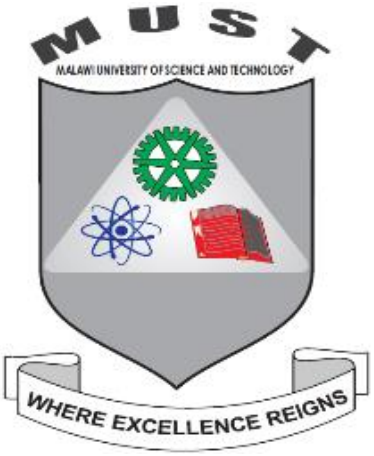


FACTORS SHAPING LIQUID FUELS CONSUMPTION: AN ANALYSIS OF PETROLEUM PRODUCTS DEMAND FORECASTING METHODS

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ABSTRACT

This research focused on evaluating how different factors affect the local demand of petroleum products in the present and future scenarios. The study aimed to achieve three objectives: first, to analyze the correlation of Urbanization, Industrialization and Income on the local demand of liquid fuels in the present and future scenarios; second, to analyze the causal relationship Urbanization, Industrialization and Income on the local demand of liquid fuels in the present and future scenarios; and lastly, to compare different data-driven modelling approaches, determine a model best suited for petroleum products demand forecasting for Malawi. The researcher utilized secondary data obtained from the World Bank online World Development Indicators database, National Oil Company of Malawi & Petroleum Importers Limited, including demographic, economic and fuel sales data for the years 2017 to 2022. Additional sources of information included Reports, Journal Articles, Books and Online Publications. The collected data was analyzed using XLMiner Analysis Toolpak in Microsoft Excel to perform Spearman rank correlation and Linear regression tests addressing objectives 1 and 2. Scatter Plots were created for linear regression analysis. Smartdraw application was used to create a flow diagram to provide guidance for the process of selecting a demand forecasting technique for petroleum products prediction thus addressing objective 3. The findings confirm a positive association between Urbanization, Industrialization, Income and local fuel demand and more importantly statistically significant relationship between Urbanization and local fuel demand. This suggests that as the Urban Population of the country keeps increasing, the Total fuel Demand will also tend to increase, highlighting the importance of close analytical monitoring of these factors is critical to short- and long-term planning of supply of fuel and other energy policies.

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ACRONYMS AND ABBREVIATIONS

ARDL	Autoregressive Distributed Lag
DF	Degrees of freedom
IEA	International Energy Agency
GDP	Gross Domestic Product
LPG	Liquefied Petroleum Gas
NCST	National Commission for Science & Technology
NOCMA	National Oil Company of Malawi
NSO	National Statistics Office
PIL	Petroleum Importers Limited
PPP	Purchasing Power Parity

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Spearman rank correlation coefficient

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1. GENERAL INTRODUCTION

1.1. Introduction

To determine the availability and number of buyers of petroleum products, various factors that influence the products' demand need to be identified and evaluated. A management study by Malawi Energy Regulatory Authority and other stakeholders, states that the economic well-being of any nation depends on maintain a proper balance between the supply and demand for petroleum products (MERA, 2021).

At a time when the country has aligned its development goals with Malawi 2063 agenda, having a balance between liquid fuel supply and demand continues to be a challenge. For 3 years running, Malawi has experienced sporadic fuel supply. There have been attempts on all fronts to alleviate the problem by petroleum industry stakeholders, literature shows it remains a matter that's yet to be fully resolved.

This research aims at understanding the factors that affect the local demand of petrol and diesel fuels, an approach that if carried out systematically could enhance knowledge in this area of petroleum economics which is continuously evolving.

1.2. Background

As countries develop and industrialize, their oil consumption grows with their economy (Abdel-Aal & Alsahlawi, 2014). As such, the fuel sector is a critical component of the energy system in many Sub-Saharan African countries, particularly those that import most of their fuel like Malawi. Petrol and Diesel are the most commonly used transport fuels in Sub-Saharan Africa (Kojima et al., 2010). These fuels play a vital role in supporting economic activity and mobility and are critical for enabling access to goods and services.

Petroleum products are the lifeblood of the economies of all Sub-Saharan African countries(Matthews, 2014). The demand for Petrol and Diesel in these countries has grown rapidly in recent years, driven by population growth, urbanization, and economic development. According to (International Energy Agency, 2023b), between 2000 and 2018, energy demand in Africa grew by 60%, more than double the global rate of growth.

However, the availability and affordability of liquid fuels can be a major challenge, particularly in non-producing countries like Malawi which rely heavily on fuel imports. Petroleum production supply disruption is the major concern in the petroleum industry in Malawi (MERA, 2021). Indeed, in recent years Malawi has experienced significant disruptions in fuel supply which has had far reaching consequences on the economy – including not limited to transportation challenges, cost-push inflation and stagnation in Industrialization mainly due to high production costs (Kojima et al., 2010; Malawi 2063, 2020).

The main challenge Malawi is facing in the energy sector is being able to meet the growing demand of the various sectors in the country (NCST,2021). Demand for liquid fuels has increased as a result of urbanization which affect energy use by its impact on urban production, mobility and transportation, infrastructure, urban density, and consumption by private households (Jones, 1991; Madlener & Sunak, 2011; Rao & Parikh, 1996). Urban population in Malawi has been on the rise from about 850,000 in 1987 to 1.4 million in 1998 to 2.0 million in 2008 to 2.8 million in 2018 (*MALAWI POPULATION AND HOUSING CENSUS REPORT-2018 2018 Malawi Population and Housing Main Report*, 2019).

The Malawi 2063 is a long-term vision that aims to transform Malawi into an inclusively wealthy and self-reliant nation by the year 2063. The vision is based on three pillars that will guide the country's development agenda for the next four decades. In Petroleum economics studies, two of these pillars i.e., Urbanization and Industrialization are critical drivers of demand that are expected to continue rising in emerging countries and understanding how urbanization and industrialization affect energy consumption is an important and timely topic to study (Sadorsky, 2014).

The dynamics of the petroleum industry in the Malawian economy make the study of the demand for petroleum in Malawi very important. Understanding the demand dynamics of different fuel types, the factors that drive changes in demand, and attempting to forecast fuel demand in future scenarios, is critical for ensuring that energy policies are effective and meet the needs of consumers and the economy as a whole(Bhattacharyya & Blake, 2009).

1.3. Problem Statement

Petroleum has become the dominating source in the energy balance of developing countries(Clô, 2000). The daily rate of national Fuel consumption stands at 1.7 million liters per day (NOCMA, 2022). However, a knowledge gap exists in understanding the local demand dynamics for petroleum products – this gap makes it difficult to plan for distribution, leading to inefficiencies(Sulaimon, 2014). Such challenges have been encountered in the years 2021, 2022 & 2023 as Malawi has had to grapple with Fuel Crises. Furthermore, Understanding the demand dynamics of different fuel types, and the factors that drive changes in demand, is critical for ensuring that energy policies are effective and meet the needs of consumers and the economy as a whole, an aspect that is missing in Malawi's fuel market.

1.4. Main and Specific Objectives

1.4.1. Main Objective

To evaluate how different factors affect the local demand of petroleum products in the present and future scenarios.

1.4.2. Specific Objectives

a) Analyze the correlation of various factors on the local demand of liquid fuels in the present and future scenarios
b) Analyze the causal relationship of various factors on the local demand of liquid fuels in the present and future scenarios
c) Compare different data-driven modelling approaches, determine a model best suited for petroleum products demand forecasting for Malawi

1.5. Research Questions

a) What factors have influenced the changes in demand for Liquid fuels?
b) How do these factors interact with each other and affect the demand of petroleum products in the present and future scenarios?
c) How do different data-driven models perform in terms of accuracy, scalability and interpretability for predicting fuel demand at different levels?

1.6. Significance of Research

The research aims to make a worthwhile contribution to the existing knowledge of petroleum economics at a domestic level. Specifically, the research will assess trends and patterns in fuel consumption and the factors that have influenced those changes. By doing so, the research aims to shed light on the current state of the fuel market in Malawi. Furthermore, the research will analyze fuel demand prediction methods and their applicability to trends and patterns of historical consumption data. Enabler 6 of Malawi 2063- Economic infrastructure- describes how Malawi's vision is to have an increased energy supply and ensured energy reliability. Today, the International Energy Agency (IEA) defines energy security as the uninterrupted availability of energy sources at an affordable price (Kashcheeva,2016). Policymakers can then develop strategies to secure the petroleum supply with the aid of the findings of this research. The insights provided by the methods analysis can be used in developing forecasts of fuel consumption, which can inform business decisions for distributors and retailers. This study will also serve as a reference to future research on the subject matter.

2. LITERATURE REVIEW

2.1. Introduction

This chapter provides a review of the pertinent works of literature on petroleum demand dynamics, forecasting, policy analysis and the global oil situation. A broad range of theoretical and experimental researches have been conducted and the most material and fundamental to the presented study topic are briefly discussed.

2.2. Demand developments by Region: Africa

According to (International Energy Agency, 2023a) in their OIL 2023 Report, African oil demand in 2028 will be 530 kb/d higher than in 2022 as GDP growth, buttressed by the continent's rapidly expanding population, exceeds 3% on average over the forecast period. This results in steady gains in road transport fuels. Africa's oil use is heavily skewed towards automotive gasoil known as diesel in Malawi (making up 40% of total consumption) as use of diesel generators remains widespread amid limited access to reliable electricity grids. Among the refined products, LPG will lead consumption growth at 4.7% per year. Urbanisation underpins this robust increase of 150 kb/d over the 2022-28 period, largely due to more widespread use of propane and butane in cooking at the expense of traditional biomass. This switch is aided by government policies that incentivise the use of LPG, a clean cooking fuel.

Table 1. Oil demand by Product: Africa, 2019-2028

Oil demand by product (mb/d): Africa, 2019-2028

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2022-28 Growth Rate	2022-28 Growth
LPG/Ethane	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	4.7%	**0.1**
Naphtha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6%	**0.0**
Gasoline	1.2	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.1%	**0.1**
Jet/Kerosene	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	4.2%	**0.1**
Gasoil/Diesel	1.7	1.5	1.6	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.6%	**0.2**
Residual fuel oil	0.3	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	2.0%	**0.0**
Other products	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1.5%	**0.0**
Total products	**4.1**	**3.8**	**4.0**	**4.2**	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**	**4.8**	**2.0%**	**0.5**
Annual change	*0.0*	*-0.4*	*0.3*	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*		

Source. EIA Oil 2023 Report

(Madlener & Sunak, 2011) identified Urbanisation and Industrialization as key drivers of petroleum products demand.

2.2.1. Urbanization as a driver of fuel demand

Urbanization is associated with large-scale movements of the labour force from the countryside into urban areas and this increase in density puts stress on the local environment. Urbanization can affect energy use by its impact on urban production, mobility and transportation, infrastructure, urban density, and consumption by private households (Jones, 1991; Madlener & Sunak, 2011; Rao & Parikh, 1996). Covering only 2% of the world's surface, cities are responsible for about 75% of the world's consumption of petroleum products (Pacione, 2009). It stands to reason therefore that of the 360 fuel retailing outlets in Malawi (MERA, 2022), most are located in the cities of Lilongwe, Blantyre, Mzuzu & Zomba.

A major factor affecting urban petroleum demand in both developed and developing countries is motorized individual transport (Jiang & Lin, 2012). Under conditions of continuous city growth and rural–urban migration, private transport is increasing substantially. Urbanization increases also inner-city private transport, because of commuter traffic, often over great distances (Jones, 2004). This tends to result in an increasing level of motorized individual transport that implies increasing fuels consumption. Usage of private vehicles strongly correlate with fuel use (Chai et al., 2012). According to NSO in the 2018 Census, 6.1% of Malawi's households own either motorcycles or motor vehicles.

(Sadorsky, 2014) concludes that the impact of urbanization on energy consumption is positive and statistically significant in emerging countries.

2.2.2. Industrialization as a driver of fuel demand

Industrialization is a term that usually refers to an increase in industrial activity and most authors assume that industrialization leads to higher energy usage because higher value-added manufacturing uses more energy than does traditional agriculture or basic manufacturing. For example, industries like petroleum refining, primary metals, chemicals, and paper and allied products tend to be more energy intensive than agriculture or textile industries (eg. Jones, 1991; Samouilidis and Mitropoulos, 1984).

In empirical models, industrialization is usually measured by industry value added as a % of GDP. According to (Blanchard, 1992) this indicator represents internal manufacturing specialization. The evolution of this indicator across time measures the productive restructuring effort. Some authors like (Rao & Parikh, 1996) use this indicator as a measure of structural change and the expectation is that larger shares of industrial activity in the economy create a demand for more energy.(Blanchard, 1992), however, points out that the evolution of this ratio across time may be due to structural changes but may also be due to divergent price effects between the two variables used to construct the ratio.

One of the key factors retarding industrialization in Sub-Saharan Africa has been the insufficient stock of productive infrastructure in power, water and transport services that would allow firms to thrive in industries with strong comparative advantages (African Development Bank, 2018a). The industrial sector's share of GDP in Malawi is lower than neighbouring countries such as Zambia (37%) and Tanzania (25%) (Plecher, 2020a,b,c). Over 80 percent of the sector's activities are dominated by manufacturing (e.g. textiles, clothing and footwear); traditional agricultural crops produce processing (e.g. tobacco, tea, coffee, sugar, soya, groundnut products, and macadamia nuts); and production of building and construction materials such as cement (Commonwealth of Nations, 2020).

2.2.3. Per capita Income as a driver of fuel demand

Many studies have shown that the energy consumption is positively correlated with economic growth where, for example, countries with high per capita GDP have shown to have high per capita energy consumption (e.g. Burney, 1995; Anderson, 1973; Samoilidis and Mitrolopulos, 1984; Leach and Gowen, 1987; (Payne, 2010).

An expansion in GDP increases energy consumption for two reasons. First, economic growth results in an expansion in the commercial and industrial sectors, which requires energy inputs. Second, higher disposable income increases demand for electronic gadgets for entertainment and comfort for households. An increase in energy consumption results in higher GDP because, in addition to the direct effect of energy consumed for commercial use which generates higher rates of economic growth, higher energy consumption results in an increase in energy production, which has the indirect effect of generating employment and infrastructure in energy services (Mishra et al., 2009). This relationship is termed as bidirectional Granger causality between energy consumption and GDP - energy consumption and GDP have a positive effect on each other. Bidirectional Granger causality implies that energy consumption and economic growth are jointly determined and affected at the same time.

GDP per Capita, PPP is a better metric than nominal GDP per Capita as it takes into account the cost of living and inflation rather than using only exchange rates therefor providing a more accurate picture of the real differences in income (Worldometer,2022). The correlation between energy consumption and GDP per capita, PPP is not always straightforward. While there is a positive correlation between energy consumption and GDP per capita, PPP, the relationship is not linear and can be influenced by a variety of factors such as the structure of the economy, availability of natural resources and government policies (European Environment Agency, 2015).

2.3. Review of Models used by researchers

2.3.1. Autoregressive Distributed Lag

Autoregressive distributed lag (ARDL) is a statistical model used to estimate the relationship between a dependent variable and its lagged values, as well as current and lagged values of explanatory variables. ARDL is a widely used model in estimating energy demand relationships(Bentzen & Engsted, 2001). In terms of accuracy, studies that used ARDL to test for long run relationship with gasoline demand found that the model performed well (Alsahlawi & Al-Titi, 2017). ARDL is a flexible model that can handle both stationary and non-stationary data(Bentzen & Engsted, 2001). A study used fuzzy ARDL to forecast energy demand and found that the model was scalable and could be used to estimate the tendency of data consistently (Maijama'a & Musa, 2020).ARDL can provide insights into the long-run and short-run dynamics of the relationships between the dependent variable and explanatory variables. A study used ARDL to estimate the nexus between CO2 emissions and economic determinants in Pakistan and found that the model provided useful insights into the relationship between the variables.

Although ARDL models have been used in econometrics for decades, they have gained popularity in recent years as a method of examining cointegrating relationships. Two seminal contributions in this regard are Pesaran and Shin (1998) and Pesaran, Shin and Smith (2001) In particular, they argue that ARDL models are especially advantageous in their ability to handle cointegration with inherent robustness to misspecification of integration orders of relevant variables.

ARDL models are linear time series models in which both the dependent and independent variables are related not only contemporaneously, but across historical (lagged) values as well. In particular, if y_t is the dependent variable and $x_1,\ldots,x_k$ are k explanatory variables, a general ARDL($p,q_1,\ldots,q_k$) model is given by:

$$y_t = a_0 + a_1 t + \sum_{i=1}^{p} \psi_i y_{t-i} + \sum_{j=1}^{k} \sum_{l_j=0}^{q_j} \beta_{j,l_j} x_{j,t-l_j} + \epsilon_t \qquad (1)$$

where ϵ_t are the usual innovations, a_0 is a constant term, and a_1,ψ_i, and β_j,l_j, are respectively the coefficients associated with a linear trend, lags of y_t, and lags of the k regressors $x_{j,t}$, for j=1,…k. Alternatively, let L denote the usual lag operator and define $\psi(L)$ and $\beta_j(L)$ as the lag polynomials:

$$\psi(L) = 1 - \sum_{i=1}^{p} \psi_i L^i \quad \text{and} \quad \beta_j(L) = \sum_{l_j=0}^{q_j} \beta_{j,l_j} L^{l_j}$$

Then, equation (1) above can also be written as:

$$\psi(L) y_t = a_0 + a_1 t + \sum_{j=1}^{k} \beta_j(L) x_{j,t} + \epsilon_t \qquad (2)$$

Recently, (Kriskkumar et al., 2022) examined the asymmetric effect of oil price on the economic growth of Malaysia by employing the Nonlinear Autoregressive Distributed Lag (NARDL) model of Shin et al. (2014) approach, which is the extended version of the Autoregressive Distributed Lag (ARDL) model as established by Pesaran et al. (2001).

2.3.2. Panel Cointegration

Panel cointegration is a statistical technique used to estimate the long-run relationship between a dependent variable and its explanatory variables in a panel dataset (El-Shazly, 2013). The technique has been used to analyse and forecast the demand for electricity and oil products (Al Yousef, 2013). A study used panel cointegration to estimate the long-run relationship between forward fuel prices of crude oil and domestic fuel and found that the model performed well (Sa'ad, 2009) .Panel cointegration is a flexible model that can handle large datasets with multiple cross-sectional units and time periods (Chang et al., 2019). Poumanyvong and Kaneko (2010) use panel data techniques to estimate the impact of income, urbanization, industrialization, and population on energy use in a sample of 99 countries covering the period 1975–2005.

Following the specifications of Bentzen (1994), Alves and Bueno (2003), Ramanathan (1999), and Polemis (2006), The model of gasoline demand is specified in log-linear form. Therefore the long-run gasoline demand takes the following form:

$$\mathrm{Ln}G_t = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 \ln P_t + \varepsilon_t.$$

Where $\mathrm{ln}G_t$, is the natural log of the annual per capita gasoline consumption at time t, $\mathrm{ln}Y_t$ is the natural log of the annual real per capita income at time t, $\mathrm{ln}P_t$ is the natural log of the annual real gasoline price at time t, and ε is a random error which is assumed to be white noise and normally and identically distributed. According to economic theory α1 and α2 are expected to be positive and negative respectively (Akinboade et al., 2008).

Before applying cointegration technique, The data is tested for stationarity using autocorrelation based tests then unit root based testing using Phillip-Peron Test, among many others (Dahl, 2001).

Having established that variables contain a panel unit root, (Mishra et al., 2009) proceed to test whether there is a long-run relationship between energy consumption, GDP and urbanization using the Pedroni (2000) heterogeneous panel cointegration test.

2.3.3. Granger Causality

Granger causality is a statistical test used to determine whether one time series is useful in forecasting another (Zhang et al., 2022). Granger causality has been used to examine causality between electricity consumption and real GDP on Malawi data (Jumbe, 2004). A study used Granger causality to estimate the relationship between oil prices and stock prices and found that the model performed well (Lorusso & Pieroni, 2018). Granger causality is a flexible model that can be used to analyze the causal relationship between multiple time series (Stokes & Purdon, 2017).

Granger causality developed in the field of econometric time series analysis. Granger formulated a statistical definition of causality based on the premises that (i) a cause occurs before its effect and (ii) knowledge of a cause improves prediction of its effect. Under this framework, a time series $\{x_i,t\}$ is Granger causal of another time series $\{x_j,t\}$ if inclusion of the history of xi improves prediction of x_j over knowledge of the history of x_j alone. Specifically, this is quantified by comparing the prediction error variances of the one-step linear predictor, $x\hat{}_jt$, under two different conditions: one where the full histories of all time series are used for prediction and another where the putatively causal time series is omitted from the set of predictive time series. Thus, $\{x_i,t\}$ Granger causes $\{x_j,t\}$ if

$$\mathrm{var}\left(x_{j,t} - \hat{x}_{j,t} \mid x_{j,0:t-1}\right) > \mathrm{var}\left(x_{j,t} - \hat{x}_{j,t} \mid x_{j,0:t-1}, x_{i,0:t-1}\right).$$

Granger causality can be generalized to multistep predictions, higher-order moments of the prediction distributions, and alternative predictors.

(Mishra et al., 2009) identified bidirectional Granger causality between energy consumption and GDP from a panel of Pacific Island countries. A 1% increase in energy consumption increases GDP by 0.11%, while a 1% increase in GDP increases energy consumption by 0.23%

3. RESEARCH METHODOLOGY

3.1. Introduction

Research methodology is a way to systematically solve the research problem (Kothari, 2004). Therefore, this chapter will describe data collection strategies, research design, research parameters and techniques adopted for this research. The data sources, location of the study, the limitations to research, analysis of data, validity and reliability, as well as ethical considerations will also be explained in this chapter.

3.2. Research Design

An embedded mixed method research design will be used for this study. Quantitative and qualitative data and methods will be combined to address the objectives of the research hence 'mixed method'. The Embedded Design is a mixed methods design in which one data set provides a supportive, secondary role in a study based primarily on the other data type (Creswell, Plano Clark, et al., 2003). The premises of this design are that a single data set is not sufficient, that different questions need to be answered, and that each type of question requires different types of data. This design is ideal for this research because the method helps to address the factors that influence demand dynamics for Liquid fuels and their interaction. Furthermore, the comparison of data-driven models for forecasting and the investigation of the relationship between agricultural mechanization and liquid fuels consumption can be effectively carried out under this method.

3.3. Materials and Methods

The study was carried out using an embedded mixed research design, which analysed how different factors affect the local demand of petroleum products in the present and future scenarios methodically. Qualitative data on determinants of liquid fuels demand was collected using rigorous documents review. Quantitative statistics on urbanization, industrialization, per capita income and fuel consumption was collected using secondary data requests. The mixed method approach aided in establishing correlations between the Pillars of Malawi 2063 to demand for petroleum products in Malawi.

3.3.1. Data Collection Strategies

For qualitative data collection, a rigorous document review was conducted to gather information on the determinants of liquid fuels demand. This review Involved analysing research articles, reports, and other relevant documents related to petroleum products demand.

For quantitative data collection, secondary data requests were formally made to obtain statistics on liquid fuel sales. Data on urbanization, industrialization and per capita income was acquired from an up-to-date Development Indicators database compiled by the World Bank. The use of secondary data allowed for a comprehensive analysis of factors influencing liquid fuels demand in Malawi.

3.3.2. Research Techniques

The research parameters in this study focused on understanding the factors that influence local demand for petroleum products in both present and future scenarios. To achieve this, various techniques were employed:

- Correlation Analysis: Statistical analysis was conducted to establish correlations between different variables such as urbanization rates, industrial growth, per capita income and fuel consumption patterns. This analysis aimed to identify significant linear associations between these factors and liquid fuels demand.

- Regression Analysis: Statistical analysis was conducted to identify causal relationships between different variables such as urbanization rates, industrial growth, per capita income and fuel consumption patterns. This analysis aimed to identify statistical significance and precision of regression models.
- Comparative Analysis: The study compared different data-driven models for forecasting liquid fuels demand to assess their accuracy and reliability. This comparative analysis aims to identify the most effective model for predicting future demand patterns in Malawi.

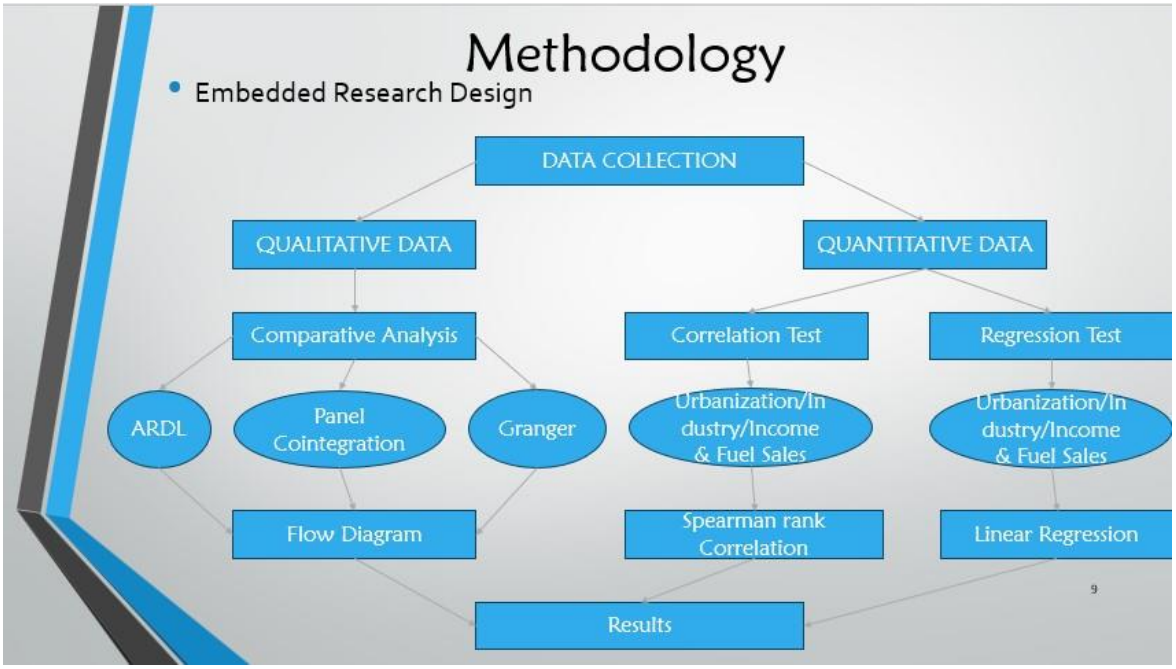


Figure 1. Summary of Embedded Research Design

3.4. Data analysis and Interpretation

Data analysis for this study was mainly achieved by use of Microsoft Excel.

3.4.1. Correlation Analysis

Correlation analysis refers to the application of statistical analysis and other mathematical techniques to evaluate or measure the relationship between variables. This study used correlation analysis to identify the relationships between urbanization & Fuel demand, industrialization & Fuel demand, Income & Fuel demand. Spearman Rank correlation coefficient (r_s) was used to measure the strength

of the association between the parameters: Urban population, Industry - value added, Per capita GDP and Fuel sales over a period of 6 years. This was entirely done in Excel

In each calculation, Urban population, Industry – value added and per capital GDP were considered to be independent variables (X) and fuel sales (Y) as dependent variable. Spearman's r measures the strength of the association between the parameters and fuel sales with a range of 1 to -1. It can be grouped as positive, negative or no correlation.

Table 2. Interpretation of Correlation Results

CORRELATION	INTERPRETATION
Positive correlation	An increase in urban population/ Industry – value added/ per capita GDP is associated to an increase in fuel sales (when r value is closer or equal to 1 and positive)
Negative correlation	An increase in urban population/ Industry – value added/ per capita GDP is associated to a decrease in fuel sales (when r value is closer or equal to -1 and negative)
No correlation	No association between any of the parameters and fuel sales (when r value is equal to zero)

In manual calculations, the formula for Spearman's rank correlation coefficient is

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where r_s is the coefficient and n is the number of points in the data set. For each point (x,y),the square of the difference in the ranks of the two coordinates is represented by d_i^2,and the sum of each of these squares is represented by the expression $\sum d_i^2$.

3.4.2. Regression Analysis

A correlation between variables is not an automatic indication that change in one variable is the cause of change in the values of the other variable. Causal Relationships are modelled by Regression analysis. This study used regression analysis to establish the nature of relationships between urbanization & Fuel demand, industrialization & Fuel demand, Income & Fuel demand. XLMiner Analysis Toolpak in Microsoft Excel was used perform the regression analysis.

The Regression analysis yielded values namely: R_2, Adjusted R_2, F ratio, Significance level, T statistic and P value.

Table 3. Regression Analysis values

VALUE	DEFINITION	EXPECTATION
R_2	Variance in one variable explained by another variable	Value should be more than 0.5
Adjusted R_2	R_2 value in case of more than 2 variables	Value should be more than 0.5
F ratio	Determines precision of the model	Value should be more than 1
Significance level	Maximum risk of error in regression result acceptable by the researcher	Level should be 95%
T statistic	Decides how close the values are to the null hypothesis (zero)	Refer to t-distribution table in Appendix. One tail test since correlation already showed positive association
P value	Amount of error present in the regression model	Value should be less than 0.05

Scatter plots showing Total Fuel Sales in the y-axis and Urban Population, Industry, value added and GDP per Capita in the x-axis were plotted in Excel. Trendline or Regression line was thereafter plotted on the same graph. The equation of the Regression line is

$$Y=a + bX + \varepsilon$$

Where Y is the dependent variable, a is the Y-Intercept, b is the slope of the regression line, X is the independent variable and ε is the residual (error).

3.4.3. Comparative analysis

A comparative analysis is a side-by-side comparison that systematically compares two or more things to pinpoint their similarities and differences. When faced with multiple options or solutions to a given problem, a thorough comparative analysis can help to compare and contrast options and make a clear informed decision. This study used comparative analysis to examine data-driven models and determine a model best suited for petroleum products demand forecasting for Malawi.

Using the Smartdraw application, a Flow Diagram was developed comparing the characteristics of Auto-Regressive Distributed Lag, Panel Cointegration & Granger Causality.

3.5. Sampling

In this research, a convenience sampling approach was employed to select the data for analysis. The following reasons justify the selection of a six-year period for this study:

i. The choice of a six-year period was influenced by the availability of historical fuel sales records and data sources from the World Bank Development indicators database.
ii. Given the limitations in terms of time constraints (data collection and data cleaning), analysing a more extended period was deemed impractical. The chosen timeframe was within the available resources
iii. The six-year period was selected to ensure the stability of the data. Using a more extended period might have introduced unnecessary variability and could hinder the identification of meaningful trends

3.6. Location of the Study

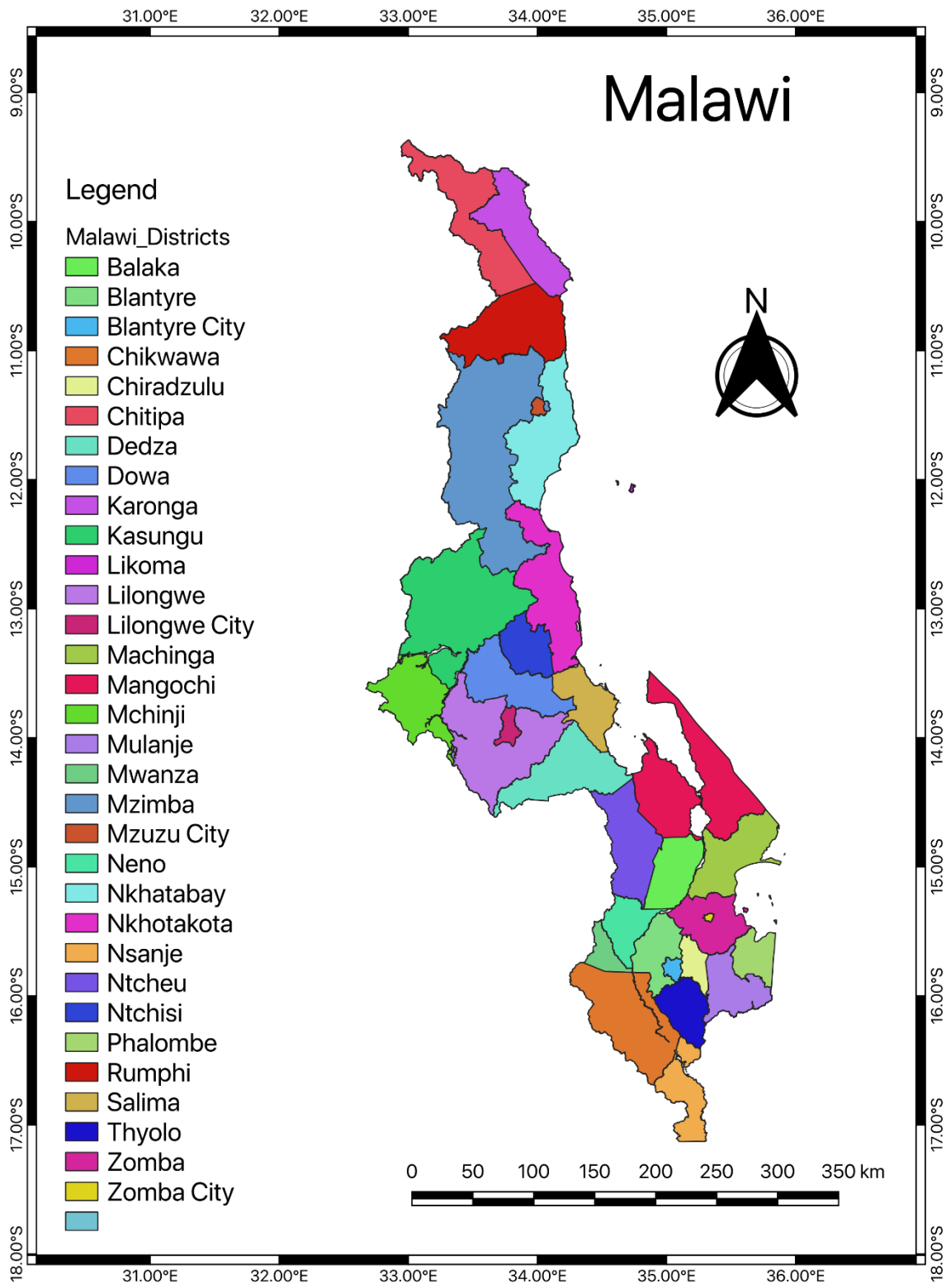


Figure 2. Political Map of Malawi (*Source: QGIS*)

3.7. Limitations of the Study

The research project presented several challenges to the researcher:

1. There is a lack of previous research studies on the topic, specifically Malawi research studies
2. Time Constraints
3. Delayed funding led to changes to the research objectives and scope.

3.8. Ethical Considerations

Ethical considerations were given due importance throughout the research process. The research did not involve any human subjects. All the datasets obtained were used solely for the purpose of this research.

4. RESULTS AND DISCUSSION

4.1. Correlation Test

Datasets for Urban Population, Per Capita GDP & Industry, Value added were correlated against volume of fuel sold over a 6-year period. The 6-year datasets were chosen conveniently.

Table 4. Demographic & Consumption Data (2017-2022)

YEAR	2017	2018	2019	2020	2021	2022
Population (10^6)	17.8	18.4	18.9	19.4	19.9	20.4
Urban Population (10^6)	2.99	3.11	3.24	3.38	3.52	3.67
GDP/Capita, PPP (10^3) USD	1.46	1.59	1.58	1.57	1.65	1.73
Industry, value added (% of GDP)	17.7	18.4	18.5	18.7	18.4	18.3
Total Fuel Sales (10^6) Litres	170	285	416	460	396	473
Petrol Sales (10^6) Litres	65.0	92.0	171	223	226	233
Diesel Sales (10^6) Litres	105.0	193.0	245	237	170	240

Source. World Development Indicators (World Bank Database), NOCMA, PIL

Urban Population shows consecutive annual growth for all 6 years showing an upward trend. GDP per Capita has bounced back after witnessing a decline between 2018-2019 and 2019-2020. In 2020, Industrial activities added the most value to Malawi's GDP as compared to the other 5 years in the dataset. Total fuel sales have been on the ascendancy in with the only slump occurring in 2021 most likely due to the impact of the COVID-19 pandemic which set back major fuel consumption areas such as Transportation.

4.1.1. Urbanization

Table 5. Ranks of Urban Population & Fuel Sales

Year	Urban Population	Total Fuel Sales (Litres)	rank urban	rank fuel
2017	2,988,658	170,000,000	1	1
2018	3,110,968	285,000,000	2	2
2019	3,240,276	416,000,000	3	4
2020	3,376,840	460,000,000	4	5
2021	3,519,490	396,000,000	5	3
2022	3,668,876	473,000,000	6	6

Correct to three decimal places, the value of the coefficient is 0.829. This is close to 1, so we can say that the ranks are in fairly strong agreement. It is a strong correlation. This then confirms that increase in Urban Population is associated to an increase in Total Fuel Sales.

4.1.2. Industrialization

Table 6. Ranks of Industry, value added & Fuel Sales

Year	Industry, value added (% of GDP)	Total Fuel Sales (Litres)	rank industry	rank fuel
2017	17.7	170,000,000	1	1
2018	18.4	285,000,000	3	2
2019	18.5	416,000,000	5	4
2020	18.7	460,000,000	6	5
2021	18.4	396,000,000	4	3
2022	18.3	473,000,000	2	6

Correct to three decimal places, the value of the coefficient is 0.429. This is positive yet far from 1, so we can say that the ranks are not in strong agreement. It is a weak correlation. This then confirms that higher values of Industry, value added do not tend to associate with the higher values of Total Fuel Sales.

4.1.3. Income

Table 8. Ranks of GDP per Capita & Fuel Sales

Year	GDP/Capita,PPP (USD)	Total Fuel Sales (Litres)	rank GDP	rank demand
2017	1455.00	170,000,000	1	1
2018	1594.00	285,000,000	4	2
2019	1582.00	416,000,000	3	4
2020	1573.00	460,000,000	2	5
2021	1645.00	396,000,000	5	3
2022	1732.00	473,000,000	6	6

Correct to three decimal places, the value of the coefficient is 0.486. This is positive yet far from 1, so we can say that the ranks are not in strong agreement. It is a weak correlation. This then confirms that higher values of GDP per Capita do not tend to associate with the higher values of Total Fuel Sales.

Spearman's Rank correlation results confirm a positive association between Urbanization, Industrialization, Income and Fuel demand. Urbanization exhibits the strongest correlation to Fuel demand while Industrialization exhibits the weakest correlation to Fuel demand.

4.2. Regression Test

4.2.1. Urbanization

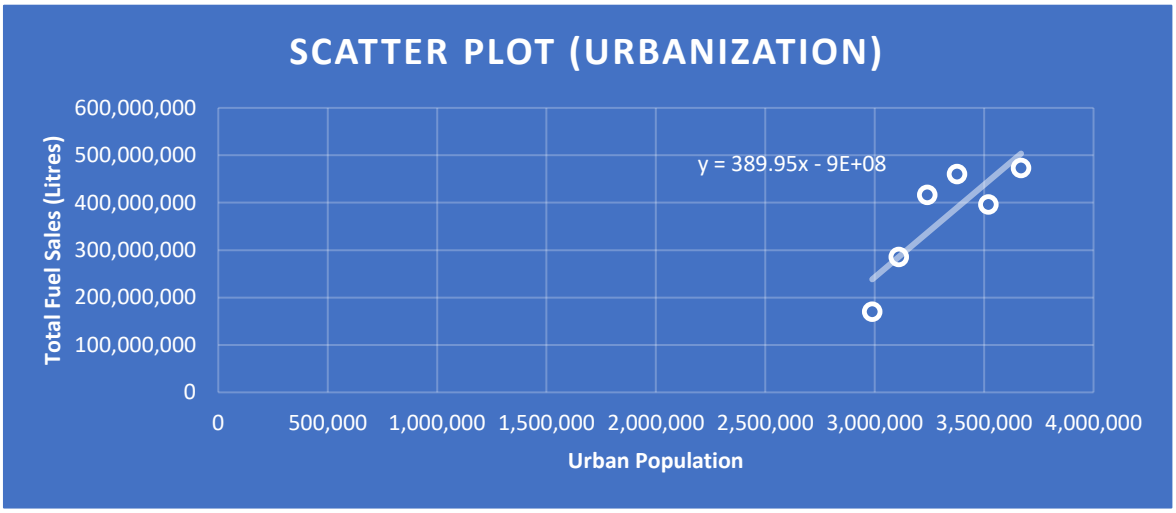


Figure 3. Urbanization – Fuel Sales Scatter plot (*Source: Excel*)

Regression Statistics								
Multiple R	0.84780578							
R Square	0.71877464							
Adjusted R Squar	0.64846831							
Standard Error	69477955.9							
Observations	6							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	4.93506E+16	4.93506E+16	10.22	0.032981976			
Residual	4	1.93087E+16	4.82719E+15					
Total	5	6.86593E+16						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	-927004080	405591846.2	-2.28555896	0.084	-2053107573	199099413.8	-2053107573	199099413.8
Urban Populatior	389.951387	121.9582928	3.197415921	0.033	51.34088285	728.5618916	51.34088285	728.5618916

Figure 4. Regression Statistics (*Source: Excel*)

From the results, R^2 value is 0.719 revealing that 72% of the variability observed in the data is explained by the regression model. F ratio value is 10.22 which is above 1, as expected – the model is precise. Confidence level of 95% was selected. T statistic value is 3.197, which is far from zero therefore rejecting null hypothesis. At df = 4, the expected value from the t distribution table is 2.132. P value is 0.033 which is less than 0.05 – the error in the regression model is acceptable. Urbanization is therefore statistically significant

4.2.2. Industrialization

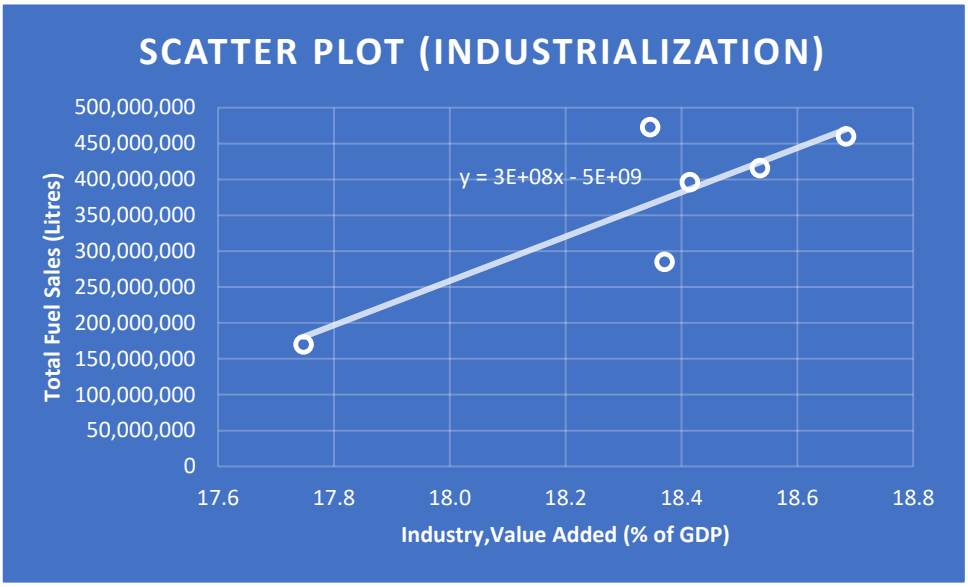


Figure 5. Industrialization – Fuel Sales Scatter plot (*Source: Excel*)

Regression Statistics								
Multiple R	0.844570255							
R Square	0.713298915							
Adjusted R Squ	0.641623644							
Standard Error	70151096.48							
Observations	6							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	4.89746E+16	4.89746E+16	9.951813272	0.034360141			
Residual	4	1.96847E+16	4.92118E+15					
Total	5	6.86593E+16						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95	Lower 95%	Upper 95%
Intercept	-5301372177	1796953638	-2.950199753	0.041961025	-10290515296	-3E+08	-10290515296	-312229057.9
Industry,value a	308884077.4	97913914.18	3.154649469	0.034360141	37031470.29	5.8E+08	37031470.29	580736684.4

Figure 6. Regression Statistics (*Source: Excel*)

From the results, R^2 value is 0.713 revealing that 72% of the variability observed in the data is explained by the regression model. F ratio value is 9.95 which is above 1, as expected – the model is precise. Confidence level of 95% was selected.

T statistic value is 3.154, which is far from zero therefore rejecting null hypothesis. At df = 4, the expected value from the t distribution table is 2.132. P value is 0.034 which is less than 0.05 – the error in the regression model is acceptable.

4.2.3. Income

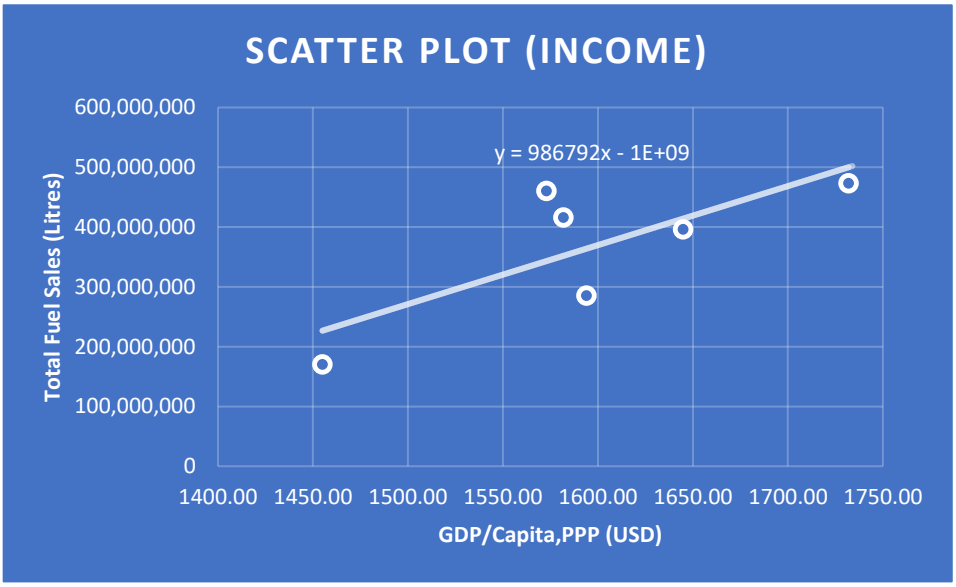


Figure 7. Income – Fuel Sales Scatter Plot (*Source: Excel*)

Regression Statistics								
Multiple R	0.767210842							
R Square	0.588612475							
Adjusted R Squ	0.485765594							
Standard Error	84032126.57							
Observations	6							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	4.04137E+16	4.04137E+16	5.723192271	0.074978674			
Residual	4	2.82456E+16	7.0614E+15					
Total	5	6.86593E+16						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	-1209075798	659560040.7	-1.833155018	0.140711378	-3040308040	622156444	-3040308040	622156444
GDP/Capita,PP	986792.0664	412483.4053	2.392319433	0.074978674	-158445.4624	2132029.595	-158445.4624	2132029.595

Figure 8. Regression Statistics (*Source: Excel*)

From the results, R^2 value is 0.589 revealing that 59% of the variability observed in the data is explained by the regression model. F ratio value is 5.72 which is above 1, as expected – the model is precise. Confidence of 95% was selected. T statistic value is 2.392, which is far from zero therefore rejecting null hypothesis. At df = 4, the expected value from the t distribution table is 2.132. P value is 0.075 which is more than 0.05 – the error in the regression model is significant.

4.3. Comparative Analysis

The characteristics of ADRL, Panel Cointegration and Granger Causality were compared using a flow diagram created using Smartdraw application.

4.3.1. Flow Diagram

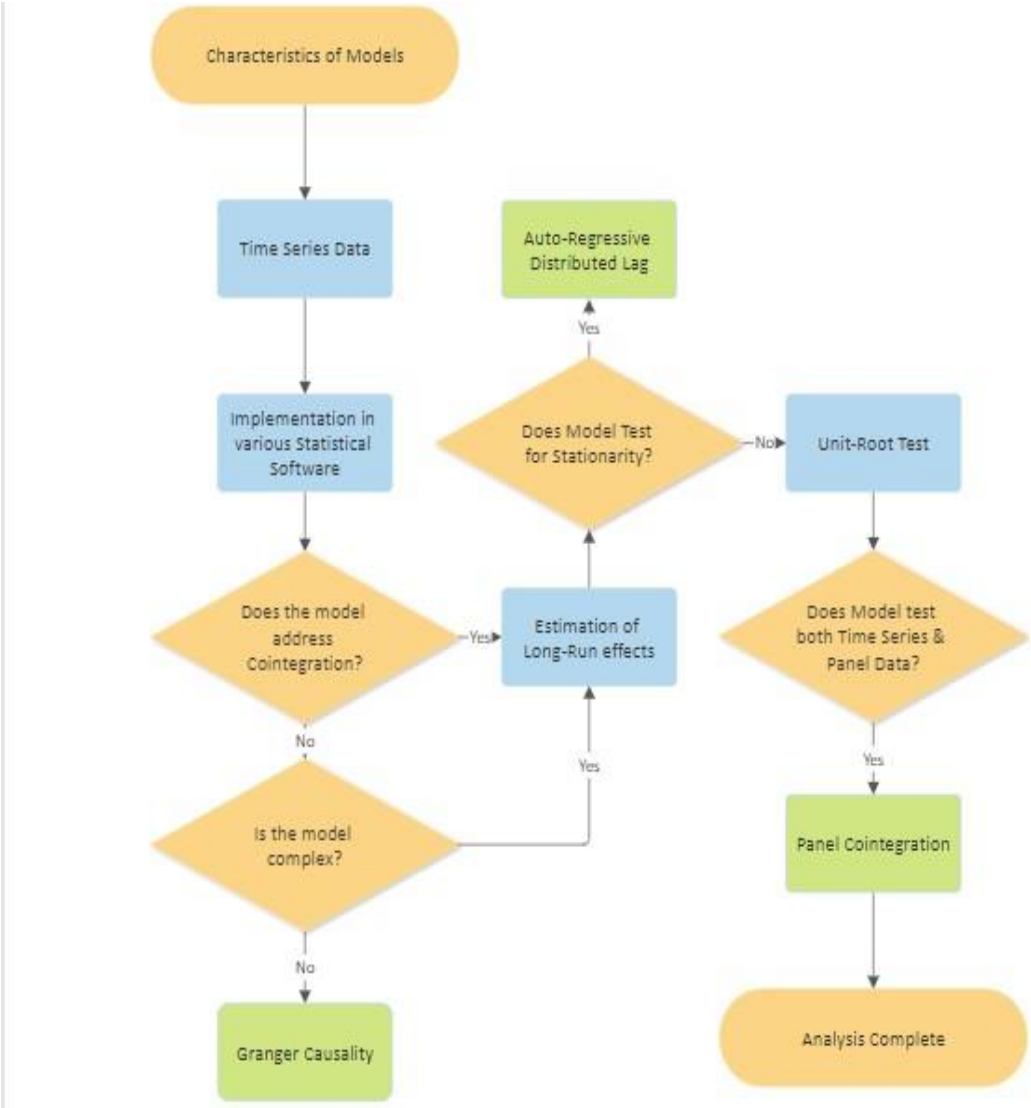


Figure 9. Flow Diagram (*Source: Own Illustration in Smartdraw*)

The flow diagram provides a decision-making tool for the forecast method selection process. Depending on the available datasets, analysis tools and objectives of the researcher, the researcher can select a technique that suits their situation.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

5.1.1. Urbanization, Industrialization, Income – Correlation to Demand

The study's findings, which were based on Spearman Rank Correlation, show a 0.429 to 0.829 positive correlation between the ranked values of Urbanization, Industrialization, Income to Total Fuel Demand for the dataset 2017 to 2022. The strong positive correlation (0.829) between Urbanization and Total Fuel Demand simply suggests that as the Urban Population of the country keeps increasing, the Total fuel Demand will also tend to increase. As such, Correlation studies are relevant to identify associations between the demographic, economic and energy factors in Malawi.

5.1.2. Urbanization, Industrialization, Income – Causal Relationship to Demand

Regression analysis from the study revealed that there exists a causal relationship showed the most statistically significant positive relationship, with R^2 of 0.719 and P value of 0.033. These results confirm that changes in Urbanization, Industry and Income can be used to forecast changes in Total Fuel demand. As such, Close analytical monitoring of these factors is critical to short- and long-term planning of supply of fuel and other energy policies.

5.1.3. ARDL, Panel Cointegration & Granger Causality for Demand Forecasting

The study's outcomes show that ARDL, Panel Cointegration and Granger Causality are all applicable methods to estimating short and long run relationships between variables and energy demand and the decision to use each method in dependant on the type of dataset, available analysis tools and the objectives of the researcher.

Granger Causality has been used before on electrical consumption Malawi Data (Jumbe,2004) therefore it is plausible to use the technique for Data on fuel consumption.

5.2. Recommendations

5.2.1. Energy Information Administration Entity

There is a need for Malawi to have an Entity preferably outside of government to collect, analyse and disseminate impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the population. Currently, MERA publishes annual highlights of energy use however the introduction of an Energy Information Administration could allow for more informative energy analyses and short- and long-term forecasts of fuel market trends.

5.2.2. Combination of Forecasting approaches

Combining different forecasting approaches can provide accurate predictions into future fuel demand compared to individual models. Moreover, combining forecasts can also reduce the impact of outliers or errors in individual models. Different models have different assumptions and uncertainties, so combining them can provide a more comprehensive view of the possible outcomes. Finally, combining forecasts can also provide greater flexibility in adapting to changing conditions or data availability. With these strengths, any forecasts to be made on fuel consumption should consider using a combination of Forecasting techniques

5.2.3. Further Research

Further research is needed to better understand the impacts of a number of factors such as population density, power generation, agricultural mechanization, vehicle ownership and fuel prices on fuel demand. Ministries, Departments and Regulators need to collaborate better to ensure that datasets for research are available and accessible. Currently, the field of energy research in Malawi is not very potent. Investing in research helps to increase efficiency and innovation,

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t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										