons, and we think a very conservative estimate of shipments into this territory will amount to fully 200,000 this year, more than that, probably overrun 240,000 tons from the fact that Chicago and several other places that annually use large quantities of pipe were not in the market last year, or last season, from the fact that they were out of funds. On the basis given above, if demand should reach 220,000 tons, which would give us our entire 40,000 tons [share of the bonus], provided we did no business, then the association would pay us the average "bonus" which might be from $3.50 to $5.00 on our 40,000. If we cannot secure business in "pay territory" at paying prices, we will be able to dispose of our output in "free territory," and of course make some profit on that. [Transcript of Record, p. 94]

What this means in terms of the proposed explanation is quite clear. First, 1896 was expected to be a relatively good year with firms operating not too far below full capacity. As we saw earlier, U.S. capacity was roughly 600,000 tons per year in the early 1890s. A predicted 220,000 tons in pay territory to be provided by the defendants represents 37 percent of that total. This amount excludes work that six took outside pay territory. At least Chattanooga and perhaps others as well expected to take a good portion of their work in free territory and in work destined for Latin America. Since the six had at most 57 percent of U.S. capacity according to daily melting capacity figures (Table 3.5), we see that even in 1896, firms expected to operate substantially above 65 percent of full capacity, how much more depending on how much "outside" work they took. Our estimate of marginal cost, unless expectations were revised considerably between January and March, applies therefore to that range of output. Second, even at such fairly high rates of capacity utilization, the Chattanooga works thought that the net prices at which firms were taking work, which we take as estimates of marginal costs, were so low that it was more profitable to take work outside pay territory and simply collect its share of the bonus.

How were the figures on cost interpreted by the courts? The prosecutors asserted that "[i]t appears quite clearly from the prices at which Chattanooga and the South Pittsburg Companies offered pipe in free territory that any price which would net them from $13 to $15 a ton at their foundries would give them a profit." [U.S. v. Addyston Pipe, 85 Fed., p. 277] Taft accepted this argument, although he denied that the reasonableness of a cartel price was something the courts should consider, [U.S. v. Addyston, 85 Fed., p. 293] Yet as we saw, $13 to $15 might have been sufficient to cover the variable costs of a plant operating short of full capacity, but not nearly enough to cover the full costs of production.

Some Qualitative Evidence on Costs. The trade reports of this period can also provide some information about the nature of plant costs. First, it was clear that plants could be shut down and often were. For example, during the first week of July of 1895, perhaps as a result of the July 4th holiday, the Howard-Harrison Pipe Works at Bessemer were shut down for a week and then reopened [Iron Age, July 9, 1895, p. 78]. Similarly, this firm closed down before the election of 1896. The candidates were William Jennings Bryan and William McKinley, and there was a slackening of economic activity generally before the election, attributed in some quarters to an excess of free silver speeches. But once the election was decided in McKinley's favor, and business picked up. "At Bessemer the Howard-Harrison Pipe Works lighted the fires for resumption of business as soon as the election was announced, with prospects of immediate business." [Iron Age, November 12, 1896, p. 923] These were, as these passages suggest, complete shutdowns; plants did not vary their output over the whole conceivable range between zero and "maximum" output, but closed rather than trundle along at one-quarter speed.

Additional insight concerning the nature of plant costs comes from the following remarks on the Bessemer plant.

> A visit to the Howard-Harrison Pipe Works, at Bessemer, disclosed the fact that they were steadily occupied and hustling for all the desirable contracts in sight. It takes a power of work to keep their machinery moving, and neither state lines nor the limits of country nor distance nor language bars them from getting contracts wherever Iron Pipe is needed. They have been lately doing a fine business with Mexico, which is reported as very satisfactory in every respect." [Iron Age, March 19, 1896, p. 714]

Passages such as these suggest high fixed avoidable costs. These fixed costs very likely arose from the nature of foundry operations. It is uneconomical to run drying ovens and cupolas at only a fraction of their designed capacities. At the same time, a substantial portion of their variable cost was quite variable indeed. Workers were laid off for only a few days before being called back [Iron Age, April 2, 1896, p. 826], although it is still possible that some economies are possible here from "running a full complement of men."

What consequence did these economies of operation have? Over a substantial range of output marginal-cost pricing will not cover all costs, not even all short-run costs necessarily. We presented evidence earlier, however, that indicates that prices could drop to this level temporarily. Other evidence on this subject is available from descriptions of conditions in the industry. In February of 1892, for example, prices reached a very low level.

> Excessive competition has reduced prices in this branch of trade until it is difficult to see how manufacturers are able to recoup themselves for the mere cost of materials they use and the labor they employ. [Iron Age, February 25, 1892, p. 353]

This article mentions a contract for Minneapolis in which 2,500 tons of pipe were priced at $22.47, delivered. Supposing that one of the southern works took it, this contract netted about $17.33 at the shop. This was still only a little more than one year after the census figures were collected, when we saw that average costs were considerably higher.

In a talk given by Peter D. Wanner in May of 1892 on the cast iron pipe trade, similar views appear.

> [O]wing to the great number of new pipe foundries constructed throughout the South and West [e.g., Ohio], and the increased capacity of the older ones, the demand fell short of supply. In other words, we have had overproduction, pure and simple... The present condition is full of anxiety and has brought about some very desperate movement, particularly on the part of Southern establishments. [Iron Age, May 19, 1892, p. 981]

As we saw, various attempts were made to consolidate the firms in the industry at this time, seven years before the merger of the six defendants in Addyston took place. In December of 1892, it was reported that

> ...the industry has been in an exceptionally depressed condition, prices having fallen to a very unremunerative level. The result has been that the Western works as one group and the Eastern pipe foundries as another have undertaken a consolidation of leading interests. [Iron Age, Dec. 22, 1892, p. 1,235].

Further evidence of the nature of cost curves can be found in the following description of the industry in early 1896.

> The Pipe trade exhibits the extraordinary condition of a heavy present and prospective tonnage coupled with prices which are unprecedentedly low in some instances.... With Pig Iron close to the low notch it will not be long before the most eager shops fill up and an end is put to this cutthroat selling. [Iron Age, Feb. 27, 1896, p. 547].

Cutthroat selling was apparently not ended, and in June it was reported that eastern shops were again trying to form a pool, at the same time that, as we now know, the southern shops were successfully operating one [Iron Age, June 4, 1896, p. 1,324]. The southern shops were making bids in the Northeast that left them with \$12.15 per gross ton (\$13.61 per net ton) at the shop. "Since it is generally estimated that the cost is somewhere between \$6 and \$6.50 over the cost of Pig Iron, some very cheap metal must be available to Southern melters."

By the next issue, however, it was realized that these bids did not allow the shops to cover full costs and that costs were being covered by other means.

> The only contract closed in this vicinity [New York] is one for 650 tons for Belmont, N.Y. at $19.90 per net ton. It was taken by a Southern shop. It has been noted lately that Western works are making low bids in Eastern territory. The Western works have an understanding in their own territory and are supposed to be eager to increase their tonnage from outside sources. [Iron Age, June 25, 1896]

The main points in these descriptions spanning the years 1892-1896 deserve a summary and translation to more familiar terms. The cast iron pipe industry was marked by a type of production in which a large portion of costs was not related to the level at which plants were operated. In addition, average cost rose quite sharply after the point of minimum average cost was reached. This is the implication of the observation above that plants were operating near full capacity, yet prices had not stiffened. Repeatedly also, there is mention that the full costs of production were not being covered.

The Puzzling Affidavits. An intriguing feature of the Transcript of Record for Addyston is that numerous buyers of pipe located in pay territory, fifty-seven in all, submitted affidavits on behalf of the defendants. These adhered, with some variation, to a standard formula:

> I am a citizen of Indiana, and the vice-president of the Indianapolis Water Company,...and as such it was my business, in the early part of 1896, to contract for and purchase a large quantity of cast-iron water pipe...
>
> Affiant further states that on account of his position as vice-president, he became familiar with the current prices of cast-iron pipe and knew the market value thereof; that the contract price with Addyston Pipe & Steel Company was reasonable and satisfactory to the Indianapolis Water Company, Company, and that there has been no objection raised thereto. [Transcript of Record, pp. 105-106]

Judge Taft in his circuit opinion hinted darkly that some conspiracy was at work to produce these affidavits. "A great many affidavits of purchasers of pipe in pay territory, all drawn by the same hand or from the same model, are produced, in which the affiants say that, in their opinion, the prices at which pipe has been sold by defendants have been reasonable." [U.S. v. Addyston, 85 Fed., p. 293, emphasis added] Certainly on the view that the agreement was monopolistic and extortionate the buyers were either naive or making deliberately false statements.

Now it might be proposed that these fifty-seven purchasers of pipe were threatened by the six defendants. Perhaps the defendants threatened that they would never send another shipment of pipe unless such a document was submitted to the court. But what would the consequences have been if testimony concerning such a threat had been presented? Suppose instead that the threat was subtle. Many of those who submitted statements were purchasing agents, city engineers, and others who would not have suffered any appreciable harm if they declined to perjure themselves. And finally, many affiants were located in states such as Ohio, Indiana and Illinois where substantial bonuses, as we saw, were paid, but in which buyers had alternative sources, plants located in Ohio, Michigan and Pennsylvania. See Table 3.16 for the distributed by state of those purchasers.

The most fascinating of these affidavits are the two submitted by employees of the city of Atlanta. Atlanta was where the price-fixing agreement was first called to the attention of federal prosecutors. Work in the city had been reserved by the cartel for the Anniston, Alabama works, and in February of 1896 they submitted a bid of $24.00 per ton of pipe. When an agent from a New Jersey firm submitted a lower bid, suspicion about a price-fixing ring was aroused, and the legal machinery set in motion. It is

Table 3.16

NUMBER OF PURCHASERS OF CAST IRON PIPE SUBMITTING AFFIDAVITS ON BEHALF OF THE DEFENDANTS, BY STATE

State	Number
Alabama	2
California	2
Florida	2
Georgia	6
Illinois	16
Indiana	6
Iowa	2
Kentucky	2
Louisiana	3
Minnesota	3
Missouri	2
Nebraska	1
Ohio	4
Pennsylvania	1
South Carolina	1
Texas	1
Tennessee	3
Total	57

Source: Transcript of Record, pp. 103-239.

puzzling then that the superintendent of the Atlanta works was among those who submitted an affidavit on behalf of the defendants. Referring to the year's supply of pipe that Anniston supplied the city, he said:

> ...the prices at which the said pipe was furnished were the lowest that could be obtained, and from my knowledge of the manufacture, capital required, and ordinary risks incident to manufacture, I consider said price fair, reasonable and moderate. I know in my official capacity of the charges made during the year 1896 against the Anniston Pipe & Foundry Co...pending an investigation of these charges the city withheld the payment of a balance of about $2,700.00, and that after making a thorough investigation, the entire balance due said company was, by resolution of the water board, paid in full, and that since that time the city has continued to purchase what pipe it has required for water-works purposes from said Anniston Pipe & Foundry, at same prices. [Transcript of Record, pp. 166-167]

The superintendent of the Atlanta waterworks also provided other information about the course of events after the high bids were submitted that led to prosecution by the government.

> ...the bids were deemed by the board too high and were all rejected. Subsequently, in April the board succeeded in making a contract for the year's supply with the Anniston Pipe & Foundry Co. for $22.75 per ton f.o.b. Atlanta. The company, however, filled some orders for $22.50 per ton upon the city's contention that such was the proper price under the conditions respecting these shipments...
> ...The Anniston Pipe & Foundry Company's dealings with the city in furnishing water pipe have been, in my judgment, uniformly fair. [Transcript of Record, p. 167]

A member of the city water board submitted an affidavit containing substantially the same description of the water board's investigation as well as the effort made by James McClure, an employee of the pipe works' cartel, to persuade the city to agree to turn over 25 percent of any funds recovered from the works in return for evidence he would provide. The water board rejected this course of action, and, as we saw, bought a good deal of pipe from the firm that year. "From the investigation made by me personally while acting as chairman of said [investigative] committee, and from my own knowledge respecting the cost of manufacture and incidents thereto, I consider...the prices paid... in all cases as honest, fair, reasonable and just." [Transcript of Record, p. 169]

It is perhaps best to take this and much similar testimony at face value and proceed with suspended disbelief. If we do so and return to the analysis of competition presented earlier, the affidavits appear less surprising. When an unrestrained competitive equilibrium is impossible, it is in the joint interests of all participants in the market to arrive at some other solution to the problem of who gets what.

By way of example, suppose in the absence of copyright laws I entered into an agreement with other publishers that none of us would print works that any of the others first presents to the public. Would it be odd if during the antitrust litigation that followed, owners of bookstores testified that this was a restraint on competition to which they did not object? Presumably I could present them with copies of Henry Kissinger's White House Years at less cost then the original publishers if I broke this agreement, but such a breach would not be in the interest of authors, publishers, book dealers, nor the public.

The analogy to cast iron pipe production is straightforward. The full cost of production has to be covered, and under entirely plausible cost and demand conditions, it is the case that marginal-cost pricing, which was what the court argued for and most economists believe to be the proper prescription, will not sustain the operation of the plants. Nor will it lead to plants being operated at the point of minimum average cost, which is what some group composed of plant owners and buyers believes to be in its best interest. In such a case other remedies are required. If some buyers of cast iron pipe paid more than marginal cost, which they did on any interpretation of these events, they may still have done so satisified that this too was the best of all possible worlds.

Chapter 4

Estimate of Plant Cost Functions

In the previous chapter we looked at the nature of short-run costs in the cast iron pipe industry using 1890 census data for the industry and records of prices. Descriptions of plant behavior in the face of fluctuating demand also proved useful in examining this issue. What we found was a) that the firms in this industry incurred certain costs during shutdowns of several months to a year, b) that they also incurred costs at positive rates of output but that these costs increased less than proportionately as output was increased, and c) that the capacity constraint that firms in this industry faced was probably rather sharp.

In this chapter we examine detailed accounting records for eleven plants in this industry. The data are on a monthly basis and span the period June 1905 to May 1906. Of particular importance for our purposes are the series covering output, sales, inventory, direct (labor and materials) and indirect (primarily repair and replacement) costs, and prices of output and pig iron. Our first task is an examination of these data for additional evidence on the nature of short-run costs. The main results are that sales fluctuated more than output, and that output was more closely linked with direct costs than with indirect costs. In fact, output sometimes varied inversely with indirect costs. The nature of indirect costs and the influence of input inventories on costs contribute to falling average costs, and falling average costs together with inventory expense explain the observed patterns of output and sales.

Our second task is to estimate the relationship between direct costs, mainly labor and fuel, and output. Our results support the view that economies existed even with respect to the use of these factors, that is, given percentage increases in output were associated with lower percentage increases in direct costs. The data do not support the hypothesis that firms typically operated over the range for which average variable costs rise. Since the period 1905-1906 was one of the best on record for this industry, we have the surprising result that these firms operated short of minimum total average cost even in a relatively good year. An implication of this finding is that marginal cost pricing could not have supported the operation of these plants.

4.1 Some Issues Concerning the Estimation of Costs

Cost figures at the plant level are somewhat hard to come by and this may explain why many empirical studies of cost functions have concentrated on public utilities. These studies have generally provided estimates that support the view that long-run average costs decline for all rates of output and that short-run average cost curves decline to capacity. Somewhat more surprising is the frequent result in studies of manufacturing costs that long-run average cost curves are L-shaped, and that short-run marginal costs are constant (sometimes even falling), at least over observed output ranges. A summary of these and other findings is provided in Walters (1963).

There are a number of reasons why these studies of manufacturing costs should be questioned, and such criticisms themselves form an extensive literature. The finding of constant marginal cost has been ascribed to a number of defects in data or procedure, including the corrections used for factor price changes, and depreciation techniques that are alleged to import a linear bias to the data. These results have also been criticized because they imply that output variations in an industry will be met by changes in the number of firms in operation, and not by changes in output at the typical firm. See Johnston

(1960) for a more detailed treatment of these and other related points. None will be important for our results here.

One issue is important for the procedure used here (and for most estimates of short-run costs), but has not been addressed by the literature in this area. This may be because there is no easy remedy. In particular, accounting statistics may not accurately reflect the costs of incremental output in each period. The incremental cost of output is not just the extra direct (labor and material) expense, or even the extra direct plus indirect expense that is statistically associated period-by-period with an increase in output. A correct notion of marginal cost should also include the extra expense that may only show up in future accounting periods, most likely as indirect expense, but perhaps as direct expense as well.

Take an extreme example. An industry faces seasonal demand and varies its output during the year. During the slowest period, however, it shuts down completely to undertake major maintenance and repair. As a matter of principle we can't object to a world in which expenses in each month of operation are directly related to output in that month, but in which the end-of-year maintenance expenses depend in a complicated way on the sheer passage of time, the total cumulated production for the previous year to that point, <u>and</u> how hard the plant and machinery were worked in any particular month. That is, high output in any month may result in higher marginal cost, but that extra cost is only reflected in greater deferred maintenance and repair. In more general models and in practice the situation will be complicated, but the nature of this particular difficulty is evident.

If we are willing to set aside such problems, the task of estimating short-run cost functions is still not trouble-free. First, we may find that there is not much variation in output rates at some plants. With little change in output we are not in a position to say what happens to costs as output changes. The second, related problem is that what change we do observe may come from random sources. In the extreme case, costs may be unaltered but we find that some stochastically determined amount of output is lost or broken. The general problem we face is one of errors in variables. If we ignore this problem we will tend to infer that fixed costs are greater than they in fact are. This was noted by Friedman (1955) in his comments on the estimation of long-run economies of scale. Cost data on a cross-section of firms will not produce reliable evidence on the nature of long-run costs, since those firms with low output will tend to be producing at an uncharacteristically low level, and those with high output at an uncharacteristically high level. If some costs are fixed despite such fluctuations in fortune, our estimates will imply long-run economies that are not there. Mundlak and Hoch (1965) and Zellner, Kmenta and Drèze (1966) were concerned with essentially the same topic, although they focused on such problems in the case of production functions.

A third problem we confront is that output may be less costly under certain demand conditions. For example, flush demand composed of large orders will, other things equal, lead to a lower cost of production for a given quantity than sporadic demand composed of small orders. Some of the higher cost may come from keeping workers in inventory, but some also comes from the understandable inefficiencies that come about with stop-and-go production. Part of the period covered by our figures was also characterized by peculiarly heavy demand for the small and medium sizes of pipe, according to trade reports. We cannot be sure, however, that this was constant over the year. Since smaller pipe was more expensive to produce, if the output mix is correlated with the volume of output, we could erroneously conclude that there were economies or diseconomies. During a typical season large diameter pipe was shipped disproportionately during the spring while winter work for inventory was composed of the small and medium size pipes. To the extent that changes in actual efficiency due to changes in the strength of demand are associated with economy-wide variables we will be able to correct for this. Similarly, if the mix of work between large and small pipe changed systematically with these aggregate statistics then our technique will also provide some adjustment for this source of variation in costs.

4.2 Types of Plant Cost and their Interpretation

The six firms which were defendants in Addyston merged in 1898 and by 1899 United States Cast Iron Pipe and Foundry was fully formed. The data which we can use to estimate the short-run cost functions of its plants cover the twelve month period beginning in June 1905. At this time USCIP&F had fourteen plants, of which three were permanently shut down. Two plants, located at Buffalo, New York and West Superior, Wisconsin, were operated during only some of the twelve months under consideration. The nine other operating plants were located in each of the industry's three major producing areas: the Delaware River Valley (where USCIP&F had one plant); Ohio, northern Kentucky and western Pennsylvania (five plants); and northern Alabama and southern Tennessee (three plants). By this time several new firms had established themselves in Ohio and in the South, particularly in Birmingham. The other firms in the industry all operated one or two plant establishments.

Overview. The data upon which this study of plant costs is based are monthly figures on sales, output, inventory, direct and indirect costs and eleven other series for each of the eleven operating plants owned by USCIP&F. These figures refer only to the production of cast iron pressure pipe and exclude the small amounts of related foundry items produced. Although the data cover what Iron Age (May 24, 1906, p. 1698) called the "banner year in inventories, stocks of skilled labor or stocks of hand tools that are "stored" in the workshop, for example, are already included in other measures of cost but not necessarily for the economically relevant period. Similarly, costs that result from holdings of physical inventory, such as handling and ordering, and the cost of storerooms, are also included in other categories. Probably the major inventory cost, however, is the interest expense, which does not appear elsewhere. While it is an interesting question why inventory costs are necessary--to what degree because of the fixed costs of ordering and delivery and to what degree to guard against supply interruptions--it will be convenient here to take them as given. A number of inventory models might be invoked. The simplest of these, the square root rule, for example, yields an economy of scale, as do other more sophisticated approaches. In general there is no reason to expect that incremental changes in current output or current sales will cause positive equiproportional changes in inventory costs, and the evidence indicates that no such association exists. In other words, inventories are a major source of fixed costs.

The chief significance of output inventories for the argument here is that they are also inconsistent with the assumption of constant costs in production. In cases where production takes place under increasing returns to scale, output inventories may be kept for consumption from one production run to the next. In cases where there is some minimum average cost of operation, even a steady stream of consumption may be most cheaply satisfied by operating the plant intermittently and storing output. (This is particularly true if a variety of products can be made at a plant.) In other cases the plant may be operated continuously, but in general, even if paths of consumption are precisely known in advance, some inventory holdings together with some changes in output will be part of a least-cost solution.

the Cast Iron Pipe business," there was still a substantial variation in output during this period. In particular, the total output of the firms dropped during the winter months, particularly for the smaller firms located in the North. This was no doubt due to the fact that water pipe cannot be put down in the North during that period. Variation in the total amount produced came through plant shutdowns and reductions in output at the small and medium-sized plants. The large plants, which tended to have lower average accounting costs, had lower proportional changes in output.

The plant costs of concern here are of four types. First, there was the cost of pig iron. We will find it convenient to ignore this category of cost because pig iron was used in constant proportion to output. The cost of iron per ton was roughly two-thirds of the total cost, at the factory gate, of output per ton. Second, there were the direct costs, largely labor and fuel. These also tended to vary in proportion to output, although there appears to have been some economy involved if the plant was operated at full capacity. Third, there were indirect costs, which included insurance, taxes, and certain salaries but which were mainly attributable to repair and replacement of equipment. Using month-by-month figures, we find that indirect costs were sometimes positively related to output, although not as strongly as direct costs, and in other cases negatively related. A negative association is plausible because periods of slower production are better suited for undertaking repair and replacement of equipment. In any event, a zero or negative correlation suggests that the costs associated with variations in any given month's output, wherever they may ultimately crop up, cannot in any large measure be found in that month's record of expenses.

The fourth type of cost is inventory cost, which is itself composed of the costs of maintaining output inventory and input inventory. Certain

A Typical Plant. Insofar as the relevant cost curves do not leap at us full blown from the accounting data, it will be useful to devote some attention to the figures in a more or less exploratory spirit. There are eleven plants for which we have figures. For the moment, however, our focus will be the one at Louisville, which may be thought of as the representative plant. It is of medium size, not located too far north or south, and exhibits an average degree of variability in its sales, output and other series. Ten monthly data series compiled from records of USCIP&F are presented in Table 4.1. If we focus on the first four columns, (sales, inventory, output, and iron used, all in tons) several patterns emerge. First, sales are not steady through the year, but dip severely in the winter months. It is important to emphasize that this figure represents the tonnage of pipe leaving the plant each month ("net sales at the works") and not the tonnage which the firm had promised that month to deliver.[1] The slack period from December to March resulted because cast iron pipe could not be installed in northern regions. The variability of output is less than for sales. It never reached the same low levels as sales, nor did it match the peak monthly sales figure. This is one type of evidence that would tend to support the view that these plants did not have constant average costs.

The next set of figures that are of immediate interest are the direct (labor and materials) and indirect (repair and replacement) costs. Although a glance at the figures will not reveal this, direct costs are more closely related to monthly output levels than indirect costs. The coefficient of correlation between output and direct costs is .860, and between output and indirect costs -.343. These are not, however, the only costs at the plant. There are inventory costs which were incurred for several thousand tons of output and pig iron, and in addition inventory costs on other materials such as coal, coke and machine parts, as well as a variety of other items.

Table 4.1

SELECTED STATISTICS FROM THE MONTHLY STATEMENT OF THE LOUISVILLE PLANT, 1905-1906

Month Ending	(1) Hub and Spigot Pipe Sold (Tons)	(2) Inventory (Tons)	(3) Yield (Tons)	(4) Direct Foundry Cost	(5) Indirect Foundry Cost	(6) Other Castings Produced (Tons)	(7) Inventory of Iron (Tons)	(8) Other Inventory
June 30, 1905	4,016	2,717	3,207	$16,693	$7,813	81	6,937	$14,400
July 31	3,191	2,490	2,964	15,306	6,289	42	5,460	15,710
Autust 31	4,270	2,168	3,968	20,293	6,131	75	5,002	15,474
September 30	3,422	2,237	3,477	17,943	4,977	118	3,584	13,389
October 31	3,588	2,667	4,018	20,720	5,930	78	3,201	12,091
November 30	4,203	1,893	3,429	19,601	6,892	152	4,329	13,132
December 31	3,167	1,616	2,890	16,810	7,961	99	4,239	12,565
January 31, 1906	2,337	1,842	2,563	16,265	5,184	75	4,919	13,484
February 28	1,254	3,920	3,332	19,485	5,695	74	5,121	15,407
March 31	2,808	4,839	3,727	22,111	5,517	95	5,110	14,748
April 30	3,901	4,591	3,653	20,763	5,081	88	5,702	16,117
May 31	4,309	4,179	3,897	21,891	5,050	88	6,391	15,775

SOURCE: Ledger of the United States Cast Iron Pipe & Foundry Company for 1905-1906.

Note: Columns (1) through (5) all refer to the figures for cast iron hub and spigot pipe.

<u>Costs in Detail</u>. Looking across plants, it will be useful to compare the components of direct and indirect cost. The figures for all eleven operating plants for the month of April 1906 expressed in terms of dollars per ton of output, are presented in Table 4.2. This table is a facsimile of one of the cost summaries that was prepared each month for the firm's managers. Direct expenses are in all cases dominated by labor and fuel costs, indirect expenses by tool repairs and replacement, and by repairs to machinery and equipment. Of all the categories of cost, only the cost of pig iron (not shown) and direct cost would immediately fall under the category of short-run variable costs. Even here, however, one can imagine a certain fixed element. Foremen and skilled workers are not always laid off in equal proportion to downturns in output. Similarly, furnaces will typically be designed to use fuel more efficiently when operated at a particular rate. Fuel costs per unit of output will be higher at low rates. If large variations are called for we may decide to shut the furnaces and drying ovens down more frequently or to close them for longer periods, although this can often be done only at the expense of incurring greater shut-down and start-up costs.

We have still less hope in the case of indirect costs that these will tend to vary largely with current output and not at all with plant capacity. Certain items such as property taxes, insurance, and repairs to buildings obviously do not depend strictly on current output. Outlays for machinery and equipment are expenses which cannot be attributed, for the most part, to the incremental production of a particular day or month. In fact, indirect costs vary inversely with current output for this and some other plants.

None of this is surprising given "the frequent conviction of entreprenuers that they are producing under conditions of diminishing average cost." [Hicks (1939), p. 82] The standard books on foundry accounting practice, presumably

Table 4.2

FACSIMILE OF MONTHLY COST ANALYSIS

COST OF MANUFACTURING PIPE during the month of Apr 1906 compiled from figures furnished by the various plants.

TONS OF PIPE CAST	6029	3779	3992	1828	5095	3263	3449	820	3653	4363	600
	Addyston	Anniston	Bessemer	Buffalo	Burlington	Chattanooga	Cleveland	Columbus	Louisville	Scottdale	West Superior
Labor	$3.25	$3.86	$3.73	$3.88	$3.14	$3.09	$3.11	$4.47	$3.39	$3.25	$3.70
Coal for Boilers	.20	.11	.12	.10	.28	.14	.08	.55	.32	.07	.72
Coal for Drying				.27	.40				.44		
Coke for Drying	.44	.79	.65		.05	.45	.78	.65	.04	.47	1.25
Coke for Melting	.61	.76	.54	.76	.58	.47	.69	1.17	.56	.41	.67
Limestone	.05	.03	.03	.03	.03	.04	.06	.07	.04	.02	.03
Wood	.01	.03	.01	.05	.03	.04	.02	.01	.01		.07
Hay	.19	.34	.33	.17	.12	.28	.14	.23	.20	.27	.26
Loam	.05			.19	.07	.04	.16		.14	.06	.03
Clay		.01	.04	.01	.02	.01	.02	.02	.03	.04	
Sand	.01	.01	.15	.19	.14	.09	.12	.24	.21	.14	.15
Facing and Blacking	.10	.14	.20	.18	.06	.12	.15	.17	.15	.08	.32
Tar	.01	.02	.11	.08	.03	.04	.05	.06	.03	.04	.19
Stores	.14	.34	.21	.23	.12	.20	.13	.29	.14	.22	.08
TOTAL DIRECT COST	5.06	6.54	6.12	6.14	5.07	5.01	5.46	7.94	5.68	5.07	7.47
Salaries not on Payroll	.08	.16	.19	.23	.20	.21	.13	.26	.27	.24	.14
Tool Repairs & Replacement	.61	.66	.03	.17	.34	.24	.33	.80	.30	.20	
Repairs to Mach. Equipment	.55	.59	1.15	.46	.56	.25	.31	.74	.60	.27	.75
Tools for Special Work											
Expense for Improvement		.05				.10	.06		.03	.06	2.36
Foundry Expense	.13	.20	.19	.54	.23	.08	.25	.12	.22	.14	
Insurance	.03	.04	.09	.07	.04	.05	.04	.07	.06	.03	.30
Taxes	.12	.03	.06	.06	.04	.08	.14	.12	.09	.05	
Accidents and Injuries	.02	.06		.02		.01	.01		.02	.01	.10
Repairs to Buildings	.02		.01	.05	.01	.04					.09
Other Items	.08					.04				.05	
Total Indirect Cost	$1.64	$1.65	$1.72	$1.60	$1.42	$1.02	$1.35	$2.20	$1.39	.95	$3.74
TOTAL FOUNDRY COST	$6.70	$8.19	$7.84	$7.74	$6.49	$6.23	$6.81	$10.14	$7.07	$6.02	$11.21

written by those in the best possible position to know what foundry costs look like, also insist that decreasing average cost is a fact of life.

> Labor costs, other than supervision, can be controlled very largely, as generally the working force is reduced either in numbers or in working hours as rapidly as there is no work for the men. There is, therefore, a fairly fixed relation of production to plant labor except that of supervision which cannot be readily reduced. Foundry materials and supplies also are closely related to tonnage, and variations in output do not ordinarily affect the unit of output cost.
>
> There are other expenses in a foundry, however, of equal importance, both in the plant and general office, which continue almost unchanged whether the plant is idle or in operation and which bear no relation to output. The common expenses of this nature are plant supervision, depreciation, taxes, insurance, heat, light, power, selling, and administrative expense, consisting of general office salaries and expenses. All expense of this character is to a large extent fixed and unchanged whether the output is, say, 30 percent of capacity or 90 percent of capacity. [Belt (1926), pp. 54-55]

Costs, Output and Capacity. Table 4.3 shows the locations, maximum monthly output, and some of the elements of production cost for each plant. Plant size as measured by maximum output varied by a factor of 10, from 776 tons for West Superior to 7,224 tons for Addyston. The smallest plant was clearly a high-cost, peak-load unit, as were the other two small northern plants at Columbus and Buffalo. Interestingly, their peak monthly output rates (1,433 and 2,157 tons) were roughly two and three times that of West Superior. The next group of plants falls in the range from 3,740 to 4,269. There are four of these. The four largest plants, Addyston, Bessemer, Burlington, and Scottdale, had capacities that fell roughly between 5,300 and 7,300 tons.

Probably the leading influence on plant location was the cost of pig iron. This varied from about $12 to $13 for the three firms located in the South to near $15 per ton for the firms located in Pennsylvania and northern Ohio. A large part of the output of the southern firms was exported to other areas, chiefly to industrialized parts of the Midwest and to western states, although

Table 4.3

PLANT LOCATION, MAXIMUM MONTHLY OUTPUT, AND COSTS PER TON OF PIPE
JUNE 1905-MAY 1906

Location	(1) Maximum Monthly Output of Pipe In Tons	(2) Direct Cost per Ton	(3) Indirect Cost per Ton	(4) (2) + (3)	(5) Cost of Iron	(6) Total Cost (4) + (5)
Addyston, Ohio	7,224	$4.597	$1.601	$ 6.198	$14.258	$20.456
Anniston, Alabama	4,269	5.920	1.586	7.506	11.826	19.342
Bessemer, Alabama	5,316	5.486	1.747	7.233	11.754	18.987
Buffalo, New York	2,157	6.755	2.496	9.251	14.820	24.071
Burlington, New Jersey	6,147	5.130	1.400	6.530	14.506	21.036
Chattanooga, Tenn.	3,740	5.364	1.055	6.419	12.037	18.456
Cleveland, Ohio	4,034	5.159	1.281	6.440	14.143	20.583
Columbus, Ohio	1,433	7.049	2.241	9.290	13.486	22.776
Louisville, Kentucky	4,018	5.541	1.763	7.304	14.091	21.395
Scottdale, Penn.	5,848	4.638	1.083	5.721	13.963	19.684
West Superior, Wisc.	776	7.146	5.332	12.478	14.589	27.067

SOURCE: Same as Table 4.1.

some went to the Northeast. The lower cost of pig iron contributed to the southern firms' tendency to export to other regions, especially since we see that they had no particular advantage in direct and indirect costs. The plant at West Superior, Wisconsin was probably operated despite its higher per unit production costs because when transportation costs are considered it could still supply the northern plains states and south central Canada at a lower price.

Table 4.3 also indicates that low capacity firms tended to have higher direct and indirect costs. This appears to imply long-run economies of scale, but we have to consider another possibility suggested by the figures in Table 4.4. First, we see that the firms with low capacities and high costs (Buffalo, Columbus and West Superior) also had the highest variability in sales and output. One consequence of U-shaped average cost curves is that variations in output will raise total cost per unit.

A second important finding in Table 4.4 is that in all cases but those two in which the plants shut down, the coefficient of variation for sales was higher than for output. Again, this indicates the existence of some optimum range of output that firms attempted to maintain. Furthermore, fluctuations in aggregate firm output were largely borne by the small northern plants. The larger northern firms (Addyston, Burlington and Scottdale) had very little output variation, but large inventory holdings. Note also that output has a coefficient of variation very similar to direct cost, although slightly smaller in most instances. (We would get this, for example, if direct cost is a linear transformation of output of the form $y = bX$, with $b > 0$.) Indirect cost, on the other hand, takes on more proportional variability than output, except again in the case of the two firms that shut down for part of this

Table 4.4

AVERAGE MONTHLY SALES, INVENTORY, OUTPUT AND COST

	Sales (Tons)		Inventory (Tons)		Yield (Tons)		Direct Cost		Indirect Cost		Mean Inventory Divided by Mean Sales
	Mean	Co. Var.	Mean	Co. Var.	Mean	Co. Var.	Mean	Co. Var.	Mean	Co. Var.	
Addyston	5854	.212	9911	.279	6356	.087	$29,222	.071	$10,173	.143	1.69
Anniston	3863	.205	2760	.335	3762	.098	22,272	.119	5,966	.381	0.71
Bessemer	4806	.129	2819	.463	4426	.107	24,279	.080	7,734	.230	0.59
Buffalo	729	1.129	1181	.527	511	1.522	3,449	1.409	1,275	.719	1.62
Burlington	5474	.304	6101	.242	5370	.112	27,550	.077	7,517	.134	1.11
Chattanooga	3663	.254	2573	.537	3240	.073	17,378	.062	3,417	.117	0.70
Cleveland	3309	.346	1926	.402	3241	.237	16,722	.186	4,151	.412	0.58
Columbus	1240	.427	2460	.170	1074	.228	7,570	.184	2,406	.288	1.98
Louisville	3372	.269	2930	.389	3427	.134	18,990	.122	6,043	.171	0.86
Scottdale	5425	.194	5577	.242	5059	.105	23,466	.045	5,478	.262	1.03
West Superior	322	.853	1057	.571	369	.991	1,923	.995	1,435	.409	3.28

SOURCE: Same as Table 4.1.

period, and for Chattanooga, where output was very nearly constant to begin with.

Finally, certain regularities in inventory holdings deserve comment. The four plants with the lowest percentage of inventory to sales are the three plants in the Deep South and the one at Louisville. They probably produced more to order, as we might expect in the case of firms whose customers are farther away. They also did not have to hold winter inventories because they could sell to the warmer parts of the U.S. or produce for export to Latin America. Other firms, notably those small ones with large output fluctuations, but also the three large northern producers held proportionately larger inventories. They suffered proportionately greater cutbacks in sales during the winter and were also better situated to fill small spot orders necessary to repair and extend the older northern water systems.

Fluctuations in output and sales are most strongly related in those cases where output underwent substantial changes (Buffalo, Cleveland and Columbus) as shown in Table 4.5. When output is relatively constant, as for the larger firms (except Cleveland), we expect less of an association, and this was the case. Chattanooga, whose output fluctuated the least (recall that it also had the lowest costs), had a negative correlation in fact. These figures are at least consistent with what rational behavior in the presence of U-shaped average cost curves and positive inventory costs implies.

Our confidence in this view of things is reinforced when we look at the correlations between current output and the two types of cost. We find a strong positive relationship in all cases between output and direct cost. This relationship is somewhat attenuated in the case of the four plants with the least output fluctuation (Addyston, Anniston, Chattanooga, and Scottdale). The fact that we can obtain rather high correlations for the remaining plants

Table 4.5

THE RELATIONSHIP OF OUTPUT TO SALES
AND OUTPUT TO COSTS

Plant	Coefficients of Correlation		
	Output and Sales	Output and Direct Cost	Output and Indirect Cost
Addyston	.496	.428	.130
Anniston	.234	.718	-.258
Bessemer	.414	.841	.313
Buffalo	.774	.996	.835
Burlington	.540	.911	-.500
Chattanooga	-.107	.532	.575
Cleveland	.868	.942	-.664
Columbus	.625	.889	.806
Louisville	.233	.860	-.343
Scottdale	.170	.550	.188
West Superior	.351	.991	.589

SOURCE: Same as Table 4.1.

does suggest that the costs included in this category are part of what one normally thinks of as variable costs.

Indirect costs showed considerably less consistency. For the smaller plants where long and wide swings in output took place, an association between the level of output and indirect costs is evident (Buffalo and Columbus, for example). This suggests that for some sufficiently long span of time these costs can be varied, although they were in fact never brought to zero. (Even plants which were shut down the whole year had substantial indirect costs.) Surprisingly, the plant at West Superior, which was closed for the winter months, did not have as strong an association between output and indirect costs as the other two small northern plants. This may have been due to the shut-down and start-up costs that were incurred at low levels of production. Where there was steadier output, indirect costs showed no correlation, or even a negative correlation with output. The negative correlation is especially plausible for a plant running at full capacity most of the time, since repairs would be deferred to those periods when production was slack.

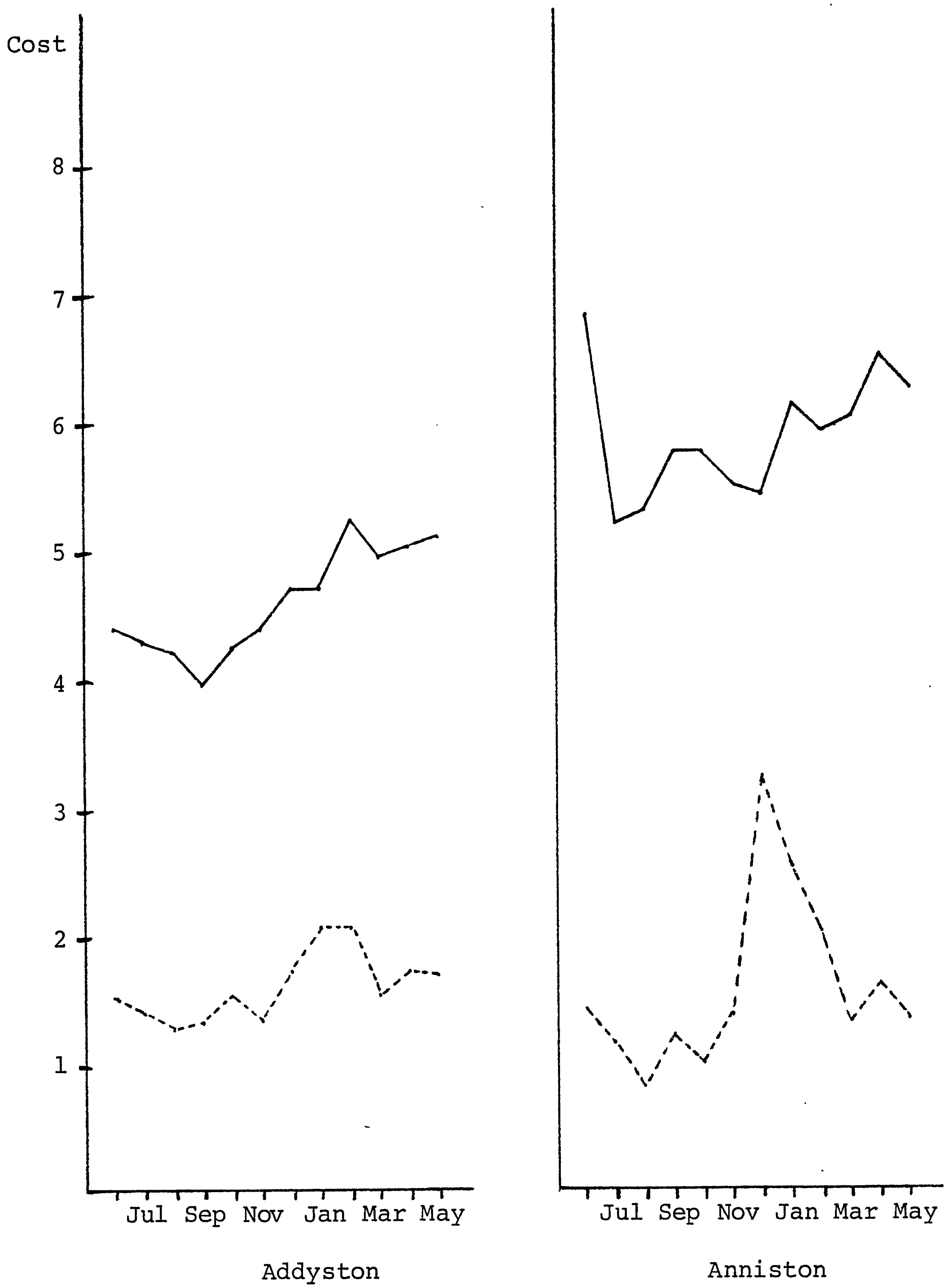
This interpretation of the pattern of indirect expenditures is also supported by the figures for monthly average cost plotted in Figure 4.1. The most striking feature of these diagrams is the tendency for average indirect cost to rise in the winter months. In several cases the absolute level of indirect costs and not just the average per ton of output crested at that point. Chattanooga and Columbus, the two small plants that were run at a fairly steady rate, are the only cases in which average indirect cost does not exhibit this seasonal pattern. Average direct costs are also higher in the winter months for some plants, but not in the same pronounced fashion. These figures also exhibit a trend for some plants. The major component of direct

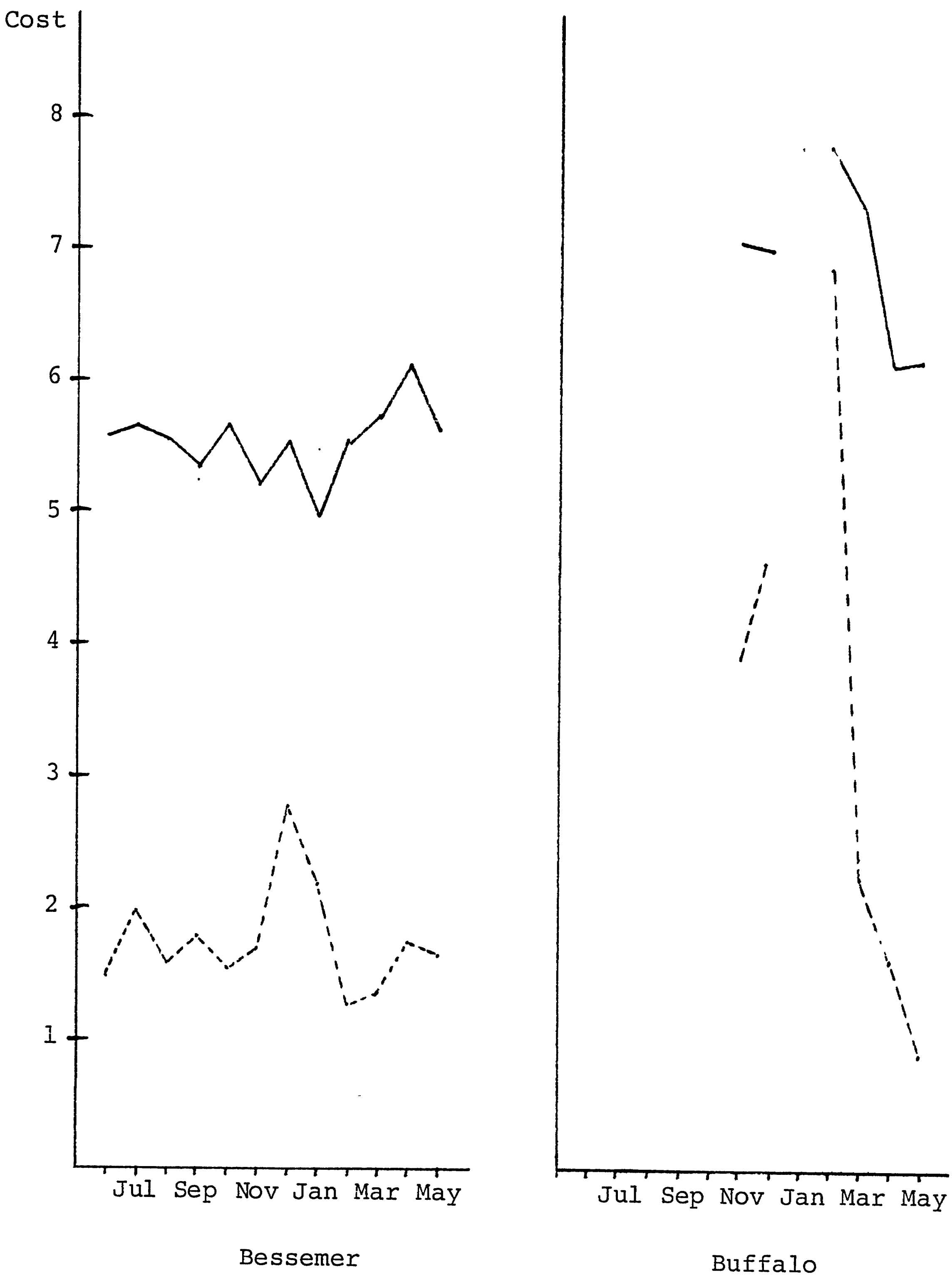
Figure 4.1

AVERAGE DIRECT AND INDIRECT COSTS,
ELEVEN OPERATING PLANTS OF USCIP&F,
JUNE 1905 TO MAY 1906

——— Average Direct Cost

----- Average Indirect Cost

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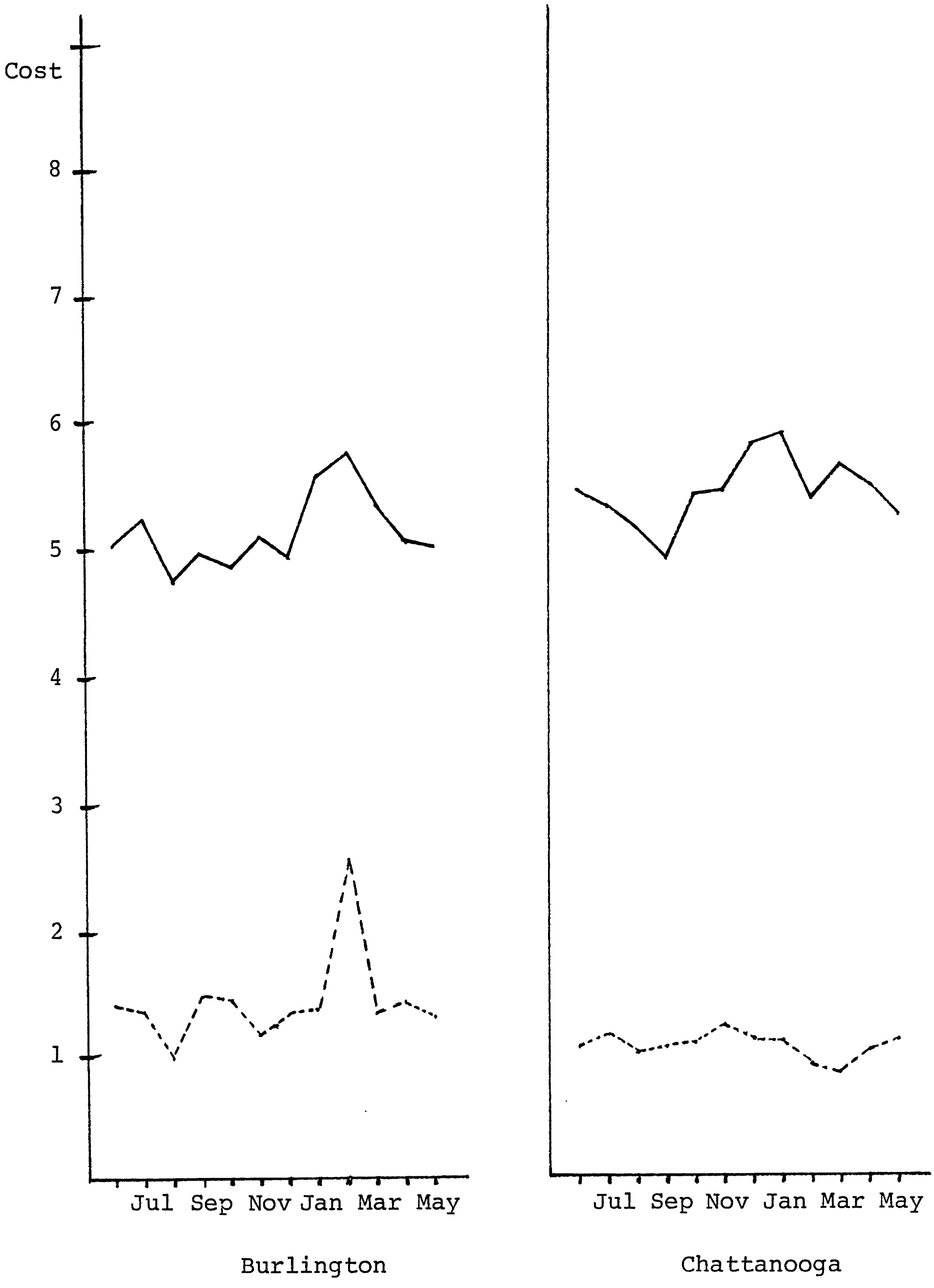
Bessemer
Jul Sep Nov Jan Mar May
Buffalo


Cost
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Burlington
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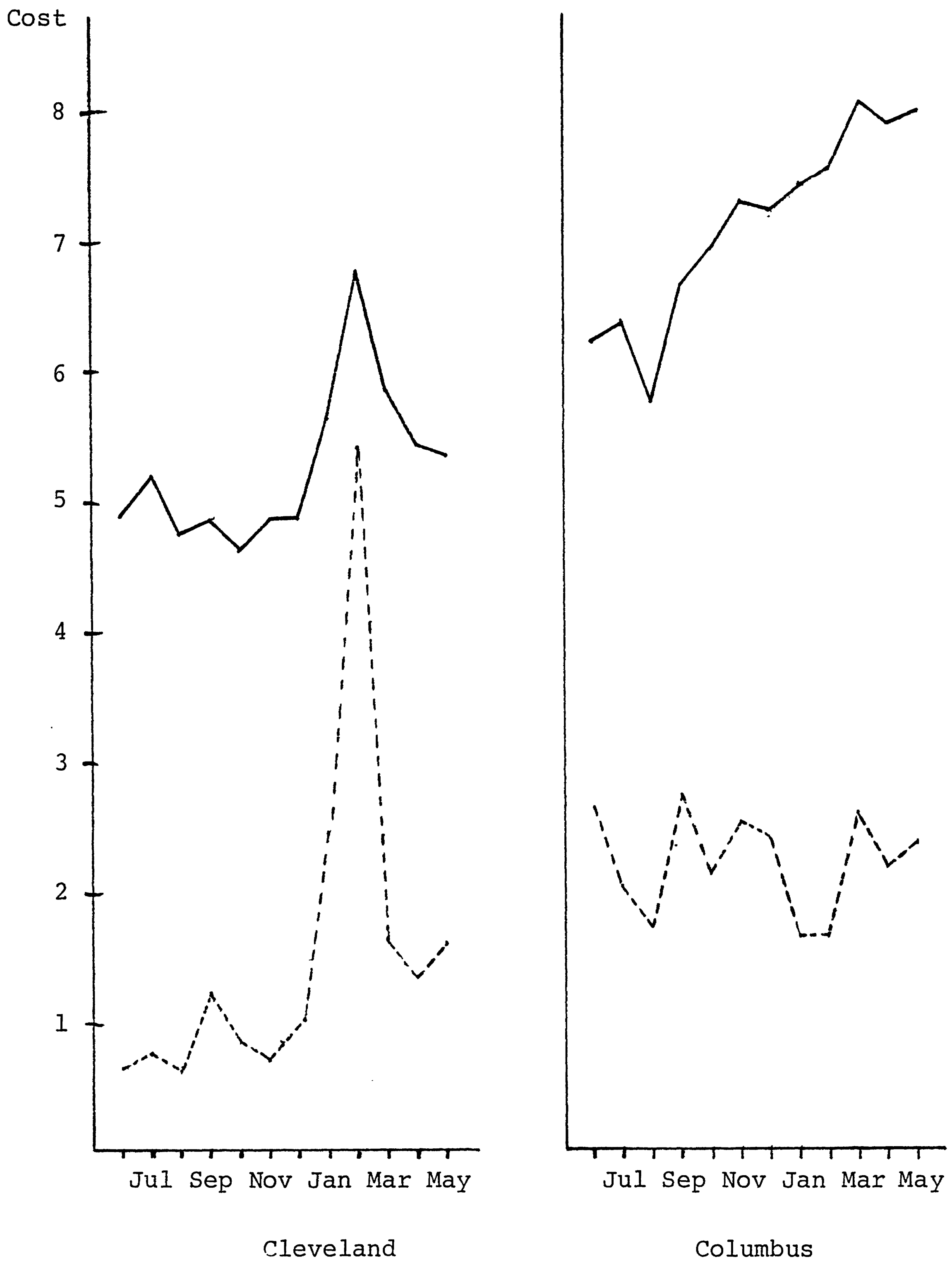
Chattanooga


Cost
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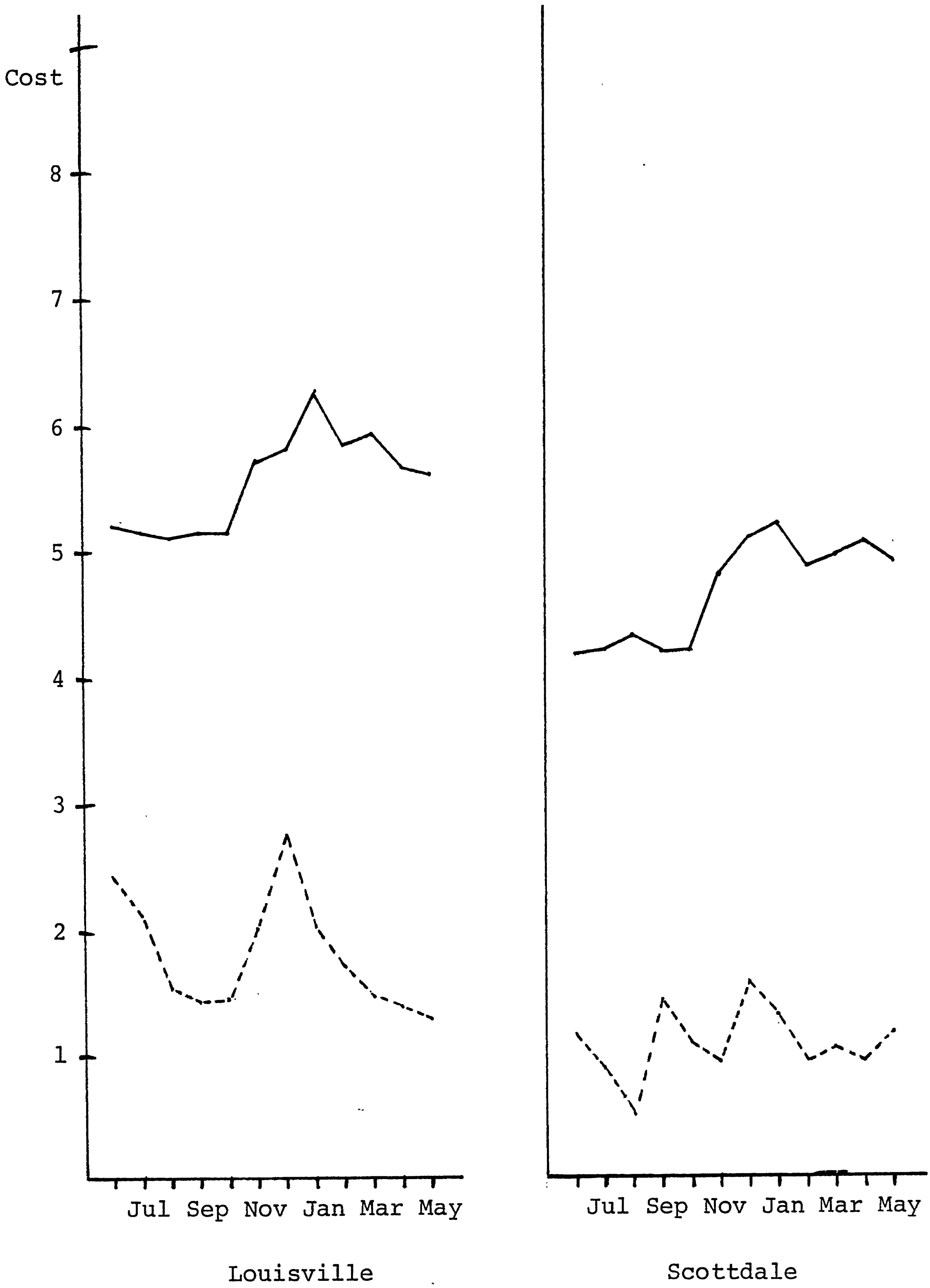
Cleveland
Jul Sep Nov Jan Mar May
Columbus


Cost
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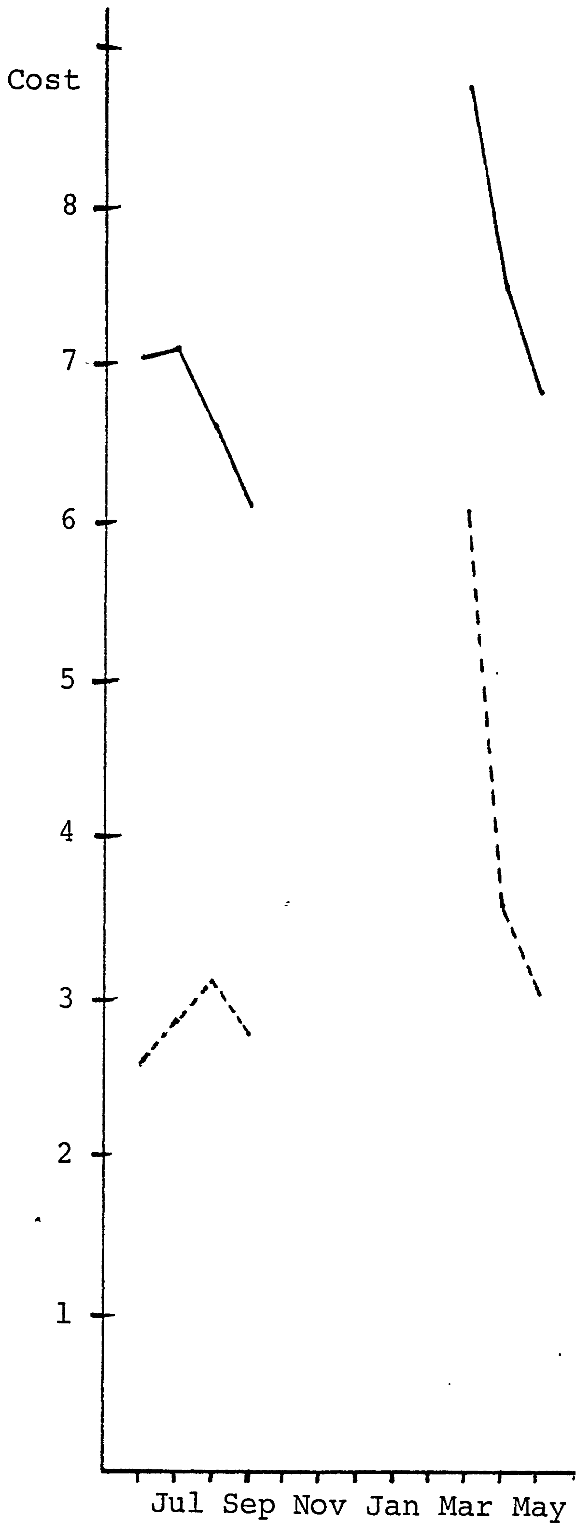
Louisville
Jul Sep Nov Jan Mar May
Scottdale



West Superior

cost was wages, and these did rise over this period. Regional differences in their rate of growth are a possible explanation for these different trends.

How should we interpret the tendency for average costs to rise in the winter months? Although production decreased during this period, this evidence does not necessarily imply decreasing average costs. Plant output in the winter was composed to a considerable degree of pipe for inventory that was sold on the spot market and in small lots. This was also smaller pipe and more expensive to produce per ton. Depending on their expectations, firms in this business also produced for inventory at other times if business was slack. It also happened at times that a sizable contract for only small or only large diameter pipe formed most of a plant's monthly output. These changes in the product, partly seasonal and partly not, probably explain a good deal of the variation in average costs over the year. In the econometric investigation of these costs we will attempt to provide a control for these sorts of influences on cost.

Finally, the curious pattern for Buffalo needs to be explained. West Superior was obviously shut down for the winter months. Buffalo, however, was shut down over the previous summer, then operated in November and December, shut down again in January, and started up a second time in February. How can this be explained in the middle of such an unusually good year? The other Great Lakes plant, Cleveland, was not shut down, nor was the plant in western Pennsylvania at Scottdale. In November of 1905 Iron Age reported the following item.

> An illustration of the high tide of activity now being realized in the pipe trade is presented in the case of a pipe manufacturer who some time since purchased a foundry that had long lain idle, for the purpose of wrecking it and selling the equipment, before doing so he found his own works becoming so crowded with orders that he decided to repair the old plant with a view to temporary operation and it is now running on full

time with several months' employment assured. [Iron Age, November 16, 1905, p. 1304]

Whether this was the Buffalo plant is uncertain, but this does offer a possible explanation for its start up in November of 1905.

Covering Costs. These plant figures will again allow us to answer certain questions raised in the court record. Recall that Judge Taft concluded that "the cost of producing pipe at Chattanooga, together with a reasonable profit, did not exceed $15 a ton. It could have been delivered at Atlanta at $17 to $18 a ton." [U.S. v. Addyston, 85 Fed., p. 293] His figures in turn appear to be based on the calculations by the Chattanooga foundry on which Table 3.15 is based, which we said was marginal cost. With foundry cost figures it becomes possible to assess Taft's claim in more detail. Phillips (1962), who did not have these figures, attempts such a calculation, but makes two mistakes. First, he uses the figures for Bessemer pig iron, an expensive high grade pig iron. Cast iron pipe was in fact cast from gray foundry iron, a softer and cheaper grade. Second, he uses the Pittsburgh figures, roughly $10 per short ton, and argues that the same price prevailed in the South. We find, however, that the same grade of pig iron was usually cheaper by one or two dollars per ton at southern points. Our figures in Table 4.3, for example, indicate that in 1905-1906 pig iron was over $2 per ton cheaper in Alabama than in Pennsylvania or Ohio. This difference existed ten years earlier, as examination of The Iron Age for those years shows.

Whan then were the actual figures? We find the following prices for soft gray forge in Birmingham, Alabama:

$9.75, Iron Age, January 2, 1896.
$8.00, Iron Age, February 6, 1896.
$7.50, Iron Age, March 5, 1896.
$6.50-$6.75, Iron Age, April 2, 1896.

This suggests that $8.00 is a reasonable price for this type of iron at Birmingham and nearby plants for early 1896. From Table 4.3 we know that direct (labor and fuel) cost in 1905-1906 at Chattanooga, which was the low cost plant, was $5.36, while indirect cost was 1.05. (Compare these figures to those presented from the 1890 census report in Chapter 3, Table 3.2.) Without any correction for changes in wages and the price of fuel, a tricky exercise at best, the cost of iron plus direct and indirect expenses in 1896 amounts to $14.41. This leaves 59 cents to cover inventory costs, capital costs (including major improvements), and central office expense, if as Taft contends $15 would have been enough to cover all costs. In 1905-1906 this would have implied an amount equal to $22,939 (59 cents times the yearly tonnage) to cover all these expenses for the Chattanooga plant. General expenses alone in that year amounted to $282,184 for USCIP&F (Table 4.6). Assets and inventories of the active plants as of May 31, 1906 were valued at $26,029,238 (using historical costs), and at an interest rate of 6.25 percent prevailing then, this implies capital and inventory expense of $1,626,827. Although the Chattanooga plant had only about 8 percent of total firm capacity, even 8 percent of general, capital and inventory expense is $152,721, very much in excess of the $26,479 that 59 cents per ton provides. In fact something like $3.92 per ton would have been required to cover these expenses.

A correction for changes in factor prices is possible, of course. The average manufacturing wage rose from 14.3 cents per hour in 1896 to 17.6 cents per hour in 1906. The wholesale price index rose from 46.5 to 61.8 over the same period. Using these increases to deflate our 1906 figures for direct and indirect cost, the cost per ton in 1896 for iron, plus direct and indirect expense, would have totalled $13.15. We see that even after correction for factor price changes, fifteen dollars would not have covered all expenses, including capital, inventory and selling costs.

The Components of General Expense. Aside from the considerable costs associated with the operation of the fourteen plants under its control, United States Cast Iron Pipe and Foundry also incurred expenses that cannot be allocated to the operation of a particular plant. For example, the firm operated nine sales offices, three of which were located at its plants in Chattanooga, Scottdale and Buffalo, and the others in Philadelphia, New York, Chicago, St. Louis, Texas (city unspecified), and San Francisco. The general expenses for June 1905 through May 1906, which include the cost of running these offices, are presented in Table 4.6, and we can see that this category of cost also includes some fraction of the firm's capital costs (interest on bonds), as well as a variety of costs connected with sales and general management.

In principle it would be desirable to include these costs in our estimate of supply. The appropriate model of the firm might then be similar to the one used for multi-product establishments. This is not necessary, however, and we will largely ignore general expenses because they make our problem more difficult without adding much to our understanding of short-run supply. Our immediate aim is an estimate of costs at the plant level. We can justify this by noting that general expenses ran to only several tons of thousands of dollars each month while the total cost of operation was typically about $1 million. It is also possible to view the sales operation and even management as one distinct enterprise and the manufacture as another, and to consider the firm we do see as the result of a set of contracts between these units. In other words, we need only to think of USCIP&F as a franchise operation.

In fact, when we think of management as a separate "plant," the figures for monthly aggregate sales, output, and general expenses can be used to re-

Table 4.6

GENERAL EXPENSES, JUNE 1905-MAY 1906

Interest on Am. P. & F. Co. Bonds	$ 90,000
General Office Expense	67,521
Sales Office Expense	93,131
Traffic Department	4,488
Legal Expense	8,054
Director's Expense	1,300
Traveling Expense	2,743
Miscellaneous Expense	31,656
Telegrams and Telephones	1,020
Postage	1,065
Commissions	12,307
Advertising and Subscriptions	3,496
Reserve to secure doubtful ac/s	12,000
Discount on anticipated payments	21,613
Interest and Discount	22,943
TOTAL	$282,184

SOURCE: Same as Table 4.1.

inforce the results we have for manufacturing costs. General expenses can again be classified into two categories in the short-run, those that can be varied and those that cannot. To illustrate, commissions and communications costs may be expected to vary with firm sales, although not necessarily with output. On the other hand, legal expense and general office expense reflect the long-run level of output at the firm.

Do sales expenses depend on the volume of sales? Table 4.7 provides some information on this point. It appears that expenses do depend on sales, in particular on next month's sales. The correlation coefficient for the two variables when matched in the same period is .101, but when sales office expense is lagged one period, this value becomes .533. While this does indicate that some portion of selling expense was a variable cost, we also see that during the lean winter months average selling expense rose, to be followed by the decline in spring. This rise could be considered a result of the one period lag imposed on the data, but it is a fact that orders for the new season were rarely taken before February. The rise in average selling costs for November, December and January very likely represents some fixed element such as office rents. The figures on "sales" are "net sales at the works" i.e., shipments and not commitments to supply. It is this that accounts for the lag since this month's shipments are related to last month's selling effort.

The Boom of 1905-1906. The twelve months from June 1905 to May 1906 were the best that the business had since the 1880s. We had evidence of this in the last chapter--in the high margins firms got on pipe, in the large increase in value of USCIP&F stock, and in the increase in the number of pipe plants constructed during this period. In June of 1905 it was reported that particularly small sizes of pipe were in high demand in the Northeast, and the next month there was a rumor of a new pipe plant to be built in Birmingham [Iron

Table 4.7

TOTAL MONTHLY SALES, OUTPUT AND GENERAL EXPENSES
FOR UNITED STATES CAST IRON PIPE AND FOUNDRY, 1905-1906

	Sales (Tons)	Output (Tons)	General Expenses	Sales Office Expense	Sales Office Expenses Divided by Next Month's Sales
June 1905	41,726	36,874	$29,175	$7,263	.188
July	38,606	34,200	16,896	8,645	.190
August	45,506	40,568	23,057	7,280	.186
September	39,133	37,800	23,795	8,286	.206
October	40,280	39,379	24,699	7,242	.176
November	41,215	37,707	22,771	7,434	.223
December	33,358	33,979	25,045	6,841	.254
January 1906	26,911	33,728	22,694	6,479	.251
February	25,822	31,123	24,452	7,965	.225
March	35,418	27,871	24,936	6,694	.152
April	43,942	36,871	20,648	7,180	.162
May	44,294	40,510	24,016	7,094	--

SOURCE: Same as Table 4.1.

Age, June 22, 1905 and July 13, 1905]. The demand, especially for moderate sizes used in extending water works systems, held up well over the summer [Iron Age, July 20, 1905, p. 175, and September 7, 1905, p. 635]. At the end of October the same situation prevailed. The following report is from New York.

> Pipe manufacturers report the demand surpassing anything previously known at this season. Usually at this time the foundries are at work on stock pipe, but this year the demand for prompt shipment has been so strong that it has been impossible so far to accumulate any stock. Small sizes are so scarce that a premium of $1 to $2 per ton can easily be obtained by those in a position to supply such a demand, most of the foundries being unable to promise deliveries on such sizes for 60 days or more. [Iron Age, October 26, 1905]

A similar situation existed in Chicago, where part of the unusual demand was attributed to the good weather so late in the fall. USCIP&F, it was reported, would not begin accumulating stock at any of its foundries until mid-December, at least several weeks later than usual [Iron Age, November 9, 1905, p. 1249]. By late November, which was unusually early, the foundries were reporting a heavy inquiry for spring deliveries [Iron Age, November 30, 1905, p. 1477]. By the end of January, 1906, the Iron Age's Birmingham correspondent was able to report that

> The Pipe industry was never in a more flourishing condition than at present. All the shops in the district are running at full capacity and are turning down orders almost daily. It is not so much a question of price as delivery just now, the foundries being booked for months ahead on certain sizes. [Iron Age, January 25, 1906]

One reason for the unusual activity at the southern plants was that freight rates were scheduled to increase by 25 cents per ton on March 1. "Inasmuch as all pipe is sold delivered the manufacturers have been making strenuous efforts to save additional freight by getting as much as possible in transit before March 1." [Iron Age, February 22, 1906, p. 700]

The favorable circumstances continued through March and April. In addition to the general business and building boom, the San Francisco earthquake increased demand for pipe yet further [Iron Age, April 26, 1906, p. 1424]. The newly constructed plant in Birmingham operated by the American Cast Iron Pipe Company reported by the end of May that it was "turning down orders on account of inability to make deliveries, its output having already been booked for several months" [Iron Age, May 31, 1906, p. 1774].

In summary, what we find is that the period covered by our numbers was one in which a remarkable expansion of plant capacity took place and in which existing foundries produced at unusually high rates. If it is true that plants do operate over the range for which average costs rise, we should be able to find evidence of it in this data.

4.3 Estimation of Short-Run Production Costs

The data we have for these plants, while remarkable in detail, is unfortunately limited to twelve observations. This will necessarily restrict our analysis to costs that are closely related to current output. Substantially longer series would be needed to investigate a model of inventory holdings or depreciation expense. Our attention will be focused on the relationship between current output and "direct costs," which will be interpreted as short-run variable costs. The results of the previous section suggest that the other types of cost are not systematically related to current output. This does leave the possibility, as indicated in Section 4.1, that these other current costs are directly related to incremental output in other periods, but without more data and in the absence of a model that might be of use here, it doesn't seem worthwhile to devote much attention to the problems this raises. Instead our focus will be on the relationship between current output and what accounting rules determine to be those costs directly attributable to that output. The econometric procedures used in this section should be thought of as an attempt to answer the question: How much more would it have cost to produce added output in a particular month, holding constant all other things, including rates of output in other months?

Several statistical problems need to be addressed. Textbook treatments of cost curves might lead us to look for a specification that could yield increasing then decreasing returns, that is, U-shaped average variable cost curves. A more restrictive formulation might be that our imbounded costs--inventory, capital and indirect expense--are the fixed and avoidable costs that contribute to decreasing returns, and that direct expenses are the variable costs that we expect to obey the law of diminishing returns over observed output ranges. This view would lead us to expect decreasing returns to labor inputs, with returns decreasing rapidly at capacity.

There is another reason for expecting a farily simple relationship between output and direct costs. Optimal capacity in an industry usually calls for some slack, so that firms will on average be operating to the left of minimum average cost. With a sharp capacity constraint and large enough variations in demand, this will also be to the left of minimum average variable cost. If both arguments apply, and it turns out that the data cover an inflection point, the residuals from an otherwise correctly specified regression should announce this fact. For simplicity, and until the data suggest something different, we will only consider the case of invariant returns, that is, a constant returns elasticity.

What model of firm behavior will we assume? It seems best to use a statistical model of production that deliberately sidesteps the question of market equilibrium. However, simple regressions of output on cost have a potential defect that imparts downward biases to the coefficient, especially if output does not vary much. This can be thought of as an errors-in-variables problem that arises because cost depends on some underlying quantity ("planned output") which our actual quantity measure reflects with some error. If this is our only problem, the "reverse-regression" of cost on output will yield an estimate that has an upward bias. On these assumptions we obtain an interval covering the best estimate of the true parameters. For our data this interval suggests increasing returns to those factors represented by "direct costs."

Another way of tackling the errors-in-variables problem is by means of instrumental variables. Although the results with this approach turn out to be encouraging for some plants in the sense that the estimates of cost elasticity move up, in other cases they move down. This suggests that our instrumental variables (levels of employment, railroad freight miles, etc.) may represent factors that have an independent and negative influence on costs. In particular they may be related to seasonal or cyclical factors that result in a change of output mix (small instead of large diameter pipe), or that otherwise affect costs. Under an alternative specification of the cost equation that includes both actual output and planned output (the latter a function of the instruments), we find that while increases in actual output are associated with increased costs, increases in <u>planned</u> output are associated with lower costs in five out of nine cases. This has the interpretation that an increase in output above what was planned has an independent and positive effect on costs. Yet even when this factor has been taken into account, a given percentage change in actual output is accompanied by a lower percentage change in direct costs. Thus we obtain with this method also the surprising result that over the observed output ranges average labor and fuel expense decreased with increases in output.

Ordinary Least Squares Estimates. Begin with the following cost function for plant i at time t

$$C_{it} = A_i Q_{it}^{\beta_i} e^{U_{it}} \qquad (4.3.1)$$

where

C_{it} = direct or variable cost of plant i

A_i = scaling constant

Q_{it} = quantity produced

U_{it} = error term with mean 0 which is normally distributed and serially independent

There are several objections to this formulation, the most prominent of which is that actual output may not represent what it is that "causes" direct costs. For example, a stochastically determined amount of output may not be included in our data because it is defective. In that case costs are really determined by planned output. To meet this objection we can rewrite our equation (4.3.1) as

$$C_{it} = A_i Q_{it}^{*\beta_i} e^{U_{it}}$$

and (4.3.2)

$$Q_{it} = Q_{it}^{*} e^{V_{it}}$$

where Q_{it}^* is planned output. The error term V_{it} has the same properties as U_{it}, and the two error terms are uncorrelated with each other and with planned output. To reduce the notational burden, express (4.3.2) in log form, without subscripts, and as deviations from mean values:

$$c = \beta q^* + u$$

$$q = q^* + v \qquad (4.3.2')$$

where $c = \log C_{it} - \frac{1}{T}\sum_{t=1}^{T} \log C_{it}$ and so on. Our other assumptions can be expressed as $E(uv) = E(q^*u) = E(q^*v) = 0$. Let $\underline{q}^*$ be the (nxl) vector composed of n observations of q^* and define $\sigma_{q^*q^*} = \frac{1}{n}\underline{q}^{*\prime}\underline{q}^*$ as $n\to\infty$, and so on. The least squares estimator $\sum cq/\sum q^2$ has the probability limit

$$\text{plim } \hat{\beta} = \frac{\beta(\sigma_{q^*q^*} + \sigma_{q^*v}) + \sigma_{q^*u} + \sigma_{uv}}{(\sigma_{q^*q^*} + 2\sigma_{q^*v} + \sigma_{vv})} \tag{4.3.3}$$

Under the assumptions proposed earlier this turns out to be

$$\text{plim } \hat{\beta} = \frac{\beta\ \sigma_{q^*q^*}}{\sigma_{q^*q^*} + \sigma_{vv}} \tag{4.3.3'}$$

so that least square estimates will have a downward bias. Note, however, that it is not at all unlikely that $\sigma_{uv} \neq 0$. For example, we can excpect that the very same influences that often lead to more output than planned will also contribute to increased production costs so that $\sigma_{uv} > 0$. A rush order might be an example of this. Such factors move plim $\hat{\beta}$ up. On the other hand, a change in the size of pipe would probably imply a negative relationship between u and v. With the appropriate techniques this can be accounted for.

Suppose for the moment that we want to be diligent in avoiding a downward bias. One approach is to run the "reverse regression" which also has a downward bias, but by virtue of that fact <u>over</u>-estimates the true value of β. Let c^* be true costs and allow for measurement error w. We then have

$$q = \frac{1}{\beta} c^* - \frac{1}{\beta} u + v \tag{4.3.4}$$

$$c = c^* + w$$

and the same assumptions as before. The transitory component determining observed quantity has simply been moved into the new error term $-\frac{1}{\beta} u + v$. Note that under the assumption that input prices are constant (i.e, c equals c^* plus a constant), which may be reasonable for a short period of time, the first equation amounts to a production function, which Zellner, Kmenta and Drèze (1966) have argued can be estimated consistently with ordinary least squares if certain conditions are satisfied. In particular it has to be true that inputs (here measured by costs) are committed to production before the error term is realized, or at least independently of it. With the more liberal assumption that changes in inputs are measured imperfectly, either because we use costs as our input variable and input prices vary or for some other reason, the bias on this production function will be negative, and our estimate of β too high. Note too that factors such as rush orders that influence the production function through the term v, giving a higher quantity for given planned costs, say, are positively related to the disturbance w. This will imply that the downward bias to the production function is partially counteracted here also. On the other hand, if $E(wv) < 0$, then the downward bias will be reinforced.[2]

The results from the normal and reverse regressions are presented in Tables 4.8 and 4.9. The coefficients on ln Q in the first table are low, particularly for those plants, like Chattanooga and Scottdale, that had small variations in output. This is consistent with the errors-in-variables explanation since large changes in quantity would most likely swamp the error term. (It is also consistent with omitted variable bias, as we shall see.) The Durbin-Watson d-statistic is intended here as in our other tables to be suggestive rather than definitive because of the small sample size. The upper and lower limits for three explanatory variables and fifteen observations are 0.95 and 1.54 (and 3.05 and 2.46 if we fear negative autocorrelation). Limits for smaller samples are not readily available.

Table 4.8

ORDINARY LEAST SQUARES ESTIMATES OF PLANT COST FUNCTIONS
LOG OF DIRECT COSTS REGRESSED ON LOG OF ACTUAL OUTPUT

Plant	Intercept	ln Q	Time	Durbin-Watson d-statistic	SSE	R-squared
Addyston	5.34	0.55	0.017	2.25	0.0081	.86
	(5.75)	(5.22)	(6.56)			
Anniston	3.47	0.79	0.010	1.60	0.0628	.61
	(1.56)	(2.88)	(1.36)			
Bessemer	5.02	0.60	0.0078	1.53	0.0115	.85
	(5.86)	(5.84)	(2.56)			
Burlington	4.82	0.63	0.005	2.72	0.0102	.87
	(6.28)	(7.10)	(0.15)			
Chattanooga	6.40	0.41	0.0028	1.75	0.0298	.32
	(3.05)	(1.58)	(0.53)			
Cleveland	3.69	0.74	0.011	0.85	0.0236	.95
	(8.20)	(13.52)	(2.39)			
Columbus	2.21	0.94	0.025	1.87	0.0161	.96
	(4.41)	(13.54)	(5.62)			
Louisville	4.07	0.70	0.016	2.33	0.0086	.95
	(7.40)	(10.27)	(6.08)			
Scottdale	5.95	0.48	0.0091	2.37	0.0099	.56
	(4.87)	(3.38)	(2.21)			

Parenthesis indicate t-statistics.

Table 4.9

REVERSE REGRESSION ESTIMATES OF PLANT COST FUNCTIONS
LOG OF ACTUAL OUTPUT REGRESSED ON LOG OF DIRECT COSTS

Plant	Intercept	ln DC	Time	Durbin-Watson d-statistic	SSE	R-squared	Implied $\hat{\beta}$
Addyston	-5.10 (-1.91)	1.36 (5.22)	-0.025 (-4.77)	1.58	0.0200	.77	0.74
Anniston	2.12 (1.01)	0.61 (2.88)	-0.0016 (-0.23)	1.96	0.0489	.53	1.64
Bessemer	-4.89 (-2.16)	1.32 (5.84)	-0.0090 (-1.75)	1.53	0.0255	.80	0.76
Burlington	-5.20 (-2.66)	1.35 (7.10)	-0.0027 (-0.61)	1.96	0.0218	.87	0.74
Chattanooga	2.92 (0.90)	0.53 (1.58)	0.0050 (0.85)	1.31	0.0379	.35	1.89
Cleveland	-4.38 (-4.69)	1.29 (13.52)	-0.015 (2.67)	0.89	0.0413	.96	0.78
Columbus	-1.90 (-2.83)	1.01 (13.54)	-0.027 (-7.22)	2.02	0.0174	.97	0.99
Louisville	-4.74 (-3.79)	1.32 (10.27)	-0.02 (-4.65)	1.87	0.0163	.92	0.76
Scottdale	-3.15 (-0.90)	1.17 (3.38)	-0.02 (-4.65)	1.08	0.0243	.80	0.85

Parenthesis indicate t-statistics.

The errors-in-variables story receives additional support from another piece of evidence. Plants with low coefficients also had low R-squares, indicating that we were running noise as our independent variable. Moreover, there were the same plants that had low reverse regression estimates, which we might expect since the scope for measurement error to influence the results is greater where output and cost variations are low. In all but two cases, however, the bounds on our interval imply increasing returns to direct costs.

Instrumental Variable Estimates. The method of instrumental variables provides an estimate of the coefficient on output that in principle can avoid the bias that results if actual output is correlated with the error term on the cost function. This covers both the problem of "measurement error" and the possibility that $E(uv) \neq 0$. Unfortunately, it raises a new problem if the instrumental variable is related to u or v. Suppose we have a variable z representing the state of the economy, perhaps employment, that is correlated with q. Represent z in log form and as a difference from its mean also. Then we have the instrumental variable estimator

$$\tilde{\beta} = \frac{\sum cz}{\sum qz} = \frac{\sum(\beta q^* + u)z}{\sum(q^* + v)z}$$

As the number of observations increases, we expect that

$$\text{plim } \tilde{\beta} = \frac{\beta \cdot \sigma_{q^*z} + \sigma_{uz}}{\sigma_{q^*z} + \sigma_{vz}} \qquad (4.3.5)$$

Unfortunately, economic theory provides us with good reason to believe that the z's we can choose are such that σ_{uz} might not equal zero even if we are satisfied that σ_{vz} does vanish. In particular, what we might expect is that increases in a variable which is usually and on average associated with greater output will, other things equal, lead to lower costs. First, plant managers can better provide for larger output, and second, we know that the mix of plant output often changed as the rate of output did. The practical result for the instrumental variables estimator is that it is biased downward for $\sigma_{uz} < 0$ and $\sigma_{q^*z} > 0$:

$$\text{plim } \tilde{\beta} = \beta + \frac{\sigma_{uz}}{\sigma_{q^*z}} \qquad (4.3.6)$$

Despite this possible objection to the technique, it seems sensible to pursue it since we can always accept those estimates that raise the estimated value of β and reject those that don't. Compared to the OLS estimator this method may be less efficient, but it is also clear that the sources of bias are fewer. Compare (4.3.3) and (4.3.5), for example.

Four instrumental variables were used: one-period lagged values of factory employment, pig iron production, railroad freight ton-miles, and building permits.[3] The technique used here can be interpreted as a two-stage estimation of a simultaneous relationship in which actual output plus error determine cost, and our four variables plus error in turn determine output. The regressions of predicted output on actual cost are presented in Table 4.10. In five of nine cases the estimate is higher, and in four it is reduced. In one case, Columbus, the new coefficient based on "predicted" output is far above the others, although not significantly different from unity. This plant had the greatest variability of sales of all those represented here, and the second highest variability of output among them. In part this is the result of a seasonal pattern, output decreasing in the winter months. (It was also the high cost plant. See Tables 4.2, 4.3, and 4.4 on these points.) It happens, however, that after the January slowdown common to the northern plants, output never revived, easing up only gradually from 813 in January to 929 tons in May, still below average. If our instrumental variables have no component that can be related to this idiosyncratic movement but only to the common broadly determined movement in output at the Columbus plant, then the

Table 4.10

INSTRUMENTAL VARIABLES ESTIMATE OF PLANT COST FUNCTIONS

Plant	Intercept	$\widehat{\ln Q}$	Time	Durbin-Watson d-statistic	SSE	R-squared
Addyston	2.41 (0.75)	0.88 (2.42)	0.023 (4.11)	2.32	0.0198	.66
Anniston	2.55 (0.38)	0.90 (1.08)	0.012 (1.16)	2.63	0.1070	.34
Bessemer	6.99 (2.62)	0.36 (1.13)	0.010 (1.68)	2.53	0.0483	.35
Burlington	1.93 (0.40)	0.96 (1.74)	0.0091 (0.79)	3.27	0.0501	.34
Chattanooga	13.92 (3.63)	-0.52 (-1.10)	0.0099 (1.61)	2.74	0.0336	.23
Cleveland	1.43 (0.33)	1.01 (1.90)	0.028 (1.10)	2.25	0.3593	.30
Columbus	-2.24 (-0.49)	1.55 (2.45)	0.059 (1.87)	1.20	0.2679	.43
Louisville	5.30 (2.08)	0.54 (1.73)	0.020 (2.45)	2.26	0.0823	.51
Scottdale	8.69 (2.80)	0.16 (0.44)	0.0022 (0.25)	3.06	0.0219	.03

Parenthesis indicate t-statistics.

predicted output will have less variability and hence imply a higher coefficient. The problem is that "error" in the form of unusual output fluctuation was incorrectly thrown out. These remarks apply to some of the other plants as well if there are reasons for variation in output that our instruments do not reflect.

An Approach Based on Expectations. The usual statistical tests and careful interpretation of the results using instrumental variables suggest that we should adopt an alternative specification that explicitly incorporates the idea that increases in output at certain times are more costly. Using our compact notation again, suppose we have

$$c = \beta_1 q + \beta_2 q^* + u \qquad (4.3.7)$$

where q^* is planned output. Note that we can define $v^* = q - q^*$, i.e., the deviation of actual output from expected. This implies $q^* = q - v^*$ and substituting above we have

$$c = \beta_1 q + \beta_2(q - v^*)$$

$$= (\beta_1 + \beta_2)q - \beta_2 v^*$$

In this second formulation, we see that when actual output is greater than expected output and costs increase as a result, β_2 will be less than zero. This implies in (4.3.7) that lower planned output, correcting for actual output, will result in higher costs.

Of course planned output is unobservable. Our approach here will be to use our instrumental variables to construct a measure of planned output. This has the advantage that we will be able to reduce information from several series into one and lose only one degree of freedom. This approach is related to the technique proposed by Hausman (1978) to test for misspecification.

Table 4.11 presents the results from this method. Note that the coefficient on quantity for Bessemer, Chattanooga, Louisville and Scottdale is greater here than for the earlier equations based either on ln Q or $\widehat{\ln} Q$. Moreover the coefficient for $\widehat{\ln} Q$ is significantly different from zero and negative in these cases. This suggests that the low estimates arrived at earlier were not necessarily due to an errors-in-variables problem, but rather to the exclusion of factors that were correlated with quantity but that exerted an independent negative influence on costs. For the other plants our estimates resulted in coefficients that are essentially unchanged from what OLS provided.

Assume for the moment that these differences across plants reflect genuine differences in the way these plants were operated. This suggests that at some plants, namely those at which output appears to be closely guided by expectations, operations were conducted without much slack in variable inputs. If output was expanded unexpectedly, penalties for such expansion had to be paid, as much as 3 to 5 percent in terms of extra costs (in addition to normal extra costs for added output of any sort) for each 10 percent unexpected increase. In the case of Chattanooga, the plant that was operated at a nearly steady rate, this penalty was higher. On the other hand, some plants were run with a certain amount of slack. This implies that these plants might have carried an "inventory" of workers, perhaps occupied with maintenance tasks that could be deferred.

Another explanation for these results comes from the fact that the output mix at plants varied and that the mix of large and small pipe changed in response to economic conditions and the season of the year. This possibility is explored at greater length below; here it is sufficient to point out that we could get results like those in Table 4.11 if certain plants changed their mix of pipe as the state of the economy changed. Since large pipe was cheaper to produce per ton, and since large pipe tended to be produced in the spring

Table 4.11

TWO-STAGE ESTIMATES OF PLANT COST FUNCTIONS
LOG OF DIRECT COSTS REGRESSED ON LOG OF ACTUAL OUTPUT AND PREDICTED
LOG OF OUTPUT

Plant	Intercept	ln Q	$\widehat{\ln Q}$	Time	Durbin-Watson d-statistic	SSE	R-squared
Addyston	4.09 (1.87)	0.50* (3.54)	0.20 (0.64)	0.019 (4.88)	2.47	0.0077	.87
Anniston	1.70 (0.31)	0.75 (2.42)	0.26 (0.36)	0.0089 (1.08)	1.79	0.0619	.62
Bessemer	6.83 (6.26)	0.76* (6.77)	-0.37 (-2.20)	0.0081 (3.14)	1.47	0.0072	.90
Burlington	5.35 (2.27)	0.64* (5.63)	-0.076 (-0.24)	-0.00066 (-0.11)	2.71	0.0101	.87
Chattanooga	13.50 (5.91)	0.82 (4.18)	-1.29 (-3.82)	0.0087 (2.37)	1.21	0.0106	.76
Cleveland	3.87 (3.18)	0.74* (10.68)	-0.027 (-0.16)	0.010 (1.38)	0.82	0.0235	.95
Columbus	3.22 (2.70)	0.99 (10.11)	-0.19 (-0.76)	0.018 (1.86)	2.04	0.0150	.96
Louisville	5.25 (7.80)	0.81* (11.02)	-0.26 (-2.35)	0.016 (7.28)	1.76	0.0051	.97
Scottdale	8.59 (4.55)	0.63* (4.04)	-0.46 (-1.73)	0.0026 (0.48)	2.56	0.0072	.68

Parentheses indicate t-statistics.

*Indicates that the coefficient is significantly different from one at the 5 percent level.

and during upswings in the business cycle, lower costs per ton associated with increases in a $\widehat{\ln Q}$ (which is simply a linear combination of the logs of several aggregate variables) might simply reflect the lower cost for large pipe. Obviously this could result in a substantial bias if we neglected it, but we can try to get useful estimates in the absence of information about the mix of pipe by using variables that might be related to that mix.

A curious empirical regularity emerges from the results in Table 4.12. It turns out that there is a very startling relationship between the estimated coefficient on ln Q and the size of a plant. Using maximum monthly output as our measure of plant size, we find that the coefficient of correlation between plant size and this estimate is -.964. One might at first assume that this is caused by the fact that large plants were operated at a steady rate. Going back to the errors-in-variables approach, we should as a result expect a larger downward bias there. This is, however, not necessarily a fact we have to take as true; Louisville and Chattanooga are medium sized plants with low variations in output, and yet these conform quite well to the pattern.

A more convincing explanation is possible. The cost function $C = AQ^{\beta}$ implies that marginal cost is equal to $\beta AQ^{\beta-1}$ or $(C/Q)\beta$, i.e., average cost times β. What is the relationship between marginal cost, average cost and plant size? Table 4.12 reveals that larger plants have lower average costs, and by our estimates, they also have lower marginal costs. (Figure 4.3 summarizes this relationship for this and a subsequent set of estimates.) Note that Chattanooga has relatively high average and marginal direct costs. It is interesting to recall that ten years earlier it was this plant that decided not to participate in the bidding system for work in pay territory and simply to collect its bonus. This is naturally what one would expect given the differences in costs among plants. See the letter quoted in Section 3.2.

Table 4.12

CAPACITY, AND MARGINAL AND AVERAGE DIRECT COSTS

	(1) Capacity (Maximum Monthly Output)	(2) Coefficient on ln Q	(3) Average Direct Cost	(4) Estimated Marginal Cost
Addyston	7,224	0.50	$4.60	$2.30
Anniston	4,269	0.75	5.92	4.44
Bessemer	5,316	0.76	5.49	4.17
Burlington	6,147	0.64	5.13	3.28
Chattanooga	3,740	0.82	5.36	4.40
Cleveland	4,034	0.74	5.16	3.82
Columbus	1,433	0.99	7.05	6.98
Louisville	4,018	0.81	5.54	4.49
Scottdale	5,848	0.63	4.64	2.92

SOURCE: Tables 4.3 and 4.11

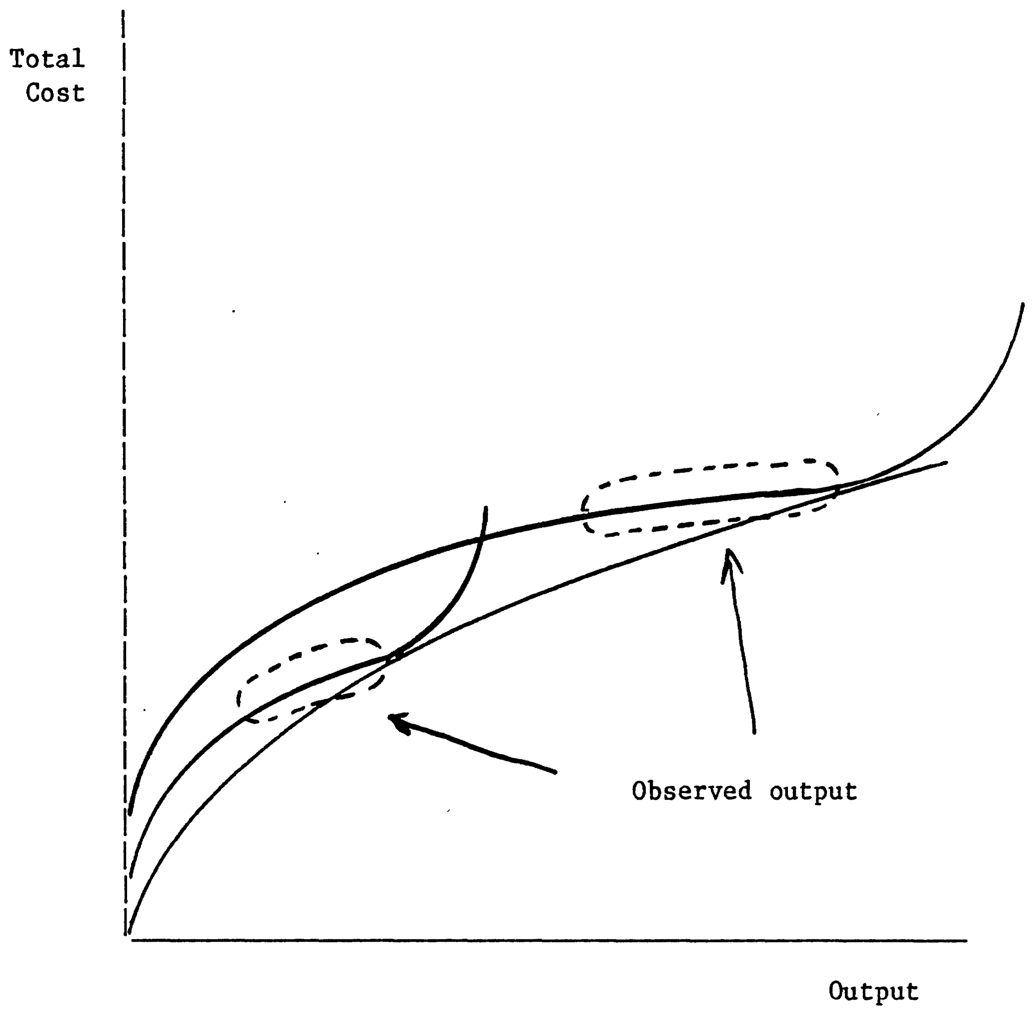
NOTE: The correlation between columns (1) and (2) is -.964, between (1) and (3) -.875, and (1) and (4) -.948.

A diagramatic exposition of this situation is presented in Figure 4.2. We see that it is possible to obtain lower average direct costs, but only by sacrificing some flexibility. An economic reason for this might be that large plants rely more on institutional arrangements and explicit delineation of duties to organize workers. Consequently changes in the rate of production are more difficult because positions and responsibilities have to be created, removed or modified as output is changed. These are expenses a firm will not gladly endure for short-run changes. Another explanation might be that larger plants have more capital and less flexibility for that reason. In many cases the use of capital introduces fixed costs not only directly but also indirectly by requiring a worker to become specialized as an operator of a particular machine. Regardless of the particular causes, this appears to be a finding that has a place in economic reasoning. Stigler (1939) suggests that firms adapt to uncertainty by using technologies that are flexible. One way of adapting of course is by flattening average cost curves. According to the results here, another way of meeting variable demand is by constructing some smaller plants which have more flexibility in their use of labor and fuel, but which have higher costs as a result, especially higher marginal costs.

The view that small plants are more flexible is supported by other data. Recall that Table 4.5 contains the coefficients of correlation between output and indirect (repair and replacement) costs. The relationship between these two series is clearly strongest at Chattanooga and Columbus, and at the two plants we have excluded in our regressions because they were shut down part of the time. These are also the four smallest plants of the nine, indicating that so far as indirect costs are concerned, these cots had a lower fixed or lump-sum element at small plants.

Figure 4.2

SHORT AND LONG RUN TOTAL DIRECT COST FUNCTIONS



Seemingly Unrelated Regressions. One more technical step is possible with these data. It is of course very likely that even after we have taken into account the effect of actual output and expected output on costs that some factors determining costs have been neglected. If these factors are common across several or all plants then one of the methods developed for handling seemingly unrelated regressions might be useful. First we must inquire whether the residuals from the second-stage estimates in Table 4.10 are autocorrelated. Without a detailed examination of the small sample properties of the Durbin-Watson statistic no precise and fully satisfactory answer is possible. However, on the argument that our sample of twelve is close to fifteen, which is the lowest reported value, only one plant, Cleveland, clearly exhibits positive autocorrelation at the 5 percent level.[4]

The possible utility of the technique of seemingly unrelated regression is demonstrated by looking at the contemporaneous correlations of residuals across plants in Table 4.13. If some neglected influence affects cost at two plants in the same way, then we would expect a positive correlation across plants. For example, if our variable "planned output" does not fully account for all factors that tend to be associated with greater expected output, then these factors, which can reasonably be expected to be correlated across plants, will reveal themselves in positively correlated residuals. This is the pattern we see among the medium and large plants. The three pairs with the highest correlations across plants are Addyston and Anniston (.57), Addyston and Lousiville (.56), and Bessemer and Cleveland (.53), and these plants have size ranks of 1, 4, 5, 6, and 7 out of the total 9. On the other hand, the six largest significant negative correlations, running from -.45 to -.17, involve in every case the two small plants, Chattanooga and Columbus. In particular note that the negative correlations of Chattanooga are with

Table 4.13

CONTEMPORANEOUS CORRELATIONS OF RESIDUALS ACROSS PLANTS

	Addyston	Anniston	Bessemer	Burlington	Chattanooga	Cleveland	Columbus	Louisville	Scottdale
Addyston		.57	.00	-.16	.04	.22	-.07	.56	.30
Anniston			.24	.15	-.17	.32	.05	.08	-.11
Bessemer				-.03	-.38	.53	-.16	.07	-.03
Burlington					.46	.03	.19	.17	.39
Chattanooga						.02	-.33	.47	.48
Cleveland							-.27	.41	.03
Columbus								-.26	-.45
Louisville									.48

Bessemer and Anniston, the two nearest plants. Note also that the residuals for Columbus are negatively correlated with the residuals of the plants near it, Addyston, Cleveland, Louisville, and Scottdale, but not for Burlington and Anniston, the two farthest plants. During the course of the year, the composition of work changed, sometimes because of seasonal factors, sometimes not. Work was either for inventory, for large orders that might have come in suddenly when a firm won a bid, or for smaller orders. If because of a large order the composition of work changed, the large (or better suited) plant would take it and be run at a steady planned pace. Whatever work on special small lots it had would be thrown to the nearby small plant. The need for constant changes in sizes, and still in this period, specifications of each pipe, very likely raised costs at this second plant, <u>ceteris paribus</u>, at the same time that costs at the first plant were lowered. It is possible but not necessary that the plant which got the irregular work at such times was the small one. On the other hand, the low average cost and steady rate of output at Chattanooga suggest that this plant may have specialized in long steady runs of restricted types of pipe. In either case, a predisposition to shift work from one plant to another as the mix of work changed would cause this sort of a pattern. Furthermore, for the plants taken as a whole, the fact that there are these correlations across plants is information that can be exploited to arrive at more efficient estimates.

The method used here is the generalized-least-squares approach to seemingly unrelated regressions proposed by Zellner (1962). This method uses the estimated variance-covariance matrix of residuals obtained from the ordinary least squares estimation of each equation.

Aitken estimator $\hat{\beta} = (X'\hat{\Omega}^{-1}X)^{-1}X\hat{\Omega}^{-1}y$. Under the assumptions here, the true variance-covariance matrix of error terms has dimensions (12x9) x (12x9), i.e. 12 observations and nine equations, and the following form:

$$\Omega = \begin{bmatrix} \sigma_{11} I & \cdots & \sigma_{19} I \\ \vdots & \ddots & \vdots \\ \sigma_{91} I & \cdots & \sigma_{99} I \end{bmatrix}$$

Here σ_{ij} represents the covariance of the true error terms from equations i and j, and I is the 12x12 identity matrix. We can construct on estimate of Ω by using the variances and covariances of residuals from the ordinary least-squares estimates, which were used in constructing the correlations in Table 4.10. This matrix, call it $\hat{\Omega}$, is then employed in the Aitken estimator $\hat{\beta} = (X'\hat{\Omega}^{-1}X)^{-1}X\hat{\Omega}^{-1}y$.

Results from this technique are shown in Table 4.14 where we see that the salient features of our earlier estimates are preserved. Figure 4.3 represents the relationship between the implied estimate of marginal cost and capacity. Moreover, a one-tailed test of the hypothesis that the true value of the returns parameter is equal to one can be rejected at the 5 percent level for all plants but Anniston and Columbus. Our conclusion from this is that average variable or direct cost decreased with increases in output, and that this carries with it the conclusion that monthly output rates were in the range where total average cost was falling. This is not a surprising result, however. Monthly output rates are really averages of daily rates, or even hourly rates. Although it might be possible and optimal to carry on production at the point of minimum average cost on some days, the uncertain flow of events will not make that the correct policy for every working day. Our monthly

Table 4.14

THREE STAGE SEEMINGLY UNRELATED ESTIMATES OF PLANT COST FUNCTIONS
LOG OF DIRECT COSTS REGRESSED ON LOG OF ACTUAL AND LOG OF PREDICTED OUTPUT

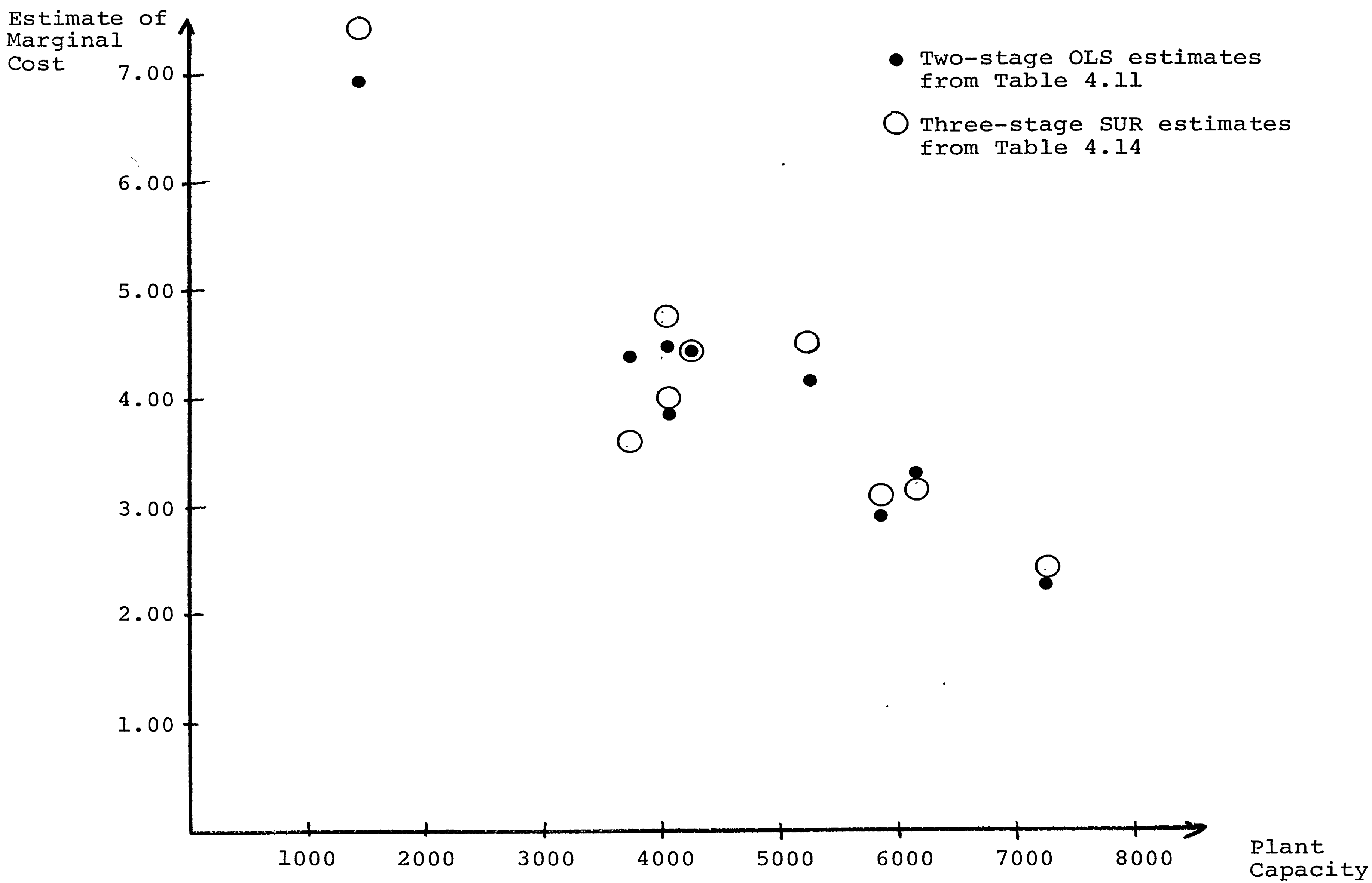
Plant	Intercept	ln Q	$\ln \hat{Q}$	Time
Addyston	2.77 (1.83)	0.52* (6.87)	0.32 (1.53)	0.02 (6.25)
Anniston	6.07 (1.46)	0.75 (5.31)	-0.28 (-0.52)	0.01 (1.51)
Bessemer	7.13 (8.89)	0.82* (9.49)	-0.47 (-3.65)	0.0080 (3.14)
Burlington	5.17 (3.29)	0.62* (11.67)	-0.035 (-0.18)	-0.00022 (-0.050)
Chattanooga	12.72 (9.41)	0.67* (5.35)	-1.04 (-5.12)	0.008 (2.49)
Cleveland	2.94 (3.05)	0.77* (15.18)	0.64 (0.47)	.014 (2.19)
Columbus	4.50 (3.88)	1.04 (17.17)	-0.42 (-2.21)	0.010 (1.20)
Louisville	5.56 (10.67)	0.86* (16.68)	-0.34 (-4.36)	0.015 (7.25)
Scottdale	9.23 (7.40)	0.66* (8.47)	-0.56 (-3.54)	0.00096 (0.23)

Parentheses indicate t-statistics.

*Indicates that the coefficient is significantly different from one at the 5 percent level.

Figure 4.3

PLANT CAPACITY AND ESTIMATED MARGINAL COST



rates indicate only that these plants were operated on average with some slack.

One more point should be mentioned. Some elements of indirect cost, which appear, for example, as repairs to machinery and equipment in Table 4.2, were incurred at positive output rates but not if plants were shut down only temporarily. The daily repair of the cupola is an example of this. Since we excluded such items, the fixed avoidable cost is probably much greater than our figures on direct costs suggest. It is true that we could have added indirect costs to direct costs and used this sum to estimate a "particular expenses" function. Unfortunately, this technique would also make estimation more difficult since, as we saw, indirect costs as a whole bear no necessary relationship to output and may even be negatively related. Yet especially with this sort of finding for indirect costs, and remembering that we have not incorporated the expense of inventory in our measure of costs, these results provide strong support for the view that incremental costs for these plants were less than average costs.

NOTES

I am indebted to Lester Telser, my thesis chairman, for his advice on the topics covered in this study. I also wish to thank Yale Brozen for bringing the _Addyston_ case to my attention and for encouraging my interest in it. The responsibility for any remaining errors rests entirely with me of course. Support for this work came from the Liberty Fund, the Winchester Foundation, and the Charles R. Walgreen Foundation. Finally, I wish to acknowledge the assistance of United States Pipe and Foundry, which provided the extraordinarily useful data on which Chapter 4 is based.

Notes to Chapter 1

1. The first case to reach the Supreme Court under the Sherman Act was that of the Sugar Trust, E. C. Knight (1895), which was decided in favor of the defendants. One case involving labor disputes followed this. Two largely forgotten cases involving livestock exchanges reached the court in 1898. The significant antitrust cases during this period were Trans Missouri (1897), Joint Traffic (1898), and Addyston (1899). By almost any measure, the merger wave began in one of these three years. See Section 3.2 below.

2. For general accounts on these aspects of U.S. industrial history see Burns (1936), Phillips (1962), Ripley (1905), Seager and Gulick (1929), Stevens (1914), and Whitney (1958). Excellent statistics on the merger wave at the turn of the century may be found in Nelson (1959). The basing point system is discussed in Machlup (1949), Stigler (1949), Stocking (1954), and U.S. TNEC Monographs No. 21 and No. 42 (1941).

3. General introductions to core theory are provided in Jones (1980) and Shapley and Shubik (1973). For extensions of core theory on which the present discussion is based, see Telser (1972) and Telser (1978).

4. This point is made in Sheshinski and Drèze (1976) and appears in a somewhat different form in Gould (1978). It should not be assumed, however, that a capital stock that is fixed in the short run, fluctuating demand, and marginal cost pricing will lead to firms operating at a loss. For an analysis of this issue see Telser (1978, pp. 117-129).

5. Sharkey (1973) presents an analysis for this problem using a particular set of cost and demand conditions. His results are summarized in Section 2.3 below.

Notes to Chapter 2

1. Baumol (1979), for example, points out that the prices that minimize social loss are equal to marginal cost only at the point where constant returns to scale prevails. He also points out that in general this is the only point at which a competitive equilibrium exists.

2. In principle it would be desirable to have a more general formulation of the cost conditions. Instead of a cost function composed of a fixed cost and a convex variable cost, we should have a function that has increasing and then decreasing returns. This makes the mathematics difficult, however. Note also that the fixed cost c has the interpretation of a fixed avoidable cost so that no costs are incurred at Q = 0.

3. Although it receives very little emphasis, this point is widely recognized. Friedman (1955, p. 231) writes that "strictly speaking, the supply curve may have tiny waves in it attributable to the finite number of firms." The usual assumption of large numbers of competitors has probably been introduced in standard textbook treatments for exactly this reason, although the precise nature of the difficulty that a violation of this assumption implies is usually not spelled out. As Section 2.1 shows, small numbers poses no necessary difficulty for competition.

4. The model of adjustment costs and supply due to Lucas (1967) appears to embody what Knight had in mind. In the short run, adjustment costs lead to U-shaped average cost curves and industry demand grows at a constant rate. It would be interesting to trace the consequences for such a model, of demand that behaves cyclically or according to some stochastic process. In particular, what are the consequences for industry equilibrium?

Notes to Chapter 3

1. Jones (1924, Chapter IV) presents a similar, more detailed explanation of the factors that contribute to declining average cost in railroading. His treatment of "ruinous competition" (Chapter V) would also be of interest to anyone familiar with the line of analysis advanced in this study.

2. An additional change proposed and carried out at the December 1895 meeting was that "upon all inquiries for prices from 'reserved cities' for pipe required during the year 1896" prices and bonuses would be fixed at regular meetings. It was also proposed that the association's headquarters be moved to Chicago because so much of its work was for that city. This topic was the subject of some disagreement among the members [Transcript of Record, pp. 92-93, pp. 95-97].

3. This letter has become the source of some misunderstanding about the cartel. Whitney (1958, p. 5), for example, comes to the conclusion "that the pool operated far from harmoniously," on the basis of this letter and a passage from Seager and Gulick (1929, p. 94) which reads:

    > Lying and cheating of the public inevitably led to lying and cheating among the members themselves to an extent that makes the inner history of this pool a depressing chapter in the record of American business.

    Seager and Gulick of course have no shortage of evidence that supports the claim that the public was cheated. However, the charge they make concerning cheating among members was either pulled out of thin air, or is deduced from the fact, which they mention earlier, that one company "found it more profitable to sell its pipe in 'free' territory." What is striking about the cartel's internal documents is how little evidence there is of discord. To be sure, the cartel had formal arrangements for monitoring behavior, but nothing unpleasant ever erupted.

4. U.S. v. Addyston Pipe and Steel Co., 85 Fed. 271 (6th Cir. 1898).

5. U.S. v. Addyston Pipe and Steel Co., 175 U.S. (1899).

6. A proof of the assertion that the core is nonvoid (and by implication, that a competitive equilibrium exists) in the case where costs are constant across all rates of output can be found in Telser (1972, p. 112).

Notes to Chapter 4

1. "Net Sales at the works" formed part of a stock-flow calculation. New production ("yield" in Table 4.1) was added to the previous end-of-month inventory and net sales were subtracted from this sum to obtain the new end-of-month inventory. The reader can easily check this in Table 4.1. This seems to suggest that "net sales" refers to the amount that left the plant's yard. Whether the firm also received payment that month is another matter, and the ledger offers no clues on this. The terms for municipal contracts were probably fairly standard, although there are some instances in which bidding firms made two bids, the lower bid for payment before an early date, the higher bid for payment by some later time.

2. The system given in (4.3.4) comes from the following three equations

$$c^* = \beta q^* + u$$
$$c = c^* + w$$
$$q = q^* + v$$

and it implies that the least squares estimator of $1/\beta$ is $\widehat{1/\beta} = \Sigma cq/\Sigma c^2$.

Consequently we have

$$\text{plim } \widehat{1/\beta} = \frac{1/\beta \ \sigma_{c^*c^*} + \sigma_{wu'}}{\sigma_{c^*c^*} + \sigma_{ww}}$$

where $u' = -1/\beta u + v$ and the variances are defined as before. For $\sigma_{wu'} = \sigma_{ww} = 0$ this is consistent. The symmetry between (4.3.2') and (4.3.4) is complete if we think of u in the first system as containing both u and w.

3. These series are from the appendix to <u>Historical Statistics</u> (1949). The calculations that resulted in the figures that appear in Tables 4.10, 4.11, 4.13, and 4.14 were also carried out using the contemporaneous values of the aggregate variables instead of their one-period lagged values. Since these results were substantially the same, and since there are good statistical reasons for using the lagged values, only one set of results is reported here.

4. Theil (1971, p. 201) citing results from Theil and Nagar (1961) argues that for independent variables that are relatively smooth in the sense that the first and second differences are small compared to the range of those variables, the upper bound on the Durbin-Watson statistic is close to the true significance limit.

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