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A PROJECTION MODEL OF THE U.S. SHRIMP MARKET

The main purpose of this paper is to demonstrate the use of a simple econometric model to explain historic levels of supply, demand, and price, and to project future levels of these factors for the U.S. shrimp market. Industry spokesmen often argue that economic variables have little impact on the shrimp market and that historic explanation and future projection are next to impossible except on the basis of a highly personal "feel for the market." The attempt here is to challenge that view. A theoretically suitable econometric model, if properly specified and estimated, can make historic explanation and future projection more secure and less subject to personal prejudice and whim.

Knowledge of some general aspects of the U.S. shrimp industry is useful in understanding the following model. The most important of these are:

1) The market for fresh and frozen shrimp is very different from the market for dried and canned shrimp. The shrimp used for the dried and canned pack tend to be substantially smaller than those sent into the fresh and frozen markets. Also, in the past twenty years canning and drying requirements have been relatively stable and small in relation to the requirements of the fresh and frozen trade. This model focuses only on fresh and frozen shrimp, and to avoid complications with other marketed forms and with foreign demand, the U.S. catch of shrimp is defined, for present purposes, as *net* of exports of fresh and frozen shrimp and canning requirements. Thus defined, the total U.S. catch is one supply source for the model.

2) The U.S. shrimp fleet, which operates chiefly out of Gulf and South Atlantic ports, has unsuccessfully tried to increase the size of its catch for the past twenty years. Although the total shrimp-catching effort (measured by boat-hours) has increased substantially since 1950, no trend increase in total shrimp catch is apparent, as is evident from Table 1. In theory it should be possible to specify a shrimp-catching production function, with the relevant arguments likely to include number of boat-hours, quality of fishing gear, number of hands engaged in fishing, skill of the boat operators, the size of the shrimp population at any time, and some random factors mostly connected with weather and fishing luck. A preliminary investigation along these lines was unrewarding—the dominant factors

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TABLE 1.—UNITED STATES SHRIMP CATCH, 1950–67*
(Millions of pounds, heads-off weight)

Year	Landings at South Atlantic and Gulf States ports	Minus: Exports, Domestic	Minus: Exports, Foreign[a]	Minus: Canned	Net catch
1950	112.0	2.7	0.1	21.9	87.3
1951	131.7	3.6	0.2	24.8	103.1
1952	133.2	3.2	0.1	24.4	105.5
1953	153.2	2.0	0.2	22.5	128.5
1954	158.2	3.5	0.1	28.1	126.5
1955	143.4	2.8	0.1	27.3	113.2
1956	130.4	1.9	0.2	27.5	100.8
1957	116.2	2.0	0.2	16.9	97.1
1958	116.6	1.9	0.5	26.4	87.8
1959	130.7	2.5	0.9	22.7	104.6
1960	141.0	3.5	0.8	26.4	110.3
1961	91.4	5.3	6.3	14.5	65.3
1962	105.8	3.8	2.5	23.3	76.2
1963	138.3	8.5	5.7	29.5	94.6
1964	124.3	8.7	7.3	17.7	90.6
1965	139.6	6.8	8.0	27.7	97.1
1966	126.3	4.9	11.4	26.1	83.9
1967	153.8	8.1	15.9	27.1	102.7
					Average = 98.7

* Data from U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, *Shellfish Situation and Outlook*.

[a] Foreign exports, mostly transshipments of Mexican shrimp through West Coast ports, should logically be subtracted from imports, but it is more convenient to make all these corrections on one series. Only in the past five years is the magnitude substantial.

turn out to be the random elements and the size of the shrimp population. The former cannot enter as an independent variable in the production function and the latter is non-observable until after the fact.[1] Since it is impossible, given current knowledge and data to fit a satisfactory production function, to explain the U.S. shrimp catch, it is treated as a random variable with the expected value of the catch in any one year in the range of 95 to 105 million pounds. No further specification of the U.S. catch is made.

3) Consumption of fresh and frozen shrimp in the United States has risen dramatically, from 119.5 million pounds in 1950 to 267 million in 1966. Broadly speaking, the increase is due to the spread of frozen food centers in supermarkets, development of breaded shrimp as a household item, and increases in population and income.

4) Stagnant U.S. production and rapidly rising consumption have induced frozen shrimp imports in ever increasing quantities—from 40.2 million pounds

[1] This is not quite true. Recent research is beginning to show a strong relationship between number of shrimp larvae in the estuary spawning grounds along the Gulf coast and shrimp population and catch later in the season. But even a large sampling program would yield at best an indication of potential population, not the population itself.

TABLE 2.—UNITED STATES FRESH AND FROZEN SHRIMP STATISTICS, 1950–66*
(Millions of pounds, heads-off weight)

Year	Domestic catch (net)	Imports (frozen)	Consumption	Price[a]
1950	87.3	40.2	119.5	62
1951	103.1	41.8	143.4	56
1952	105.5	38.5	154.9	62
1953	128.5	43.1	162.1	78
1954	126.5	41.5	160.7	57
1955	113.2	53.8	177.0	60
1956	100.8	68.6	169.1	76
1957	97.1	69.7	159.5	88
1958	87.8	85.4	162.4	90
1959	104.6	106.6	204.8	75
1960	110.3	113.4	217.7	73
1961	65.3	126.3	223.4	77
1962	76.2	141.2	208.4	102
1963	94.6	151.5	232.0	91
1964	90.6	154.6	263.3	82
1965	97.1	163.0	274.2	90
1966	83.9	178.5	267.0	110

* Data from source cited for Table 1.
[a] Wholesale, raw headless, 26–30 count, Gulf browns at Chicago, in cents per pound.

in 1950 to 178.5 million pounds in 1966. A summary of the relevant annual statistics is shown in Table 2.

Since the annual data set is only 17 or 18 observations long (depending on whether 1967 is completely available), no econometric model was estimated with this set. Instead a quarterly data set from 1957 I to 1966 IV, containing 40 observations, was used. Correction for seasonal influence (very necessary for the shrimp industry) costs only three of these observations, so the quarterly data set is quite sufficient for extensive multi-variable regression estimation. No especial interest lies in the quarterly estimates, however; the ultimate aim of the model is medium term projections—one to five years into the future—on an annual basis. There is an advantage to using quarterly data to generate annual estimates. In summing the quarterly estimates errors tend to cancel out, and the annual estimates have a much smaller average absolute per cent error than the quarterly estimates.

THE MODEL

Supply.—Two structural equations, one for supply and one for demand, form the core of the model. There are three potential sources of supply for fresh and frozen shrimp—domestic catch, imports, and depletion of cold storage holdings. Cold storage holdings can also absorb supplies, however, so they are not included in the supply equation. This leads to some bias in the very short run, but over the years it is safe to assume that cold storage holdings are constant and do not contribute to supply. The U.S. shrimp catch is treated as a normally distributed random variable, as already indicated. Thus the supply of shrimp from imports is left to be explained.

It is difficult to specify a satisfactory import equation *a priori*. The results of short-run and long-run decisions are inherently mixed together—the supply of imported shrimp can be altered somewhat in the short run by influencing foreign producers' decisions to sell in their own locale or to export. In the long run the supply can be affected by influencing investment decisions about new shrimp catching and freezing facilities. At first glance a Nerlovian dynamic supply response model might seem appropriate. The decision to supply foreign shrimp to the U.S. market would be based on expected price, which would be some function of all past prices. When this model is set in appropriate form and properly manipulated, an estimating equation containing price and lagged imports results.

But the model is not satisfactory in the present context because of the two separate decision-making processes—one short-run and one longer-run. Consequently a somewhat *ad hoc* model is specified that retains some features of the Nerlovian model, but sacrifices its elegance in favor of more real world flavor.

To measure the impact of the short-run decision-making process (supply locally or export to U.S.), the U.S. wholesale price of shrimp lagged one quarter is included in the equation. A one-quarter lag is specified to cover the fairly significant transport time for frozen shrimp from the main U.S. foreign shrimp suppliers—Mexico, Panama, Venezuela, Iran, India, and Pakistan.

The longer-run decision-making process depends on what are potentially two separate factors, although they are difficult to separate. The first is a capital stock adjustment mechanism in a perfectly knowledgeable but dynamic world. Even when investment decisions are made instantaneously as *new* information becomes available (about consumer behavior, shrimp-catching potential, etc.) a substantial lag exists before the decision has any output effects. In the shrimp industry this lag depends on the area being exploited, but it seems to vary from two to eight years before the impact of an investment decision is felt. To measure the effect of this decision-making process, average annual wholesale price of shrimp in the U.S. was included in the equation, with the lag varying from three to five years. Only the three-year lag was significant.

The second potential factor of importance in the long-run decision-making process reflects the less than perfect knowledge of our real world. It is dubbed a "learning by doing" process with the proviso that the form in which this process is included in the present model bears little resemblance to the sum of capital expenditures model of Arrow. This aspect of the decision-making process is not directly related to price response but rather to the accumulation of knowledge and effort with respect to foreign suppliers of shrimp to the United States. The first shrimping effort in the Gulf of Kuwait may have been predominantly motivated by high U.S. shrimp prices, and the investment decision was that the exploration costs were worth the candle. But further exploitation of the Kuwait shrimp resources was presumably less price sensitive as the magnitude of the resource and cost of production became apparent. The same argument holds, of course, for the opening up and development of all new resources.

It is difficult to find a suitable proxy for this factor that fits into an equation. Two alternative variables are tried—a simple time trend and the peak level of imports recorded in any one quarter in the past (due to the strong seasonality in this variable—also the independent variable—the past peak is always represented by a fourth-quarter volume). The time trend variable is a potential measure of our ignorance, admittedly, but it might also serve as a reasonable proxy for accumulating knowledge. The past peak variable must understate the level of knowledge, for it depends on what was definitely accomplished in the past. If the bias does not change substantially over the period studied, however, the past peak variable too may serve as a reasonable proxy for this "learning by doing" aspect of long-run decision-making. It is unlikely, of course, that both of these variables will be significant, although it is to be hoped that the two aspects of the long-run decision-making process will reveal enough independence for both a long-run price variable *and* a "learning by doing" variable to be significant.

Demand.—Consumption equations are almost always easier to specify and estimate than supply equations, perhaps reflecting the extent to which our theoretical understanding of the consumption decision-making process exceeds that of the supply decision under uncertainty, imperfect knowledge, and less than pure competition. In the case of shrimp consumption, the relevant variables *a priori* should be own price, price of competing goods (meat, poultry, and fish), income, and some variable to reflect changing tastes or increasing consumer awareness of the availability and convenience of frozen shrimp. Although the consumer's buying decision is presumably based on retail shrimp prices, these prices are not available for the period under study, and wholesale prices are used instead. Since the consumption data do not reflect purchases by consumers but disappearance from wholesale hands into retail stores, the wholesale price is probably the correct one to use anyway—the decision about quantity purchased is made by grocery managers in anticipation of consumer demand. Since retail shrimp prices are much less variable than wholesale prices, the grocer's decision will be mostly determined by the level of the wholesale price.

Two of the variables that are relevant *a priori* are not relevant statistically. The price of competing goods—i.e., either wholesale or consumer price indices for meat, poultry, and fish—does not significantly affect shrimp consumption as measured by the data. It is possible that consumer decisions are affected by competing goods' prices, but that the impact is not strong enough to be measured one step removed, i.e., through the grocer's decision-making.

Disposable personal income has an entirely satisfactory sign and magnitude in the estimated regression so long as no time or time-related variables are included. When these are included, however, the standard errors for both terms explode due to the multicollinearity. Apparently there is not enough independent variation in the income variable during this period to statistically separate its effects from a straight time trend—a sort of tribute to the "new economics." Consequently, the equation ultimately used in the model contains only own price, a time trend, and possibly some sort of learning variable (plus the usual seasonal dummies).[2] Since the consumption variable is in per capita form, no correction for population change is necessary. Some added flexibility in projection is achieved

[2] The time trend rather than the income variable is used because it seemed extremely artificial to attribute all steady increases in shrimp consumption to income changes. A suitable cross-section study might help clarify this.

TABLE 3.—DATA AND VARIABLE SPECIFICATIONS*

Year and quarter		Supply				Demand			
		S_1	S_6	S_7	S_8	D_1	D_6	D_7	D_8
1957	1	16.36	20.93	77.6	57	.227	.227	84.3	.620
	2	14.49	20.93	84.3	57	.215	.227	94.5	.597
	3	19.21	20.93	94.5	57	.253	.227	90.8	.571
	4	23.83	20.93	90.8	57	.246	.253	83.6	.593
1958	1	16.10	23.83	83.6	60	.221	.253	90.5	.600
	2	18.28	23.83	90.5	60	.208	.253	92.4	.579
	3	22.13	23.83	92.4	60	.258	.253	89.8	.555
	4	33.86	23.83	89.8	60	.251	.258	86.6	.590
1959	1	25.74	33.86	86.6	76	.244	.258	87.3	.604
	2	27.34	33.86	87.3	76	.243	.258	79.3	.606
	3	22.05	33.86	79.3	76	.336	.258	69.1	.605
	4	37.71	33.86	69.1	76	.334	.336	62.7	.699
1960	1	26.36	37.71	62.7	88	.304	.336	66.8	.753
	2	28.35	37.71	66.8	88	.286	.336	78.9	.755
	3	23.56	37.71	78.9	88	.333	.336	73.4	.738
	4	41.79	37.71	73.4	88	.332	.336	72.3	.774
1961	1	33.61	41.79	72.3	90	.318	.336	69.7	.794
	2	27.26	41.79	69.7	90	.277	.336	69.0	.794
	3	23.66	41.79	69.0	90	.292	.336	80.3	.752
	4	49.04	41.79	80.3	90	.353	.336	89.7	.742
1962	1	38.62	49.04	89.7	75	.271	.353	93.5	.798
	2	32.90	49.04	93.5	75	.305	.353	98.8	.750
	3	24.85	49.04	98.8	75	.305	.353	108.7	.756
	4	52.02	49.04	108.7	75	.326	.353	108.2	.759
1963	1	38.55	52.02	108.2	73	.275	.353	104.2	.782
	2	30.97	52.02	104.2	73	.291	.353	101.7	.744
	3	29.20	52.02	101.7	73	.364	.353	82.3	.737
	4	50.72	52.02	82.3	73	.364	.364	75.2	.807
1964	1	38.38	52.02	75.2	77	.351	.364	77.1	.847
	2	33.59	52.02	77.1	77	.310	.364	76.4	.858
	3	31.31	52.02	76.4	77	.378	.364	81.4	.825
	4	54.85	52.02	81.4	77	.378	.378	92.7	.874
1965	1	41.19	54.85	92.7	102	.293	.378	92.4	.902
	2	40.35	54.85	92.4	102	.341	.378	91.9	.834
	3	34.73	54.85	91.9	102	.373	.378	86.0	.841
	4	52.24	54.85	86.0	102	.408	.378	89.3	.878
1966	1	41.59	54.85	89.3	91	.319	.408	99.7	.934
	2	41.15	54.85	99.7	91	.323	.408	110.3	.877
	3	40.85	54.85	110.3	91	.386	.408	118.3	.847
	4	62.64	54.85	118.3	91	.363	.408	112.7	.892

* Basic data from the source cited for Table 1.

VARIABLE SPECIFICATIONS FOR TABLE 3

Import Equation

Dependent variable:

S_1 = Imports of fresh and frozen shrimp for the quarter, in millions of pounds, adjusted to heads-off peel-on weight.

by this specification as well; differing rates of assumed population growth can be used. A habit formation variable of the type used by Houthakker and Taylor (*1*) was also introduced but was relatively insignificant.

ESTIMATION

Table 3 lists the data used in estimating the model and the exact specification of the variables.

Ordinary least squares regression was used to estimate linear coefficients for various combinations of the variables shown in Table. 3. The more interesting results are summarized in Table 4.

The Import Equation.—Equation 1 shows that seasonal dummy variables alone can account for about a third of the variation in quarterly U.S. shrimp imports. Adding a straight time variable, as in equation 2, increases the explained variance to about 91%, and in terms of corrected R^2 this is just about all that can be explained, even with several other variables added. In fact, simply adding lagged price to equation 2, as in equation 3, reduces the corrected R^2 somewhat, as the price coefficient does not exceed its own standard error. But even though equation 2 has an R^2 nearly as high as for any of the following equations, it is not satisfactory from either an economic or a projection point of view. The strongly significant time variable asks more questions than it answers, and the absence of any price response is suspicious. Consequently, equations 4–6 were estimated in

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Independent variables:

S_2, S_3, S_4 = Quarter dummy variables, taking a value of 10 for quarters I, II, and IV respectively.

S_5 = Time variable, with 1957 I = 10, 1957 II = 11, etc.

S_6 = Past peak quarterly imports as measured in S_1.

S_7 = Quarterly price of shrimp, wholesale, raw headless, 26–30 count, Gulf browns at Chicago, for period $t-1$ (i.e., the previous quarter).

S_8 = Annual price of shrimp, same specification as S_7, with three-year lag. Thus the figure for 1957 I, II, III, and IV is the annual average for all of 1954.

Demand Equation

Dependent variable:

D_1 = Per capita consumption of fresh and frozen shrimp, in pounds, adjusted to heads-off weight. [This series is not regularly reported and is available only in *Shellfish Situation and Outlook*, September 1967, p. 41.]

Independent variables:

D_2, D_3 = Quarter dummy variables, taking a value of 10 for quarters III and IV respectively. A dummy for quarter II was not significant. Subsequent examination of graphed data revealed that quarters I and II were unlikely to be significantly different, as in fact was the case. In addition, the magnitude of the seasonal impact in quarters III and IV seemed to be the same, although substantially different from I and II. Comparison of the estimated coefficients of D_2 and D_3 in Table 4 confirms this judgment. The model was not re-run using only a single dummy for quarters III and IV, however, as the gain would be only a single degree of freedom.

D_4 = Time variable, with 1957 I = 10, 1957 II = 11, etc.

D_5 = Time variable, with $D_5 = \log_{10} D_4$.

D_6 = Past peak quarterly consumption as measured in D_1.

D_7 = Quarterly price of shrimp, as in S_7 above, but for the same quarter as the consumption figure.

D_8 = Depreciating habit formation variable. Each quarter's figure is $D_{1\ t-1} + 0.6D_{1\ t-2} + 0.6^2D_{1\ t-3} + \ldots$ The starting point assumes a constant 0.250 lb. per quarter per capita consumption into the past. The 0.6 depreciation factor is the average for all food as determined by Houthakker and Taylor (*1*, p. 15).

TABLE 4.—IMPORT EQUATIONS

Equation No.	Corrected R^2	Durbin-Watson	Coefficients (t-values)							
			Constant	S_2	S_3	S_4	S_5	S_6	S_7	S_8
1	.3563	0.271	27.15 (9.227)	0.4495 (1.080)	0.2313 (0.5557)	1.8715 (4.4966)	—	—	—	—
2	.9110	1.752	5.7067 (3.1706)	0.5925 (3.8207)	0.3028 (1.9554)	1.8000 (11.6241)	0.7149 (15.0105)	—	—	—
3	.9103	1.722	2.6337 (0.6518)	0.6113 (3.8873)	0.3122 (2.0031)	1.8068 (11.6064)	0.6989 (13.5993)	—	0.0398 (0.8503)	—
4	.9142	1.8462	−6.4488 (−0.9332)	0.6142 (3.9942)	0.3137 (2.0582)	1.8230 (11.9506)	0.5939 (7.1877)	—	0.0830 (1.5625)	0.1062 (1.6018)
5	.9147	1.8552	−17.2820 (−2.8697)	0.5204 (3.3794)	0.2668 (1.7535)	1.8883 (12.4485)	—	0.5299 (7.2177)	0.1282 (2.5930)	0.1353 (2.1519)
6	.9191	1.9898	−10.5183 (−1.4799)	0.5637 (3.7066)	0.2885 (1.9403)	1.8531 (12.4276)	0.3082 (1.6826)	0.2831 (1.7351)	0.0951 (1.8278)	0.1016 (1.5782)

TABLE 4.—DEMAND EQUATIONS

Equation No.	Corrected R^2	Durbin-Watson	Coefficients (t-values)							
			Constant	D_2	D_3	D_4	D_5	D_6	D_7	D_8
7	.8715	2.4374	0.2828 (14.1412)	0.0041 (5.6363)	0.0044 (6.0034)	0.0039 (13.9380)	—	—	−0.0013 (−5.3091)	—
8	.8507	2.0679	0.0486 (1.7518)	0.0041 (5.2072)	0.0044 5.5987	—	0.2225 (12.7454)	—	−0.0009 (−3.6803)	—
9	.8271	2.3075	0.1028 (3.7607)	0.0047 (5.5661)	0.0044 (5.1635)	—	—	0.7638 (11.6378)	−0.0008 (−3.0037)	—
10	.8716	2.6152	0.2419 (5.3683)	0.0042 (5.7281)	0.0044 (5.9713)	0.0031 (3.6210)	—	0.1745 (1.0125)	−0.0012 (−4.7058)	—
11	.8678	2.4767	0.2713 (4.4923)	0.0042 (5.0052)	0.0044 (5.8555)	0.0038 (4.1380)	—	—	−0.0013 (−4.3973)	0.0184 (0.2016)
12	.8529	2.3693	0.0422 (1.5036)	0.0045 (5.2731)	0.0045 (5.7643)	—	0.1669 (3.4564)	—	−0.0009 (−3.3050)	0.1042 (1.2343)
13	.8271	2.4318	0.0822 (2.4060)	0.0050 (5.5375)	0.0046 (5.2577)	—	—	0.5347 (2.2562)	−0.0007 (−2.6861)	0.1194 (1.0058)

hopes of solving both problems. Equation 4 includes a three-year lagged price variable as well as the one-quarter lagged price variable of equation 3. The results are surprising—whereas the short-run price response variable was insignificant when included alone, both it and the longer-run price response variable are significant when included together (although significant at only a 90% confidence level).

The next step is to achieve a more satisfactory explanation of the straight time trend which remains so significant. Equation 5 substitutes a "learning by doing" variable, in the form of past peak quarterly imports, for the straight time trend. The reasoning is that foreign shrimp exporters must "know" at least enough to accomplish in the present and future what they were able to accomplish in the past. This measure of knowledge must be downward biased, of course, but if the bias remains unchanged over this period then it should serve as an adequate proxy for state of knowledge among foreign suppliers to the U.S. market. The resulting estimates in equation 5 are very satisfactory. All coefficients (except the second-quarter dummy) are significant at the 95% level or above. The corrected R^2 is marginally higher than any yet achieved, and the Durbin-Watson statistic continues to improve.[3] Short-run and long-run price responses are both substantial. The short-run price elasticity is approximately 0.25 at recent price and import levels. A 10% increase in price in one quarter calls forth an additional 2.5% in imports the next quarter—approximately one and a quarter million pounds of shrimp, or about five million pounds if the price remains at the new level for a year. If the price stays up for several years (three or more), then additional investment brings still more shrimp to the U.S. In fact, the long-run elasticity is about double the short-run elasticity. Thus if the price stayed 10% higher for three or more years, an additional five million pounds of shrimp would enter the U.S. in each of the first three years, and then the amount would jump to ten million pounds thereafter. This is a substantial price response.

The impact of "learning by doing" is also substantial. Approximately half the level of current imports is accounted for by the historic peak level of imports. The fact that inclusion of this variable rather than a linear time variable results in highly significant price variable coefficients strengthens the case for its use. The straight time variable apparently masks some of the impact of price changes.

Equation 6 is included to show that the "learning by doing" variable does not explain everything, however. When both time and the "learning" variable are included the corrected R^2 reaches its peak of almost 0.92 and the Durbin-Watson statistic is almost exactly 2.0. The level of significance of most of the coefficients drops below the 95% level, but, except for the constant, *not* below the 90% level (the three-year lagged price does not quite make the 90% level). The overall significance of equation 6 can best be viewed in terms of the relative coefficients of the time and "learning" variables. When included alone (as in equations 4 and 5) each variable had a coefficient between 0.5 and 0.6. When both are included in equation 6, the weights are almost exactly split, with the time coefficient about 0.31 and the learning coefficient about 0.28. Thus it is too strong a statement to say that

[3] There is no significant evidence of autocorrelated residuals in any of the supply equations 2 through 6. Equation 1 rather naturally has strongly autocorrelated residuals since only seasonal dummies are used as explanatory variables.

about half the current level of imports is accounted for by the state of knowledge. In fact, something like a quarter of the level can be so accounted, while another quarter remains largely unexplained but revealed by the time trend. One possible means of accounting for this is that the downward bias of the "learning" variable became progressively greater over time due to better communications, the introduction of large, well-financed corporations into foreign shrimping areas, and increased profitability, not reflected by the price variables, of supplying the U.S. shrimp market. Although equation 5 is most satisfactory statistically, equation 6 makes somewhat more sense. For this reason both will be used for projections.

The Demand Equation.—A total of seven equations is shown in Table 4, none of which has a corrected R^2 of less than 0.82 nor as high as 0.88. Equation 7 is the simplest and also most satisfactory statistically. In this equation all *t*-values are over 5.0. The own price coefficient is the right sign and highly significant (this is true for all seven equations). The time variable, while not explaining very much, does not hide anything either. The R^2 is the second highest (and then by only 0.0001) shown. This equation is, in fact, used for the projections in the next section.

But the other equations reveal some marginal information about the determinants of shrimp consumption. Equation 8 substitutes a log of time variable for the linear time variable in equation 7. Two things happen: the Durbin-Watson statistic drops to almost exactly 2.0 (the difference is not significant), and the price response coefficient drops by a third. But the *t*-values for the price and time coefficients in equation 8 are somewhat smaller than in equation 7. There is thus no strong reason to substitute the declining time trend for the linear one, when the cost is a smaller and less significant price response. The same arguments hold for equation 9 as for equation 8. A "learning by doing" variable, measured by past peak quarterly consumption, is introduced in place of time. It is, of course, highly significant, but less so than the straight time trend, and again the price coefficient drops sharply. It is clear that D_5 and D_6 are close substitutes.

Equation 10 has the highest corrected R^2 of any demand equation estimated, and also the worst Durbin-Watson statistic, although not bad enough to be significant evidence of autocorrelated residuals. Both the linear time variable (D_4) and the "learning by doing" variable (D_6) are included. This time the price coefficient retains its prior magnitude and significance (almost). The time variable is also strongly significant, but the learning coefficient, while of the right sign, is only marginally significant (i.e., only at the 50%–60% confidence level). Thus while the learning process seems to have some impact apart from the time effect, little confidence can be placed in its magnitude.

Equations 11–13 experiment with a habit deterioration variable of the type introduced by Houthakker and Taylor (*1*). The extent of habit retention in any one period was specified at 0.6, about the level reported by Houthakker and Taylor for all food. It would have been possible to estimate a coefficient specific for shrimp, but special programming requirements, different data specifications, and the unpromising preliminary results made this appear to be an unprofitable course. Equations 11–13 reveal that the habit variable never achieves more than marginal significance when included with other time-related or learning variables. Nor does its inclusion improve any other aspects of the equations. The lack of significance has two potential causes. In order of increasing likelihood, they are: incorrect rate of habit deterioration used in the model, and habit formation not important in determining shrimp consumption.

Although brave words were spoken at the outset about the ease of estimating demand functions, the one to be used here (equation 7) reveals to all a large measure of ignorance. What the linear time trend represents, and why it fits better than other types of time-related trends, are difficult questions. Rising incomes, increasing consumer awareness of a new product, new marketing and storage techniques, and wider geographical dispersion of the product all likely make some contribution. But it is impossible, at present, to sort out their separate impacts.

PROJECTIONS

A projection model should work from the known toward the unknown. The most reliable information and estimates should form a base to which progressively less certain information and estimates are added, culminating in a single projection for the issue in question. The advantages of such a progression are very great. Information subject to much uncertainty is likely to be revised frequently. If the revisions affect only the calculations on the top of the pyramid rather than the whole structure, substantial economy is achieved in the effort required to generate new predictions as new data become available.

This shrimp model offers a particularly good example of the use of the progressive technique for making projections. The desired target is a projection of the annual average shrimp price for some year in the future. Three factors are used in this model to make that projection: U.S. demand, U.S. catch, and imports. The factor subject to the greatest uncertainty, and also to frequent revision, is the size of the U.S. catch. Substantially better quantitative understanding has been achieved for the determinants of demand and imports, both of which are partly determined by the ultimate projected price. But since all other factors determining demand and imports can be specified exogenously, it is possible to solve both equations in terms of price. Thus we have:

$$D = \phi\,(P_d) = D_1 \text{ population}$$
$$S_1 = \theta\,(P_i)$$
$$S_c = \,?$$

For equilibrium on an annual basis, $D = S_1 + S_c$ and $P_d = P_i = \hat{P}$ although P_d and P_i are separated by one quarter. The assumption of annual equilibrium requires that these two prices be equal throughout the year. Formally then, the projection model simply states that $\phi\,(P_d) = \theta\,(P_i) + S_c$. This equation is then solved for $\hat{P}$ $(\hat{P} = P_d = P_i)$ in terms of the structural parameters of ϕ and θ, and in terms of the unknown S_c. Thus $\hat{P} = \phi' + \theta' + \psi\,(S_c)$ where ϕ' and θ' are determined from the estimated equations and S_c is specified on the basis of historic U.S. catches, or as knowledge of fishing success for the year in question becomes available. Full knowledge of S_c is only built up as the year progresses, so it is subject to frequent revision. The model is designed to make the effects of this revision as immediately visible as possible, for the final form is ultimately $\hat{P} = A + \psi\,(S_c)$. In the present model the form of ψ is a constant divisor, so the predicting equation is $\hat{P} = A + \frac{S_c}{B}$.

This equation can be used in a number of ways. The simplest is to assume some value for S_c on the basis of historical experience—e.g., a ten- or twenty-year mean —and solve directly for $\hat{P}$. Alternatively, a "cutoff" level of $\hat{P}$ can be specified, say $\hat{P}^*$, and the S_c needed to make this the equilibrium $\hat{P}$ can be found. The advantage of this approach is that it is frequently desirable to know the probability of a price below or above a certain limit. This is easily calculated in the following manner:

$$Prob\ (\hat{P} < \hat{P}^*) = Prob\ [S_c > B\ (\hat{P}^* - A)\ ]$$

The probability on the right side can be determined from the historic distribution of S_c.

Two projections, for 1967 and 1970, will be made to demonstrate the projection technique and test the model (for the 1967 projection). To make an annual projection it is easiest to convert the quarterly form of equation 7 to an annual form—the result is:

$$D_1 = 1.2158 - 0.0052\, D_7 + 0.0156\, D_4.$$

The time variable (D_4) has an average value of 51.5 for the year 1967, and population was 199.1 million,[4] so the resulting equation for total shrimp consumption in 1967 is:

$$D = 402.023 - 1.0353\, D_7.$$

Import equation 5 in annual form is:

$$S_1 = -42.3726 + 2.1196\, S_6 + 0.5128\, S_7 + 0.5412\, S_8.$$

For 1967, $S_6 = 62.64$ and $S_8 = 82$, so the equational form with short-run prices as the only undetermined independent variable is:

$$S_1 = 134.778 + 0.5128\, S_7.$$

In general, $S_7 \neq D_7$ because they are prices in different time periods. In fact, the lagged form of S_7 made it predetermined in all the import equations, thus eliminating the necessity to estimate the entire model with some simultaneous equation technique. But multi-period equilibrium is assumed in making annual price projections, so it follows that $S_7 = D_7 \equiv \hat{P}$. Accordingly, the import equation can now be subtracted from the total demand equation. With the appropriate manipulations performed, the resulting equation with price as a function of net U.S. catch (S_c) is:

$$\hat{P} = 172.6 - \frac{S_c}{1.5481}.$$

The *ex ante* price projection, based on a projected S_c of 95 to 105 million pounds, would be 104.8¢ to 111.3¢ a pound. The *ex post* catch was 102.7 million pounds,

[4] The consumption figure from equation 7 must be multiplied by population to put it in the same units as the import equation.

resulting in a projection of 106.3¢ a pound. The actual price average in 1967 was 107¢.

The 1970 projection is more difficult because some of the variables that are predetermined in the model are not predetermined without the prior year's data. Two solutions are possible: 1) assume values for these variables based on historical trends or *a priori* expectations, or 2) generate the necessary data by working through the model year by year using the last available data as a starting point. If the model worked perfectly then the latter technique would be the correct one to use, but since random shocks have an impact in the real world, there is considerable justification in specifying at least some values of the lagged endogenous variables *a priori.*

A case in point is in using equation 6 to project import levels in 1970. Variable S_6 is past peak quarterly imports, which are, of course, an unknown for this projection. When the model is cranked forward from 1966 through 1969 on a quarterly basis, the peak value of imports achieved in 1966 IV (62.64 million pounds) is surpassed by 1969 only if price equals 120¢ a pound in 1969. At first this is surprising until it is realized that the model underestimated 1966 IV imports by about 3.5 million pounds. It thus takes several years at high prices for the *model* to generate a new peak. It might happen quicker in the real world. To allow for this two values for S_6 are assumed: the old record high of 62.64 million pounds for the low estimate and a new peak of 70 million as a high estimate (the low import estimate will, of course, give rise to the high price estimate).

The magnitudes of all other variables in the supply equation for 1970 are all predetermined—the time variable has a value of 63.5 (annual basis) and the three-year lagged price is 107¢ a pound (the price is for 1967, the last year real data are available). In annual form equation 6, solved for all predetermined variables and expressed with only price as undetermined, appears as:

$$S_{low} = 177.681 + 0.3804\,P$$
$$S_{high} = 186.015 + 0.3804\,P.$$

The demand equation for 1970 needs only one outside projection, a population estimate. The Series D estimate of the Bureau of the Census, 204.9 million, is used here. The corresponding total consumption equation, in terms of price only, is:

$$D = 452.091 - 1.0655\,P.$$

The same manipulations as before are performed, with the import equation being subtracted from the total demand equation to get a residual to be met by net U.S. landings. The success of the U.S. shrimping effort then determines price according to the following functions:

$$\hat{P}_{high} = 193.833 - \frac{S_c}{1.4157}$$

$$\hat{P}_{low} = 187.947 - \frac{S_c}{1.4157}\,.$$

If an average net catch of about 100 million pounds is assumed, then the projected price in 1970 is in the range of 117¢ to 123¢ a pound. The entire range is higher than any average price experienced up through 1967, and this is true despite the fact that no allowance has been made for an apparent upward trend in shrimp exports, both domestic and foreign. Accordingly, it is very likely that shrimp prices will be higher in the future.

CONCLUSIONS

The weaknesses of this model are perhaps more visible than the strong points. The lack of a satisfactory supply function for domestic shrimp catch is particularly distressing. Also, the form of the demand function is inadequate both theoretically and empirically.

The success in estimating the import equation, however, justifies the inclusion of the less than satisfactory demand function and explanation of U.S. catch into a complete model. The results here, in fact, are quite exciting. Both short- and long-run price variables have a significant impact of substantial magnitude. A "learning" variable is highly significant by itself, and retains much of its significance in the presence of a straight time variable, for which it might be thought to substitute. The contributions of "learning by doing" and the diffusion of knowledge have been extensively discussed recently in the theoretical literature. It is satisfying to obtain some empirical measure, rough as it is, of their impact. The usefulness of the concepts should certainly be put to further test.

Lastly, the overall model is a success, at least so far. Its *ex ante* and *ex post* price projections for 1967 were quite accurate. And its indication of higher prices for 1970 than any experienced up to 1967 also seems reasonable in light of preliminary data for 1968 and early 1969. The model's usefulness beyond 1970 is, of course, limited. Data for 1966 were the most recent utilized in estimating the structural parameters. For projections beyond 1970 more recent data should be incorporated.

CITATION

1 H. S. Houthakker and Lester D. Taylor, *Consumer Demand in the United States, 1929–1970,* Harvard University Press, Cambridge, Massachusetts, 1966.