Improving Current Sales Estimates with Econometric Models

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July 1977

Published only on the Internet. Cite as Tessier, T.H. & J. S. Armstrong (1977), "Improving Current Sales Estimates with Econometric Models,"
http://www.fourps.wharton.upenn.edu/forecast/paperpdf/improvingsalesestimates.pdf

Abstract

An econometric model for the U. S. lodging market was developed from time series data. Estimates from this model were then combined with preliminary sales estimates. The resulting combination greatly improved the estimates of the "final sales" figures and also reduced the error in two forecasting tests. These improvements were achieved at a low cost.

Introduction

People who have worked with statistics on industry sales levels are aware of the problems and costs involved with obtaining reliable and valid data on a timely basis. One approach to improving upon the statistics collected from sellers or buyers is to use econometric methods. Econometric methods are expected to be especially useful in cases where the sales figures are subject to much uncertainty.

The hypothesis that econometric sales estimates are useful in estimating current sales levels was previously tested (Armstrong 1970). In that study, sales of photographic equipment in each of 17 countries were estimated using a cross-sectional regression model. These estimates were then combined with trade data to provide the current sales estimates for making long-range forecasts. The resulting forecasts were superior to those obtained when only trade data were used for estimating current status. Beyond the study cited, however, little direct evidence exists on the value of such an approach. The current study attempts to test the same hypothesis, but differs from (Armstrong 1970) in that:

1. a different market was studied,
2. different time periods were involved,
3. time series rather than cross-sectional data were used,
4. different procedures were used for validation.

In other words, the question is whether the hypothesis holds in a different situation.

The Market

The study examined the U.S. lodging market, using data from 1958 through 1970. Interest focused on estimating lodging sales (including room, food, and beverage sales) in current dollars.

Lodging sales are estimated annually by the U.S. Department of Commerce and published in the *U.S. Industrial Outlook*. Various sources are used by the Commerce Department in making its estimates: during the years 1958, 1963, and 1967, business census data were the primary source: during non-census years, sales were estimated from sample surveys, tax returns, and information from private sources. Estimates of lodging sales are made at the end of each year. These estimates are revised in later years as additional data become available. The revisions are often substantial. For example, at the end of 1968, the U. S. Department of Commerce estimated that 1968 lodging sales were approximately $7.3 billion. The following year this estimate was revised to 7.6 billion. In 1970, the amount was adjusted to $7.1 billion. The current and presumably "final" estimate of 1968 lodging sales is $6.5 billion. In this example, the preliminary estimate of $7.3 billion made in 1968 was 11% higher than the final estimate in 1971. The mean absolute percentage error of the Commerce Department's preliminary estimates during the 1965-1970 time period was 10.5% (see their Exhibit 7, column 1). The substantial revisions imply that there is much uncertainty in these estimates. This, then, is a situation where econometric methods should improve upon the preliminary sales estimates.

The Econometric Model

The development of the econometric model followed standard procedures. A heavy emphasis was placed on the a priori analysis because limited data were available for the lodging market.

The first step in the *à priori* analysis was to specify the variables related to lodging sales. In conceptual terms, lodging sales were expected to be a function of market size, ability to buy, and consumer needs. Using this model, and considering the data that were available, we selected five operational variables – U. S. population (as a measure of market size); corporate profits and lodging rates (as measures of ability to buy); and aircraft speed and intercity passenger miles (as measures of needs). In addition, the problem was recast in terms of constant dollars to control for inflation.

The direction of each relationship in the model was specified using standard economic arguments. A positive relationship was specified for the coefficients relating sales to corporate profits and intercity passenger miles. A negative relationship was specified for lodging rates and aircraft speed.

Standard econometric practice was also used to select the functional form. This was the multiplicative (log-log) model, which assumes constant elasticities.

The effect of market size was fixed *à priori* at 1.0; in other words, the dependent variable was transformed to per capita figures. A range was then estimated subjectively for each of the four remaining elasticities. Previous studies on similar products and services provided guidelines here – e.g. (Houthakker and Taylor 1970). This phase of the *à priori* analysis was subject to much uncertainty, however, previous research has suggested, surprisingly, that the accuracy of econometric models is not very sensitive to magnitudes of the relationships (Claudy 1972 and

Dawes and Corrigan 1974). In short, one needs only to find a reasonable estimate; beyond that, improvements are expected to be minor.

The *à priori* analysis yielded a completely operational model, except for the constant (scaling) term. A summary of this model is presented in Exhibit 1. The midpoints of the *à priori* range for the coefficients are presented in the equation, and the ranges are listed in the right hand column.

Exhibit 1
***À Priori* Model to Estimate Sales Level in U. S. Lodging Market**

$$Y_t = aB_t^{1.5} T_t^{0.8} A_t^{-0.6} S_t^{-0.7}$$

where:

			À priori range
Y	=	lodging sales in constant dollars per capita	—
?	=	scaling constant	—
B	=	corporate profits per capita in constant dollars	1.0 to 2.0
T	=	intercity passenger miles per capita	0.6 to 1.0
A	=	lodging rates in constant dollars	-0.4 to -0.8
S	=	aircraft speed in miles per hour	-0.4 to -1.1
t	=	the year	—

Data from 1958 to 1964 were used to update the model. These data are summarized in Exhibit 2. While limited, these data allow for an estimate of the scaling constant. Furthermore, they provide a check on the a priori signs. Finally, they provide information on whether the magnitudes of the coefficients are reasonable.

Exhibit 2
Data on the U. S. Lodging Market (Final Estimates)

Year	Lodging Sales[a]	Corporate Profits[b]	Intercity Passenger Miles[c]	Lodging Rates[d]	Aircraft Speed[e]	Consumer Price Index	U.S. Population
	Y	B	T	A	S		
1958	3644	22.3	702	6.95	219	0.866	175
1959	3996	28.5	763	7.40	223	0.873	178
1960	4248	26.7	782	7.76	235	0.883	181
1961	4327	27.2	788	7.92	253	0.896	184
1962	4616	31.2	815	8.27	274	0.906	187
1963	4667	33.1	849	8.59	287	0.917	189
1964	5013	38.4	892	9.58	297	0.929	192

[a] U.S. Department of Commerce, *U.S. Industrial Outlook*. Data in millions of current dollars.
[b] Council of Economic Advisors, *Economic Report of the President*. Data on profits are after tax profits in billions of current dollars. Data on population given in millions. Consumer price index based on 1967 = 1.00.
[c] Automobile Manufacturer's Association, *Automobile Facts and Figures*, Detroit, Michigan. Includes auto, air, bus, and train miles in billions.
[d] Computed from Harris, Kerr, Forster & Co, *Trends in the Hotel Business* and U. S. Census Bureau data: represents daily gross income per occupied room in current dollars.
[e] U.S. Department of Transportation, *FAA Statistical Handbook of Aviation*. Data in miles per hour.

"Conditional regression analysis" was used to update the coefficients. This approach is similar to that described in Wold and Jureen (1953). The procedure was to first obtain an *à priori* (subjective) estimate for each of the coefficients in the model. Regression analysis was used to obtain another estimate for each coefficient. A combined estimate of one of the coefficients was then made by taking an average of the *a priori* and the regression estimates. Calculations were made to remove the effect of this first variable from the equation. (Both sides of the equation were divided by this variable). The regression was run using the remaining variables with the revised dependent variable. This provided a new set of regression estimates. A second variable was then selected and the procedure was repeated until updated estimates were obtained for each of the coefficients.

The conditional regression analysis required subjective inputs by the analyst; decisions had to be made about the order the variables were introduced and the weight which was placed on the a priori estimates. Because of this subjectivity, a number of alternative models were examined. The model that provided the most accurate fit to the 1958-1964 data was.

$$Y_t - 660\ B_t^{0.9} T_t^{-0} A_t^{-0.6} S_t^{-0.3}$$

(See Exhibit 1 for a description-of the variables)

A sensitivity analysis was performed to determine the effect of the subjective estimates. Thirteen models were examined and the results are presented in Exhibit 3. The first seven models in Exhibit 3 represent an exploratory analysis of extreme points of the *à priori* ranges. The final six models represent fine tuning, examining small variations around the "best fit" of the exploratory models (which was model number 3).[1] Note that the coefficients all have the same signs as in the *à priori* model. Furthermore, the updating did not lead to substantial changes in the magnitudes; the final estimates were within or close to the *à priori* ranges. Finally, the errors for each of the 13 models were lower than the average error between the Commerce Department's preliminary and final estimates (10.5%).

[1] The criterion for best fit was the adjusted mean absolute percentage error (MAPE), which was calculated as follows:

$$(\overline{MAPE}) = \frac{A - P}{1/2(A + P)}$$

where A = lodging sales in current dollars
P = the predicted value from the econometric model

This criterion was selected because it was felt that errors in scale (percentage errors) were just as serious on the high side as on the low side.

Exhibit 3

Econometric Model: Sensitivity Analysis (1958-1964 Final Estimates

Model Number	Corporate Profits	Intercity Passenger Miles	Lodging Rates	Aircraft Speed	$\overline{MAPE}$
	B	T	A	S	
1	1.5	0.9	-0.6	-0.7	8.1
2	2.0	0.9	-0.6	-1.1	9.8
3	1.0	0.9	-0.6	-0.4	5.1
4	1.5	0.6	-0.6	-0.6	7.7
5	1.5	1.0	-0.6	-0.8	8.1
6	1.5	0.9	-0.4	-0.9	7.9
7	1.5	0.9	-0.8	-0.6	8.3
8	1.1	0.9	-0.6	-0.4	6.0
*9	0.9	0.9	-0.6	-0.3	4.6
10	1.0	0.8	-0.6	-0.3	5.3
11	1.0	1.0	-0.6	-0.4	5.6
12	1.0	0.9	-0.5	-0.4	5.7
13	1.0	0.9	-0.7	-0.3	5.7
				Average	6.8

* denotes selected model

Testing The Validity of the Econometric Estimates

Two approaches were used to test the validity of the econometric estimates. First, preliminary survey figures were compared with a **combination estimate** in an attempt to predict the final survey estimate for each of the years 1965 to 1970. The second approach compared the accuracy of two forecasts of "final" lodging sales, the first using preliminary survey estimates for current sales, and the second using a combined estimate.

Predicting "Final" Estimates

To examine whether econometric methods could improve upon the data available in year t' a comparison was made between the Commerce Department's "preliminary" survey and their "final" survey estimate of lodging sales for the years 1965 to 1970.

Econometric estimates were made by inserting values of the independent variables into the econometric model for the appropriate years. Data for the independent variables used in the econometric model are shown in Exhibit 4. These data are "preliminary" estimates that would have been available at the time of the forecasts.

Exhibit 4
Data for Testing the Lodging Sales Model

Year	Corporate Profits	Intercity Passenger Miles	Lodging Rates	Aircraft Speed	Consumer Price Index	U.S. Population
	B	T	A	S		
1965	44.5	884	9.03	315	0.937	194
1966	48.1	937	10.10	320	0.963	197
1967	47.2	979	11.43	354	0.989	199
1968	51.0	1070	12.28	369	1.028	201
1969	50.8	1066	12.83	390	1.088	203
1970	44.2	1126	13.90	400[a]	1.165	205

[a]subjective estimate Sources and Units: same as in Exhibit 2

It was hypothesized that the combined estimate would be more accurate than one that relied solely on the preliminary survey. This is what occurred; as shown in Exhibit 5, the combined estimate was off by 5.0% over this time span, while the preliminary survey was off by 10.5%. These differences were statistically significant at the .05 level (Wilcoxon matched-pairs signed-ranks one-tail test from Dixon and Massey 1969). These improvements in accuracy were achieved at low-cost and would appear to be of practical importance.

Exhibit 5
Accuracy of Preliminary vs. Combined Estimates of Current Lodging Sales

Year	Final Estimate	Preliminary Survey		Combined Estimate (Equal Weights)		Econometric Estimate	
	($\$x10^6$)	($\$x10^6$)	$\overline{MAPE}$	($\$x10^6$)	$\overline{MAPE}$	($\$x10^6$)	$\overline{MAPE}$
1965	5489	5200	5.4	5634	2.6	6067	10.0
1966	6365	5900	7.6	6156	3.3	6413	0.8
1967	6533	6700	2.6	6342	3.0	5983	8.8
1968	6531	7300	11.1	6990	6.8	6679	2.2
1969	6418	7800	19.4	7181	11.2	6562	2.2
1970	6801	8043	16.7	7013	3.1	5983	12.8
Average	$\overline{MAPE}$		10.5		5.0		6.1

A sensitivity analysis was carried out using the 13 models from Exhibit 4 and considering various weighting schemes. The results, presented in Exhibit 6, show that the combined estimates reduced the error in the preliminary estimate (10.5%) in 63 of the 65 cases examined in the columns labeled 15% to 85%. The optimum combination was achieved with equal weights.

Exhibit 6
Predicting the "Final" Estimate 1965-1970
(Entries are $\overline{MAPE}$ s)

	Percent Econometric Model Contribution						
Model	0%	15%	33%	50%	67%	85%	100%
1	10.5	7.6	8.1	6.0	5.5	10.4	12.4
2	10.5	7.0	6.1	8.6	11.4	14.5	18.0
3	10.5	8.1	5.8	4.6	4.8	6.0	7.2
4	10.5	7.4	5.2	5.9	8.0	9.7	12.6
5	10.5	8.0	5.0	5.6	7.8	10.0	12.4
6	10.5	7.5	4.9	5.7	7.6	9.8	12.4
7	10.5	7.4	5.0	5.6	7.6	9.9	12.4
8	10.5	8.1	6.0	4.9	5.8	7.5	9.9
9	10.5*	8.6	6.0	5.0*	4.6	5.3	6.1*
10	10.5	8.2	6.0	6.5	5.0	6.5	7.5
11	10.5	8.4	6.1	5.1	5.2	6.7	8.0
12	10.5	8.2	6.0	5.0	5.0	6.4	7.7
13	10.5	8.2	6.0	5.0	5.0	6.4	7.6
Average	10.5	7.9	5.9	5.7	6.4	8.4	10.3

* Detailed results for these models are provided in Exhibit 5.

Forecasting Tests

The accuracy of a forecast depends on two factors: first, the accuracy in estimating sales at time t; and, second, the accuracy in forecasting changes from time t to t+f. Thus, if the econometric estimates improve the estimates of current sales, more accurate forecasts should result. To assess this, two forecasting tests were devised. The tests involved a comparison of the accuracy of two forecasting models. The first model used the preliminary estimate of lodging sales made by the U.S. Department of Commerce for **"current status."** The second model used an equally weighted average of the preliminary and econometric estimates to provide a combined estimate for "current status." Both models in each test used the same forecasts of "change."

The only way that the two tests differed was in the model used to forecast change. In one test an econometric model was used to forecast change; in the second test an extrapolation model was employed. The two change models provided an opportunity to examine whether the results were sensitive to the forecasts of change.

The forecasting tests were conducted for the 1965-1971 period. To obtain the largest possible sample size, current status for each: of the years from 1964 through 1970 was used as a starting point. This provided a total of 28 different forecasts; 7 for a one-year horizon; 6 for a two-year horizon; etc. as shown in Exhibit 7.

Exhibit 7
Forecasting Scheme for Lodging Market

		Year forecast was prepared						
		1964	1965	1966	1967	1968	1969	1970
Forecast Year	1965	F_{64-1}						
	1966	F_{64-2}	F_{65-1}					
	1967	F_{64-3}	F_{65-2}	F_{66-1}				
	1968	F_{64-4}	F_{65-3}	F_{66-2}	F_{67-1}			
	1969	F_{64-5}	F_{65-4}	F_{66-3}	F_{67-2}	F_{68-1}		
	1970	F_{64-6}	F_{65-5}	F_{66-4}	F_{67-3}	F_{68-2}	F_{69-1}	
	1971	F_{64-7}	F_{65-6}	F_{66-5}	F_{67-4}	F_{68-3}	F_{69-2}	F_{70-1}

Key: F_{i-j} is the forecast for the j^{th} year from the i^{th} starting year.

The econometric model for change was:

$$Y_{t+f} = (1.01)^f \, Y_t \left(\frac{B_{t+f}}{B_t} \right)^{0.8} \left(\frac{A_{t+f}}{T} \right)^{0.7} \left(\frac{A_{t+f}}{A_t} \right)^{-0.6} \left(\frac{S_{t+f}}{S_t} \right)^{-.05}$$

(See Exhibit 1 for description of variables: f is the number of years in the future.)

It was developed with procedures similar to those used for the econometric model that estimated current status. The coefficients in the model were not updated when each successive starting year was used; only the initial sales level was changed. Forecasts of the independent variables were based on linear extrapolations from data that would have been available at the time of the forecast.

The extrapolation model was based on an average forecast from two sub-models: a constant unit change model developed from a five-year moving average of the yearly unit changes; and a constant percentage change model developed from a five-year moving average of the yearly percentage changes. Data from 1958 up to the year of the forecast were used to develop these extrapolations. Then, as the starting year was changed, data from the years 1965 to 1970 were used to update the extrapolation model. Only data that would have been available at the time of the forecast were used. The results are summarized in Exhibit 8 where the average $\overline{MAPE}$ for each forecast horizon from 1 to 7 years is presented. The combined estimates yielded

a substantial reduction in the forecasting error: the $\overline{MAPE}$ s were reduced by about l/3 (from 12.7 to 8.6 for one test, and from 17.5 to 12.7 for the other test).

These improvements were each significant ($p < .01$ using the Wilcoxon matched-pairs signed-ranks one-tail test). Because the econometric estimates alone would have led to further improvements, it follows that any estimate of current sales that puts weight on the econometric estimates would have been superior to one that used only the preliminary survey by the Commerce Department.

Exhibit 8
Forecasting Error: Direct vs. Combined Estimate of Current Sales
(Entries are $\overline{MAPE}$ s)

		Change predicted by:					
		Econometric model			Extrapolation model		
		Current status estimated by			Current status estimated by		
Forecast horizon	No. of forecasts	Preliminary survey	Combination (equal weights)	Econometric model	Preliminary survey	Combination (equal weights)	Econometric model
1	7	15.4	8.0	6.0	14.9	7.4	4.5
2	6	16.0	11.6	7.4	16.8	11.8	7.9
3	5	14.8	11.2	9.5	16.8	12.4	11.6
4	4	10.5	8.9	9.2	14.3	12.1	13.0
5	3	8.6	6.9	9.4	11.9	11.2	15.3
6	2	10.5	4.8	6.4	17.0	11.8	15.4
7	1	13.1	8.8	4.7	30.9	22.0	14.6
Average	$\overline{MAPE}$	12.7	8.6	7.5	17.5	12.7	11.7

Conclusions

Further tests were made on the hypotheses studied in Armstrong (1970). This study differed substantially from that previous study in that:

(1) a different market was studied (the U. S. lodging market rather than the international photographic market);

(2) different time periods were involved for model development (1958-1964 for the current study vs. 1960-1965 for the 1970 study); and for validation (1965 to 1971 vs. 1954);

(3) time series data were used for model development in the current study vs. cross-sectional data for the earlier study;

(4) different procedures were used for validation. The current study predicted final estimates; in addition, two forecasting tests were made. The previous study used one backcasting test.

Results from the study of the U. S. lodging market supported the results from Armstrong (1970). Econometric estimates of current status provided useful information. A simple average of preliminary survey estimates and econometric estimates reduced the error in predicting "final" survey estimates from 10.5% to 5.7%. It also reduced the errors by about 1/3 in two forecasting tests.

The results were not very sensitive to the weighting scheme used to combine the econometric and direct sales estimates. A simple average of the two estimates provided nearly optimum results, but any estimate that incorporated information from the econometric models was superior to one that used only the preliminary survey estimates.

A sensitivity test supported the conclusion from previous studies that the accuracy of an econometric model is not highly sensitive to the estimates of the coefficients. Each of 13 different models provided improvements in predicting the “final” sales estimates.

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