Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management Dhaka, Bangladesh, January 9-10, 2010

A Market Driven Demand Estimation Model for the Indian Petroleum Industry

Uttiya Bhattacharyya
Indian Oil Corporation Limited
Mumbai, Maharashtra 400051, India

Rizwan S. Dhalla
Institute of Technology & Management
Vashi, Navi Mumbai, Maharashtra 400705, India

Abstract

Volatile oil prices and uncertainty in oil supplies had a significant impact on the petroleum industry in India as dependency on imported crude is very high. This paper examines the deficiencies of the existing demand estimation process in the Indian petroleum industry. It proposes the formulation of a market driven demand estimation model which incorporates inter-fuel substitution, technological developments in energy efficiency, environmental regulations, major national socio economic issues and price of petroleum products in the international markets along with the historical trend and seasonality. The market driven demand estimation model envisages efficient resource utilization in the Indian petroleum industry.

Keywords

Demand estimation model, multiple regression, inter fuel substitution

1. Introduction

The energy challenge over the next several decades is to meet the ever growing demand with affordable reliable supply, while ensuring environmental protection and quality. World oil demand has grown faster than the refining capacity due to better capacity utilization. Global energy demand grew despite high world oil and natural gas prices [4]. India's self sufficiency in petroleum product has reduced to 25% from 29.4% during 03-04 [7]. India consumes 3.1% of world's oil with 0.5% reserves [2]. Petroleum oil is the single largest export commodity currently from India. Surplus refining capacity is expected to increase to 140 MMTPA by 2030 [7]. As per Integrated Energy Policy 2006, India's energy mix comprising of coal, oil and gas are to play a major role till 2030-31 [5]. The most notable increase in share would be natural gas and nuclear power, while share of oil will reduce. Indian petroleum industries therefore should have a support system available for quick response to the market dynamics and align its supply chain to remain competitive with respect to its objective.

2. Review of Literature

Ramsey et al. (1974) analysed the market for the total United States annual supply of motor gasoline to private individual and to commercial use and concluded saying that the analysis of commercial demand points up the need for examining simultaneously the demand and supply of other fuels especially in the heating oil market [8]. Andrew et al. (1991), build a model for energy demand, by considering four economic sectors and four important fuels like gas, electricity, oil and coal. He made a methodological contribution to the way in which factor augmenting technical progress can be modelled [1]. Chase Jr. (1998), identified that the classical multiple regression methods can be utilized to model marketing activities [3]. Cooper (2003) used a multiple regression model to estimate both the short and long-run inelasticity of crude oil demand with respect to its price [6].

The literature does not suggest of incorporating inter fuel substitution in the demand estimation process in the petroleum industry. This paper proposes to use a multiple regression model to estimate the demand for petroleum products by incorporating multiple factors like price, inter fuel substitution, technological progress with historical time series and seasonality.

3. Model Formulation

In this paper, the demand estimation process for a major Indian petroleum company is studied and analysed. The existing demand estimation process for Naptha does not incorporate inter-fuel substitution by Natural Gas and Furnace Oil. This leads to a significant deviation between the actual demand and the demand estimated leading to idle refining capacity and/or shortages of Naptha.

Naphtha was the main feed stock in the fertilizer industry for production of fertilizer like Urea. It is also used by the fertilizer and the power producing companies as a heating fuel either to produce heat energy and electrical energy. This petroleum product enjoyed premium over other industrial fuels in India and added value to both the top and bottom line of the companies. Over the last decade, slowly when LNG (Liquefied Natural Gas) availability increased, the fertilizer and the power producing companies shifted to cheaper gas as both feed stock and as fuel. Due to the change in user demand, Naphtha started becoming surplus, requiring huge export mostly at cost price or at times at loss. However, this shift in demand is not captured by the industry or company through a model that incorporates inter fuel substitution.

Using a simplistic approach, the basic multiple linear regression model is used for estimation of the demand of Naphtha incorporating inter fuel substitution by natural gas and furnace oil.

$Y = b_0 + \sum b_i X_i \quad i = 1, 2, \ldots\ldots p$

Y	- dependent variable (predicted by a regression model)
p	- number of independent variables
X_i $(i = 1,2,\ldots p)$	- ith independent variable from the total set of p variables
b_i $(i = 1,2,\ldots p)$	- ith coefficient corresponding to X_i
b_0	- intercept (or constant)

Here, the dependent variable Y is the estimated demand of Naptha. There are 4 independent variables: Natural Gas Sales, Furnace Oil Sales, Price of Naptha and Price of Furnace Oil.

The model is developed with real time data from the fiscal (April – March) 2001-2002 to 2008-2009 of a major petroleum company in India. The data was de-seasonalised before estimating the causal relationship. The predicted value of dependent variable from the model has been used for the period, fiscal (April-March) 2005-2006 to 2008-2009 for comparison.

The model is validated by real time real time quarterly sales data of a major petroleum company in India from the fiscal (April – March) year 2005-2006 to 2008-2009 as tabulated in Table 1. The estimation model developed through multiple regression showed considerable improvement on demand estimation for the last four years when the inter fuel substitution was incorporated.

The predicted dependant variable, in this case the sales of Naphtha, was compared with the actual naphtha sales over four fiscal years (2005-06 to 2008-09). The error in absolute terms was less than -0.5%. This error of -0.5% is much less than the error of 9.1% derived by using the existing demand estimation model for the same data. Further, the Error of Sum of Square (SSE) is 156353 as compared to the SSE of 548148 from the existing demand estimation model. This clearly illustrates the effect of inter fuel substitution on the demand estimation of Naptha.

Table 3: summarises the results of progressive introduction of factors. In all the cases, the dependant variable were Naphtha sales (Y) and level of significance considered 0.05% and degrees of freedom 31.

Table 1: Comparison of Error Sum of Square between conventional and Regression model

	Naphtha sale	Regression Predicted Y	Residual	From Regression model SSR	Naphtha sale	From conventional model Y	Error	SSE
	TMT	TMT	TMT		TMT	TMT	TMT	
2005-06	559	605	-46	2113	559	743	-183	33508
	650	697	-47	2170	650	683	-32	1054
	624	705	-80	6466	624	757	-133	17760
	525	698	-173	30091	525	658	-133	17598
2006-07	567	666	-99	9721	567	720	-153	23376
	559	633	-75	5624	559	476	82	6760
	703	587	116	13436	703	545	158	24957
	786	598	188	35326	786	514	271	73456
2007-08	657	580	77	5864	657	738	-81	6548
	393	544	-151	22755	393	488	-95	9072
	597	563	35	1192	597	270	327	107220
	666	586	80	6461	666	369	297	88421
2008-09	541	576	-35	1199	541	610	-69	4711
	602	573	29	853	602	418	184	33987
	620	596	24	574	620	437	183	33451
	689	577	112	12507	689	431	258	66474
	9738	9783		156353	9738	8856		548354
	(a)	(b)		(d)	(a)	(c)		(e)
	(a) – (b)	-45			(a) – (c)	882	(d) –(e)	392001
	%	-0.46			%	9.1	%	71.49

TMT: Thousand Metric Tonne

Table 2: Summarises the improvement in demand estimation by the suggested regression model

		Error(Abs)	
Period 05-06 to 08-09	TMT	TMT	%
Actual Naphtha sale in TMT=	9738		
Predicted sale through regression model =	9783	-45	-0.46%
Predicted sale through conventional model =	8856	882	9.10%
Square Sum of Error by Regression model =		156353	
Square Sum of Error by conventional model =		548148	
Improvement in Square Sum of Error =		71.49%	

Table 3: summarises the results of progressive introduction of factors

	Independent variable	R	R Square	Residual Sum of Squares	F	Significance F	Coefficient	t	Significance t
1	Gas sale	0.862	0.743	478548	86.7	0.000	Intercept	30.3	0.000
							Gas sale	-9.3	0.000
2	Gas sale	0.865	0.749	467241	43.2	0.000	Intercept	15.5	0.000
	Naphtha price Rs/MT						Gas sale	-4.0	0.000
							Napta Price per MT	-0.8	0.406
3	Gas sale	0.871	0.758	450517	29.2	0.000	Intercept	1.56	.129
	Naphtha price Rs/MT						Gas sale	-3.95	0.000
	FO sale						Naptha price per MT	-0.4	0.694
							Furnace Oil sale	1.0	0.317
4	Gas sale	0.871	0.758	449746	21.17	0.000	Intercept	1.2	0.229
	Naphtha price Rs/MT						Gas sale	-3.9	0.001
	FO sale						Naptha price per MT	-0.35	0.727
	FO price Rs/MT						Furnace Oil Sales	0.98	0.333
							Furnace Oil Price per MT	0.21	0.831

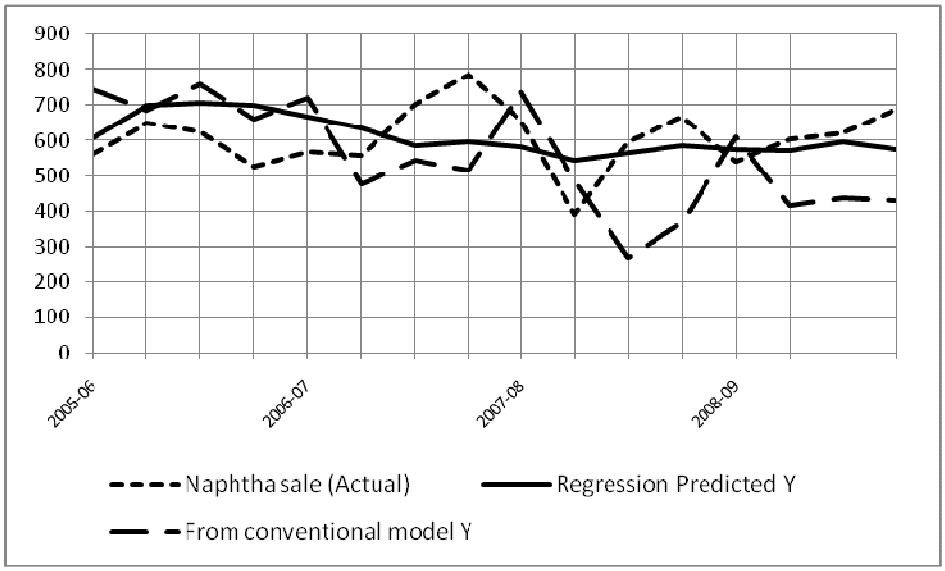
(FO; Furnace Oil, another liquid fuel used as heating fuel in furnaces)

It is evident that by progressively introducing various factors (Gas Sales, Naptha Price, Furnace Oil Sales, Furnace Oil Price) that affect demand of Naphtha, the over all significance of regression improved. The coefficient of determination, R squared, is the measure of the regression model as a whole. The improvement of the value of R square indicates the improvement in goodness of fit and that at least one independent variable strongly explains the changes in the dependent variable and the adequacy of the model.

While R squared represent the overall fitness of the model, 't' statistics explains the fitness of individual model parameter. If the t-statistics of a parameter is less than t distribution with degree of freedom n-2 (n is the number of experimental observations), at significance level $\alpha/2$, that parameter cannot explain the model well. For practical purposes, for more than n>30 samples, value of normal distribution can be used to approximate the t distribution. For significant level $\alpha = 0.05$, a threshold of 1.96 is considered. The value of coefficient for Gas Sale is negative. The negative value of the coefficient is also in line with the fact that, when gas sale increases the sale of Naphtha reduces. In other words gaseous fuel is substituting the liquid fuel Naphtha affecting the demand estimation. The value of coefficient of Naptha Price is also negative which validates the inverse relationship between demand and price. The value of coefficient for Furnace Oil Sale is positive. This shows that Furnace Oil acts as a complementary product to Naptha. There is no substitution of Naptha by Furnace Oil.

4. Conclusion

Over the years there is a shift towards uses of natural gas. There has been a substitution of Naphtha by gas. The existing demand estimation gives a high residual as compared to the demand estimation model incorporating the inter fuel substitution. The improvement in estimation by the suggested model is also shown by the graph below.



(X axis = Fiscal year April-March, Y axis = Quarterly Naphtha sales in TMT)

Figure 1: Naphtha Sales in TMT

We are entering a new world energy order with concerns about volatile world oil markets and uncertainty about supplies. The primacy of fossil fuel to continue, however there will be substantial improvement in energy efficiency and intensity. The criticality of petroleum business is felt by the facts that the input cost is rising, The refining capacities are becoming excess, the freight costs are increasing, the energy demand is on the rise whereas there is a strong resistance to due supply delay or change in prices. In this context, the sustainability of the petroleum industry in India is under threat. It is strongly felt that the days of inventory balancing and cushioning is over and the business should focus on the real need of the market with complete offering from efficient procurement, production and distribution. The correct estimation will lead to higher capacity and resource utilisation and reduce the shortages. Another major factor that affects the demand estimation of petroleum products is the technological advancement. Improvement in engine efficiency of the transport vehicles is another cause of shift in transport fuel like Motor spirit and High Speed Diesel sales. Through a suitable model the effects may be captured for better demand estimate in subsequent studies.

References

1. A. C. Harvey, and P. Marshall, Inter-fuel substitution, technical change and the demand for energy in the UK economy. Applied Economics, 1991, 23, pp. 1077-1086.
2. British Petroleum Statistics, 2008.
3. C. W. Chase, The role of the demand planner in supply chain management. Strategic Marketing Research and modelling Manager/ Director The Coca-Cola Company. The journal of business forecasting, 1998; editorial, pp. 23-25.
4. EIA (Energy Information Administration), USA, IEO (International Energy Outlook) 2007.
5. Integrated Energy Policy, 2006, Planning commission, Government of India.
6. Cooper, J.C.B., Price elasticity of demand for crude Oil: estimates for 23 countries-, Organization of the Petroleum Exporting Countries. OPEC Review, March 2003, pp. 1-8
7. PPAC (Petroleum Planning and Analysis Cell of Ministry of Petroleum and Natural Gas, India), 11th Plan document, internal estimates
8. Ramsey, J., Rasche, R. and Allen, B. An Analysis of the private and commercial demand for Gasoline. The review of economics and statistics, 1974, August 1.