AN APPLICATION OF CORE THEORY TO THE ANALYSIS OF OCEAN SHIPPING MARKETS*

STEPHEN CRAIG PIRRONG
University of Michigan

I. Introduction

The theory of the core implies that competition is frequently unstable and inefficient under some fairly common cost and demand conditions. In particular, when costs are characterized by indivisibilities (for example, avoidable costs) and demand is finely divisible, the core may be "empty." In other words, a competitive equilibrium frequently fails to exist, and, as a consequence, competitive interactions between firms cannot generate an efficient allocation of resources.

There are various means of addressing the empty core problem. Collusion between producers, for example, can limit competition efficiently. Thus, cartelization may be an efficient response to the cost and demand conditions that preclude the existence of a competitive equilibrium.

In this article, I test the ability of the theory to explain the organization of ocean shipping markets. An examination of these markets reveals that the theory works well. Firms in liner shipping markets, where costs are indivisible while demand is finely divisible, have colluded consistently since the industry's birth in the mid-nineteenth century. Conversely, bulk shipping markets (where demand is indivisible and, hence, empty core problems are not a serious concern) have always been organized competitively. This evidence is consistent with the theory's predictions.

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This article draws on the theoretical work of Telser and Sharkey and follows the previous empirical tests of core theory by Bittlingmayer (who examined the cast iron pipe industry and the great merger wave) and Sjostrom (who also investigated ocean shipping).[1] It differs from its predecessors in several ways. First, these works do not explicitly recognize the important effect of demand divisibility on the status of the core and do not test for its relevance. Moreover, Sjostrom's work on ocean shipping recognizes only one cause of an empty core—inefficient entry—while this article emphasizes that marginal cost pricing can disrupt competitive equilibrium when costs are indivisible, even if further entry is precluded or if the threat of entry does not constrain prices. I also emphasize that the possibility of discontinuities in marginal cost at capacity makes tests of the often-asserted relation between the status of the core and market size problematic, and I explicitly test for the existence of such discontinuities in cost data, while the aforementioned articles do not. Despite these different approaches, the fact that Sjostrom's, Bittlingmayer's, and my research draws similar conclusions strongly supports the core analysis.

The remainder of the article is organized as follows. Section II gives an overview of core theory and outlines its major predictions. Section III discusses cost and demand conditions in liner shipping. Section IV discusses the history and forms of collusion that characterize this sector of the shipping market. Section V describes cost and demand conditions and market structure in the bulk shipping sector. Section VI summarizes the work.

II. Core Theory

A. *An Introduction*

The notion that competition is destructive under certain circumstances is an old one. It is now commonly accepted that the existence of free riders, for example, makes unlimited competition inefficient and that property rights in the form of patents, resale price maintenance, exclusive dealing, and copyrights may improve resource allocation. The assertion that fixed costs and variable demand may preclude the efficient operation of competitive markets as well is more controversial. Many influential

[1] George Bittlingmayer, Decreasing Average Cost and Competition, 25 J. Law & Econ. 201 (1982); George Bittlingmayer, Did Antitrust Policy Cause the Great Merger Wave? 29 J. Law & Econ. 77 (1985); William Sjostrom, Collusion in Ocean Shipping: A Test of Monopoly and Empty Core Models, 97 J. Pol. Econ. 1160 (1989).

economists—notably Marshall, Knight, Ely, Eliot Jones, Taussig, Cady, and Viner—have argued, however, that this may indeed be the case.[2]

The fundamental insight underlying these arguments is that, when firm average costs are U-shaped, competition will not sustain marginal cost prices (which are the efficient prices for firms to charge) unless demand is such that the optimum production plan requires all firms to produce where marginal cost equals average cost. This is true because entry drives prices to minimum average cost. Competition is unstable in these cases, and no "invisible hand" guides self-interested agents to act optimally.[3]

Core theory makes similar predictions concerning the relation between costs and the feasibility of competition. It models the self-interested interactions of economic agents as cooperative games. Contracting between buyers and sellers, for instance, is a form of cooperation. Consider a producer of a commodity and several persons who wish to purchase it. By forming a coalition—that is, by contracting among themselves to produce, buy, and sell the commodity—these individuals can generate gains from trade that they can divide among themselves. The division of these gains among them depends on the prices paid to the seller by the buyers and the quantity of the good sold.

Since a given consumer may be able to patronize several sellers and thus participate in several coalitions, coalitions must compete for membership by offering larger shares of the gains from trade. The core models competition under the assumption that contracting between buyers and sellers is costless and unrestricted. Firms, for example, must offer lower prices (and thus a higher allocation of surplus) to draw customers from other coalitions served by other firms.

A particular division of the gains from trade (surplus) among the various buyers and sellers is an equilibrium one if two conditions hold. First, no group of individuals can do better by forming a coalition and contracting among themselves. If, under a proposed division of surplus among all the buyers and sellers, for instance, a certain seller and ten buyers earn less surplus than they could achieve by contracting among themselves, this proposed division cannot be an equilibrium one. Instead

[2] See references in note 3 *infra*.

[3] For discussions of these issues, see John M. Clark, Studies in the Economics of Overhead Cost (1923); George Johnson Cady, The Economics of Business Enterprise (1950); Richard T. Ely, Outlines of Economics (1937); Eliot Jones, Principals of Railway Transportation (1924): Frank Knight, Cost of Production and Price, 29 J. Pol. Econ. (1921) 304; Alfred Marshall, Principals of Economics (1927); F. W. Taussig, Principals of Economics (1925); and Jacob Viner, Cost Curves and Demand Curves, in Readings in Price Theory 198 (George Stigler & Kenneth Boulding eds. 1952).

of accepting the proposed allocation, these buyers and the seller would simply contract to divide the larger surplus they can create and thereby make themselves better off than they would be under the proposed equilibrium allocation. Second, in equilibrium, the aggregate of the surplus allocated to all of the various buyers and sellers must be feasible: this aggregate cannot exceed the maximum gains from trade that these buyers and sellers can generate given their endowments of resources.

Under certain conditions there exists an equilibrium division of surplus when agents can form any coalition, that is, when they can contract freely among themselves. This equilibrium is frequently Pareto optimal. There is an appropriate mix of cooperation and competition when this is true. Under other circumstances, however, no stable equilibrium results for the process of competition between coalitions. It is impossible to simultaneously satisfy the two necessary conditions for an equilibrium. Such a state is called an "empty core." With an empty core, individual demands for surplus (which depend on their contracting opportunities, preferences, and costs) are larger than the maximum amount of surplus that can be created (which depends only on preferences and costs). Several examples of empty cores are provided in the following section.

Empty cores have a significant implication. When the core is empty, no competitive equilibrium exists. The unrestricted competition cannot sustain any allocation of resources, including the efficient allocation. Participants in a market plagued by empty core problems have incentives to devise restrictions on the freedom to form coalitions, that is, to restrict the freedom to compete and contract. Indeed, they have incentives to devise an efficient set of restrictions. Such constraints, which may include property rights, entry barriers, and limits on contracting, should eliminate enough of the competition that drives imputations out of the core so as to achieve a stable equilibrium. Thus, one should observe restrictions on the ability of agents to contract and bargain where the core is empty.[4]

The following sections demonstrate that whether the core in a given market is empty or not depends crucially on the nature of costs and demand in that market. The core is frequently empty when demand is finely divisible but production costs are not. Thus, competition may not survive in markets with these cost and demand characteristics, and some restrictions on contracting may be required to restore an equilibrium. Subsequent sections of this article examine whether these cost and demand considerations explain the organization of ocean shipping markets.

[4] Many different restrictions may lead to a non-empty core, and the theory cannot predict which one will be observed.

B. *Cost Indivisibilities, Divisible Demand, and the Status of the Core*

Telser, Sharkey, Pirrong, and others have demonstrated that indivisibilities in production processes frequently result in empty cores when demand is finely divisible. Specifically, if the cost functions of individual plants contain regions of both increasing and decreasing returns, demand is variable, and if plants serve several customers simultaneously, the core is almost always empty.[5]

This is best illustrated through some examples. Assume that demand is variable. With variable demand it is frequently optimal to build several plants to satisfy that demand if there are fixed costs required to construct plants and if short-run production costs do not exhibit constant returns to scale. If demand is stable, under plausible cost conditions it is efficient to build only one plant matching the constant demand or several plants that always operate at capacity.[6]

When demand is variable, however, it is usually cost minimizing to build several plants and periodically idle one or several in response to changes in demand. Given variable demand, moreover, sometimes it may be optimal to operate some of the active plants below capacity. Since it is the existence of excess capacity—in the form of either idle plants or active plants producing less than their capacity—that leads to an empty core, variable demand is a crucial factor contributing to the failure of competition.

Given the distribution of demand, assume that each of three independent firms has constructed a plant to produce output. Plant 1 has a capacity of 2 units, plant 2 a capacity of 4 units, and plant 3 a capacity of 8 units. Each plant must incur an indivisible cost if it produces a positive output but incurs no cost if it remains idle. This cost is therefore an ‘‘avoidable'' cost. Plant 1's avoidable cost is 8, plant 2's is 12, and plant 3's is 16. Thus, larger plants have lower average avoidable costs at capacity. Marginal costs are assumed to equal zero for all outputs less than

[5] Lester G. Telser, Economic Theory and the Core, at ch. 3 (1978); Lester G. Telser, A Theory of Efficient Competition, and Cooperation, at ch. 5 (1987); and Stephen Craig Pirrong, An Application of the Theory of the Core to the Study of Ocean Shipping Markets, at ch. 3 (unpublished Ph.D. dissertation, Univ. Chicago 1987). Although these applications of core theory are relatively new, the theory itself has a long and illustrious history. It was originated by Francis Ysidro Edgeworth, in his Mathematical Psychics (1881), and extensively developed by John von Neumann & Oscar Morgenstern, The Theory of Games and Economic Behavior (1944).

[6] George J. Stigler, Production and Distribution in the Short Run, 47 J. Pol. Econ. 305 (1938); William Sharkey, A Study of Markets Involving Increasing Returns and Uncertain Demand (unpublished Ph.D. dissertation, Univ. Chicago 1973); Telser, Economic Theory and the Core, *supra* note 5, at 67–81.

capacity: marginal costs are consequently below average costs for all feasible outputs.

A Pareto-optimal production plan specifies the plants that should produce given the state of demand. Assume that the demand curve takes the following form. Each active customer wishes to purchase 1 and only 1 unit of output at a price not to exceed 5: this is the consumer reservation price. Thus, the demand curve takes the form of an inverted L. The demand curve shifts as the number of customers who wish to purchase the product varies.

Consider the status of the core when eleven customers appear. Here it is optimal for plants 2 and 3 to produce and for plant 1 to remain idle; this minimizes the total cost of serving this demand. Note that this solution requires firms to operate with excess capacity. Idling plant 2 would ensure that the remaining plant operates at capacity, but this would be inefficient: the consumer surplus of 20 lost by idling plant 2 exceeds the cost of 12 required to operate it. This illustrates an important effect of indivisibilities: it is frequently inefficient to match capacity and demand exactly. Sometimes plants should operate with excess capacity.

Call the imputation ("profit") of firm i_{y_i} the imputation ("consumer surplus") of the identical consumers x. Call the "characteristic function" of a coalition consisting of firm i and j customers $V(i, j)$. The value of this function equals the maximum amount of surplus a coalition of firm i and j customers can obtain by contracting among themselves. Consider, for example, a coalition between firm 2 and four customers. By producing its capacity of 4 units and selling them to the four customers, it incurs a cost of 12 but generates a consumer benefit of 20 for a net surplus of 8. Thus, $V(2, 4) = 8$.

Since agents must do at least as well in equilibrium as they could by entering some coalition and bargaining among themselves, these imputations must satisfy the following core constraints (that is, these inequalities are necessary conditions for an equilibrium):

$$y_2 + 4x \geq (4)(5) - 12 = 8 = V(2, 4),$$

$$y_3 + 7x \geq (7)(5) - 16 = 19 = V(3, 7),$$

$$y_3 + 8x \geq (8)(5) - 16 = 24 = V(3, 8),$$

and

$$y_1 + y_2 + y_3 + 11x \leq (11)(5) - 28 = 27 = V(N),$$

where $V(N)$ is the characteristic function for the "grand coalition" consisting of all eleven buyers and three sellers.

The first constraint states that, since a coalition of firm 2 and four customers can generate a net surplus of 8, in equilibrium the aggregate total return received by the individual members of this coalition must be at least this large. The other constraints have similar interpretations. The last constraint states that sum of the individual imputations cannot exceed 27, the maximum feasible surplus.

An examination of these constraints shows that those corresponding to $V(2, 4)$ and $V(3, 7)$ must hold as equalities. Subtracting the $V(3, 7)$ equality from the $V(3, 8)$ inequality implies that $x \geq 5$. Since $(11)(5) > 27$, and since $y_i \geq 0$ for $i = 1, 2, 3$, together consumers and producers can demand more than the maximum feasible surplus. The core is therefore empty.

The intuition behind this result is straightforward. Since there is excess capacity under the optimal plan, at least one firm must serve fewer customers than it is capable of serving. That is, the coalition it serves under the optimal plan must be smaller than the largest coalition the plant can serve. It is willing to offer an additional customer any price above marginal cost in order to induce him to join the coalition. This increases the amount of surplus available to divide between the firm and the other members. Since any customer can take advantage of such an offer, each demands an imputation equal to the difference between reservation price and marginal cost. These marginal cost prices do not cover avoidable costs, however, so firms would rather remain idle than follow the optimal production plan. That is, to satisfy buyers' demands for surplus, sellers must accept losses equal to the avoidable costs they incur. Since they can lose nothing by remaining idle, the necessary conditions cannot all be satisfied. The core is therefore empty.

To illustrate another cause of empty cores, assume that there are ten customers in the market. Here the optimal plan calls for firms 1 and 3 to satisfy demand. These firms must operate to capacity under this plan, but firm 2 can make potentially profitable arrangements with customers. Thus the following constraints must hold:

$$y_1 + 2x \geq 2 = V(1, 2),$$

$$y_3 + 8x \geq 24 = V(3, 8),$$

$$y_2 + 4x \geq 8 = V(2, 4),$$

$$y_1 + y_2 + y_3 + 10x \leq 22 = V(N),$$

and

$$y_i \geq 0,$$

for all i. The constraints for $V(1, 2)$, $V(3, 8)$, and $V(N)$ imply that each must hold with equality and that $y_2 = 0$. If $y_2 = 0$, then the $V(2, 4)$ constraint implies $x \geq 2$. Hence, $y_3 \geq 4$. Moreover, $y_3 + 10x = 24 > V(N)$. Thus the core is again empty.

The explanation for this result is as follows. Under the optimal plan, the plant with the highest average cost should produce, while one with a lower average cost should remain idle. The idle plant with the lower average cost can offer customers a price equal to its average cost. This competitive offer puts a ceiling on price, and this ceiling is less than the average cost of plant 2. This plant therefore cannot produce profitably, and it would rather remain idle than follow the optimal plan.

These examples illustrate the two basic causes of empty cores. In the first example, firms must operate with excess capacity—that is, where marginal cost is less than average cost—under an optimal plan. Competition drives price to marginal cost, but, given the assumed cost conditions, marginal cost prices do not cover total avoidable and variable costs. Thus, firms have no financial incentive to follow the optimal plan. Given variable demand and indivisible production costs, it may often be the case that Pareto-optimal production plans require firms to operate sometimes with such excess capacity because an exact matching of capacity and output is more costly.

In the second example, an optimal plan requires that some low-average-cost firms remain idle. But they can make mutually agreeable bargains with some customers that force prices below the average avoidable and variable costs of some optimally active firms.[7] Taken together, these examples show that free entry *may* lead to an empty core, but empty cores may result even if entry is unimportant. The first example shows that there is no equilibrium when firms operating with excess capacity compete even though the threat of entry does not constrain imputations.

These results can occur under more general cost and demand conditions. In particular, the assumptions of constant marginal cost and inverse-L-shaped demand are sufficient but not necessary to obtain an empty core. The works by Telser and Sharkey provide examples of empty cores with downward-sloping demand curves and various assumptions concerning cost.[8] The intuition behind their results—that excess capacity

[7] Sjostrom, *supra* note 1, seems to recognize only inefficient entry as a source of an empty core. The fact that a competitive equilibrium need not exist even when capacity is fixed, however, demonstrates that inefficient entry is a sufficient, but not necessary, condition for an empty core.

[8] Telser, Economic Theory and the Core, *supra* note 5; Sharkey, *supra* note 6.

among active plants or the existence of idle plants can cause empty cores—is identical, however, to the reasoning behind the examples presented here.

The particular shape of the cost function is an issue of empirical importance in certain circumstances, however, and therefore deserves scrutiny. In particular, when plant cost functions are continuous functions of output, the severity of empty core problems decreases as the size of the market increases.[9] This is due to the fact that the indivisibility problem becomes less acute as the size of the market increases because it is easier to match active capacity with demand. When marginal cost functions are discontinuous, however, this result is no longer true. Very large markets may have empty core problems as severe as those faced by small markets because these discontinuities make it more difficult to match capacity and demand.

To see the effect of discontinuities on the relation between market size and the status of the core, consider the following simple model. Assume that the buyers of a certain product, who wish to purchase only 1 unit thereof, are distributed uniformly along a continuum $[0, \infty]$. All plants are located at the origin of the continuum. The cost of transport equals 5 per unit of distance. Each consumer is willing to pay a price of d for a unit of the commodity delivered to his location, so a consumer located at point $x \geq 0$ is therefore willing to pay $\max[d - 5x, 0]$, where $d > 0$ for a unit of the commodity at the origin. Thus, the demand curve for the product at the origin is linear and downward sloping and equals $P = d - 5q$, where q is the consumption of the good and P is the price that the marginal consumer (that is, one located distance q from the origin) is willing to pay.

The independent plants, each with a unit of capacity, produce with an avoidable cost of 2 and a marginal cost of zero for outputs below 1 and with a marginal cost of 500 (or any very large number) for outputs greater than 1. This production technology includes a marginal cost discontinuity at capacity and is essentially identical to that employed in the preceding examples. It is costless to transport the good from producers to any point along the demand continuum.

The optimal number of active plants depends on d. It is straightforward

[9] Telser, Economic Theory and the Core, *supra* note 5, at 100–117; William Sharkey, The Theory of Natural Monopoly, at ch. 6 (1986); Robert Aumann, Markets with a Continuum of Traders, 32 Econometrica 39 (1964); and William J. Baumol, John C. Panzar, & Robert D. Willig, Contestibility and the Theory of Market Structure, at ch. 2 (1982), all note that, with continuous preferences and costs, increasing market size can reduce the severity of disequilibria.

to show that, if $5n - .5280 < d < 5n + 4.472$, then $n = 1, 2, 3, \ldots$ plants should produce. This is true because the consumer benefit lost (that is, the decrease in the area under the demand curve) resulting from the inactivation of a plant is greater than the avoidable cost of 2 that would be thereby saved if $d \geq 5n - .5280$. The consumer surplus gained by adding a plant, however, is less than the avoidable cost of 2 thus incurred if $d \leq 5n + 4.472$. Note that d determines the size of the market. To represent this relation, call the optimal number of plants $n^*(d) = \text{int}[(d + .5280)/5] = \text{int}[(d - 4.472)/5] + 1$. This is an increasing step function.

Now consider the status of the core in this market. Even if there are only $n^*(d)$ plants available (that is, further entry is impossible), the core is still empty if $5n^*(d) - .5280 \leq d < 5n^*(d) + 2$. This is true because competition in these circumstances drives price to the reservation price of the marginal customer, and this price is too low to cover the avoidable costs that should be incurred.

To see this, consider the extreme case where $d = 5n^*(d) - (.528 - .001)$. Here the reservation price of the marginal customer equals the marginal cost of zero because the $n^*(d)$ plants can produce $n^*(d)$ units of output at a marginal cost of zero, but only $n^*(d) - .1054$ customers are willing to pay a positive price. Thus, efficient output equals $5n^*(d) - .1054$, and competition drives price to marginal cost (as in the first example above). Firms cannot cover their avoidable cost given this price, and the core is empty as a result since they would rather remain idle than produce according to the optimal plan. Now consider the alternative extreme where $d = 5n^*(d) + 1.99$. Here the $n^*(d)$ plants will optimally produce at capacity. Competition will drive price to the reservation price of the marginal customer, which, in this case, equals 1.99. This price is still less than the average avoidable cost of 2, which again implies that the core is empty as firms cannot cover their avoidable cost.

Given the relation between the optimal number of active plants and d, it is readily apparent that the size of the market has no systematic effect on the status of the core: as d grows, the core is periodically empty, and the divergence between minimum acceptable and maximum feasible surplus does not systematically decline. For example, if $d = 14.472$, then three plants should produce under an optimal plan, and each would lose 2 if they were to do so. Similarly, if $d = 14{,}999{,}999.472$, then 3,000,000 plants should produce, and each would lose 2 if they were to do so. Thus, when there are discontinuities in marginal cost, one cannot expect market size to mitigate the severity of empty core problems.

One should also note that it is not inefficient entry that leads to an empty core here and that, as a consequence, it does not arise from the existence of idle, low-average-cost plants. Instead, the following facts can cause the empty core: (1) marginal cost prices fail to cover costs when firms operate below capacity, (2) with the assumed production technology it is frequently optimal to operate plants below capacity, and (3) competition drives price to marginal cost. Thus, even if additional entry is impossible, the core may be empty in very large markets. Entry just further complicates matters: if entry is possible, the core is empty unless $d - 5n^*(d) = 2$.

The intuition behind this result follows. The core is non-empty if and only if the *industry* total cost curve (ITCF) is subhomogeneous (that is, homogeneous of degree 1 or smaller). When the ITCF is homogeneous of degree 1 at a particular output, the industry average total cost function (IATCF) is perfectly elastic. When *firm* cost curves are continuous, the IATCF becomes more and more elastic the larger the number of optimally active firms. As the industry grows, therefore, the IATCF becomes more elastic at the efficient level of output, and the empty core problem consequently becomes less acute because the divergence between average and marginal costs (which leads to empty cores) becomes smaller. In the limit, with an infinite number of firms, the IATCF is perfectly elastic, and the core is therefore non-empty because there is no divergence between average and marginal costs. When *firm* cost curves are discontinuous, however, IATCF does not become increasingly elastic as the number of active firms increases. Indeed, this function is perfectly *in*elastic at each output where it is optimal to activate an additional plant. At this point, therefore, the necessary condition for a non-empty core is not satisfied, and the core is empty. This is true regardless of the number of optimally active firms.

The foregoing analysis suggests that the nature of the cost function can have a marked effect on the relation between the feasibility of competition and market size.[10] When there is a discontinuity in marginal cost at

[10] Lester G. Telser, Industry Total Cost Functions and the Status of the Core, 39 J. Indus. Econ. 240 (1991), demonstrates a similar result in a more complicated model. Telser shows that, if the industry total cost function is discontinuous whenever a new firm becomes active, the disparity between the minimum acceptable surplus and maximum feasible surplus does not decline as the size of the market increases; that is, the severity of the empty core does *not* decline as market size increases. An examination of the example presented here shows that this condition on industry total cost holds.

The slope of the demand parameter is also important in determining the disparity between minimum acceptable and maximum feasible surplus: the flatter the demand curve, the narrower the range of d that leads to an empty core. Flattening a linear demand curve does not imply that increasing market size will reduce the severity of an empty core: if there is some range of d such that the core is empty at small outputs, there will be such a range for arbitrarily large outputs.

an output where marginal cost is less than average cost, the core may be empty even in very large markets. There are plausible conditions that could lead to such a discontinuity. In particular, upper bounds on the output that a plant can produce could lead to them: that is the role of the capacity constraints in the examples. The amount of cement that a given mill can produce in any specific time period, for instance, is limited by the physical dimensions of its kilns. With respect to the industry studied here, ocean shipping, the amount of cargo a ship can load without sinking is also constrained by the vessel's characteristics.

It may be argued that such discontinuities are unrealistic representations of real world cost functions. In the case of the ship, for example, adding cargo beyond some level may rapidly increase the probability of sinking and thereby substantially increase the marginal cost of that cargo but may do so in a continuous way. That is, marginal costs may be continuous but rise very, very steeply once a certain output is reached.

In this case, the severity of empty core problems will abate somewhat as market size increases, but very large markets could face empty core problems nonetheless. This is true because the cost penalty of expanding output at a given set of plants becomes very large as each plant's output surpasses the point where marginal costs rise rapidly: discontinuous marginal cost is just an extreme case of this phenomenon. Under these circumstances, it may be desirable to expand output by activating an additional plant and utilizing the producing plants below their capacity rather than increasing production at the currently operating plants and thus paying this large cost penalty. Put another way, given these cost conditions, it may be very costly to match varying demand and capacity even in very large markets, and, as a result, for many levels of demand, firms should operate where average cost exceeds marginal cost. Since this excess capacity can lead to an empty core, an equilibrium may not exist in such markets.

This discussion demonstrates that testing for a relation between the status of the core and market size requires significant information concerning cost structures. An assertion of such a relation makes important implicit assumptions about costs. The assertion will not be correct if these assumptions are violated. Indeed, Section III of this article provides some evidence that discontinuities of the sort that can cause empty cores in large markets exist in liner shipping.

C. *Responses to Empty Cores: A Theory of Institutions*

The foregoing analysis implies that the combination of increasing returns, capacity constraints, and variable demand will lead to mismatches between capacity and demand that can frequently disrupt the stable and efficient functioning of a price system, even in large markets. If competition fails, the question arises, What replaces it?

Since competition is inefficient under the cost and demand conditions described above, agents have incentives to devise institutions that sufficiently and efficiently restrict the freedom to contract. Pirrong and Telser show that cartels of plants can achieve an efficient and stable equilibrium through the use of appropriate organizational techniques.[11] These techniques essentially require the cartel to act as a sort of "superfirm." By limiting the actions of individual plants in one of three ways, the superfirm can attain a Pareto optimum. First, it can set the prices that plants can charge and specify the plants that can operate. The superfirm can minimize the cost of producing the efficient level of output by allowing only the efficient set of plants to operate; the price floor ensures that these plants cover costs even if some must operate below capacity. Second, the cartel can set output quotas for each plant. Plants that produce below capacity (or do not produce at all) under an optimal plan cannot disrupt an equlibrium by attempting to operate at full capacity if the output quotas prevent them from doing so. The cartel need not set prices in this case; the correctly chosen quotas imply prices that cover variable and avoidable costs. Finally, the cartel can establish revenue quotas and set prices; this combination implies an output level for each plant. Again, the cartel can choose prices and revenue quotas to ensure efficient production and the coverage of costs.

Telser and Pirrong also show that, if a cartel attempts to set only minimum prices, it will eliminate destructive price competition but may produce inefficiently. Price floors may induce inefficient entry and lead to suboptimal capacity utilization. In particular, with indivisible costs and a variety of plant sizes and costs, setting a price that ensures that the efficient set of plants can profitably operate will frequently allow an inefficient set of plants to operate profitably as well. This often leads to excess capacity.[12]

The core model also implies that, if a cartel does not control all plants, the entry of outsiders can disrupt the efficient allocation the cartel could otherwise achieve. This implies that both buyers and sellers have an

[11] Telser, Theory of Efficient Cooperation and Competition, *supra* note 5, at ch. 5; Pirrong, *supra* note 5, at ch. 3. Other forms of institutions may also rectify empty core problems. These include monopoly, long-term contracts, and vertical integration.

[12] For a formal proof of this excess capacity result, see Pirrong, *supra* note 5, at ch. 3. Telser, A Theory of Efficient Cooperation and Competition, *supra* note 5, at 169, 176, and 180–81, demonstrates that setting prices alone will not lead to an efficient allocation of resources when indivisibilities lead to an empty core.

incentive to prevent destructive entry. Thus, the model predicts the existence of contracts tying buyers to the cartel.[13] It also predicts that buyers will tie themselves to a group of sellers even in the presence of alternative sellers. Most important, the theory implies that cartels' ability to induce customer loyalty may allow them to persist even if entry is costless. The threat of entry may prevent the cartel from earning supernormal returns, but if the cartel enhances market surplus, it has survival value.

It should be noted that in a one-period model such stable cartels cannot form if the core is empty; the emptiness of the core implies that no stable coalitions (and a cartel is simply a coalition of firms) can survive. With multiple periods, however, this difficulty can be surmounted. Producers can form cartels prior to the revelation of demand, for example, and devise allocation mechanisms like those defined above. These mechanisms specify output quotas or prices and active plants as a function of the state of demand. Once demand is realized, the cartel implements the specified solution. When the core is empty, the firms could not reach any such agreement after the realization of demand, but the feasibility of ex ante contracting raises the possibility of devising institutions that bind the future actions of agents and thereby eliminate episodes of destructive competition.[14]

This process of restricting the future actions of producers raises the specter of cheating. Indeed, given a level of demand that would produce an empty core under competitive conditions, some cartel members have an incentive to cheat on the solution specified by the allocation mechanism. Consider, for example, a quota-setting cartel that requires one firm to operate below capacity under a Pareto-optimal production plan. This plant could enhance its profit by increasing its output and selectively shading price in order to attract customers from other producers. In order to implement an allocation mechanism, then, the cartel must somehow deter these defectors. Policing and performance bonds may serve this purpose. Alternatively, the cartel can punish dissenters by cutting prices during suspected episodes of cheating. When firms expect to continue to

[13] Stephen Craig Pirrong, Long-Term Contracting and Market Equilibrium (working paper, Univ. Michigan, Grad. School of Business Administration 1989), demonstrates how long-term agreements between buyers and sellers can eliminate empty core problems and achieve a Pareto-optimal allocation of resources under many (but not all) circumstances. In general, these efficient long-term contracts do not bind a buyer to a single seller, or, if they do, they are supplemented by trade between producers in order to achieve efficient production.

[14] It is possible that the core of this ex ante bargaining game is empty as well. If this is the case, agents will not be able to negotiate these binding agreements.

produce in a market for an indefinite period of time, such threats can effectively enforce the cartel allocation mechanism.[15]

D. *Competition with Large Demanders*

The foregoing analysis depends crucially on the assumption that buyers are small relative to the capacity of active plants. On the one hand, in this case each buyer wants to purchase only a small fraction of a plant's capacity. Thus, a plant can form coalitions including many different buyers. This ability to form a large number of coalitions is what precludes the existence of an equilibrium. On the other hand, if each buyer is large relative to the capacity of plants and output is indivisible, each plant can form fewer coalitions than if buyers are small. Pirrong shows that in many instances this reduction in the number of feasible coalitions (and therefore the number of core constraints) is sufficient to generate a non-empty core. This implies that, even if producers in a market incur indivisible avoidable costs, competition is feasible if demanders are large. Thus, the model predicts the existence of competitive markets under these circumstances.[16]

To see this, consider a variant of one of the previous examples. Assume that the set of available plants is the same as before. Now assume, however, that there are only two demanders, one of whom wishes to purchase 4 units of output and another that wishes to purchase 7. Each is willing to pay 5 per unit received. Thus, the market demand curve is the same as in the first example of Section II*B*. The optimal plan requires the one buyer purchasing 4 units to buy from firm 2 and the other buyer to buy from firm 3. The following core constraints must hold (with x_1 giving the imputation of the small buyer and x_2 the imputation of the large buyer):

$$y_2 + x_1 \geq 8,$$

$$y_3 + x_2 \geq 19,$$

$$y_3 + x_1 \geq 4,$$

$$y_2 + x_2 \geq 8,$$

and

$$y_1 + y_2 + x_1 + x_2 \leq 27.$$

[15] See Lester G. Telser, A Theory of Self Enforcing Agreements, 53 J. Bus. 27 (1980), for a detailed discussion of these issues. The literature on repeated moral hazard is also pertinent in this context.

[16] Pirrong, *supra* note 5, at ch. 3.

TABLE 1

COST STRUCTURE, DEMAND STRUCTURE, AND MARKET STRUCTURE

	Demand Structure	
Costs	Finely Divisible	Indivisible
Nonhomogeneous cost curves	Competition infeasible Price wars Collusive or monopolistic market structures	Competition feasible
Subhomogeneous cost curves	Competition feasible	Competition feasible

It is readily demonstrated that the imputations $x_1 = 8$, $x_2 = 9$, $y_2 = 0$, and $y_3 = 11$ satisfy all the core constraints. Although the maximum feasible market surplus and the set of optimally active plants remain unchanged from the earlier example, the core is non-empty here. The mathematical reason for this result is that there are fewer constraints when demand is indivisible. In economic terms, this means that buyers have fewer competitive opportunities available to them. This reduction in competition is frequently sufficient to restore a competitive equilibrium.

E. *Summary and Implications*

The theory of the core predicts that the feasibility of competition depends crucially on the characteristics of cost and demand. Table 1 summarizes the relations between cost, demand, and market organization. It contains information concerning predicted market structure under various assumptions about cost and demand. Entries in the first column are relevant when demand is finely divisible, that is, when plants can contract with many buyers simultaneously. Entries in the second column relate to markets where demand is indivisible, that is, buyers are large relative to the size of plants. The first row pertains to the case where plants incur avoidable costs, while the second row refers to cases where firm costs are infinitely elastic.

Core theory implies that competition is infeasible in a market described by the intersection of the first row and first column (under the heading "Finely Divisible"). One should observe restrictions on the ability of agents to contract in these circumstances. Competition is feasible, however, in the cost and demand conditions described in the rest of the table.

One may test these predictions by examining the cost and demand structures that prevail in a given industry and comparing the industry's organization with the predictions summarized in Table 1. The following sections analyze the ocean shipping industry. I examine the cost and demand structures in this industry in order to determine the status of the core and subsequently compare the implications of these results to the actual organizations that prevail (and have prevailed in the past) in a wide variety of shipping markets. The empirical results are broadly consistent with the theory. All types of ships incur avoidable costs and have finite capacities, but demand structure varies widely among markets.

In the market where demand is divisible—the liner market—collusion has predominated since the industry's birth. Moreover, these liner cartels have consistently employed output quotas, revenue quotas, and operating restrictions. They have also offered tying contracts to demanders, and buyers have entered into such agreements in the presence of alternative suppliers. These cartels have survived despite the fact that entry into these markets is relatively easy.

Large demanders characterize most other shipping markets—revealingly called "bulk shipping" markets. Competitive bidding for shipping services occurs (and has occurred since the dawn of oceanborne commerce) in all of these markets. In some cases, long-term contracts coexist with short-term competitive contracts, but these contracts appear to be a coordinating device rather than an attempt to restore a competitive equilibrium by restricting the short-term bargaining freedom of agents.

III. Cost and Demand Structures in Liner Shipping

A. Introduction

Although the first cargo liners were sailing ships, the liner industry came into its own with the introduction of steam vessels. When steam engines became sufficiently reliable and efficient to permit a vessel to carry significant quantities of cargo in addition to the coal needed to propel it, regularly scheduled liner services proliferated. By the late nineteenth century, liners served virtually every major trade route in the world. The following evidence demonstrates that indivisible costs and divisible demand distinguish the liner sector of ocean shipping markets.

B. The Demand for Liner Shipping

The nature of demand in the liner trade is illustrated by one of the industry's early names: the packet trade. The name relates to the fact that liner vessels carried small "packets" of cargo such as mails and highly valuable commodities shipped in small lots.

Although the name went out of fashion in the nineteenth century, liner trades have always been exclusively packet trades. Britain's royal commissioners investigating the industry in the early twentieth century stated that "the cargo of a liner . . . consists of a large number of small parcels shipped by several merchants to several consignees abroad."[17] One submission to the commissioners asserted that liners operating in the Indian trade carried an average of 1,500 separate parcels on each voyage.[18] In the 1960s, a maritime economist estimated that the average liner shipment utilized between .2 percent and 5 percent of a vessel's capacity.[19] These conditions prevail today as well. No single shipper provides a significant fraction of all liner cargo on any of the major U.S. trade routes.[20]

In addition to being finely divisible, demand for liner services varies significantly over time. I use as an example the six liner markets (as defined by the U.S. Maritime Administration [MarAd], with three routes inbound to the United States and three outbound) in which the firm whose cost data is studied below operated: the volume of liner shipments in the six liner markets varied significantly over the sample period of the analysis, 1983–85. The coefficient of variation of the monthly shipments (as measured in long tons by MarAd) range from .15 on the eastbound U.S. North Atlantic–North Europe/U.K. route to .28 on the westbound leg of this route: the other four coefficients are distributed evenly between these extremes. Adjusting the shipment data for a trend only slightly reduces the measured volatility of liner shipments: the standard error of the regression of cargo tonnage versus time for these routes varies between 10 percent and 20 percent of the average shipping volume during the sample period. Thus, for the time pertaining to the cost data studied below, liner shipments in the relevant markets varied significantly. Moreover, an examination of the history of liner shipping provides sufficient qualitative evidence to infer that such variation is ubiquitous.

C. *The Costs of Liner Shipping*

The discussion in Section II*B* implies that production cost nonhomogeneities will frequently lead to empty cores when plants serve several

[17] Royal Commission on Shipping Rings, Report 13 (1909).

[18] *Id.*

[19] R. O. Goss, Studies in Maritime Economics 26 (1968).

[20] U.S. Department of Commerce, Maritime Administration, Oceanborne Commerce Statistics (1985), reports U.S. liner cargoes by commodity classification. The largest categories include catchall groups, such as "Miscellaneous Manufactured Articles," which account for only 28 percent of total liner shipments in the Pacific trades. Two categories—dominated by large shippers, automobiles, and electronic equipment—make up only 6 percent of the total liner shipments in the U.S.–Far East trades. Alcoholic beverages make up a large proportion of total shipments on the Europe–U.S. trades, but literally dozens of importers divide this trade between them. Industry sources assert that the largest shipments in the U.S.–Europe trade are only 40 TEUs, while ship capacities in this trade exceed 1,000 TEU.

customers simultaneously. Moreover, if average costs exceed marginal costs for all feasible outputs, the severity of empty core problems will not diminish with increasing market size. Competitive failure will be especially severe when capacity-constrained plants incur avoidable costs and constant marginal costs.

Heretofore there have been no published econometric or statistical analyses of liner shipping cost structures due to the unavailability of data.[21] I have collected, however, cost records for a liner operator in the North America–northern Europe trade. The data indicate that indivisibilities/nonhomogeneities pervade modern liner shipping cost structures. Moreover, the data suggest that average cost exceeds marginal cost for all outputs below capacity for at least some vessels. Furthermore, a simple linear specification of costs—an econometric version of the avoidable cost/constant marginal cost model—is very robust. The linear specification outperforms one model incorporating the possibility of increasing marginal costs (and U-shaped average costs), while another such specification is not significantly more powerful than the linear model. It is reasonable to conclude that these results hold for other markets and earlier eras as well.

The records under study relate to 266 voyages made over a 133-week period, 1983–85. One voyage per week was made on each of two basic routes: from the North Atlantic U.S. ports to North Europe and from the South Atlantic/Gulf of Mexico to the same European ports served on the northern route. There are thus 133 observations in the sample for each of the two trades.

The ships studied are full container ships. These vessels carry cargo enclosed in standard-size steel containers: most containers come in lengths of twenty and forty feet. Output is commonly measured in "twenty-foot-equivalent units" or TEUs. The TEUs of an individual container are determined by dividing its length by twenty. Each ship has a number of "slots" capable of carrying containers. The amount of cargo a ship can carry is effectively limited by the number of these slots. It can carry only a small number of additional containers strapped to the deck. For this reason, I call the number of slots on a ship its capacity.

The operator under study employed six (C class) ships of 15,872 gross registered tons (GRT) capable of carrying 932 TEUs, one (A class) ship of 15,299 GRT and 1,422 TEU, one (B class) of 15,872 GRT and 1,074 TEU, and another B class of 15,872 GRT capable of lifting 1,053 TEU.

[21] There are a plethora of cost studies of other industries, however. See, for instance, J. Johnston, Statistical Cost Analysis (1960); and Alan Walters, Production and Cost Functions, 31 Econometrica 1 (1963). Bittlingmayer, *supra* note 1, estimates the cost function for cast iron pipe in order to test core theory as well.

These vessels are slightly smaller than the median ships in the trade. All are of similar age and design.

The voyage cost records specify by category all costs incurred by a ship on a single round-trip voyage. These records do not allocate costs to each voyage leg separately: given the nature of costs, there is no obvious way of doing so. Since eastbound and westbound cargo shipments each must satisfy a vessel's capacity constraint, one must interpret the cost relations as multiproduct functions subject to two output constraints. Formally, if $C(E, W)$ is the avoidable cost of shipping E units eastbound and W units westbound and X represents vessel capacity, marginal cost pricing (which core theory predicts will occur under competition) implies revenues on a voyage cannot exceed $EC_E(E, W) + WC_W(E, W)$ for $E, W < X$. If $EC_E(E, W) + WC_W(E, W) < C(E, W)$ (where subscripts represent partial derivatives) for all such E, W, then the core will be empty if an optimal plan requires firms to operate below capacity on both legs regardless of market size. If this holds, firms will cover cost only if they operate at capacity on at least one leg of a voyage.[22]

Shipping operators traditionally divide their costs into three basic categories: capital costs, voyage costs, and cargo handling costs. Capital costs are a very significant portion of total costs but are not of direct relevance in determining the characteristic function, so I ignore them here. Voyage costs are the costs required to send a vessel on a trip between two points. These costs include fuel, the wages and subsistence for the crew, entering and docking in the various ports of call, insurance, and repairs and maintenance on the trip. Cargo costs include obtaining cargo, getting it to the vessel, loading and unloading, and transporting it to its final destination. Cargo costs also include the expense of handling empty containers. As ships commonly carry a full complement of containers (both full and empty), they must load and unload empty containers whenever the number of full containers loaded is less than capacity.

Summary statistics for the various components of cost and output for each route are presented in Table 2. Costs are measured in U.S. dollars.

[22] This is a necessary, but not sufficient, condition for firms to cover cost (and therefore for a non-empty core) given competitively determined prices. It can be easily shown that, if output equals capacity on a leg of a voyage under an optimal plan, then price equals the reservation price of the marginal customer served on this leg. Call this marginal value on route i V_i. It is possible that $(V_E + V_W)X < C(X, X)$. That is, even if firms operate at capacity, the core may be empty. This is most readily seen in a single-product model. If average cost is greater than marginal cost at capacity, then it is possible that average cost is greater than the reservation price of a marginal customer is greater than marginal cost, even if all firms operate at capacity under an optimal plan. The core is empty under these circumstances.

TABLE 2

SUMMARY STATISTICS FOR COST AND OUTPUT

Variable	Mean	Standard Deviation
A. Northern route:		
Fuel	165,744	18,865
Crew	223,137	18,576
Port	101,130	18,577
Total voyage	490,011	87,112
Handling	460,168	72,718
Commissions	228,134	30,080
Terminal	92,755	15,875
Transport	128,586	66,383
Total cargo	909,643	147,140
Output east	524	238
Output west	910	107
Total output	1,434	282
B. Southern route:		
Fuel	235,152	26,383
Crew	303,936	71,197
Port	105,646	16,044
Total voyage	644,734	90,209
Handling	293,875	38,196
Commissions	25,988	28,671
Terminal	113,890	13,003
Transport	168,191	54,338
Total cargo	601,944	82,702
Output east	748	130
Output west	954	145
Total output	1,702	188

NOTE.—Output is measured in twenty-foot-equivalent units (TEUs). Costs are measured in dollars.

The heading "Northern Route" refers to summary statistics for ships calling North Atlantic U.S. ports, while the heading "Southern Route" refers to summary statistics for those serving South Atlantic U.S. ports.

It is common in discussions of shipping costs to treat voyage costs (also called vessel costs) as avoidable and cargo costs as variable; the reasoning being that voyage costs must be incurred if the vessel makes a trip regardless of whether cargo is carried or not. Examining Table 2, this convention implies that avoidable costs make up about 35 percent of costs on the northern trade and 43 percent on the southern route.

An examination of the correlations between output and various elements of cost indicates, however, that further analysis is required to quantify the importance of avoidable costs in liner shipping. Table 3 gives

TABLE 3

CORRELATIONS BETWEEN COSTS AND OUTPUT

Variable	Correlations with Total Output
A. Northern route:	
Fuel	.68
Crew	.38
Port	.74
Total voyage	.74
Handling	.65
Commissions	.88
Terminal	−.02
Transport	.50
Total cargo	.83
Total cost	.88
Average handling	−.60
Average cargo	−.53
Average total	−.66
B. Southern route:	
Fuel	.26
Crew	.09
Port	.34
Total voyage	.20
Handling	.65
Commissions	.79
Terminal	.39
Transport	.05
Total cargo	.61
Total cost	.71
Average handling	−.28
Average cargo	−.52
Average total	−.71

NOTE.—Output is measured in twenty-foot-equivalent units (TEUs).

these correlations between output (measured in TEUs) and various elements of cost. Fuel and port costs are positively correlated with output. Moreover, average cargo and handling costs are negatively correlated with output. This suggests the existence of increasing returns for these cost categories.

In order to determine the form of the cost functions for these vessels (plants), I ran regressions on several cost specifications; two are reported here. The first is a linear model:

$$C_o = a_o + a_e Q_e + a_w Q_w + a_x Q_x + \boldsymbol{a}_d' \boldsymbol{D} + u,$$

where C_o represents a cost variable, Q_e is the amount of cargo carried eastbound, Q_w is the amount of cargo carried westbound, Q_x is the number of empty cargo containers (measured in TEUs) handled over the wharf, and $\boldsymbol{D}$ is a vector of ship-type dummy variables. The coefficient

a_o is a measure of avoidable cost elements, while a_e and a_w measure the marginal costs of shipping cargo. The vector $\boldsymbol{a_d}$ measures avoidable cost differences between the C class and non–C class ships.[23] The theory presented in Section II*B* implies that large market size will not mitigate the severity of empty core problems if this model accurately describes liner costs.

The second specification is semilogarithmic:

$$\log C_o = b_o + b_eQ_e + b_wQ_w + b_xQ_x + \boldsymbol{b_d'D} + w.$$

Marginal costs are rising under this specification and equal b_iC_o, with $i = E, W$.[24] This specification implies that average costs are U-shaped. If this model accurately describes liner costs, revenues derived from marginal cost prices will cover expenses at outputs Q_E and Q_W if $b_EQ_E + b_WQ_W > 1$. If, however, $b_EX + b_WX < 1$, where X is a ship's slot capacity, average costs will exceed marginal costs at capacity. If this is true, marginal costs are discontinuous at capacity, and, therefore, market size will not mitigate the severity of the empty core problem.

Two measures of output are used for each regression: the number of loaded TEUs carried on a voyage and the total number of containers carried on a voyage. The TEUs measure the amount of space occupied aboard ship by cargo, but it is not always true that costs vary directly with cargo cubic volume. The total number of manhours required to handle a forty-foot container, for example, is not much different from that required to handle the smaller box. Moreover, the different box sizes often carry similar weights because the larger units are mainly used to carry "measurement cargo"—high-volume, low-density items. These considerations imply that the total number of containers may be a more accurate measure of output.[25]

[23] I also estimated models including interaction terms between output and ship-type dummies to determine whether marginal costs depend on ship types. These coefficients are never statistically significant, so I do not report the results including these terms here.

[24] I also tried several other specifications of costs, including one that is quadratic in output, one that is logarithmic, and one that is quadratic in the logarithms of outputs (that is, a special case of a translog cost function). Since I cannot reject the hypothesis that the coefficients on the higher-order output terms (including an interaction term) are zero at the traditional levels of significance for all but one of the cost regressions, I do not report the results for the quadratic regression. The modified translog specification produces results concerning the minimum average cost output that are virtually identical to those reported for the semilog regressions. The logarithmic specification implies increasing returns for all cost categories for all outputs, but *F*-tests imply that one can reject the hypothesis that the coefficients of higher-order log of output terms equal zero. I therefore do not report these results either.

[25] The method of calculating the number of empty containers handled requires the use of TEU figures rather than total container figures for all regressions.

This discussion of output data suggests that both containers and TEUs are noisy measures of true output. This raises the possibility of an errors-in-variables problem. As a consequence, ordinary least squares (OLS) coefficients may be biased and inconsistent. I therefore use instrumental variable techniques to obtain parameter estimates for the cost equations.

There is another technical issue to be addressed: whether output is truly exogenous as the specifications outlined above assume. If the firm studied here responded to shocks in costs by adjusting price (or by adjusting output directly), the error term would be correlated with the independent variables. It is unlikely that this is a serious concern here. The carrier obtained output a considerable period in advance of actual shipment. Given that many of the factors that affect costs (for example, weather, breakdowns, and loading delays) are unobserved and unpredictable at the time that cargo is secured, the operator could not respond to them when making output and pricing decisions. Output is thus almost certainly unrelated to these shocks.

Table 4 presents output for the linear total cost instrumental variable regressions. (Total costs are defined as the sum of handling, sales commission, fuel, and port costs.) These regressions correct for residual autocorrelation (which follows a fourth-order autoregressive process) using an iterative filtering technique and use the lead of each relevant output variable as their instrument.[26]

These results demonstrate the importance of avoidable costs in liner shipping. They indicate that ships of the C class on the northern route incur an avoidable cost of \$270,000–\$275,000, while those of that class on the southern route pay an avoidable cost of \$290,000–\$380,000. The positive ship-type dummies indicate that the larger ships incur somewhat larger avoidable costs.

Similar results hold for semilog total cost regressions. Table 5 reports the relevant output. The point estimates of the output coefficients from the regressions using TEUs as the output measure imply that $EC_E(E, W) + WC_W(E, W) < C(E, W)$ for all outputs $E, W < X$ on each route for each of the three types of vessels. Although the semilog regressions using containers as the output measure imply that, if the largest ship carried only twenty-foot containers, its marginal costs would modestly exceed its average costs at capacity; given the usual mixture of container lengths, this is not particularly relevant. On average, the number of containers

[26] The use of the lead of an independent variable as an instrument is appropriate when measurement errors are serially independent. See G. S. Maddala, Econometrics (1981), for a discussion of this topic. See, also, note 28 *infra* for a discussion of the performance of this instrument.

TABLE 4

INSTRUMENTAL VARIABLE TOTAL COST REGRESSIONS

Independent Variable	Northern Route: TEU Regression	Northern Route: Container Regression	Southern Route: TEU Regression	Southern Route: Container Regression
CONSTANT	275,015	270,993	291,169	379,577
	(2.11)	(2.01)	(1.71)	(2.37)
EMPTY	53.81	63.65	115.08	68.65
	(.68)	(.41)	(1.28)	(1.00)
ETEU	392.99	. . .	402.99	. . .
	(1.88)		(1.77)	
ECON	. . .	480.00	. . .	542.10
		(2.04)		(1.47)
WTEU	275.74	. . .	241.10	. . .
	(1.47)		(2.57)	
WCON	. . .	509.20	. . .	522.71
		(2.52)		(3.06)
DA	31,965	33,175	61,327	56,909
	(1.98)	(1.98)	(1.90)	(1.58)
DJ	45,046	44,006	35,401	42,087
	(1.54)	(1.65)	(1.99)	(2.75)
DF	23,315	22,305	46,220	38,301
	(2.01)	(1.92)	(3.45)	(2.63)
R^2	.631	.639	.734	.755

NOTE.—*t*-statistics are in parentheses. Explanation of variables: EMPTY = number of empty containers; ETEU = eastbound twenty-foot-equivalent units; WTEU = westbound twenty-foot-equivalent units; ECONT = eastbound containers; WCONT = westbound containers.

carried equals .7 times the number of TEUs carried, and marginal costs do not exceed average costs in the regressions using containers when the number of containers carried equals .7 times rated capacity. Moreover, if the ships studied had charged marginal cost prices on each voyage included in the sample, given the observed outputs and point estimates of marginal cost, revenues would have averaged about 60 percent of voyage and cargo costs on the northern route and about 70 percent on the southern route. Moreover, they would have exceeded these revenues on each of the 266 voyages.[27]

These results demonstrate the importance of indivisibilities in liner shipping costs. Two facts stand out. First, the simple linear specification

[27] This is not a competitive route, so capacity utilization is probably lower than it would be under competition, and so one must interpret these last results with care. The fact that the minimum average cost point is about 1,500 containers in each direction implies, however, that it is highly unlikely that revenues in a competitive regime would cover voyage and cargo costs, let alone capital costs.

TABLE 5

INSTRUMENTAL VARIABLE LOG (Total Cost) REGRESSION

Independent Variable	Northern Route: TEU Regression	Northern Route: Container Regression	Southern Route: TEU Regression	Southern Route: Container Regression
CONSTANT	12.98	12.91	13.26	13.14
	(81.89)	(92.27)	(72.67)	(73.92)
EMPTY	5.27E−5	5.00E−5	3.62E−5	5.00E−5
	(1.33)	(1.03)	(.10)	(.67)
ETEU	3.96E−4	. . .	3.26E−4	. . .
	(1.69)		(.911)	
ECON	. . .	4.93E−4	. . .	5.36E−4
		(1.88)		(1.29)
WTEU	3.76E−4	. . .	3.90E−4	. . .
	(1.95)			(4.34)
WCON	. . .	6.49E−4	. . .	6.37E−4
		(3.14)		(3.31)
DA	2.75E−2	2.67E−2	5.75E−2	5.74E−2
	(.83)	(.77)	(.36)	(1.42)
DJ	2.94E−2	3.02E−2	4.90E−2	5.10E−2
	(.96)	(1.08)	(.75)	(3.02)
DF	1.67E−2	1.72E−2	3.81E−2	4.02E−2
	(.71)	(.70)	(1.06)	(2.46)
R^2	.634	.653	.720	.748

NOTE.—*t*-statistics are in parentheses. See Table 4 for an explanation of variables.

performs very well. One cannot reject the hypothesis that higher-order output terms are zero with a high degree of confidence, particularly for the southern regressions. Furthermore, given the fact that the R^2s for the linear specifications are approximately equal to the R^2s for the semilog specifications (and are higher in some cases), one cannot reject the possibility that the avoidable-cost model (in which marginal costs are discontinuous at capacity) effectively describes shipping costs.[28] Second, for a

[28] Previous versions of this article included separate regression results for the various components of total cost. The constants in the OLS regressions for northern handling costs and northern and southern commissions costs are positive and significant. Given that these services are obtained on a per-unit-shipped basis, this is puzzling and probably due to the errors-in-variables problem. Indeed, instrumental variables regression constants for these cost categories (not reported) are far closer to zero than the OLS coefficients, which is consistent with this interpretation. This correspondence between the estimated coefficients and a priori beliefs about cost structures gives me some confidence, moreover, that the instrument employed is uncorrelated with the measurement error. The instrumental variables approach does not lead to any appreciable change in the coefficients in the fuel and port-cost regressions. This implies that either the errors in variables problem are not as severe here or the instrument is correlated with the error for these cost categories. Given the relatively good performance of the instrument in the cargo-cost regressions, however, this last possibility seems remote.

specification that admits the possibility of decreasing returns, the data strongly reflect increasing returns over virtually the entire relevant range of outputs.[29] These two findings strongly suggest that increasing market size will not mitigate empty core problems in liner shipping markets, as they are consistent with the notion that marginal costs are below average cost and discontinuous at ship capacity.

These regression results illustrate the importance of nonhomogeneities in liner costs and imply that competition between individual ships for cargo is infeasible. Moreover, I conjecture that these cost conditions would lead to findings of "economies of density" in a cross-sectional study of cost across liner firms that would be similar to those found for railways by Friedlander and Spady and airlines by Caves, Christensen, and Tretheway.[30] In other words, given a set of ships and other capital utilized by a line and a schedule/network, costs fall as throughput (in TEUs or tons) rises.

A different interpretation of the core model outlined above implies that these density economies make competitive pricing infeasible in liner markets.[31] If several firms compete by offering scheduled services on a route, they have an incentive to cut the price to marginal cost in the face of excess capacity: excess capacity will occur periodically due to variations in demand. The existence of economies of density in turn implies that these prices will be too low to cover the costs of operating an efficient set of schedules. The core is again empty.[32]

[29] The translog specification produces results similar to those generated by the semilog specification. The translog regressions imply that there are decreasing costs for all cost categories for all outputs below the capacities of all vessels on the Southern route, while the minimum average cost point for the Northern route approximately equals the capacity of the A class vessel: costs are falling at outputs less than 1,450 TEU in each direction on this route.

[30] Ann F. Friedlaender & Richard H. Spady, Freight Transport Regulation: Equity, Efficiency, and Competition in the Rail and Trucking Industries (1981); Douglas W. Caves, Laurits R. Christensen, & Michael W. Tretheway, Economies of Density versus Economies of Scale: Why Trunk and Local Service Airline Costs Differ, 15 Rand J. Econ. 471 (1984).

[31] As long as economies of scale in firm, route, or network size do not produce a Marshallian natural monopoly. Under these circumstances the core is not empty. Stephen Craig Pirrong, Market Equilibrium When Costs Vary with the Duration of Production Runs (working paper, Univ. Michigan, Grad. School of Business Administration 1989), studies this type of model in detail and arrives at much the same conclusion as the model outlined in Section II above: in an intertemporal model, where there are cost components that vary with capacity but not with output, the core is frequently empty.

[32] This model implicitly assumes that cost functions at time t are independent of actions taken at times $t' < t$. This assumption does not hold if firms must incur costs to startup and shutdown operations or if firms can hold inventory. Under these circumstances, marginal cost pricing at t may not induce chaos at that time, as firms may choose to "weather the storm" and produce at a loss rather than shut down and incur shutdown and startup costs when demand rebounds. Given such intertemporal linkages in costs, the feasibility of competition depends on the relative duration of low-demand and high-demand periods. See

It is important to note that, if a schedule on a route (rather than a single voyage) is the relevant unit of analysis, then the costs of establishing such a network—payments to crews and the opportunity cost of ship and terminal capital, for example—will almost certainly lead to more pronounced density economies than those attributable to the cost elements analyzed here. These costs are part of the avoidable cost of establishing a schedule on a route. This makes the existence of a core even more unlikely.

Thus, regardless of whether one considers competition between individual vessels (where the variable cost elements quantified here are relevant) or between schedules of ships operated by several firms (where the costs of establishing a scheduled service are also important), the cost conditions found here combined with the demand conditions described above are inconsistent with competitive institutions for markets of all sizes. The core is empty under these cost and demand structures. Thus, some sort of restriction on contracting—such as a cartel—is required in the liner shipping market. An examination of the history of liner shipping reveals that collusion has been almost the sole form of organization since its commencement in the mid-nineteenth century.

IV. The Organization of Liner Markets

Given the cost and demand structures described above, the theory of the core implies that competition is infeasible in the liner sector and agents have the incentive to formulate alternative economic organizations in order to achieve an efficient allocation of resources. One such organization is a cartel.

The earliest suppliers of liner shipping—the pioneering sail packet lines such as Black Ball, Black X, and Morgan—did not cooperate with one another. At first blush this would seem to contradict the predictions of core theory, but there are mitigating circumstances. First, in certain cases the packet lines operated under long-term contracts with various national postal authorities. Moreover, the small size of the packets and the high demand for their quick, reliable, regularly scheduled passenger and freight services meant that the packets seldom sailed less than full. Continuous full-capacity operation would significantly reduce the need to cooperate because the core is frequently not empty in this case.[33]

Stephen Craig Pirrong, Equilibrium in Markets Where Costs Depend on the Duration of Production Runs (working paper, Univ. Michigan, Grad. School of Business Administration 1989).

[33] See Richard C. McKay, South Street: A Maritime History of New York (1969); and Charles E. Fayle, A Short History of the World's Shipping Industry (1933), for the history of the sailing packets.

No such ambiguity clouds the history of the organization of steam packet/liner markets. An examination of this history reveals that competition between rival lines in a given market has inevitably given way to cooperative forms of organization. In most of these episodes, the operators claimed that competition between lines invariably led to low prices and crippling financial losses. Unable to withstand the costs of these rate wars, independent liner firms seized on the shipping conference—a cartel of liner firms that sets shipping rates (as well as capacity: see below)—as the panacea.[34]

The liner conference system followed the development of the liner trade. After pioneering attempts in the 1850s, the liner operators established a conference on the New York–Liverpool and New York–Glasgow routes in 1869. Conferences were formed on the India–Europe trade in 1875, the Far East–Europe trade in 1885, the Australia–Europe route in 1884, the entire U.S.–Europe trade in 1892, the various Europe–South America trades in 1895, 1896, and 1906, the U.S.–South America trades in 1895 and 1901, the Europe–South Africa trade in 1893, the U.S.–Australia trade between 1899 and 1909, the U.S.–Far East trade in 1904, and the U.S.–Africa trades shortly after the turn of the century.[35] By the beginning of the twentieth century's second decade, conferences existed on all major liner shipping markets.

Conferences are not simply historical artifacts. The history of collusion between liner operators extends without serious interruptions (excepting the world wars) to the present. As of 1973, 360 conferences operated in international liner trades. The number has fallen recently due to the merger of some conferences serving parallel trades, but today 301 conferences exist in markets incorporating 139 different zones of origin and destination.[36]

[34] See Paul Gottheil, Historical Development of Steamship Agreements and Conferences in the American Foreign Trade, 55 Annals 48 (1914); S. S. Huebner [Foundation], Steamship Line Agreements and Affiliations in the American Foreign and Domestic Trade, 55 Annals 75 (1914); and the U.S. House of Representatives, Committee on Merchant Marine and Fisheries, Steamship Agreements, Vols. 1–3 (1913) (the Alexander Committee Report and Hearings), for the histories of conference development in various American trades. Royal Commission on Shipping Rings, *supra* note 17, at 1–23; and Brian M. Deakin & Thelma Seward, Shipping Conferences: A Study of their Origins, Development, and Economic Practices 23–28, 36–42 (1977), provide similar information for the major European trades.

[35] 1 U.S. House of Representatives, *supra* note 34; Deakin & Seward, *supra* note 34, at 48–75; Royal Commission on Shipping Rings, *supra* note 17, at 12–23; Gottheil, *supra* note 34, at 48–75; and Christopher von Schirach-Szmigiel, Liner Shipping and General Cargo Transport 18–20 (1979). Domestic U.S. routes were either cartelized or monopolized prior to the passage of the Interstate Commerce Commission Act. This act regulated domestic shipping rates and therefore vitiated the need for a conference.

[36] Croner's Directory of Freight Conferences (1986).

This ubiquity of liner conferences is strongly consistent with the theory of the core. It is important to note, moreover, the very broad diversity of the cartelized trades. In particular, the incidence of collusion is completely unrelated to market size: conferences exist in both "thin" and "thick" markets. This is consistent with the cost data analyzed above, which exhibit the marginal cost discontinuities, and the theory presented above, which demonstrates that these discontinuities can lead to empty cores even in large markets.

Table 6 illustrates this point. For each of several container liner trade routes, the table lists the total number of voyages made per month in 1980. The trades range in size from 52 voyages per month on the U.S. West Coast–Japan trade to 2 voyages per month on the various U.S. and Australasia and U.S. West Coast–Mediterranean routes.[37]

One may argue that the broad markets listed in Table 6 are not relevant economic markets and that "port pairs" of origin and destination are more accurate representations of these markets. This is suspect for two reasons. First, liners do not transit exclusively between two ports on a single voyage. Instead, they service port ranges. As a consequence, a liner may stop at New York, Boston, Philadelphia, Norfolk, London, Le Havre (France), Rotterdam, and Hamburg on a single voyage. Since most liners serving a given geographic area call each of the major ports in that area, the number of voyages between any two such ports in the U.S. East Coast and northern Europe ("North American East Coast–Northern Europe" in Table 6) will be only slightly smaller than the total number of voyages between those two large geographic port ranges. That is, if one believes that port pairs are the relevant market, the figures reported in Table 6 only modestly overstate the number of voyages between major port pairs in the markets listed.

Moreover, in the modern age of intermodal transport (that is, where cargo is transported on both ship and railroad and sometimes truck), it is doubtful that a port pair is a relevant market. A large fraction of cargo shipped on container vessels originates in or is destined for internal points

[37] Sidney Gilman, The Competitive Dynamics of Container Shipping, at ch. 1 (1983); and Roy Pearson & John Fossey, World Deep Sea Container Shipping: A Geographical, Economic, and Statistical Analysis, at ch. 1 (1983). Note that Sjostrom, *supra* note 1, finds evidence from some U.S. trades that market shares are lower for conferences in large markets. He interprets this to be consistent with the conjecture that empty core problems are less severe in large markets. This depends on the assumption that conference market share measures the severity of empty core problems. He asserts such a relationship but provides no theoretical justification for it. Indeed, since his evidence is cross sectional, and since the core is either empty at a point in time or not, it is difficult to rationalize this assertion.

TABLE 6

MONTHLY VOYAGES ON LINER ROUTES DURING 1980

Route	Voyages per Month
U.S. West Coast–Japan	52
U.S. West Coast–Far East	40
U.S. East Coast–Northern Europe	36
U.S. East Coast–Japan	18
Northern Europe–Far East	18
Northern Europe–Japan	16
United Kingdom–Far East	16
U.S. East Coast–Far East	14
United Kingdom–Japan	14
United Kingdom–Eastern Mediterranean	11
Northern Europe–Eastern Mediterranean	10
Mediterranean–Far East	10
Northern Europe–Arab Gulf	9
U.S. Gulf Coast–Northern Europe	8
U.S. East Coast–Mediterranean	8
United Kingdom–Arab Gulf	8
Europe–Western Africa	7
Europe–Australasia	5
U.S. East Coast–Australasia	5
Far East–Australasia	4
Europe–Southern Africa	4
U.S. Gulf Coast–Australasia	2
U.S. West Coast–Mediterranean	2
U.S. West Coast–Australasia	2

SOURCE.—Roy Pearson and John Fossey, World Deep Sea Container Shipping 2 (1980).

(for example, shipments from Chicago to Frankfurt, Germany). Given the nature of inland container transport via rail or truck, a shipper in Chicago can economically route his cargo through several U.S. or European ports. Thus, Norfolk competes directly with New York, and Rotterdam with Bremen or Hamburg for intermodal cargoes. Defining a liner market as a pair of ports served by liners is thus obviously too narrow. This suggests that the broader ranges reported in Table 6 are more realistic representations of markets than the narrow city-pair definition.

There is economic content to these observations: if the relevant market is the city pair, one would expect to see conferences regulating city-pair markets. If the relevant market is the port range and interior points, one would expect to see conferences regulating these ranges and interior points. The "narrower" conferences prevailed in the precontainer era, but in the container era—where intermodal transport is economical—the "broader" conference dominates.

The universality of conferences is not the only feature of liner shipping markets that is consistent with the theory of the core. Conferences also have consistently utilized output and capacity restrictions in addition to cooperative pricing. These restrictions have been of four basic types. First—and rarest—is the cargo tonnage quota. Under this system, the conference allocates tonnage carriage rights to member firms. Second, conferences have widely utilized revenue and profit pools of various sorts. Under these systems, conference members allocate some fraction of revenues among themselves according to agreed-on percentages. In certain cases, all revenues are pooled; in other cases, lines pay revenues net of marginal costs (usually handling costs) into the common pool. Revenue-pooling conferences invariably set a common price schedule that all conference members must adhere to. Third, conferences commonly assign sailing rights to members. These rights usually specify the number of sailings a given line can offer in a year; they often restrict the ports of call of the member lines as well. In many cases, these port-right assignments give lines exclusive rights to serve certain ports. The final form of organization is the conference consortium, which is of recent origin. In this system, the consortium acts as a "superfirm"; individual member lines remain responsible for the operation of their vessels, but they make cooperative decisions regarding schedules, the allocation of cargo and revenues, and, in certain cases, vessel design. Moreover, some (but not all) consortia market the liner services on behalf of the member lines.[38]

Table 7 lists the output/capacity-setting policies of major conferences for three eras: pre-1914, 1945–70, and 1970–86. These figures indicate that a substantial fraction of conferences have employed these policies. All conferences on the major European trades utilized one form of output or capacity constraint during each period in question. Conferences serving fourteen American trades before the passage of the 1916 Shipping Act also allocated output, revenues, or capacity cooperatively. Conferences in the American trades have not engaged in these practices extensively since the passage of the 1916 act, probably due to regulatory restrictions imposed by this legislation. Recent liberalization of rules regarding joint services in the 1984 Shipping Act, however, have led to the creation of a considerable number of service consortia in the U.S. trades.

[38] See Royal Commission on Shipping Rings, *supra* note 17, at 12–23; Deakin & Seward, *supra* note 34, at 27 and 42; U.S. House of Representatives Committee, *supra* note 34; 1 *id.* at 27, 66, and 79–81; 3 *id.* at 1375–87; W. G. Sickel, Pooling Agreements, 55 Annals 144 (1914); U.N. Conference on Trade and Development, The Liner Conference System (1970); U.N. Conference on Trade and Development, Liner Shipping in India's Overseas Trade (1967); and Pirrong, *supra* note 5, at ch. 7, for histories and descriptions of various output and capacity setting agreements.

Conference members have routinely stated that the objective of these output and capacity restrictions is to ensure efficient operations. Although it may be a predictable response of colluding firms to criticism of cartel behavior, this explanation is consistent with the theory of the core. Moreover, there is some evidence that liner conferences that "rationalize" through the use of these restrictions do indeed operate more efficiently than conferences that do not. This evidence is presented in Table 8; it shows that "rationalized" conferences utilized larger fractions of their capacity than nonrationalized conferences in each year from 1979 through 1984.[39] Over the entire period, rationalized conferences utilized capacity at an average rate of 86 percent, while unrationalized ones achieved a utilization rate of only 65 percent. This is consistent with the predictions discussed in Section II*C* above.

The interaction between liner conferences and entrants is also consistent with the theory of the core. The theory predicts that, since conferences have survival value in industries with cost and demand characteristics like those found in liner shipping, they should persist even in the face of competition from entrants. The theory also implies that, since entry can disrupt the conferences' ability to achieve an efficient level of service, conferences and their customers should enter into exclusive service contracts. The evidence supports both predictions.

Liner markets offer few shelters from potential entrants. This is primarily due to the nature of the industry's technology. Shipping tonnage is obviously mobile, and it is very nonspecific: a given ship can efficiently serve a wide variety of liner markets.[40] Moreover, the existence of liquid ship rental and resale markets permits the acquisition and disposal of tonnage without sunk costs. Furthermore, an entrant can obtain most other inputs, such as cargo handling, terminal and port facilities, and marketing services, without precommitting substantial resources.

The ability to enter without making irreversible investments suggests that entry should occur in response to profit opportunities. The history of liner shipping is replete with examples of such entry. Both "hit-and-run" and permanent entrants have dogged conferences throughout their existence. Despite this entry, the conferences have survived; until very recently, they routinely carried upward of 80 percent of liner trade cargoes. This is strongly consistent with the theory of the core.

It is difficult to reconcile this conference durability with more tradi-

[39] Pirrong, *supra* note 5, at ch. 7, analyzes this issue in more detail.

[40] In the precontainer era, ships could serve both liner and bulk markets. Today, the economics of ship operating make some vessels unsuitable for certain trades due to their size and differences in the cargo handling equipment employed in various ports.

TABLE 7

CONFERENCE QUOTA AND CAPACITY-SETTING POLICIES

	Policy Type			
Conference	Sailing, Port, or Output or Revenue Quota	Capacity Restriction	Joint Service Consortium	No Policy
A. Pre-1914:				
Northern Europe–United States (Passenger)	X			
Northern Europe–United States (Cargo)	Westbound	Eastbound		
United Kingdom–United States (Passenger)	X			
United Kingdom–United States (Cargo)				X
Baltic–United States	X			
Mediterranean–United States (Passenger)	X			
Mediterranean–United States (Cargo)	X			
United States–West Africa	X			
United States–East Africa	X			
United States–South Africa	X			
United States–Australia	X			
New York–India			X	
U.S. West Coast–Calcutta	X			
New York–Far East	X	X		
U.S. West Coast–Far East				X
United States–Brazil		X		
United States–River Plate–Central America	X			
United States–Haiti	X			
Europe–India	X	X		
Europe–Far East	X			

Europe–Australia	X			
Europe–South Africa	X	X		
Europe–East Coast South America	X			
Europe–West Coast South America	X			
Total: 24 conferences				
Number of agreements: 22 (91.75% of all conferences)				
B. 1945–70:*				
Europe–India	X	X		
Europe–Far East	X			
Europe–Australasia	X		X	
Far East–Australasia	X			
Europe–South Africa		X		
Europe–East Coast South America	X			
Europe–West Coast South America	X			
C. 1970–87:*				
Europe–India				X
Europe–Far East	X			
Europe–Australasia	X		X	
Far East–Australasia	X			
Europe–South Africa		X	X	
Europe–East Coast South America	X		X	
Europe–West Coast South America	X		X	
Europe–East Africa			X	
Europe–Indian Ocean			X	
Europe–Central America	X		X	
Europe–Caribbean			X	
Far East–South Africa	X		X	

NOTE.—As a result of the recent liberalization of U.S. law, conferences serving the two most important routes in the American trades—the U.S.–Europe and the U.S.–Far East routes—have implemented capacity agreements in 1992 and 1990, respectively.

* Lines in the American trades did not utilize output, sailing, or capacity restrictions during this period, with the exception of Japanese lines serving their homeland and North America, and lines participating in cargo-sharing agreements negotiated with South American national lines.

TABLE 8

AVERAGE CAPACITY UTILIZATION ON MAJOR LINER TRADES

	YEAR						AVERAGE,
	1979	1980	1981	1982	1983	1984	1979–84
A. Conferences using output or capacity restrictions*	.89	.89	.87	.83	.85	.85	.86
B. Conferences not using output or capacity restrictions†	.65	.66	.65	.61	.66	.66	.65

SOURCES.—For panels A and B: Proprietary data obtained by author from liner operators, and Containerisation International Yearbook (1979–84); for panel B: U.S. Department of Commerce, Maritime Administration, Containerized Cargo Statistics (1985).

* Routes included Europe–Far East, Japan–Mediterranean, Japan–Arab Gulf, Japan–Red Sea, Japan–Australasia, Far East–Australasia, Far East–South Africa, Europe–Australasia, Europe–South Africa, Europe–Central America.

† Routes included Europe–U.S. East Coast, Far East–North America, Europe–U.S. West Coast, North America–Mediterranean/Middle East.

tional interpretations of the goals of collusion. Although there is no single, accepted statement of the received theory of collusion, the ability of cartels to survive the constant pressure of entry is clearly at odds with the view of cartels as inefficient monopolizers. If conferences raise prices above the level that covers the costs of offering the efficient level of service, and if entry can occur easily, entrants will quickly appear to take advantage of the profit opportunity thus offered. Simply accepting the newcomers into the conference will not solve the problem. As long as the conference attempts to raise prices above the level that generates normal profits for the efficient set of vessels, new firms will enter profitably. Unrestricted entry implies that colluders will earn only normal profits: So why collude in the first place? Core theory answers that riddle: collusion is an efficient response to competitive chaos.

Loyalty agreements have been a ubiquitous feature of liner conferences since their introduction by the Calcutta Conference in 1877: this is also consistent with the predictions of core theory. The Far Eastern Conference introduced the system in 1885, and the Australian Conference used these contracts from the beginning of its operations. The South African Conference started to offer loyalty contracts sometime prior to 1892. By the time of the Royal Commission investigations in 1908, over sixty-three conferences serving the United Kingdom utilized loyalty agreements. About the same time, twenty-three of 110 American conferences offered loyalty agreements.[41] Many of the conferences that did not employ a

[41] U.S. House of Representatives, *supra* note 34, at 436; U.S. House of Representatives, Committee on Merchant Marine and Fisheries, The Ocean Freight Industry, 307–8, 930 (1958); Deakin & Seward, *supra* note 34, at 225–48; Royal Commission on Shipping Rings, *supra* note 17, at 3–11; Daniel Marx, International Shipping Cartels (1953).

loyalty fee served passenger trades where such agreements were infeasible. (Liner conferences, however, did attempt to secure the loyalty of passenger agents booking passages.) By 1960, sixty-three of 100 conferences serving the United States offered tying contracts. In 1971, all of the thirty-one conferences connecting Australia, the Indian subcontinent, and the Far East to Europe used loyalty ties.[42] Virtually all conferences outside of the U.S. trades currently offer various forms of tying contracts.

Liner conferences typically have offered three types of loyalty tie. The first is the deferred rebate agreement. Under this form of contract, the shipper agrees to ship aboard conference vessels exclusively and pays the full conference tariff. Provided the shipper has indeed remained loyal during a specified period of time, the conference pays the shipper a specified fraction of the freight paid during the first half of the period. This system allows the conference to collect on a continuous basis a performance bond to insure shipper loyalty.

The second form of loyalty agreement is the immediate rebate contract system. Under this system, a shipper signs a legally binding contract obligating him to ship aboard conference vessels exclusively. In return for this promise, and provided the shipper has remained loyal during the recent contract period, the conference offers the shipper a certain percentage discount from the tariff rates.

The third system—the dual-rate contract—is similar to the immediate rebate contract. Under this system, the loyal shipper pays a discounted rate and is contractually liable for proven breaches.

The prevalence of these contracts is indirect evidence of the ease of entry into liner markets. Moreover, in a large number of instances, conferences have successfully introduced these loyalty agreements in the face of nonconference competition.[43]

In summary, the organization of liner shipping markets is consistent with the predictions of core theory. Liner markets have always been organized collusively. Moreover, these shipping cartels have extensively utilized output and capacity restrictions and loyalty contracts. Most important, conferences have persisted despite the lack of significant entry barriers. The following section demonstrates that the theory effectively explains the organization of the other major ocean shipping markets as well.

V. The Organization of Bulk Shipping Markets

As their names suggest, the primary distinction between packet (liner) and bulk shipping markets is the size of cargo consignments offered by

[42] Deakin & Seward, *supra* note 34, at app. 1.

[43] See Pirrong, *supra* note 5, at ch. 8, for histories of these incidents.

demanders. While the consumers of liner services utilize small fractions of vessel space, bulk shippers control quantities of cargo sufficient to fill entire ships. The structural differences between these markets are as marked as the differences in the size of cargo lots; while liner markets are exclusively collusive, competitive institutions flourish in bulk markets. This contrast is consistent with the predictions of core theory.

This correlation between competitive market structure and demand structure dates back to the earliest epoch of oceanborne commerce. Virtually all of the basic forms of competitive shipping contract were developed in the classical era. The Mediterranean merchants of this period traveled from port to port in search of markets to purchase and sell their wares. Some merchants owned their vessels, while others hired them from vessel owners on contracts commonly called "charters." Some charters granted control of the vessel for a specified period of time, while others allowed the merchant to utilize the vessel on a single voyage between a specified set of ports. Charterers obtained the services of complete vessels under these agreements. Moreover, shippers and ship owners arrived at these agreements through competitive negotiations.

Ship owners and shippers refined the basic forms of ship charter as the age of sail progressed into the nineteenth century. Moreover, as the volume of commerce expanded, sophisticated centralized competitive markets for shipping services were established throughout western Europe. As in the classical era, buyers obtained the services of entire ships through these competitive exchanges.[44]

This relation between cargo consignment size and market structure persists today. Shippers of coal, iron ore, grain, petroleum, lumber, sugar, fertilizers, cement, wood chips, automobiles, heavy machinery, plants and equipment, oil rigs, vessels for salvage and scrap, and bauxite/alumina demand large quantities of shipping space; they regularly supply these goods in quantities sufficient to fill several vessels in a month's time. Demanders in each of these markets can obtain the tonnage required to transport their cargoes by chartering complete vessels on well-organized competitive shipping exchanges in London, New York, Tokyo, Piraiévs (Greece), Oslo, and elsewhere; here, brokers representing ship owners and ship users exchange bids and offers for the services of ocean-going bulk carriers in much the same way as stockbrokers or commodity traders negotiate financial transactions.[45]

[44] See Fayle, *supra* note 33, for the history of the development of bulk shipping contracts.

[45] See various issues of H. P. Drewry, Studies in Shipping, for descriptions of shipping market organization for these and other bulk commodities.

This correlation between competition and the size of demanders corresponds to the predictions of core theory; since demanders can fill an entire vessel, ship owners have no incentive to cut prices to the marginal cost of a ton of cargo to add marginal customers. There is no indivisibility problem simply because the capacity of a bulk carrier—unlike that of the liner—need not be divided among many shippers (at a given point in time) in order to satisfy demand efficiently at that point in time.

Although shippers of all the commodities enumerated above obtain shipping tonnage on competitive exchanges, they also rely extensively on long-term contracts to secure their shipping needs for some goods. Since long-term contracts can be a means of addressing an empty core problem, the existence of these contracts seems to contradict the core model presented here.

There are two objections to this interpretation. First, there are no obvious differences in cost and demand conditions between bulk markets that would lead to empty cores in some, but not others. Second, spot and long-term contracting coexist in markets for a particular commodity: long-term deals dominate in some sectors, but spot trades are not uncommon in these sectors.

There are differences in transaction costs, however, that would lead to different contracting practices in the various bulk markets. An examination of these markets' characteristics reveals that long-term contracting is the predominant form of organization when shippers require continuous flows of a good, when the sources of supply of this good are specialized to the shipper, and when inventories are expensive. In these circumstances, even a brief disruption of cargo flows is very costly. Moreover, the specialization of supply sources reduces the shipper's flexibility in responding to these disruptions. Spot contracts prevail where these considerations are of lesser importance. Since a long-term contract can serve as a coordinating device that reduces the probability of supply disruptions, these differences between bulk markets can explain the differences in contracting practices.

The coking coal and iron ore shipping markets provide an illustration of the relevance of these factors. Demanders of these inputs usually obtain them from either integrated mines or from particular mines under long-term contracts. Spot markets for these inputs are not well developed, making it difficult for demanders to obtain alternative supplies on short notice. Inventories of these materials are costly to hold, and specialized capital must remain idle without sufficient input supplies. Production of goods utilizing these inputs takes place continuously. A continuous flow of these inputs is therefore essential to demanders. They utilize long-term contracts with shippers in order to coordinate the flows of these inputs from the mines to the mills and power plants.[46]

The existence of a wide variety of alternative cargo sources reduces the probability of supply disruption and thus the need for coordination between shippers and ship owners. Moreover, idiosyncratic cargo flows increase the need for flexibility in shipping arrangements. When these conditions prevail, one would expect shippers to rely on short-term shipping contracts.

This is indeed the case. Grain and oil shippers, each of whom has access to a wide variety of supply sources, rely on voyage and short-term time charter contracts for shipping services. Long-term agreements are relatively rare here. Similarly, short-term contracts are the rule in markets where cargo flows are highly variable, such as the grain and the salvage towing markets.[47]

In summary, competitive markets for the services of entire vessels have existed since the earliest days of ocean commerce. This is consistent with the core model outlined above. Although collusion among shippers has never survived in shipping markets where demanders supply cargo in ship-sized lots, long-term contracts have become common in certain bulk shipping submarkets. These contracts do not appear to be a response to "destructive competition," however; instead, these contracts serve as a coordinating device in markets where temporary disruptions in shipping supply are very costly and cargo flows are relatively stable.

VI. Summary and Conclusions

The theory and evidence outlined above coincide closely. Core theory predicts that cost and demand structures are important determinants of market structure. In the case of liner shipping, which is characterized by indivisible "avoidable" costs and divisible demand, the theory predicts that competition is inefficient and should not be observed. Instead, one would encounter output-setting cartels that persist despite the ease of entry into liner markets. This has indeed been the case since the birth of the liner sector in the mid-nineteenth century. In the case of the bulk shipping industry, which is characterized by demanders that supply cargo in ship-sized lots, it is consistent with the theory to observe competitive exchange of the services of whole vessels. Such competitive markets

[46] See *id.* at nos. 78, 79, 112, and 132, for descriptions of the contracting practices in these markets.

[47] See *id.* at nos. 53, 63, 98, 112, 132, and 133, for descriptions of the structure of shipping contracts in these markets.

have existed since the earliest age of oceanborne commerce and continue to flourish to this day. Although some sectors of the bulk shipping market rely more on long-term contracts than spot competitive exchange, this is due to transaction cost considerations rather than empty core problems.

The results of this article are consistent with those found in other empirical case studies of core theory, including Bittlingmayer's study of the Addyston Pipe case and Sjostrom's study of liner conferences. In particular, this work complements that of Sjostrom, as his work and this article test different implications of the model on the same industry over different time periods and markets yet arrive at similar conclusions.

In summary, a core-based model effectively explains the incidence of collusion and competition in ocean shipping markets. In addition to these positive economic contributions, the theory has important normative implications as well. In particular it suggests that "noncompetitive" institutions such as cartels may actually enhance economic efficiency, instead of retarding it. Although the model does not imply that all cartels are efficient, it does rebut the prevailing wisdom that all cartels are inefficient. Given the robust empirical performance of the theory in the case of the shipping industry, this possibility must be seriously considered in future investigations of collusion.

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