IMPROVING PROCUREMENT THROUGH REGRESSION ANALYSIS: A CASE STUDY OF PREDICTING ARGENTINE JET FUEL PRICES

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ABSTRACT. Of all oil products consumed by the Argentine Air Force (AAF), jet fuel is the resource with highest demand and at the end of the day the most expensive support item procured by the AAF. Accurate predictions of Argentine jet fuel prices are necessary to improve AAF financial and logistics planning. Multiple regression analysis is one such tool that can aid in accurately forecasting the amount required when procuring this valuable commodity. Using this methodology, we develop and illustrate a highly predictive model that has an adjusted R^2 of 0.98 and an average percentage absolute error of 4%.

INTRODUCTION

Oil distillates are considered important elements to accomplish the missions of the Argentine Air Force (AAF). Of all oil products consumed by the AAF, jet fuel is the resource with highest demand and at the end of the day the most expensive support item procured by the Argentine Air Force. The AAF consumes more than 12 million gallons each year and spends almost 35% of its total material budget in the acquisition of this resource (Argentine Air Force Command of Material, 2006).

Crude oil is the main element in the production of jet fuel. During recent years, crude oil price instability has brought additional

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problems to budget and logistics planning. Inaccurate fuel price forecasts can cause major problems in the AAF budget. Predicting too high of a price results in the AAF receiving more funds than required for this commodity. This in turn results in fewer funds available to meet other priorities. In contrast, low jet fuel predictions mean that the received funds are not sufficient to pay for the cost of fuel, prompting the AAF to either request a supplemental appropriation or transfer funds from another account which produces other significant negative effects over the organization.

Accurate oil predictions are therefore an important strategy for the AAF to protect taxpayer contributions. Individual efforts have been attempted in the AAF to solve this issue such as the use of simple regression models, but the results have never been universally accepted in the organization. Not only is there a lack of understanding of the variables that affect the problem, but also there are difficulties in finding the appropriate tools to address this issue. This article attempts to rectify this by demonstrating the utility of using multiple regression techniques to improve the prediction of jet fuel prices for the AAF and thereby minimizing errors when procuring this valuable commodity.

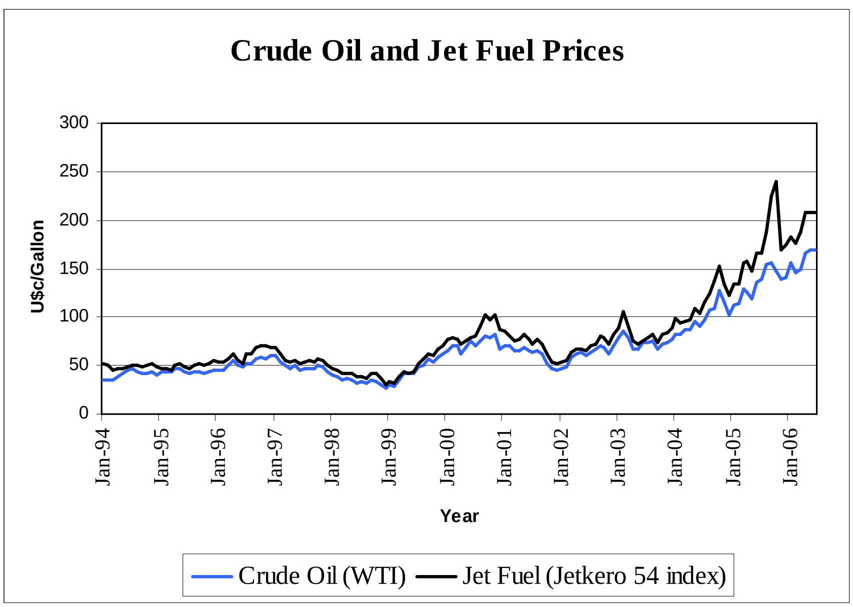
BACKGROUND

Accurate oil price predictions have not been easy to achieve since the oil embargo occurred in 1973. Especially during the last decade, jet fuel, a light oil distillate obtained by a chemical process called hydrocraking, has displayed extremely volatile prices, led by the erratic behavior of crude oil prices, the main component in jet fuel production. Figure 1 illustrates the erratic behavior of crude oil prices (WTI) and jet fuel prices (JetKero 54) from 1994 to 2006.

Several methods have been used to predict jet fuel prices with varied results over the years. Artificial networks (Kasprzak, 1995), multiple regression models (United States Department of Energy, 2002) and econometric forecasting (Coloma, 1998; Mercuri, 2001) have proved to be effective to forecast oil distillates prices like gas, fuel oil and jet fuel prices. Unfortunately, these models have been developed to forecast the variable of interest in the particular environment of the market, primarily the United States, but not in the Argentina market. Because of this, the direct application of these models to the particular conditions of the Argentine market to forecast jet fuel prices has brought meager results.

Finding a comprehensive model to predict jet fuel prices in Argentina is a real challenge for many reasons. The history of oil in Argentina has suffered from a lack of visionary thinking since its beginning on December 13th, 1907, when Humberto Baghin and Jose Fuchus, discovered oil; this lack of a clear vision has been the principal characteristic of the Argentinean oil policy (Gadano & Sturzenegger, 1998). Since 1907, the history of oil in Argentine has been associated with the ups and downs of the Argentine public policy. In practice until 1989, the Argentine oil industry was always under the strong influence of the state, limiting private participation in the sector (Gadano & Sturzenegger, 1998).

FIGURE 1
Crude Oil and Jet Fuel Prices 1994-2006



Source: Platts Co. (2006).

The 1989 economic crisis in Argentina found the oil sector in one of its more difficult moments. High foreign debt of the public company and a remarkable incapacity of increasing production rates showed that the ability of the country to maintain oil self-sufficiency was only a dream (Gadano & Sturzenegger, 1998). To overcome the situation of the energy sector, Argentina initiated that year a series of privatization actions in its oil sector. By 1993, the country had totally privatized its oil production and exploration.

Introducing these changes has not been an easy task; arguments in favor for and against the privatization process can be heard even today. Yet despite these arguments, Argentina on the average has almost doubled its oil production. This level of production has allowed the country to achieve self-sufficiency, to respond to the domestic increase in demand, and to increase its level of exportations (Argentine Secretary of Energy, 2006). In that process, jet fuel has followed a similar pattern; since 2002, the country has reached self-sufficiency and today the product is exported to other countries (Argentine Secretary of Energy, 2006). It is clear that the changes to the Argentina oil sector have begun to provide dividends to the country.

Although developing a model to predict jet fuel prices may help maintain these dividends, this is perhaps not the most important issue related to the necessity of accurate jet fuel price predictions. A long-term, fixed price contract with an adjustment clause ties the AAF to its main jet fuel provider, REPSOL-YPF S.A. When international and domestic circumstances change, contractually the parties are called to discuss the required adjustments in jet fuel prices that will apply until the next change in conditions. Accurate jet fuel price prediction will help the AAF to trace a better strategy that would help to protect taxpayer contributions.

In spite of Argentina's historical instability and economic problems, during the last five years the country has achieved an economic stability that allows for modeling accurate jet fuel prices. In this vein, we look to build a regression model assuming that the current stable Argentine economic conditions will continue into the future.

MODEL DATABASE

No statistical modeling is possible without the existence of data. In this light, we investigate potential domestic and international factors that could be predictors of Argentine jet fuel prices (measured in Argentine Peso per liter). The domestic factors we consider comprise of supply and demand relationships, domestic policies, inflation rates, and production capacity. The international factors involve aspects that are related with the international conditions of the oil market and how they affect the domestic oil price or the prices of its distillates.

As a crude oil derivative, jet fuel prices have shown strong correlation with crude oil prices and all the factors that affect oil prices (government policies, economic growth, energy demand and supply) (Kasprzak, 1995; U.S. Department of Energy, 2002; De Dicco, 2004; Mercuri, 2001; Coloma, 1998). Supply is influenced by the total capacity to produce jet fuel and the relation of this product with other oil products that are obtained with the same process from the same basic product (crude oil). In that sense, heating oil has been highlighted as a good predictor for jet fuel (Kasprzak, 1995; BMO Commodity Derivatives Group, 2005). Additionally, supply and demand for the product are also influenced by causes related to season and natural disasters (Kasprzak, 1995).

With respect to the domestic market, specifically for Argentina, studies clearly emphasize that fuel prices are highly correlated with international oil prices (De Dicco, 2004; Mercuri, 2001; Coloma, 1998). In his work, De Dicco analyzes how domestic oil prices are related with domestic production costs and international oil prices. He concludes that production costs (finding, development and lifting cost) in the country have been relatively stable over the last four or five years. However, the domestic costs that companies use to price oil derivatives for internal consumption have followed the increase of prices of crude oil in the international market. According to this finding, the behavior of the Argentine jet fuel market and the pricing policies used by the companies reflect fluctuations in the international oil market. Moreover, variations in domestic and international stock levels (Scheimberg, 1998) have been also indicated as factors that exert some influence over oil prices and the prices of jet fuel.

Although not meant to be all inclusion, the following list comprises of the explanatory variables (as explained in Table 1) that this study considered when developing a multiple regression model to predict Argentine jet fuel prices. Besides each variable, we display the variable's abbreviation used for parsimonious reasons while model building.

TABLE 1
Variables Used to Predict Argentine Jet Fuel Prices

Factors	Variables	Explanations
International factors	West Texas Intermediate (WTI)	a type of crude oil used as a benchmark in oil pricing, measured in US Dollars per barrel (monthly average)
	JetKero 54 index (JK 54)	the price of jet fuel in the Gulf of Mexico, measured in cents of dollar per gallon (monthly average)
Domestic factors	Value of the Argentine Peso in relation to the US Dollar (VPD)	measured in pesos per dollar
	Argentine Industrial Growth (IG)	recorded as a percentage of the previous month
	Consumption Inflation Rate (IR)	recorded as a percentage of the previous month
	Price Index of Argentine-Produced Wholesale Goods (IPP)	Base year equals 1993
	Internal Wholesale Price Index (IPIM)	Base year equals 1993
	Price Index of Argentine-Produced Wholesale Goods (natural gas and oil) (IPP O&G)	Base year equals 1993
	Argentine Total Jet Fuel Production (TJFP)	measured in cubic meters
	Argentine Jet Fuel Demand (TJFD)	measured in cubic meters
	Relation between the Argentine jet fuel demand and Argentine jet fuel production (RDP)	RDP = TJFD / TJFP

Because developing a model to predict a future price inherently involves forecasting, we also consider as possible predictors those aforementioned variables' lag effects, primarily the previous month's values. Using that for example, WTI (Lag 1) reflects using the previous month's WTI value to predict the current procurement price of Argentine jet fuel. We also consider past prices of jet fuel as an explanatory variable to predict current or future procurement of jet fuel.

With the aforementioned variables, we built a database using historical data provided from the Argentine Secretary of Energy (2006), the Argentine Institute of Statistics and Census (2006), and the Energy Information Administration (2006). We collected monthly information from March 2002 to November 2006 involving Argentine jet fuel prices, as well as data from the same period concerning the described domestic and international factors. The data was selected from March 2002 to avoid possible distortions in prices produced during the financial crisis that affected Argentina in 2001-2002.

Although the analysis of this crisis is beyond the scope of this work, it is important to highlight that this crisis was one of the most difficult situations that affected Argentina. This crisis had politic, economic and social implications. Five presidents governed in a two-month period. The default of the public debt (which reached values close to 150 billion dollars) had international implications (inability to access international credit and loss of international credibility) as well as internal implications (instability and fiscal insolvency). Other ramifications included the devaluation of the Argentine currency with respect to the U.S. Dollar and the consequent lost of people's purchasing power (Cortés Conde, 2003).

From this historical database, we used all 55 data points to build the regression model and to validate, with two exceptions. These two anomalies involved the recorded jet fuel prices of June and July of 2006. For a reason unknown to us, the data column corresponding to jet fuel prices as listed by the Argentine Secretary of Energy (2006) had incomplete inputs for this time period. Usually broken down by provinces, the data only had two points for the entire year. A follow up to the main AAF jet fuel provider, REPSOL-YPF S.A., provided the rest of the data but the aggregate number was much higher than the months before June/July and after this time period. Although suspect of what we had received, we temporarily placed the new information into the database. When the model diagnostics flagged these two points as being atypical of a mean jet fuel price, we quickly and permanently removed them from further consideration.

ANALYSIS AND DISCUSSION

Multiple regression analysis is widely accepted in several, very different disciplines such as business, economics, engineering, and the social and biological sciences (Kutner et al., 2004). As such, we turn to this procedure to build a predictive model for Argentine jet fuel prices to aid in procuring this valuable commodity. In building this model, we must keep in mind that "all models are wrong" (Box, 1976, p. 792). This quote is appropriate for those who are too incredulous of models, and for those who are not skeptical enough. Since models are by their nature approximations to a complicated reality, they are of course literally false. But, on the other hand, models are in practice the only instruments we have for understanding complex phenomena.

Building regression models for real data in general is not a simple process. The use of regression methodology assumes that we have specified the appropriate model; i.e., we have been able to find an appropriate set of significant and useful independent variables to explain the behavior of our dependent variable (Freund, Littell & Creighton, 2003). To aid in this endeavor, we turn to a well known statistical method known as stepwise regression. Stepwise regression can be used to help sort out the relevant explanatory variables to introduce in the model (Makridakis, Wheelwright & Hyndman, 1998). Three approaches, forward, backward and forward/backward regression, have been used to conduct this analysis. The last one of these approaches is more complex, but gives the better results because it involves an iterative process that combines the forward and backward methods (Makridakis, Wheelwright & Hyndman, 1998). This is what we used.

Several software packages can serve as the platform to compute the statistics required for the regression process; JMP® (SAS Institute, 2005) is one of them and has been chosen to perform our analysis. At this point, it is important to highlight that there is not an exclusive way of searching for a good subset of independent variables to introduce in the regression model; subjective elements like analyst judgment can play an important role into the exploratory process.

This means that no automatic procedure will always come across with the "best" model and judgment should play a key role in model building especially for explanatory studies (Kutner et al., 2004).

The final step in all model-building process is the validation of the model. Validation can be defined as a process in which the model and its behavior are compared to the real system and its behavior (Banks, Carson, Nelson & Nicol, 2004). The objective of the process is a judgment regarding how well suited a particular model is for a specific application (Hughes & Rolek, 2003). In our case it includes the model assumptions of normality, constant variance, and independence of model residuals. Additionally, we look to ensure that the model does not possess outliers, influential data points, or multicollinearity issues (linear redundancies) that may erroneously askew the results.

To assess the predictive ability and performance of the final model, we turn to the Mean Absolute Error (MAE), the Mean Absolute Percentage Error (MAPE), and empirical prediction intervals. The first two measures can be mathematically expressed as follows (Makridakis, Wheelwright & Hyndman, 1998):

$$MAE = \sum_{i=1}^{n} |e_i| / n$$

and $MAPE = \sum_{i=1}^{n} |PE_i| / n$,

Where $PE_i = (Y_i - \hat{Y}_i) / Y_i \times 100$,

n represents the number of data points used in the error calculations, and

$Y_i, \hat{Y}_i, e_i$ represent the observed, predicted, and residual values from the regression model.

The MAE error has the advantage of being more interpretable because it represents the average of the absolute error of the forecast. On the other hand, the MAPE measure is the average percentage of the absolute error of the forecast and it is considered an important measure especially when we want to compare different forecasting models (Makridakis, Wheelwright & Hyndman, 1998).

Preliminary results revealed that jet fuel prices are highly correlated with the international factors, WTI and JetKero 54. In relation to the considered domestic factors, a strong correlation exits between jet fuel prices and the indexes of inflation for wholesales: IPIM, IPP and IPP (O&G). Small or no correlation can be detected between jet fuel price and jet fuel production, jet fuel demand, demand/production relationship, value of Argentine peso in relation to U.S. dollar, consumption inflation rate, and industrial growth. Also a strong correlation exists between WTI and JK 54 index, and between the three selected wholesale inflation indexes. To mitigate multicollinearity issues, we selected only one of the international and domestic factors, that which displayed a significant correlation.

We list in Table 2 the explanatory variables, parameter estimates, and associated hypothesis p-values for predicting Argentine jet fuel prices two months into the future. We selected the two-month forward timetable for it provided a good compromise between applicability and data availability. Although the information needed to use the model is updated monthly on the relevant web-sites, we allowed for some cushion. Additionally, the oil commodity market can change very quickly given the relatively current instability of the Middle East. Thus, predicting too far into the future may be a risky endeavor indeed.

TABLE 2
Multiple Regression Model for Predicting the Cost of Jet Fuel Prices for the Argentine Air Force (Argentine Peso per Liter)

Variable	Estimate	P-value
Intercept	0.0988746	0.0216
X_1: WTI (L2)	0.0153382	*0.0001
X_2: IPP (O&G L2)	0.0011855	*0.0001
X_3: PostJan06	0.3100395	*0.0001

Note: * Actual p-value equates to a number smaller than 0.0001.
Parameter estimates significant at $\alpha = 0.05$.
L2 stands for lagged two months.

As seen in Table 2, one of the predictor variables includes a discrete event that affects the average cost of jet fuel from February 2006 onwards. That is, the model building analysis detected a significant increase in jet fuel prices that could not be attributable or easily modeled by any of the predictor variables we considered. Although this discrete event cannot be easily associated to a specific fact, it can be simulated by the use of a dummy variable to be introduced in the model. This dummy variable takes on the value of 1 when predicting jet fuel prices from February 2006 onwards and 0 otherwise.

The mathematical equation of the model in Table 2 (after some rounding for display purposes only) is:

$$\hat{Y} = 0.0989 + 0.0153 * WTI(L2) + 0.00119 * IPP(O \& G\ L2) + 0.31 * PostJan06$$

Where:

$\hat{Y}$ represents the predicted Argentine jet fuel price in Argentine Peso per liter,

WTI (L2) is the West Texas Intermediate in US Dollars per Barrel lagged two months,

IPP (O&G L2) is the Price Index of Argentine-Produced Wholesale Goods for natural gas and oil also lagged two months, and

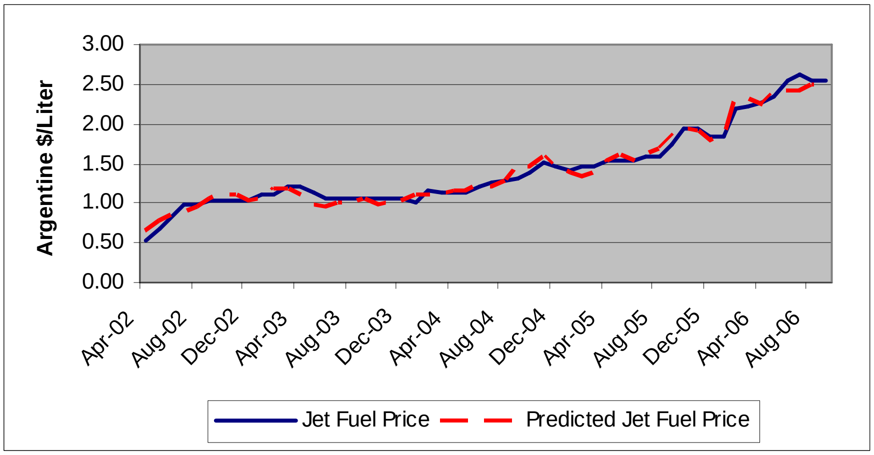
PostJan06, a dummy variable, takes the value of 1 for calculations from February 2006 onwards and zero otherwise.

This multiple regression model is highly predictive with an adjusted R^2 of 0.98 and an overall model p-value of less than 0.0001 (much lower than the customary level of significance of 0.05).

With respect to theoretical soundness, the presented equation satisfies all assumptions required of multiple regression analysis. At the 0.05 level of significance, the model's residuals passed the requisite assumption of normality, constant variance, and independence. The analysis utilized the Shapiro-Wilks test, Breusch-Pagan test, and the Durbin-Watson test to verify this (Kutner, Nachtsheim, Neter & Li, 2004). Additionally, none of the diagnostics detected outliers or influential data points.

Having met the theoretical model assumptions, we now need to know if the model performs as the real system behaves. Figure 2 illustrates the real price of jet fuel during the analyzed period of time and the results obtained by applying the constructed model to predict Argentine jet fuel prices. As seen in Figure 2, these two lines track fairly closely. To corroborate this good visual fit we turn to statistical measures that allow us to quantify the model's predicted response to the real system behavior. As mentioned previously, we use three different measures to determine the accuracy of our model: Mean Absolute Error, Mean Absolute Percentage Error, and percentage of times the true jet fuel price fell inside the prediction interval.

FIGURE 2
Comparison of Observed and Predicted Jet Fuel Prices



To ascertain the accuracy of the presented equation, we look for low forecasting errors and relatively high empirical coverage of the calculated prediction intervals. From the calculations, we observe that the average absolute error is equal to approximately 5 cents of Argentine pesos, while the average absolute percentage error is 4.24%. These validation measures indicate that our model shows good predictive behavior compared to the real system. Utilizing 95% prediction intervals, one would expect comparable empirical coverage if the presented equation was a predictive model. Of the 55 calculated intervals, the model missed only twice in its jet fuel predictions (and in both times the model overestimated the fuel cost). This accuracy rate of 53 out of 55 or 96.4% empirical coverage is in good agreement with the theoretical rate of 95% and further bolsters the validation of the equation.

To illustrate the use of the developed model, we propose a hypothetical situation. Suppose one wished to predict the price of jet fuel for the Argentine Air Force in February 2007. Back in December 2006, the WTI monthly spot price was $61.96 a barrel, while the IPP (O & G) Index was 712.49. Putting these values into the equation and rounding for illustration purposes, we then get $\hat{Y}$ = 0.099 +

0.015*61.96 + 0.0012*712.49 + 0.31*1, which is approximately equal to $2.20 Argentine pesos per liter.

CONCLUSION

Multiple regression models have shown to be effective to predict the prices of oil and its derivatives in the United States market. Although other methods such as econometric forecasting and neural networks have normally shown better results, their complexity have been an impediment to select one of these models. Additionally, it makes no sense to believe that a model that has proven to be useful with predicting jet fuel prices in the U.S. market or any other non-Argentine market can be directly applied to the Argentine market. However, one can adopt the methodology of multiple regression to aid the Argentine Air Force (AAF) in its procurement of this valuable commodity. Introducing any methodology in a complex environment such as the AAF requires a balance between complexity and accuracy. Multiple regression analysis provides a good trade off between these two aspects permitting us to obtain a model easy to understand, practical and useful.

Accordingly, eleven variables including international and domestic factors that may affect Argentine jet fuel prices were analyzed to select the best predictors. Using a stepwise regression process, we reduced these original potential predictors to a set of three significant predictors of Argentine jet fuel prices. These explanatory variables include the following: West Texas Intermediate Index (WTI), Price Index of Argentine-Produced Wholesale Goods (natural gas and oil) (IPP O&G), and a categorical variable for predictions from February 2006 onwards. Both WTI and IPP O&G are lagged two months, allowing jet fuel prices to be predicted two months out. The adjusted R^2 of the resultant model is high (approximately 0.98) showing an excellent goodness of fit to the real data in the analyzed period of time. The model's average absolute percentage error of 4.24% further corroborates this fact.

All these calculations have proven that the model could provide a useful planning and decision aid for the Argentine Air Force. Moreover, model complexity has been reduced through the use of only three variables, which are easily available in normally consulted URL addresses such us the Argentine Secretary of Energy, the Institute of Statistics and Census, and the Energy Information

Administration. This fact increases the usefulness of the model, and at the same time facilitates its introduction in the AAF environment. As a result, the application of the presented model in this article would help the AAF to increase forecast accuracy of jet fuel prices facilitating budget process and logistic planning.

Jet fuel is considered an important asset to accomplish the Argentine Air Force (AAF) missions; it is also the element with highest demand and the most expensive item supported by the AAF. Crude oil price instability, the main component on the production of jet fuel, added to high consumption rates and other unique factors of the Argentine market have caused problems that have directly affected budget process and logistics planning. The situation has created a real challenge for military personnel working in the acquisition of jet fuel for the Argentine Air Force. For years, they have tried to predict the price of this asset to improve financial and logistic planning, but the great number of variables that affected the problem and the lack of an adequate methodology have been the biggest impediments in achieving an acceptable solution. The presented model hopefully allows a more objective tool to use when procuring this valuable commodity and demonstrates this usefulness of multiple regression to consider for other cases.

NOTES

The views expressed here are those of the authors and do not reflect the official policy or position of the United States Air Force, Argentine Air Force, the United States Government or the Argentine Government.

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