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RESEARCH ARTICLE OPEN ACCESS

Determinants of the Demand for Alternative Energy in the U.S. Public Transportation System.

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ABSTRACT
The process of improving the present transportation system to a more renewable structure is a global challenge because the sector is still heavily dependent on fossil fuels which inadvertently produces a significant proportion of greenhouse gas. There is increased awareness of the use of alternative fuels to improve air quality and promote cleaner energy in the public transportation system. This study aimed to examine the determinants of demand for alternative energy in the U.S. public transit system. Secondary data extracted from Clean Cities Alternative Fuel Price Reports, US EIA,and Bureau of Transportation Statistics were subsequently analyzed with the vector autoregression (VAR) technique. The findings demonstrated that alternative energy sources and their conventional counterparts are close substitutes. The variation of their quantities and prices shows that the popularity of one is a drag on sales of the other. The U.S. population and total registered buses appear to have only marginal effects on the promotion of alternative fuels in U.S. public transportation.The paper concluded that efforts to promote alternative fuels need maximum coordination from the authorities. The demand for alternative energy should be cushioned by regulating its prices and promoting its availability.

Keywords: *Alternative fuel, Public transit, Demand, VAR*

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I. INTRODUCTION

Fossil fuel formation takes millions of years and comes from ancient animals and microorganisms. It is not renewable.Huang et al [1]. It has been predicted that fossil fuels may not be available for the next 65 years. However, the United States transportation sector relies heavily on petroleum products. EIA 2009[2]. In the U.S., initiatives to minimize dependence on the usage of fossil fuels range from the establishment of the National Highway Traffic Safety Administration program to the Department of Transportation's law on minimum fuel economy standards for minimum and heavy-duty vehicles. Public transport as the major means of travel releases emissions that cause environmental noise while national income is plunged into the importation of fuel. Yet, the demand for conventional fuels keeps rising. EIA 2009[2]. According to Amrouche et al. [3], transportation is the major source of particulate matter and greenhouse gas emissions through gasoline and diesel engines.

Vehicles have different engines and capacities which make their level of fuel consumption differ. Varieties of fuels that can be used to propel

public transit were summarized by Tong et al. [4] to include biodiesel, diesel, hydrogen, liquefied natural gas, electric trolley bus, propane, ethanol, dimethyl ether, and BEB. Nonetheless, biofuel, biodiesel, ethanol, methanol, and hydrogen are proven sources of alternative energy that reduce fuel carbon content and can sustain the future because it is environmentally friendly. Tong et al. [4]. Amrouche et al. [3] explainedthat these fuels have been one of the leading alternative fuels to fossil fuels in Algeria – it is cheaper when compared with gasoline or diesel, generate low emissions, and can be used ingasoline and diesel engines. The calculation of fuel usage used to be fuel consumed per mile.

The National Academy of Science [5] reported that the distance covered per gallon of fuel is used as a metric for fuel economy and is measured in miles per gallon (mpg). Fuel consumption is calculated based on the amount of fuel used in driving a specific distance. It is usually measured in gallons per 100miles or gallons per kilometer. Considering the efficiency of fuel, with a gallon per mile, it was discovered that the relationship between fuel economy and fuel consumption was not linear. Hence, there is a need to clearly understand the difference between fuel economy and fuel consumption. TRAX [6] conducted experiments to determine the level of fuel reduction with the aid of improving the technologies of different vehicles. The changes in aerodynamics, auxiliary load, rolling resistance, mass weight reduction, idle reduction, and intelligent vehicles were used. It was discovered that there was a significant change in the dollar per fuel saved, and greater fuel economy was attributed to alternative fuels. The authors, therefore, expressed a puzzle as to why alternative fuels are not yet popular on the roads. Taking the challenge up, this study was intended to analyze factors that may determine the demand for alternative fuels in U.S. public transportation.

II. A BRIEF TOUR OF THE LITERATURE

The transport sector, from private to public buses and trucks, intensively uses diesel and gasoline. Huang et al [1]. According to Davis et al. [7], there were close to 2000 transit agency operators in the United States in urban and suburban areas as of 2014. These agencies transport 19.4 billion passengers with 2.2 billion vehicles with 69,500 vehicles per mile Davis et al. [7]. The increase in demand for fossil fuel, however, brought the challenge of the cost of importation, environmental pollution, and fuel efficiency. According to [1], 80% of global energy is derived from fossil fuels. Hence, pollution and resultant effects on climate change have contributed to the need to seek alternative fuels. Also attempting to reduce the cost of importation of fuel in the United States is one of the reasons to find an alternative fuel. Tong et al. [4] explainedthat hydrogen, biodiesel, natural gas, ethanol, and propane are all better in terms of containing emissions, unlike fossil fuels. Although they may be costlier to procure and use, alternative fuels burn cleaner than fossil fuels. However, the reaction of Americans to the possible depletion of fossil fuels and the ever-growing demand for the products and non-replaceable ability necessitated the need for alternative fuels.

Alternative fuel can be regarded as non-conventional fuel or materials used instead of fossil fuel but from biomass, chemically stored electricity, hydrogen, non-fossil natural gas, propane, bi-alcohol, and biodiesel. Franzitta et al [8] identified hydrogen as an efficient renewable source that has one–half times more electricity when heated and is a very good mix for transportation whichcan further assist to mitigate climate change. Fossil fuels, however, are localized, not renewable, and unevenly found in certain parts of the world making it to be expensive. The quality of life has been described as directly related to the level of energy consumed. Therefore, energy which is produced through fuel combustion is useful for domestic activities and most importantly mobility of goods and passengers. The specific reasons identified for the use of alternative fuels are reduction in global warming, pollution reduction, reduction in the cost of fuel, and the possibility of reusing waste. Thus, alternative fuels promote sustainable development. The Federal Transit Administration [9] indicated some reasons for the adoption of alternative fuels include the manner in which state and federal governments render assistance to operators of alternative fuel buses, the regulations on air quality, the need to reduce particulate matter and toxic gases, incessant increase in oil prices, dependency on foreign importation of oil, perception of customers boarding the transits, some industry requesting for a certain type of fuel and the need to harness local resources in the United States.

A brief description of alternative fuels is as follows: *Methanol* is a colorless, odorless product from natural gas, coal, biomass, or oil. CH_3OH is the organic formula for methanol. Another fuel is *ethanol* which is produced through the fermentation of sugar from grains, wheat, or biomass. It is also colorless and can also be produced from wood fibers, yeast, starch, or cellulose. Some trees, grasses, and crop residues can be used in the production of ethanol. Although propane (C_3H_8) is also colorless and added with

odorant as a warming agent. It is usually regarded as fossil fuel (a form of liquefied petroleum gas). It is a by-product of refined petroleum and natural gas processing. As a fossil fuel, it is non-renewable. *Biodiesel* is made basically through the reaction of alcohol and vegetable oils or fats in form of recycled products. It requires special engines called diesel engines for them and is mostly blended with 20% of B20 or 100% of B100. Biodiesel is an alternative fuel that is usually made through the combination of oil or natural oil with alcohol. Trans esterification is the process by which biodiesel can be produced with the mixture of soya beans with methanol in addition to an acid catalyst. Mott et al [10], Jahanian&Jazayeri[11]. There is a clear difference between petroleum-derived diesel and biodiesel as the former is non-renewable while the latter is renewable. To produce in large quantities, plant oils are used with the aid of catalysts like carbonates, alkoxides, or sodium hydroxides. The hydrogen fuel cell makes use of hydrogen and oxygen which has water as its product. It is a promising alternative fuel even in the future as improvements on it increase daily. Mott et al [10]. The invention of electric vehicles has also worked complementarily on general awareness of alternative fuels.

III. METHODOLOGY

This study was anchored by the behavior of six variables: alternative fuel, conventional fuel, population, registered buses, and prices of alternative and conventional fuels. Both fuel types are substitutes – the popularity of one affects the demand for the other. Alternative fuel is defined as an energy source that is cleaner, safer, and has little or no contribution to carbon emissions. The alternative energy sources included in this study are biofuel, biodiesel, ethanol, methanol, and hydrogen. In contrast, conventional energy is sourced from fossil fuels, which contribute to greenhousegas emissions. The conventional energy sources included in this study are gasoline, diesel, propane, and compressed and liquefied natural gas. Total registered buses are also considered as more buses on the road imply more energy used. The U.S. population also matters because the degree of traffic reflects a great extent the size of the population. Finally, according to economists, the major determinant of demand for a commodity is its price and the price of the related commodity. Hence, both prices of alternative fuel and conventional fuel are included as explanatory variables. While the price of alternative fuel is proxied by the price of E85, the price of conventional fuel is represented by the price of gasoline.

Given that alternative and conventional fuels can influence each other, allowing alternative fuel to exclusively be treated as an independent variable seems a misguided process. Thus, this study solves this problem by employing a vector autoregression (VAR) technique. While both fuel types feature as dependent-independent variables, the other four variables are exclusively exogenous variables. More formally, the VAR model is specified as follows:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + BX_t + \mu_t \qquad (1)$$

Where Y is a 2×1 vector of dependent variables (alternative fuel and conventional fuel), A_1 and A_2 are parameters related to the lagged "Y". Note that the lag order is 2, which was selected based on the Akaike and Schwarz information criteria. X is a 4×1 vector of exogenous variables (registered buses, population, price of alternative fuel, price of conventional fuel). B is a vector of parameters of exogenous variables and "μ" is a vector of error terms.

More specifically, equation (1) can be unpacked as follows:

$$ALTFUEt = \alpha_{11,p}\Sigma_{p=1}^{2} ALTFUE_{t-p} + \alpha_{12,p}\Sigma_{p=1}^{2} CONFUE_{t-p} + \pi_k \Sigma_{k=1}^{4} X_{kt} + \mu_{1t} \qquad (2)$$

$$CONFUE_t = \alpha_{21,p}\,\Sigma_{p=1}^{2} CONFUE_{t-p} + \alpha_{22,p}\,\Sigma_{p=1}^{2} ALTFUE_{t-p} + \lambda_k \Sigma_{k=1}^{4} X_{kt} + \mu_{2t} \qquad (3)$$

Where *ALTFUE* is alternative fuel,*CONFUE* is conventional fuel, X_1 is U.S. population, X_2 is registered buses, X_3 is price of alternative fuel and X_4 is price of conventional fuel. Secondary data on these variables were extracted from the Clean Cities Alternative Fuel Price Reports, U.S. Energy Information Administration, Bureau of Transportation Statistics, and American Public Transit Association. The data covered the period 1999-2019.

IV. RESULTS AND DISCUSSION

Table 1: Descriptive statistics of the variables

	Mean	S. Deviation	Min	Max
Alternative fuel (millions of gallons)	36.40	26.39	0.80	75.30
Conventional fuel (millions of gallons)	293.71	134.96	90.40	468.97
U.S. population (millions)	305.45	15.59	279.00	328.30
Total registered buses	830656	85289	666064	992152
Price of alternative fuel ($)	2.96	0.97	1.72	4.71
Price of conventional fuel ($)	2.44	0.76	1.17	3.65

Source: Author's computation (2022)

Table 2: Results of VAR analysis

	Dependent variables	
Independent variables	*Alternative fuel*	*Conventional fuel*
Alternative fuel (-1)	-0.44*	2.21*
Alternative fuel (-2)	-0.36**	1.08*
Conventional fuel (-1)	0.13*	0.44*
Conventional fuel (-2)	0.02*	0.38**
U.S. Population	0.08**	0.20**
Registered buses	-0.439*	0.124*
Price of alternative fuel	-25.34*	48.98*
Price of conventional fuel	18.84*	-65.85*

R-squared = 90%; F-stat= 14.2*
* Indicates statistical significance at 5%; ** indicates no statistical significance at 5%
Source: Author's computation (2022)

Table 1 contains the descriptive statistics of the variables. The average quantity of conventional fuel (293.71 million gallons) is about eight times as much as the average value of alternative fuel (36.40 million gallons). This projects the dominance of conventional fuel in the U.S. public transportation sector. The standard deviation of alternative fuel (26.39 million gallons) is relatively close to its mean value, suggesting that alternative energy sources are prone to large fluctuations in the U.S. However, the standard deviation of conventional fuel (134.96 million gallons) is somewhat far from the mean value. The minimum and maximum values of both fuel types consolidate the interpretations of their means and standard deviations. The mean price of alternative fuel ($2.96) is more than that of conventional fuel ($2.44). This suggests that alternative fuel is more expensive to purchase than conventional fuel. While the regression analysis below bring into the limelight the effect of the price differential, it is tempting to assert that the demand for alternatives is relatively low among the stakeholders of road transportation because it is more expensive than conventional fuel. The standard deviations of prices of the two energy types identify that their prices have not been disturbed by large volatilities – their prices have been stable until the Russian invasion whichcaused major shake-ups in the U.S. energy markets. Also, given the proximity of the mean, minimum and maximum values of the U.S. population, it follows that the population has not been changing markedly over the period that this study covers. A similar explanation holds for the total registered buses in the U.S. public transit system.

As presented in Table 2, past values of alternative fuels have a negative effect on the present value. The previous-year value has a greater impact (-0.44) than the value in the two preceding years (-0.36). This suggests that using alternative fuels in the U.S public transit system is discouraging. Potentially, there are limited gains from using alternative fuel – past decisions to use non-fossil fuel energy sources are met with no corresponding payoffs. On the other hand, past values of conventional fuel have a positive, significant impact on its present value. Again, the preceding-year value has more power (2.21) to change the decision to keep using conventional fuel than the

value in two previous years (1.08). Intuitively, using conventional fuel is systemically rewarded – there are large returns to the operating costs – so users of such fuel are encouraged to keep using it.

Table 2 also shows that using conventional fuel today triggers patronage for alternative fuels in the future. This is evident as a 1-million-gallon increase in the preceding-year value of conventional fuel increases the demand for alternative fuel by 0.13 million gallons. The same increase in the quantity of conventional in the two-preceding years increases the demand for alternative fuel by 0.02 million gallons. Apparently, there is a wide interest among Americans to reduce greenhouse emissions, having been exposed to some of the horrible consequences of global warming and climate change. Expectedly, the quantities of conventional fuel in the prior years have a positive nexus with their quantities in the current year: regular users of conventional fuel appear to find the switch to alternative fuel unattractive. Nonetheless, the lagged values of alternative fuel seem to have the same but opposite effect on the current values of alternative fuel as the lagged values of conventional fuel on current values of conventional fuel.

As for the exogenous variables, the U.S. population has a positive impact on both demands for alternative fuel and conventional fuel. It shows that an increase in the number of people living in the U.S. is a gateway to increasing the demand for both energy sources. However, conventional fuel is likely to experience more increase (0.20 million gallons for every 1 additional person) than alternative fuel (0.08 million gallons for every addition). It is also noteworthy that an increase in the number of registered buses would likely reduce the demand for alternative fuel by 0.44 million gallons while it increases the demand for conventional fuel by 0.12 million gallons.

This leads us to the impact of prices, with the coefficient of the price of an energy source being negative on demand for such source and negative if otherwise, it goes that both energy sources face normal demand curves – the higher the price of a fuel type, the less the demand for it. Comparatively, it indicates that both energy sources are substitutes – the higher the price of a fuel type, the higher the demand for the rival fuel type. This follows the standard microeconomic principle on demand for a commodity that has a close substitute. In essence, these findings signal that alternative fuels and conventional fuels are hardly complimentary. They are rather considered substitutes in the baskets of goods of their users. What determines the demand for an energy source is therefore the perceived returns of the user and the individual consciousness of the need to reverse climate change.

The R-squared measures the variation in the dependent variables (alternative and conventional fuel) that is accounted for by all the regressors, and the F-stat is a measure of statistical significance of all the regressors. In Table 2, the R-squared of the VAR estimates is reported as 90%. This shows that the regressors (independent variables) are sufficient to cause changes in the dependent variables. The F-stat also shows that all the regressors are statistically significant at 5%. For the estimates, (with the exception of)alternative fuel (-2), conventional fuel (-2), and the U.S. population, all other coefficients are statistically significant at 5%.

V. CONCLUSION AND IMPLICATION

The impact of climate change and global warming is already an issue of great concern. From intense heat, bushfires, and flooding to food insecurity. The identified factors have made living less comfortably. Global leaders and decision custodians have been on the consistent calls in reversing climate change. The major solution is decarbonization. As stated earlier that the transportation sector has been identified as a major polluter of the atmosphere, thus reducing greenhouse emissions in the sector is a step with huge multiplier effects in reversing climate change. One of the major strategies for neutralizing carbon emissions is the use and promotion of non-fossil fuel sources of energy (otherwise known as alternative fuels). To capture the dynamics of the carbon-limiting sources of energy, this study has investigated the determinants of the demand for alternative energy in the U.S. public transportation system.

It was established that conventional and alternative energy sources are best treated as substitutes. This implies that the prominence of one overshadows the demand for the other. However, gains from using alternative fuels appear non-supportive of their continuous patronage. Arguably, the high average price of alternative fuel is not more than compensated by the revenues and profits made from the commercial purpose for which the fuel is used. The demand for alternative fuel in the U.S., therefore, appears to be facing unpromising trajectories. This conclusion cannot be extended to conventional fuels whose previous quantities are reinforcing the current level of demand. In other words, more registered buses on U.S. roads do not lead to increasing demand for alternative fuel, whereas they generate more sales of conventional fuel. This

elucidates the notion that not only is the actual demand for alternative fuel low, but its desired demand among new drivers and workers in U.S. public transportation is equally low.

Furthermore, it is important to state that the two energy sources are close substitutes, though the quantity demand of conventional fuel is more responsive to a change in the price of alternative fuel than the alternative responses to the price of conventional fuel. This explains that a slight increase in the price of alternative fuel will trigger a sharp increase in the demand for conventional fuel. Nevertheless, a little increase in the price of conventional fuel will not generate a significant increase in the demand for alternative fuel. That is, the demand for alternative fuel is less elastic than the demand for conventional fuel. This is the main area that calls for the intervention of the U.S. authorities. Prices of alternative fuels should be regulated in a way that blows up the demand for such fuel types. This will promote the efforts of the U.S. government in combating climate change across the country and as well as the globe.

FUTURE WORK

Future researchers may be interested in examining rival alternative fuels, taking into account the latest technological developments, and deciding upon the best-performing fuel that would be beneficial.

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