ENERGY FORECASTING FOR COST BENEFIT ANALYSIS OF IMPLEMENTING ZERO EMISSION VEHICLES IN USA

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Abstract - The present study is concerned with estimation of the financial feasibility of implementing combination of Battery Electric Vehicles (EVs) and Fuel Cell Vehicles (FCVs) in North America using what-if approach. For this study authors have developed a framework to perform the Cost Benefit Analysis of implementing Zero Emission Vehicles (ZEVs) by estimating number of vehicles that are expected on road on year to year basis till 2050, of which Gasoline Powered Vehicles (GPVs) will be gradually replaced by EVs for short range transportation and FCVs for long range transportation. This framework has been applied to North America from 2018 to 2050. Our calculations show that estimated benefits of implementing Zero Emission Vehicles will be very significant as compared to continuing with Gasoline Powered Vehicles. It has been estimated from the model that Cost Benefit of switching to ZEVs will result in significant reduction of operations costs which is approximately equivalent to 130 billion USD of oil imports per year together it will be good for environment.

Keywords - Cost Benefit Analysis, Forecasting, Time Series Analysis, Hydrogen Vehicles, Electric Vehicles, Public Policy and Environment, ARIMA.

I. INTRODUCTION

Zero Emission Vehicles (ZEVs) which include Electric Vehicles (EVs) and Fuel Cell Vehicles (FCVs) are being promoted as zero tail pipe emission and environment friendly option alternative to Gasoline Powered Vehicles (GPVs) which translates to the fact that ZEVs have the capability to reduce carbon emissions in the atmosphere since an ZEV will not emit any tailpipe emissions [1]. Policy makers will also consider the economic costs of running these vehicles and need a profitable business plan if GPVs were to be 100% expendable. Policy decision makers such as International Energy Agency (IEA) want to create policies so that replacement of GPVs by ZEVs may curb indicated 28% (of 2016) of energy-related CO_2 emissions by road transport vehicles [2]. This effect is touted to increase over time as the number of vehicle requirement will also increase over the time. It is therefore critically important to develop a long-term, cost-effective strategy for reducing CO_2 emissions from the transport sector [3]. Many of the earlier studies are divided into two approaches [4]. In the first approach, researchers focus on hydrogen and electric supply given the infrastructure for production and distribution of charging and hydrogen supply. In the second approach, researchers determine the operational demand needed after estimating the number of FCVs or EVs. We adopt the second approach to examine the benefit and costs of the diffusion of FCVs and EVs and their effect on both emissions and the cost saved by following assumptions:

- Infrastructure costs remains the same whether it runs on batteries or fuel cells due to advancement in efficiency targets of Department of Energy (DOE) [5].
- Operational Cost of Gasoline saved by implementing ZEV by predicting the operational cost till year 2050.

The objective of the current study is to provide a model that builds on these studies. It compares EVs & FCVs with GPVs for the US market, without considering any indirect incentive tools (carbon tax on transport emissions) nor direct incentive tools for EVs/FCEVs (tax reduction, subsidies or bonus) because of simplicity and the focus of the study to study problem from statistics point of view. In our study we conduct Cost-Benefit Analysis (CBA) to evaluate the validity of ZEVs diffusion. CBA is useful technique to determine the feasibility of a project from an economic standpoint. In other words, it’s a tool used to determine the worth of a project or policy to benefit the society. The strength of the method is that it provides a framework for analyzing proposal and should the proposed project or policy be undertaken? In our study, we have used the benefit/cost ratio (B/C) as a validity indicator for diffusion and assuming infrastructure cost remains similar.

Typical costs of a CBA proposal would include:

- Operational Cost of ZEVs
- Capital Cost of the vehicles;
- Capital costs of any buildings, equipment, or facilities;
- Costs which can be valued vaguely in money terms (often described as 'intangibles').

CBA [4] involves the following steps to determine whether a project is worthwhile:

- Identify the costs and the benefits that will result from a course of action.
- Measure in dollar value the costs and benefits so that both costs and benefits that can be compared with potential alternative from local government policies.
- Incorporate the time dimension in the evaluation, because costs and benefits must be examined for the entire life of the project or program, not just for the current fiscal year.

Decide whether the result of the first three steps yields a large enough social profit (net social benefits) to justify the expenditure of limited funds.

II. PROCEDURE

The study is broken into two parts. First, we estimate the variables such as number of vehicles on road in US till year 2050 (to estimate travel miles), cost of gasoline till year 2050 and cost of electricity for charging EV till year 2050 through Auto Regressive Integrated Moving Average (ARIMA) time series analysis to find the values of useful variables described above. Cost of hydrogen till year 2050 is taken from already estimated values from literature. Second part of the study focuses on carrying out the cost benefit analysis by comparing two scenarios: Base case when all the vehicles in USA by the year 2050 are GPVs. Second scenario is when alternative fuel vehicles start to penetrate the consumer market based on whether the operational expenditure is negative or positive [7]. Based on our study there is currently equivalent cost of oil import and CO_2 emissions in tons. Based on the world energy exchange policies, the carbon footprint saved by these alternative vehicles will generate revenue using carbon trading, but we will not consider those here which remains a topic of another study. Here CBA is used to compare the cost with and without the alternative fuel vehicles in use. The calculations for CBA are based on the following basis:

- Estimation of GPVs and their operational costs proportional to the number of GPVs and price of gasoline estimate by year 2050. The procedure for estimation is ARIMA.
- Operation Cost due to EV charging, proportional to electricity retail price expected by year 2050 in USD/kWh.
- Operational Cost of FCV hydrogen retail price per kg.
- For estimation of Cost Benefit of implementing ZEVs across USA the following variables have been used:
- Monthly Residential Electricity Price from 1976 according to Energy Information Administration [11] [16].
- Yearly Cost of hydrogen based on the California Fuel Cell Partnership [7]. While future price is uncertain, NREL estimates that hydrogen fuel prices may fall to the $10 to $8 per kg range in the 2020 to 2025 period [7].
- Yearly Cost of Retail Gasoline Prices from year 1929 from [10].
- Monthly GPV sales data, which added to average registrations across a decade gives our vehicle data from year 1960 [15] [17].

Prediction for this problem has been carried out using ARIMA technique. There are number of different techniques through which cost benefit are calculated. The ARIMA gives prediction with lowest MAPE from Out of Sample (OOS) approach. Several other approaches to time series OOS are [9]:

- Simple exponential smoothing
- Trend corrected exponential smoothing
- Holt-Winter's exponential smoothing
- Autoregressive Integrated Moving Average (ARIMA)

The current framework incorporated stochastic models underlying the various forms of exponential smoothing and enabled the calculation of maximum likelihood estimates of smoothing parameters. It also enabled the use of Akaike's information criterion [10] for method selection. The sample is divided into two parts: the fitting sample and the validation sample. The fitting sample is used to find sensible values for the smoothing parameters, often with a sum of squared one-step ahead prediction error criterion. The validation sample is used to evaluate the forecasting capacity of a method with a criterion such as the mean absolute percentage error (MAPE) given in RESULTS section.

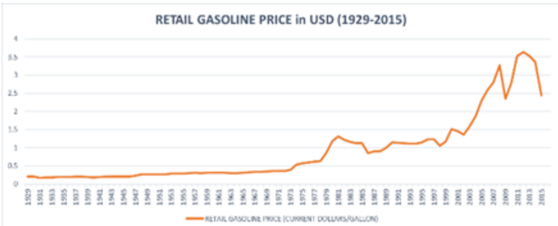

Figure 1: Price of retail gasoline price in USA.

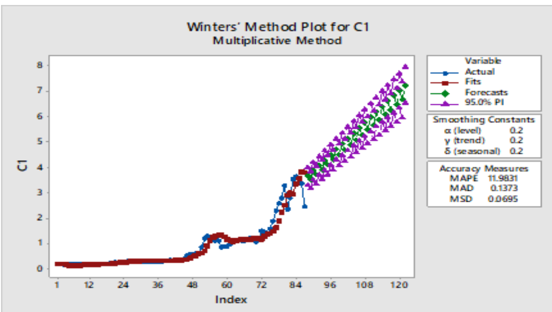

Figure 2. Winter's Method Forecasts.

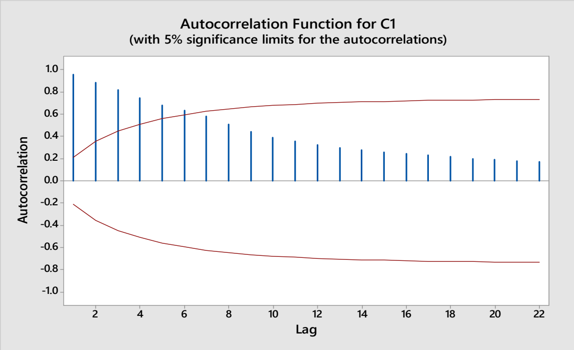

Figure 3. Autocorrelation function of retail gasoline price.

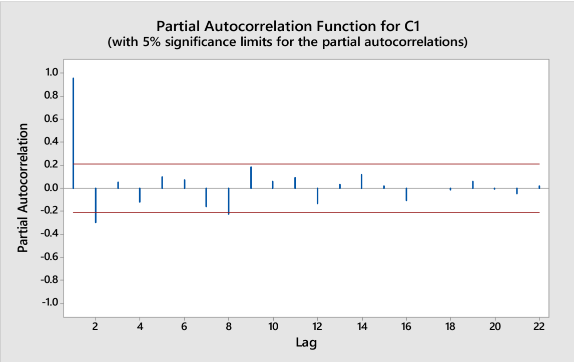

Figure 4. PACF of retail gasoline price.

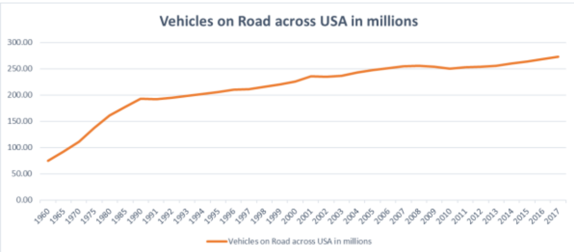

Figure 5. Vehicles on Road in USA.

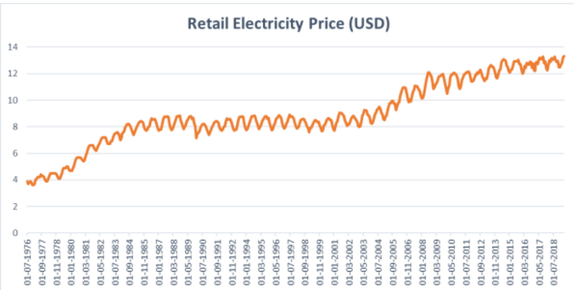

Figure 6. Retail Price of electricity in USA.

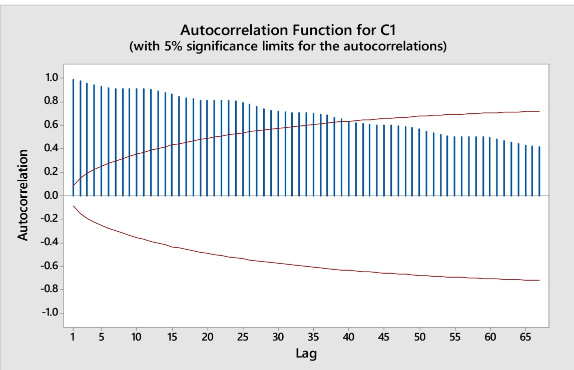

Figure 7. Autocorrelation for electricity price.

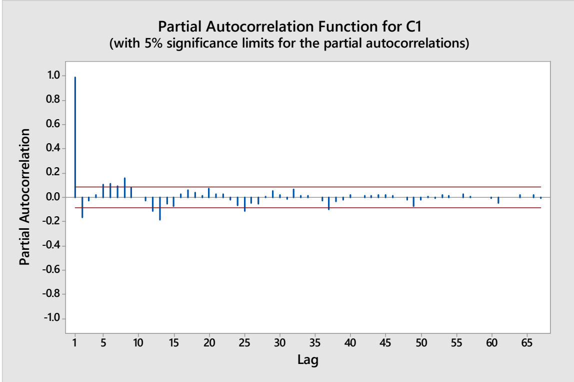

Figure 8. PACF for retail price of electricity.

The ARIMA procedure was also analyzed using SAS STAT and then forecasted for each univariate time series data for each variable by using the ARIMA and autoregressive moving-average (ARMA) model. Here Number of Vehicles on road was analyzed to be ARMA (1,1). An ARIMA model predicts that the forecasted value is a function of combination of its historical values and previous errors (if any in case of White noise or Autocorrelation).

The procedure of time series analysis was divided into 3 steps [14]: In the identification stage where we read the time series of each variable, possibly differencing them in case of non-stationarity, and calculated their autocorrelations and partial autocorrelations. In Gasoline retail price data differencing was done to detrend the time series. The analysis of the identification output usually suggested one or more ARIMA models that could be fit together with stationarity tests. ARIMA model of Retail electricity price with regular seasonality required differencing operators and autoregressive and moving-average parameters at different lags that are multiples of the length of the seasonal cycle i.e.6/12/18/24. The last part of the identification stage is the check for white noise. This is an approximate statistical test of the hypothesis that none of the autocorrelations of the series up to a given lag are significantly different from 0. If this is true for all lags, then there is no information in the series to model, and no ARIMA model is needed for the series, which turned out false for Gasoline price and retail price of electricity data.

The second stage of our parametric analysis was estimation and diagnostic checking, where we performed specified ARIMA model to fit to the variable and estimated the parameters of that model. This step also produced diagnostic statistics to helped judge the adequacy of the model, which came out be significant above 0.95 level of confidence. Extra terms of in the model were judged using significance of parameters and determined where additional terms are required in the model or not. The null hypothesis in this case was rejected and proved the significance of the hypothesis. Goodness-of-fit statistics helped in model comparison. The outlier statement provided a tool to check whether the currently estimated model accounts for all the variation in the series.

In the forecasting stage, we forecasted future values of the time series and generated confidence intervals for these forecasts from the ARIMA model produced by the preceding estimations stage.

III. RESULTS

Gasoline price data is extracted from Energy Information Administration [10]. The t values provide significance tests for the parameter estimates and indicates whether some terms in the model might be unnecessary. In this case, the t value for the autoregressive parameter is more than 10, so this term is highly significant. The t value for mean indicates that the mean term adds little to the model. Since the time series was non-stationary the obvious next step was to differentiate the series. The test statistics for the residual's series indicated negative for whether the residuals are uncorrelated. In our case, the test statistics reject the no-autocorrelation hypothesis at a high level of significance (p = 0.0001 for the first twelve lags.) This means that the residuals are not white noise, and so the AR (1) model is not a fully adequate model for this series. Refer Figure.7 for this explanation. Both the moving-average and the autoregressive parameters have significant t values. Number of vehicles sold in US is taken from US department of Commerce, Bureau of Economic Analysis [11]. Here the variance estimates, AIC, and SBC are all smaller than they were for the AR (1) model, indicating that the ARMA (1,1) model fits the data better without over-parameterizing. The normality plots also show no departure from normality. Thus, the ARMA (1,1) was taken as adequate for the time series. Later we employed a Cost-Benefit Analysis (CBA) to evaluate the validity of FCV and EV diffusion by evaluating % GPVs conversion to ZEVs [12]. From economic point of view the CBA is useful for determining the benefits of a GPV conversion to ZEVs. In our study, the differences between net present value between benefit and cost is seen as a goodwill measure for the society.

Here we examined the potential change in primary emissions from replacing current U.S. fossil-fuel vehicle fleet with ZEVs. We conclude that total health and climate cost reductions from hydrogen FCVs may be $33.3 billion per year in the U.S. for hydrogen from Wind Energy. The $33.3 billion in annual benefits of the ZEV Future scenario in 2050 would translate to an average of $1,045 in annual climate and health savings per-household across the ZEV States [8].

a) Cost of the hydrogen for the period of 2019-2050: The projected costs since the year 2050 for the hydrogen are $4/Gallon equivalent [13].

b) Electricity costs for the period of 2019-2050: Forecast of the residential electricity price by the year 2050 is 34.85 Cents/kwH:

Lag	Chi-Square	DF	P-Value
12	230.8	5	0.000
24	462.4	17	0.000
36	689.0	29	0.000
48	919.9	41	0.000

Table 1. Modified Box-Pierce (Ljung-Box) Chi-Square statistic

c) Cost of the gasoline for the period of 2019-2050: Forecast using Double Exponential Smoothing by the year 2050: 8.86 USD. Accuracy Measures were as follows:

MAPE	MAD	MSD
19.4851	0.1875	0.1080

Table.2 Accuracy Measures for Gasoline Prices

d) **Increase in the number of gasoline powered vehicles for the period 2019-2050:** Using Exponential Smoothing with a factor of 0.4 the expected number of vehicles are 13 billion. Accuracy Measure were as follows:

MAPE	MAD	MSD
10.926	17.033	439.640

Table 3. Accuracy Measures for Vehicle Count

Net benefit by running all gasoline vehicles is financial deficit of 74.60 Billion Dollars.
Once the 60 % of vehicles on roads are Zero emission Vehicles the net benefits starts to rise and for 100% ZEV the net benefits US can generate is 60.6 Billion Dollars. Equivalent of the savings in USD is estimated to be oil imports of 5.25 billion USD per month using the Cost-Benefit formula i.e. the difference between Oil imports saved minus charging/refilling cost for ZEVs.

IV. CONCLUSION

Cost Benefit Analysis is performed on several important variables to forecast the cost benefits when Zero Emission Vehicles (Electric Vehicles and Fuel cell Electric Vehicles) are implemented across USA till 2050 and simultaneously calculating the benefits as difference of operational cost between the two scenarios. Infrastructural costs are assumed to be same as they would be in case GPVs still remain active on road. Time series analysis is performed for forecasting. Cost of yearly operational costs change from deficit of 74.6 billion USD to 60 billion USD net profits. Hence the total benefits of ZEVs implementation are estimated to be 134.6 Billion USD per year. The operations cost can be further decreased if FCVs are deployed with lower operating cost of half i.e. up to 7 cents per mile.

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