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Estimating the Structure of Capacity Utilization in the Fishing Industry

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INTRODUCTION

Research in industrial market structure has usually included capacity utilization behavior as a measure of market performance. Traditionally, this capacity has been used to gauge an industry's ability to absorb increased production without adding fixed resources. This includes, for example, some extraordinary situations such as World War II, or, as in fisheries, the extension of the U.S. coastal economic jurisdiction to 200 miles. Recently, however, there has been much research that has both expanded the definition of capacity behavior and improved the accuracy of analytical techniques. It has thus become possible to apply a capacity analysis in an expanded framework and to look at certain types of industry behavior that have been relatively neglected.

This paper discusses a consistent methodology for estimating the capacity utilization structure of an industry at various stages of processing. The empirical examples deal with the canned tuna and shrimp industries. These were chosen because they met two requirements: 1) Both have a volatile natural resource to harvest, and 2) both have a large and relatively stable processing sector.

Relating to the first point above, a major problem in analyzing an industry dependent upon the harvest of a scarce natural resource is that the output of the industry may not be directly related to the inputs of producing factors. For example, weather or fish migration patterns may have as much effect upon output in fisheries as the economic efforts of the industry. This uncertainty will, in turn, affect the functioning of capital and labor markets that determine the future economic potential. With few exceptions, this situation is almost entirely outside the realm of traditional economic analysis.

Secondly, a normally stable processing sector, but one that deals with an uncertain supply of inputs, will itself be affected. By adapting to a volatile set of conditions, the processing sector will tend to undercapitalize when it depends heavily on domestic supplies. This, in turn, creates an additional framework of uncertainty and possible bottlenecks affecting the harvesting sector.

This paper focuses on the relationship between the volatile structure of harvesting versus the processing sectors in fisheries. To accomplish this, the capacity utilization behavior of each is first examined independently and then combined into an integrated framework. The results concentrate primarily on the differential effects that a change in the utilization rate of one of the sectors would have on the overall economics of the industry.

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BACKGROUND

There have been recent theoretical and research advances in the study of capacity. Most have centered on definitional and analytical approaches to suit certain types of common problems.

This section contains a brief reveiw of the economic literature on capacity. Several interpretations of the term (Gang, 1974; Hertzberg et al., 1974; Christensen, 1975; Spielmann and Weeks, 1975) are contrasted starting with the traditional view of capacity defined as "the maximum amount of output that can be produced during a given period with existing plant and equipment." The phrase "can be produced" is the key to three primary interpretations discussed below.

Engineering Capacity

Engineering capacity refers specifically to the physical capabilities of the industry given a constant level of capital, skilled labor, and technology. The primary constraint on the amount that can be produced is the physical capacity of the existing plant and equipment as it operates around the clock, 7 days a week. There is no reference to the economic incentive to produce, to the relevant issues of capital-labor substitution, nor to the proportion of available time to which each of the factors is applied. The definition is thus more applicable to an "extraordinary demand" or stress situations and appears less relevant for the fishing industry. Moreover, this approach makes no provision for seasonal variability. In terms of measurement, this interpretation is mostly dependent upon extensive secondary data that are often lacking.

Economic Capacity—Microeconomic Approach

This refers to a program of production in which the profit-optimizing objective underlies the firm's decision-making process. Thus, under traditional microeconomic theory, maximum capacity will be the point at which all firms operate where marginal cost (MC) equals marginal revenue (MR). (This makes the standard assumption that short-run average cost is less than or equal to marginal revenue.) In practice, firms try to minimize short-run average costs to maximize or approach maximum profit.

The economic theory for this measurement is irrefutable. The major limitation of this approach lies in its application to an imperfect world where factors other than short-run profit maximization may affect decision making. For example, if we consider cases of imperfect information, there will be a suboptimal production level, so at a given marginal revenue price the system will be operating at under 100 percent capacity (MR> MC). On the other hand, if we consider factors such as firms' reluctance to turn away customers in the desire for long-run profit maximization, then the system can operate at over 100 percent capacity (MC >MR). By definition, this economic capacity will always be below the engineering capacity. Finally, despite its economic bias, this approach would have limited applicability because it overlooks the highly institutional response of producers.

Economic Capacity—Macroeconomic Approach

This is defined in Klein and Summers (1966) as "the maximum sustainable level of output which the industry can attain within a very short time if the demand for its product were not a constraining factor, and when the industry is operating its existing stock of capital at its customary level of intensity." Taken on a macroeconomic level, the capacity utilization concept is now reduced to an empirical observation of how much producers have been willing to operate. There is no explicit reference to profit maximization, prices, or acceptable patterns of producer behavior. However, profit maximization is to some degree implied here because it is one of the major factors used by the industry to determine the maximum output.

Although theoretically weaker, this approach becomes effective largely where there are noneconomic factors, such as special producer-supplier relationships that affect the production process. With a large number of institutional factors, the inferential nature of the approach would tend to be more empirically accurate than the other techniques in defining the potential output levels.

CAPACITY ESTIMATION: THEORETICAL BACKGROUND

As with many other capacity studies, we have started by defining a production function that is Cobb-Douglas or first degree linear homogeneous. This is shown by

$$Q_t = A\, L_t^{\alpha}\, K_t^{\beta}\, T_t. \qquad (1)$$

Here, the output, Q_t, which can be produced in the current time period t, is determined by the available labor inputs, L_t, and capital inputs, K_t, and adjusted by a technology trend, T_t, and a constant or aligning coefficient, A.

Labor and capital inputs are adjusted in the equation by their marginal factor products, α and β. Because we have defined the system to be Cobb-Douglas, the relationship is considerably simplified, although the marginal factor products must sum to one:

$$\alpha+\beta=1. \qquad (2)$$

To adapt our methodology to the available data, a second contraining relationship has been added. This is shown by

$$Q_t=AV_tT_t, \qquad (3)$$

where

$$V_t=L_t^{\alpha}K_t^{\beta}. \qquad (4)$$

In Equation (3), the labor and capital inputs have been combined into a single production unit, V_t. This structure in effect limits the factor inputs of labor and capital to roughly constant proportions. The inputs would always be applied in the same proportions when $\alpha=\beta$. For the analysis discussed in Results, we use the relationship of Equations (3) to (4) to circumvent the need for labor and capital data, as neither are adequately available in fisheries.

For the empirical analysis, we have modified Equation (3) into the final relationship:

$$\frac{Q_t}{V_t}=AT_t \qquad (3a)$$

We now have output per producing unit (productivity), which in fisheries is measurable, as a dependent variable, and a technology trend to determine the capacity potential.

To estimate the technology trend, we apply the peak-to-peak methodology discussed in Results. Here the level of technology in a particular time period, t, is determined by the average rate of change in productivity between peak years.

$$T_t = T_{t-m} + \left[\frac{\left(\frac{Q_{t+n}}{V_{t+n}}\right) - \left(\frac{Q_{t-m}}{V_{t-m}}\right)}{\left(\frac{n+m}{m}\right)}\right] \qquad (5)$$

Relative to a particular year, t, the values of n and m correspond to the length of time from the previous and following peak years.

RESULTS

The empirical methodology used in this paper is based upon the third or macroeconomic approach and uses published secondary data. Capacity utilization is estimated and based upon Equations (3a) and (5) in the previous section and demonstrated here using a graphical analysis. Here, annual productivity figures for one industry are plotted over time with a trend line to indicate the industry's maximum potential performance. The trend line is derived by connected peak years. Peaks are defined a posteriori: Years in which the industry was recognized as achieving the maximum sustainable output in the short run, i.e., 100 percent capacity. In practice, a peak year is often identified as of having a yield per producing unit that is significantly higher than both the preceding and following years. Percent capacity in any year is then calculated as the ratio of actual output per producing unit divided by the accompanying value from the trend line.

This section briefly discusses the results of the capacity calculations using the methodology discussed in the section on Capacity Estimation. The results are divided into three parts: 1) The harvesting sector, dealing directly with the natural resource; 2) the processing sector, dealing with the canners; and 3) an example integrating both the harvesting and processing analyses showing how changes in capacity utilization in the production system affect prices.

Harvesting Sector

The level of resource availability and the producing facilities on existing vessels primarily determine the rate of capacity utilization in the harvesting sector. Common to many other industries, certain institutional factors dictate that nearly all of the harvesting facilities will be used during the season and that all the catch will be sold. In this sector, no current period market forces would regulate the harvesting production levels. The price level is the main short-run regulating mechanism. In the long-run, the investment in new capital is very upward flexible to meet changes in demand; however, because of long life and the very limited applicability of the vessels to other fisheries, the downward adjustment of the capital market is very slow.

Tropical Tuna

From 1960 through 1968, the tropical tuna fleet had a relatively high capacity utilization rate, and a large expansion effort started in the purse seine fleet. Since that time, tonnage has increased about 200 percent; landings have been increasing rapidly, but have not kept pace because of limited stocks and restrictions on yellowfin tuna catch in the Inter-American Tropical Tuna Association area. For the past several years, the capacity utilization rate has been steadily declining from 77 percent to a low of 43 percent in 1975 (Fig. 1).

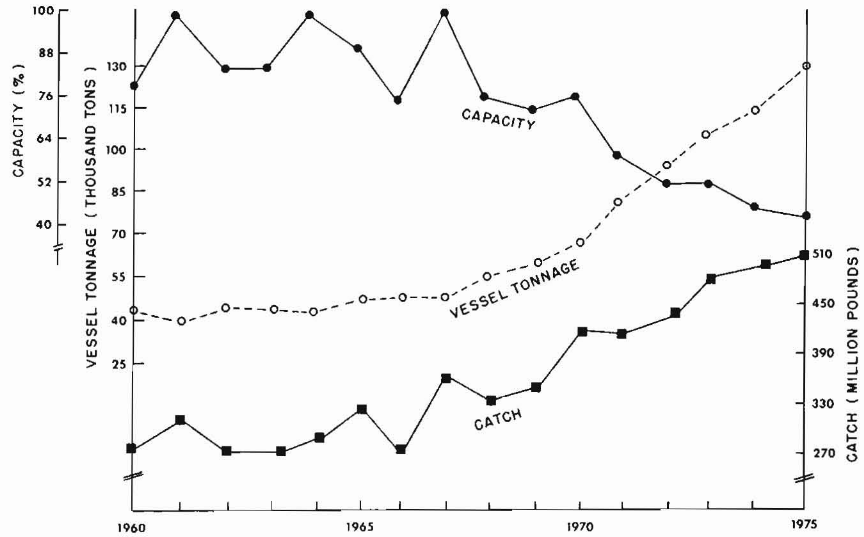

Figure 1.—Capacity rate, vessel tonnage, and catch of the U.S. tropical tuna harvesting sector, 1960-75.

Pacific Shrimp

Regular cycles of about 4 years characterize the capacity rate of the Pacific shrimp fishery. Although this cyclical fluctuation has been wide in the past (32-100 percent), the trend of the last 5 years suggests that swings in productivity may be moderating.

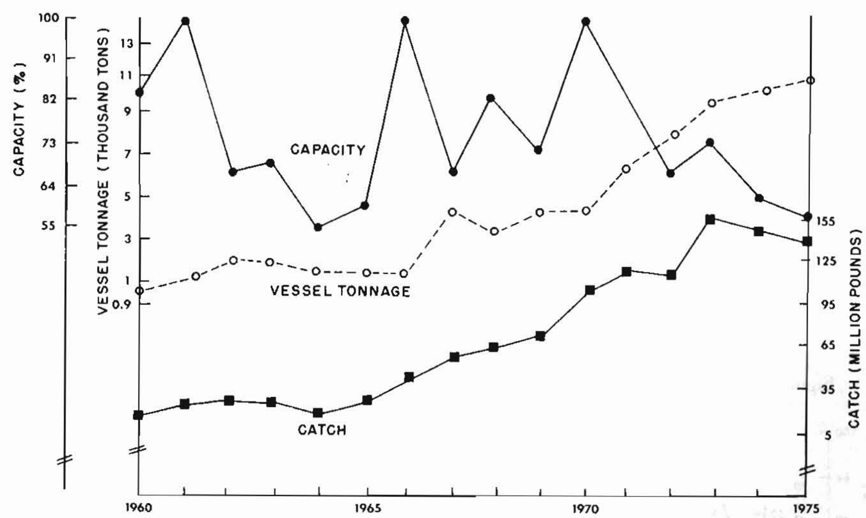

Figure 2.—Capacity rate, vessel tonnage, and catch of the Pacific shrimp harvesting sector, 1960-75.

In earlier years, this fishery was not highly utilized. After 1966, however, because of increased demand for shrimp products, the fleet has been steadily expanding and catch has fully kept pace with this increase. As a result, productivity has been increasing and maintained at a consistently high level (Fig. 2).

Processing Sector

The main factor that determines the rate of capacity utilization in the processing sector is the fluctuation of the harvesting output. However, two constraints affect the current impact of the raw material availability. First, unlike the harvesting sector, there can be major downward adjustments in the levels of both short- and long-run capacity and possibly use of nonfish food items. This is traditional in the food processing industry where both resource availability and seasonal factors necessitate a high degree of flexibility. Second, the industry uses cold storage and/or imports of raw materials to balance the levels of production over time.

Canned Tuna

Conjointly with the increased demand for canned tuna, domestic processors have significantly increased capacity since the early 1960's. During the 1960's, the capacity utilization rates are generally near 100 percent. Any excess capacity is mostly reflective of the start-up periods in new plants, i.e., the time between the actual building of the plant and when it becomes fully operational and efficient.

During the 1970's increases in demand for canned tuna started to taper somewhat. With the addition of several new plants and a lower than expected level of demand, the utilization rates have steadily declined over the 1972-75 period (Fig. 3).

Canned Shrimp

Until 1965, the demand for processed shrimp products was relatively stable with the production in the Pacific area at around 10 to 20 million pounds per year. The capacity utilization rate was normally under 50 percent. Since 1963 the demand and price for the small shrimp became exceptionally strong and processing increased dramatically to a peak of 117 million pounds in 1973. Because of these rapid increases in demand, the capacity utilization rate for the period after 1964 has hovered near or at 100 percent. For the most part, the plants that process shrimp are also used to process other fishery and agricultural commodities. The number of plants thus tends to be flexible, both upward and downward, by adjusting to current production requirements (Fig. 4).

Price-Capacity Utilization Relationships

This section quantifies the relationship between prices of the wholesale and ex-vessel levels with capacity utilization rates for the canned tuna and shrimp industries. The relationship is actually symbiotic, i.e., the level of capacity utilization depends, in part, on price; and the price level for the commodity depends, in part, on the capacity rate. Thus, changes in underlying economic forces that affect the price level can indicate a change in capacity utilization rate, and vice versa.

The basic estimating technique used was two-stage least squares taken from Cooper (1973). Each industry was modeled with four equations—two equations wherein price at the ex-vessel and wholesale levels are a function of several variables including capacity; and two equations wherein the capacity

Figure 3.—Capacity rate, number of processing plants, and production of the U.S. tropical tuna processing sector, 1960-75.

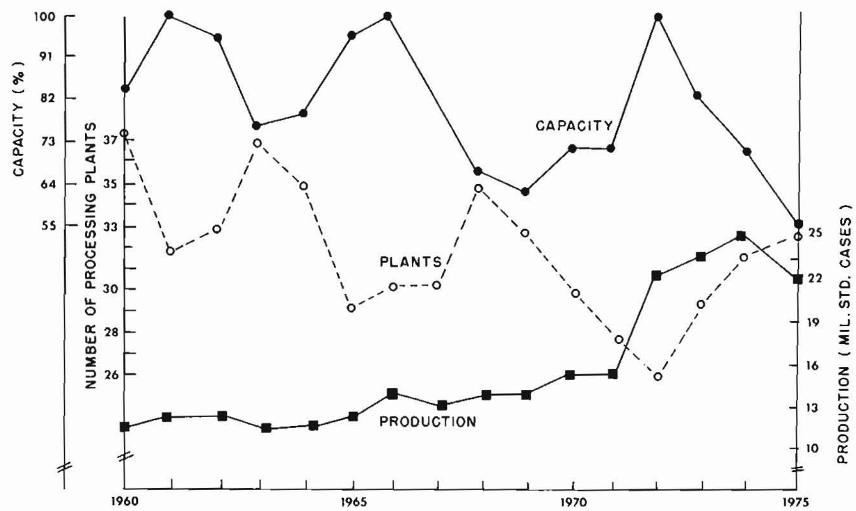

Figure 4.—Capacity rate, number of processing plants, and production of the U.S. Pacific shrimp processing sector, 1960-75.

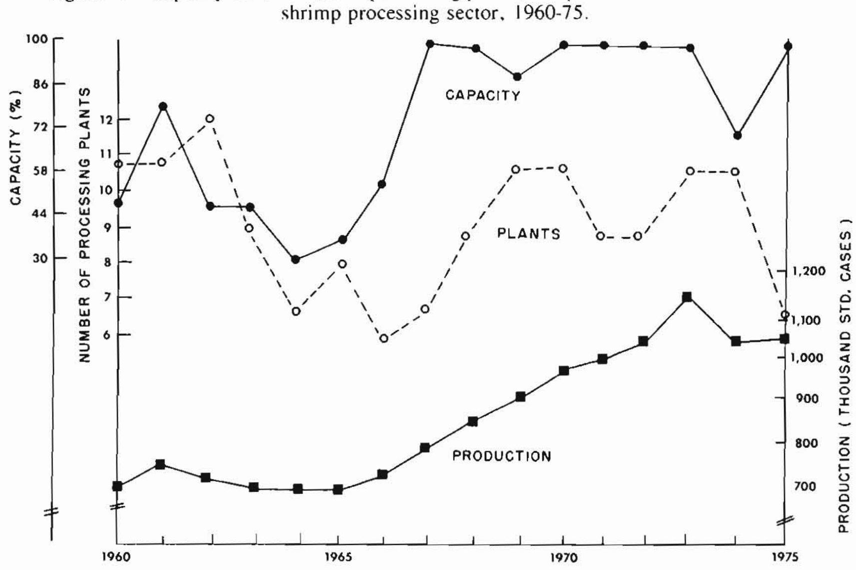

Table 1.—Estimates of tuna price and capacity utilization function coefficients, 1961-75.

Jointly determined variables[1]		Intercept value	A	B	D	Imports[2]	Dummy variable[3]	Wholesale price index (1967 100)	Time (linear)	GVT[4]	Processing plants	R^2	S.E.
Ex-vessel price $/lb	(A)	−0.0509		0.01293	0.0025	0.000004	−0.0102					0.969	0.009
				(18.53)	(1.26)	(0.92)	(−0.69)						
Wholesale price $/lb	(B)	6.884	10.8535		0.02414	0.00002		7.6432				0.998	0.182
			(3.22)		(3.21)	(1.09)		(9.17)					
Capacity rate in % ex-vessel level	(C)	90.7246		4.1228		0.000007			−0.3379	·1.0356		0.061	3.762
				(1.44)		(· 0.02)			(−0.63)	(· 2.38)			
Capacity rate in % processing level	(D)	195.516		3.964		−0.0006			−2.341		3.183	0.956	2.771
				(2.31)		(−2.33)			(3.13)		(−7.34)		

[1]Estimated with two-stage econometric method, autocorrelation adjusted by Cochrane-Orcutt technique; t-values in parentheses.
[2]Imports of light, chunk tuna, in millions of pounds.
[3]Zero-one variable for 1974-75.
[4]Gross vessel tonnage in Pacific tropical tuna fleet, in thousands of vessel-tons.

Table 2.—Estimates of shrimp price and capacity utilization function coefficients, 1961-75.

Jointly determined variables[1]		Intercept value	A	B	D	Imports[2]	Wholesale price index (1967=100)	Dummy variable[3]	Time (linear)	GVT[4]	Processing plants	R^2	S.E.
Ex-vessel price $/lb	(A)	·0.0725		0.0745	0.00033		0.095	−0.0154				0.966	0.007
				(2.32)	(0.97)		(5.05)	(−1.98)					
Wholesale price $/lb	(B)	0.777	5.7005		0.0027		−0.4322					0.837	0.066
			(3.07)		(1.87)		(−1.54)						
Capacity rate in % ex-vessel level	(C)	20.6111		483.355	0.2305	−0.00014			3.538	18.476		0.875	4.699
				(3.22)	(1.29)	(−4.09)			(3.90)	(−6.77)			
Capacity rate in % processing level	(D)	61.0438		34.3227		−0.00014			0.783		-2.7179	0.940	6.094
				(1.48)		(−4.18)			(0.78)		(−1.91)		

[1]Estimated with two-stage econometric method, autocorrelation adjusted by Cochrane-Orcutt technique; t-values in parentheses.
[2]Imports of "Northern" borealis shrimp, in pounds.
[3]Zero-one variable for 1969-72.
[4]Gross vessel tonnage for the Pacific shrimp fleet, in thousand of vessel-tons.

utilization rates at the ex-vessel and wholesale levels are a function of several variables including price.

The primary relationship in both industry models is between prices and capacity utilization. We hypothesize that this relationship is positive with respect to the direction of change in one variable caused by a change in the other. We reason that because capacity is defined using the economic approach, i.e., using producer expectations of prices and costs, increases in capacity utilization must be an indication of a demand- pull movement in the market. Thus, increases in price, ceteris paribus, will cause an increase in capacity utilization, and vice versa. It is only until the capacity rate is over 100 percent that we would expect price to go in the opposite direction. However, the measurement process defines peak historical capacities as 100 percent.

The results of the two-stage econometric estimation are provided in Tables 1 and 2. Data were used from National Marine Fisheries Service and Bureau of Labor Statistics sources. All but one of the right-hand-side variables exhibited the expected sign in our hypothesized relationships. The explanatory power of the relations is quite high, and the standard errors in measuring the dependent variables are encouragingly small. In addition to the economic variables, we have included dummy variables in two equations where unexplainable abberations in the dependent variable were found.

Tuna Prices

The capacity rate at the processor level, as hypothesized, influences both price levels; marketing margins and input prices had a significant effect as well on ex-vessel and wholesale prices, respectively. The Wholesale Price Index (WPI) also influences wholesale prices greatly, reflecting overall costs of operation. Canned imports of tropical tuna had a very negligible impact on both prices; it was only 5 to 8 percent of the total supplies annually.

Tuna Capacity Utilization

As expected, wholesale tuna prices had the greatest effect on capacity utilization at the harvesting and processor levels. Increases in price increased the capacity utilization rate. Furthermore, increases in physical facilities—vessel tonnage and number of processing plants—decreased capacity at the harvesting and processor levels, respectively. The time trend variable at the processor level presumably reflects the rapid build-up in processing plants yet limits in the resource base. Again, imports have a negligible impact.

Shrimp Prices

Marketing margins and input prices, reflected by wholesale and ex-vessel prices, had the greatest effect on prices at the ex-vessel and wholesale levels, respectively. A positive coefficient on the WPI at the ex-vessel level reflects increased costs of fishing; a negative coefficient at the wholesale level may be owing to the relative stability of prices and an increasing WPI. Capacity utilization is seen to have a negligible impact on prices, possibly due to little variation in the data or stronger economic forces in other variables.

Shrimp Capacity Utilization

Wholesale shrimp prices primarily affected capacity utilization at the ex-vessel and processor levels; the relationship was positive, as hypothesized. As in tuna, increases in physical facilities had a negative impact on the utilization rate. Although the coefficients for imports were statistically significant at the 1 percent level, the magnitude of the coefficients was very small. A statistically significant coefficient for the time trend variable at the ex-vessel level reflects increased exploitation of the resource. At the processor level, facilities are often shared with fish and other food commodities.

CONCLUSIONS

We have attempted to build a conceptual framework to measure capacity utilization at various marketing levels for the canned shrimp and tuna fisheries. With this base, we then integrated our approach so that the effect of changes in capacity utilization on prices can be analyzed. Although this is a generalized methodology, results may vary from fishery to fishery because of the usually volatile nature of natural resource-based industries.

Results indicated that capacity utilization rates for the processing and ex-vessel levels for Pacific shrimp remained at relatively high levels. Factors include: 1) The resource was gradually exploited during the time period; 2) growth in physical facilities was stable. For the Pacific tropical tuna industry, capacity utilization had a generally negative trend, caused by the limitations in the resource and large increases in physical facilities. When capacity utilization was put into an integrated framework, prices at the ex-vessel and wholesale levels moved in the same direction as changes in capacity utilization.

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