Forecasting Market Share Using A Flexible Logistic Model

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association

Annual Tulsa, Oklahoma, February 18, 2004

ABSTRACT

There is a strong competition from low-priced imported catfish fillets resulting in a declining market share for domestic farm-raised catfish fillets. To match the competition, catfish processors are embarking on pricing policy measures that are volume-oriented instead of profit- or image-oriented. This could be an effective short-run pricing policy measure for optimal long-run sustainability and profitability of the industry. Volume pricing strategies are aimed at meeting target sales volumes or market shares. This paper explores and compares the performance of the standard logit, the inverse power transformation (IPT) logit and the logarithmic version of the inverse power transformation logit models in terms of generating forecasts for market share of U.S. farm-raised catfish fillets. The results suggest a better performance of the log-IPT in every aspect compared to the linear standard logit and the IPT logit models.

[EconLit citation: Q130, C250, C530]

Key words: market share, forecasting, flexible logit

1. INTRODUCTION

Forecasting is an important part of economic decision-making, especially important to firms for predicting earnings, sales, or market shares. Market shares can be of particular interest to managers because they reflect the market performance of a firm's product relative to the performance of similar competing products. High market share establishes a firm's position in the market place and could allow the firm to operate at efficient levels. Thus, in highly competitive markets, such as the catfish fillet market, firms usually set target sales levels that can be achieved at a given price. Unlike price, forecasting market shares could be relatively simpler because shares are less sensitive to the impact of seasonal fluctuations.

There is a large body of literature on alternative econometric approaches to forecasting market shares, including forecasting of competitors' actions. Store-level scanner data as well as aggregate market-level data have been used to model market share responses (Alsem, Leeflang and Reuyl, 1989; Chen, Kanetkar and Weiss, 1994; Christen et al., 1997; Kumar, 1994; and Kumar and Heath, 1990). Ordinary least squares (OLS) and generalized least squares (GLS) estimation procedures have been employed in some cases with a focus on forecasting market shares at the brand level. The benchmark model for such market share models has been the naïve model, which is a first-order autoregressive model. Other researchers have adopted variants of the logit formulation because market shares are constrained within the [0, 1] interval, and to ensure that market share forecasts are always positive. Leeflang et al. (2000) provides a survey of modeling and forecasting market shares.

The objective of this paper is to explore alternative sigmoid-shaped formulations and apply them to forecast the market for the U.S. frozen farm-raised catfish fillets. Specifically, flexible logit models are employed to forecast market shares for farm-raised catfish. The forecasting performances of the alternative models are compared. The study is particularly useful to the U.S. catfish industry because, with high inventory levels of catfish fillet products, the industry is exploring price-setting policies to compete effectively with increased import competition by increasing market shares.

2. THE U.S. FARM-RAISED CATFISH MARKET

A major portion of processed U.S. farm-raised catfish products is fillet, constituting over 65 percent of products. This is because fillets are the preferred products of the major buyers of catfish including restaurants, commercial cafeterias, and social caterers. Imported catfish products come mainly in the form of frozen boneless fillets and are meant for the food service industry as well.

The 1980s and early 1990s were periods of expansion in the production of catfish as growers were encouraged by consecutive years of profitability. This resulted in an expansion of processing activities and hence expansion in the market share for farm-raised catfish fillets, despite competition from catfish products imported from Brazil and Canada. In 1986, processors' revenue from the sale of frozen catfish fillets was about $71 million. By 1996, revenues had reached $249 million and, in 2002, revenues were estimated at $313 million (USDA-NASS).

The market share of U.S. farm-raised catfish fillets peaked in 1997, with the introduction of catfish fillets from Vietnam, commonly known as *tra* and *basa*, to the U.S. market (see figure 1a). Thereafter, the market has seen a continued decline in the share of domestic fillets as well as processor and producer prices. The declining market share and the associated prices of catfish prompted various actions from the industry that has resulted in the filing of an anti-dumping suit against Vietnam, and the passage of Section 747 of the 2001 Agriculture, Rural Development, Food and Drug Administration and Related Agencies appropriations bill (Public Law 107-76), which prohibits the FDA from allowing the importation of fish or fish products labeled "catfish" other than from the family *Ictaluridae*. The catfish species imported from Vietnam is from the family *Pangasidae*.

The average price of frozen fillets has declined from $2.86 per pound in 1995 to an average of $2.38 per pound in 2002. Dillard (1995) suggests that there are no short-run economic profits accruing to the catfish processing industry and estimates an average processing cost for catfish to be $2.41 per pound in 1994. The catfish industry is therefore exploring strategies for long-term sustainability and profitability of the industry. In particular, the processing industry is exploring volume-pricing objectives, i.e., price setting strategies that will tend toward meeting target sales volumes or market shares. The price of imported catfish fillets is relatively lower so it is anticipated that such a pricing strategy would allow a more efficient and optimal level of processing operations.

3. THEORETICAL AND EMPIRICAL MODELS

3.1 The Logit Formulation

The logit formulation in marketing studies is commonly expressed as

$$s_{it} = \frac{\delta_i}{1+\exp[-f(X)]} \qquad 0 \le \delta_i \le 1 \qquad (1)$$

and

$$f(X) = \sum_k \beta_k X_{ik} \qquad (2)$$

where s_{it} is the market share for product i; X_{ik}s are explanatory variables; β_ks are parameters associated with X_{ik}s; and δ_i is a parameter that sets the eventual or saturation level of s_{it}.

The linear nature of equation (2) makes the logit formulation symmetric and sigmoid-shaped with an inflection point occurring at s_{it} = $\delta_i/2$. The symmetric sigmoid shape has implications for the impact of changes in explanatory variables (Gaudry, 1981; Train, 2003). The shape implies that at low or high market share levels, small changes in the explanatory variables have little effect on market shares. The point at which changes in explanatory variables have the greatest effect on market share is close to $s_{it} = \delta_i/2$, where small changes in explanatory variables induces a large change in s_{it}. This property has been criticized in the literature as restrictive and inappropriate for a meaningful forecasting and market strategizing.

The other limitation of the logit formulation is the well-known independence from irrelevant alternatives axiom (IIA). This property implies that a gain in say 5 percent of market share by a new product means the existing shares of the other products have to be reduced by 5 percent. There is exclusion of complementary relationships of competing products.

3.2 Flexible Logit Models

Various modifications of the logit formulation has been proposed and used for forecasting market shares of products and the rate of market development over time. These include the Gompertz model of Chow (1967) and Dixon (1980); the log-logistic model of Tanner (1978) and Defries and Fiebig (1984); the inverse power transformation (IPT) logit model of Gaudry (1981); the exponential and flexible logistic model of Bewley and Fiebig (1988); and the mixed logit of Revelt and Train (1998). This paper adopts variants of the IPT logit model of Gaudry (1981). The IPT logit allows for complementary relationships for products instead of proportional substitution relationships in the standard logit model.

In many instances, researchers find it useful to allow equation (2) to be non-linear (Gaudry, 1981; Train, 2003). The inverse power transformation logit derives from the principle of Box-Cox transformations (Box and Cox, 1964) where

$$f(X) \quad = \quad \sum_k \beta_{ik} X_{ik}^{\lambda_{ik}} \qquad\qquad 0 \le \lambda_{ik} \le 1 \qquad (3)$$

Equation (3) implies that the transformation is continuous for all possible values of λ but defined only for positive variables and would exclude variables that are constants, dummies or variables that have negative observations. To overcome this limitation, Gaudry (1981) suggests a general inverse power transformation (IPT) of equation (2) in the form of

$$f(X) \quad = \quad [(1+\lambda_i \sum_k \beta_{ik} X_{ik})^{1/\lambda_i} - \mu_i] \qquad \lambda_i \ge 0 \quad \& \quad \mu_i \le 1 \qquad (4)$$

where λ_i and μ_i are parameters to be estimated. Equation (4) nests the standard logit as a special case when $\lambda_i = 1$ and $\mu_i = 1$. The IPT logit model is asymmetric in shape and is not constrained by the IIA property.

The problem in the specification above is over-parameterization. Gaudry (1981) sets $\delta_i = 1$ and estimates λ_i and μ_i as free parameters. In this paper, a saturation level δ_i for the market share of farm-raised catfish fillets is estimated given that the U.S. is a net importer of fish. Thus, $\mu_i = 1$ is fixed but δ_i and λ_i are estimated as free parameters. A test is then conducted for the null hypothesis H_o: $\lambda_i = 1$. The logarithmic version of the IPT logit, assuming $\mu_i = 0$ (Bewley and Fiebig, 1988), can be expressed as

$$f(X) \quad = \quad \frac{1}{\lambda_i} * \log{(1+\lambda_i \sum_k \beta_{ik} X_{ik})} \qquad (5)$$

In the marketing literature, market shares are commonly hypothesized to be a function of time, price, advertising, scale of production, sales growth, research and development, etc. The advantage of the log-IPT logit is that it removes the problem of an arbitrary scale on time as an explanatory variable and also nests the standard logit model as a special case because as λ_i approaches zero, the limit of $f(X)$ is linear (Bewley and Fiebig, 1988).

4. DATA AND ESTIMATION PROCEDURE

Using the standard logit as a benchmark, out-of-sample forecasting performance based on the IPT and the log-IPT logit were studied for the U.S. farm-raised catfish fillet market. The data series are monthly, from January, 1986 to December, 2002. Equations (2), (4) and (5) were specified in the logit formulation (1) and estimated separately using data from January1986 to June 2002. Based on the estimation results, an out-of-sample forecast of six months ahead was calculated, i.e., July, 2002 to December, 2002.

The explanatory variables used in the model are the price premium of U.S. farm-raised catfish fillets, real personal consumption expenditure, demand for catfish fillets and a time trend. The real personal consumption expenditure is incorporated as an explanatory variable because catfish is mainly consumed away-from-home (Engle et al., 1990). The premium is the difference between the average price of frozen fillets and the unit value of imported fillets and demand for catfish fillets is calculated as the sum of the total of imported and domestic frozen fillet sales. The data series were obtained from USDA's National Agricultural Statistics Service, the National Marine Fisheries Service, the Department of Commerce, and the Federal Reserve Bank. Estimation of the models was accomplished using the nonlinear iterative procedure in *SHAZAM* econometric software.

5. RESULTS

Table 1 presents estimates of the model parameters and diagnostics tests. The values of the R^2 suggest a better fit for the log-IPT than the standard logit and the IPT logit. In addition, the Durbin-Watson (D-W) statistics suggest that autocorrelation is not a problem in the log-IPT model. The IPT logit nests the standard logit as a special case when $\lambda_i = 1$ and the log-IPT logit nests the standard logit model as a special case as λ_i approaches zero. A look at the log likelihood functions (LLF) of the standard logit and the IPT logit indicate that the two models are equivalent. The equivalence of the two models is confirmed from a test of the null hypothesis that $\lambda = 1$ in the IPT logit model. The estimated χ^2-statistic is 1.77. The observation is different when the log-IPT is compared to the standard logit. The t-statistic of 2.61 for the λ estimate in the log-IPT model suggests a rejection of the null hypothesis that $\lambda = 0$ in the log-IPT.

All three models provide an estimate of δ that is unity or close to unity, suggesting that the eventual saturation level of market shares is unity. Regarding the determinants of market share, all three models indicate that an increase in the premium of U.S. catfish fillet price negatively affects market shares. The wholesale price of U.S. farm-raised catfish fillet is generally higher than that of imported catfish fillet. Essentially, the result suggests that as the gap between wholesale prices of domestic fillets and imported fillets widens, catfish buyers would substitute U.S. farm raised catfish with imported catfish, assuming a homogenous product. If the processing industry's pricing policy with the premiums is reinforcing a quality image of U.S. farm-raised catfish over imported products, it does not appear that catfish buyers are differentiating between the two products. A pricing strategy based on higher sales volumes to address the declining market share situation could be an effective short-run pricing policy measure for optimal long-run sustainability and profitability of the industry. The strategy would allow more efficient levels of catfish processing.

The coefficient on real personal consumption expenditure appears positive and significant in the IPT logit but negative and significant in the log-IPT logit model. Since major buyers of catfish are restaurants, commercial cafeterias, and social caterers, a positive coefficient suggests that as personal consumption expenditures increase, market share of U.S. catfish fillets increase. However, given that these restaurants and commercial cafeterias are also the buyers of imported catfish, a negative coefficient suggests that as personal consumption expenditures increase, catfish buyers purchase more of the low-prices imported products, resulting in a decline in the market share of U.S. catfish fillets. With the current market situation, the latter seems to be the case.

Plots of the actual as well as the predicted shares from the three models are presented in figure 1. All three models predict an increasing trend in the market share of domestic fillets up to the peak in 1997. Thereafter, only the log-IPT is successful in predicting the downturn of market shares, suggesting a relatively better performance of the log-IPT. The three models are then used to estimate the successive out-of-sample forecast from July 2002 to December 2002. Table 2 reports the estimates of root mean squared error (RMSE) for each step, which is calculated as

$$\textbf{RMSE} = \sqrt{\frac{\sum_{f=t+1}^{T}(s_{t+1} - \hat{s}_{t+1})^2}{T-t}} \tag{6}$$

where $\hat{s}_{t+1}$ denotes the out-of-sample forecast of the market share. In Table 3, the estimates of the mean squared percentage error (MSPE) are presented, calculated as

$$\textbf{MSPE} = \sum_{f=t+1}^{T}\left(\frac{(s_{t+1} - \hat{s}_{t+1})}{s_{t+1}} * 100\right)^2 \Big/ T-t \tag{7}$$

As can be seen from Tables 2 and 3, the log-IPT logit model performs better in forecasting market shares with the smallest errors for each forecasting horizon except the 4-month forecast. The difference in forecasting performance of the different models is relatively larger for the 1-, 2-, and 6-month ahead forecasting than for the 3-, 4-, and 5-month forecasts. The relative performances of the models are clearer when the forecasts are plotted against the actual series (figure 2). The plot shows that the log-IPT logit model successfully forecasts the out-of-sample ups and downs in market share unlike the linear standard logit and IPT logit models.

6. CONCLUSIONS

In this paper, the performance of the standard logit, the inverse power transformation logit and the logarithmic version of the inverse power transformation logit models are compared in terms of generating forecasts for the market share of U.S. farm-raised catfish fillets. The econometric models included explanatory variables of price premium, real personal consumption expenditures and demand for fillets to determine their effects on market shares. The flexible logit models are reported to have various advantages over the standard logit in terms of implications for the impact of changes in explanatory variables as well as allowing complementary relationships for fillet products instead of restrictive proportional substitution relationships implicit in the standard logit model.

The results suggest a better performance of the log-IPT in every aspect compared to the linear standard logit and the IPT logit models. In terms of out-of-sample forecast, the log-IPT model forecasts market shares with the smallest percentage errors and is able to predict successfully, the ups and downs in market share.

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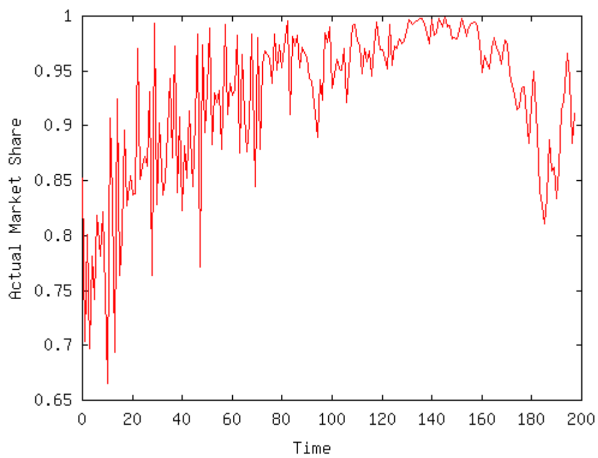
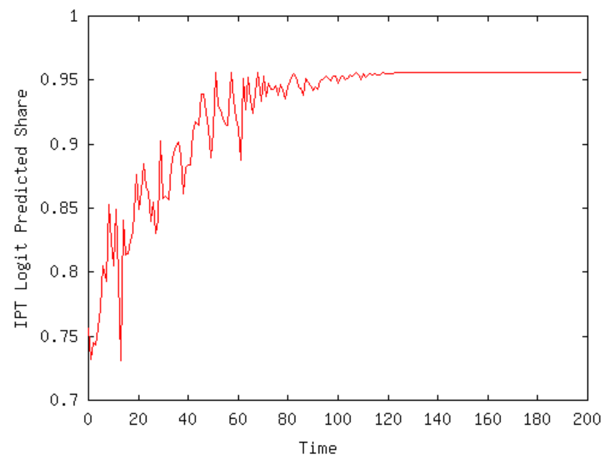
Figure 1 Plot of Market Shares (January 1986 - June 2002)

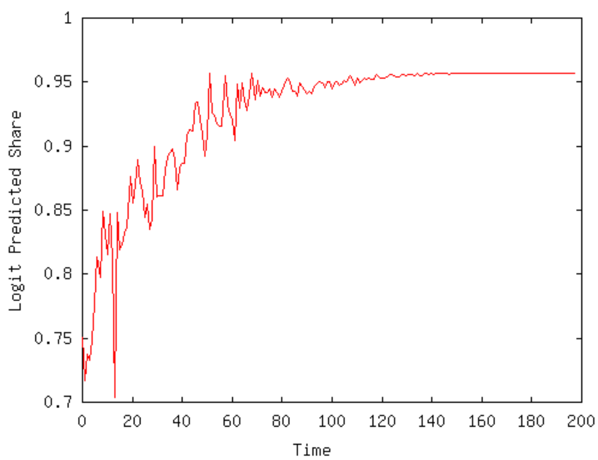
(a) Actual Series



(c) Predicted Shares - IPT Logit



(b) Predicted Shares - Logit



(d) Predicted Shares - Log IPT Logit

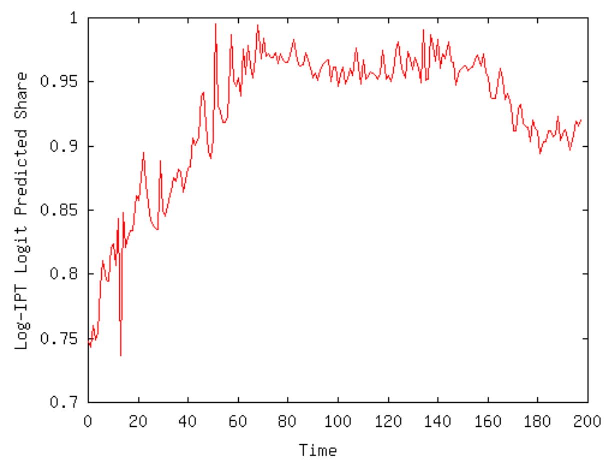


Figure 2 Comparison of 6-Month Out-of-Sample Forecasts (June - December 2002)

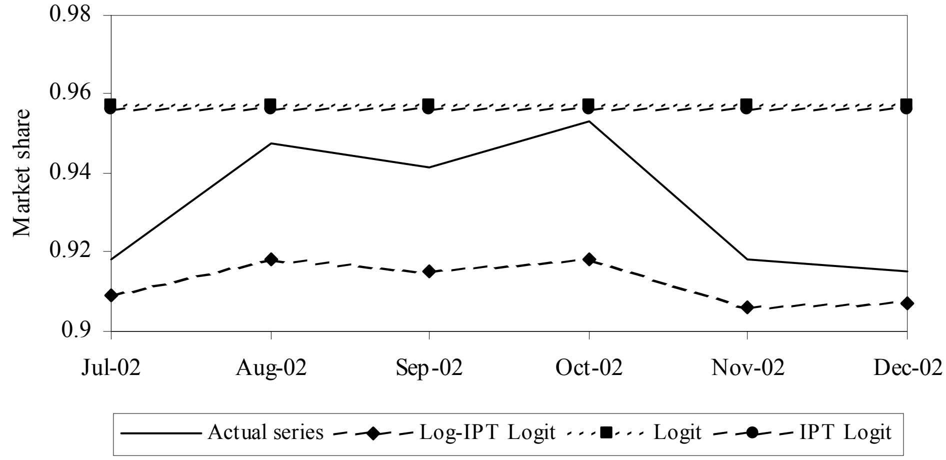


TABLE 1. Estimated Parameters from the three models

	Standard Logit		IPT Logit		Log-IPT Logit	
	Estimate	t-statistic	Estimate	t-statistic	Estimate	t-statistic
δ	0.96*	213.46	0.96*	213.24	1.00*	61.58
λ	1.00		0.66*	2.54	0.01*	2.61
Constant	-6.12	-0.85	-14.24*	-2.01	11.91*	3.44
Premium	-2.56*	-4.11	-2.57*	-3.73	-1.65*	-2.93
Economy	14.39	1.52	22.28*	2.41	-11.25*	-3.05
Demand	-0.81	-0.96	-0.79	-0.97	-0.42	-1.18
Time	0.01	0.37	-0.01	-0.44	0.07*	4.98
D-W value	1.40		1.43		1.89	
R^2	0.57		0.58		0.65	
LLF	332		333		350	

* indicates significance at the 0.05 level.

Note: D-W value is the Durbin-Watson statistic and LLF is the log likelihood function.

TABLE 2. RMSE for successive step forecast (July 2002 - December 2002)

	Logit	IPT Logit	Log-IPT Logit
1-month	386	377	92
2-month	281	273	219
3-month	246	238	235
4-month	214	206	268
5-month	258	251	246
6-month	290	283	227

Note: RMSE multiplied by 10^4.

TABLE 3. MSPE for successive step forecast (July 2002 - December 2002)

	Logit	IPT Logit	Log-IPT Logit
1-month	177	168	10
2-month	93	88	54
3-month	71	66	62
4-month	54	50	80
5-month	79	74	67
6-month	100	95	58

Note: MSPE multiplied by 10.