Computational Analysis of Economic and Environmental Impacts of Energy Policies in Pakistan: A Statistical Approach

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Abstract: **The prevailing opinion in the present day is that petroleum/oil is a significant driving force behind economic progress and development. As a result, its usage has become increasingly crucial for both the advancement of society and the growth of businesses. The current study aimed to construct a robust model that coul d accurately predict future oil/petroleum usage in Pakistan, with a particular focus on its utilization. The research analyzed data on oil/petroleum consumption (P.C), Gross Domestic Product (GDP) per capita, and population from 1972 to 2020. The findings indicated a strong correlation between the P.C of various sectors such as transport, industrial, power, and others, with the population data of Pakistan. The correlation values for these sectors were respectively 0.974, 0.646, 0.826, and -0.680. Additionally, there was a similar correlation between the P.C of these same sectors and Pakistan's GDP. The correlation values for these sectors were respectively 0.934, 0.474, 0.740, and -0.520. These results suggest that population and GDP are vital factors that impact gas and oil/petroleum consumption patterns in various sectors of Pakistan's economy. The study employed multiple linear regressions to examine the relationship between gas demand, population, and GDP in Pakistan. The goodness-of-fit tests indicated that the polynomial model was the best fit for population and GDP. Based on this model, the study estimated that oil/ petroleum demand in Pakistan would be 26345308.86 (tons) in 2025, 29023960.17 (tons) in 2030, 31753738.11 (tons) in 2035, 34534646.46 (tons) in 2040, and so on. The findings of this study provide valuable insights into the various factors that influence gas consumption in Pakistan. This information can be used to identify how gas is produced and distributed across the country. The study also highlights the importance of considering the effects of population growth and economic development on gas usage when planning to address the gas crisis in Pakistan. The insights gleaned from this study can have far-reaching implications in areas such as Gas, healthcare, planning, growth, and other related fields.**

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INTRODUCTION:

Pakistan is endowed with an abundance of natural resources, including a broad variety of minerals. There are numerous undiscovered deposits of valuable minerals and useful crystals within the country. In Pakistan, the mining and quarrying industry grew by 3.8% in 2014-2015, which was a significant increase from the previous year's growth rate of 1.6% (2017). Soapstone, petroleum oil, gypsum, coal, and limestone are examples of minerals that exhibited a positive growth rate during this period. Soapstone's growth rate was 41.68 percent, petroleum oil's was 14.03 percent, gypsum's was 8.11 percent, coal's was 4.12 percent, and limestone's was 3.73 percent. Despite these improvements, Pakistan's mining and quarrying industry has a great deal of potential for expansion. For instance, the growth rates of Sulphur (42.06 percent), dolomite (46.87 percent), bauxite (25.69 percent), phosphate (47.75 percent), and magnesite (7.44 percent) during this period were relatively modest. Therefore, it is necessary to completely explore and exploit Pakistan's numerous mineral resources [1].After analyzing the mineral life cycle and the products derived from them, it has been determined that every product or service consumes energy either directly or indirectly. Every production process necessitates a certain quantity of energy, which contributes to the growth of the national economy but has negative environmental effects.

Energy plays an essential part in the smooth operation of the economy, as its availability in sufficient amounts is imperative for the sustained and progressive development of economic activities. Therefore, energy has been recognized as a fundamental element of the economy. Energy is an indispensable element that is utilised across all sectors of the economy, and its significance cannot be underestimated. The correlation between energy and the economy is both positive and statistically significant, as evidenced by previous studies [2,3]. Numerous techniques may be used to produce energy, but only the most reliable and modern energy sources have been instrumental in the expansion and advancement of the US economy. Petroleum has historically served as the dominant catalyst for energy generation [4]. Energy consumption plays a crucial role in all sectors of the economy.

Research findings indicate that the processing sector exhibits higher energy consumption in comparison to other sectors. Nevertheless, in the quest to fulfil constantly growing global energy requirements, society has turned to employing energy generation sources that have detrimental effects on the environment. Non-renewable energy sources are a prominent contributor to the deterioration of the environment. The relationship between economic growth, environmental pollution, and energy consumption has been examined using Granger's causality test, which has garnered considerable attention in relation to these factors [5,4]. The existing energy policy of Pakistan exhibits limitations in its ability to adequately mitigate the energy crisis prevailing within the nation. Nevertheless, the introduction of an integrated Energy Planning (IEP) process at different stages could potentially address the deficiencies of current policies and practices, and steer the nation towards a more logical and sustainable trajectory [6]. Energy is a fundamental necessity for human beings in contemporary society; however, it is accompanied by enduring detrimental consequences for the environment. Therefore, it is crucial for nations to develop energy strategies that not only cater to their energy needs but also consider the environmental consequences associated with energy consumption. The emission of significant amounts of carbon dioxide (CO_2) into the atmosphere is a consequence of energy consumption throughout different life stages. The levels of carbon dioxide (CO_2) have exhibited a significant and swift escalation over a span of 29 years, specifically from 1979 to 2014 [7]. The production and operations of various industries exhibit a significant reliance on the availability of energy resources. The mining and quarrying industry is a processing sector that engages in the refinement and purification of diverse minerals and valuable elements, encompassing activities such as excavation and extraction. The mining and quarrying sector in Pakistan has experienced substantial growth over the past few decades and is projected to sustain this growth in the foreseeable future. Similar to other sectors, the mining and quarrying industry also exhibits a substantial energy consumption pattern, leading to the direct emission of carbon dioxide through the combustion of fossil fuels and environmental degradation. The Input-Output (IO) approach is employed to effectively assess the carbon dioxide (CO_2) emissions associated with the mining and quarrying sector. This method incorporates data sourced from the Pakistan Statistics Board to ensure the accuracy of the measurements. The input-output (IO) approach is extensively employed for examining the interdependencies between different sectors of the economy. Its widespread utilisation across various disciplines can be attributed to its straightforward methodology. The model that has been developed aims to optimise the calculation of CO_2 emissions specifically within the mining and quarrying industry. Its primary purpose is to provide precise and reliable results. This model is predominantly utilised for short-term analysis [8]. The CO_2 emissions generated by the mining and quarrying sector have been quantified based on data pertaining to petroleum consumption within this industry. In the IO table analysis, the sector of mining and quarrying was regarded as a unified entity, and this approach is likewise adopted in the present study. Pakistan is classified as a developing nation, wherein numerous industries play a pivotal role in contributing a substantial portion of their production towards the progress and development of the country. Fossil fuels serve as the predominant sources for energy generation, representing a versatile form of energy that can be harnessed without limitations in terms of location or timing. Based on the findings of the BP Statistical Review of World Energy 2010, there was a notable decline of 4.9% in the oil demand within the United States of America during the year 2009, in comparison to the preceding year of 2008. In less economically developed countries, there was a substantial decline in oil consumption, reaching its lowest level since 1997.

In contrast, it is worth noting that China experienced a notable surge in its oil consumption, with a growth rate of 6.7% observed in 2009 [9]. In the year 2010, a notable decline in oil prices was observed, marking the first instance of such an event since 1982. The aforementioned decline demonstrated a certain degree of advantage for less developed nations, such as Pakistan [10, 11]. Pakistan is heavily dependent on oil imports due to insufficient domestic oil production, which fails to adequately meet the nation's energy requirements. Based on available data, it can be observed that in July 2016, Pakistan's oil imports amounted to 35.57 million barrels, indicating a 3.4% growth compared to the previous year's import volume of 34.35 million barrels. In 2016, the total monetary worth of imported oil amounted to US $3.59 billion, exhibiting a notable increase from the preceding year's figure of US $1.97 billion. The escalating energy demand is accompanied by a corresponding increase in the demand for petroleum products. Extensive research has demonstrated that the heightened combustion of fossil fuels is directly linked to environmental degradation and has detrimental consequences for the Earth's ecosystem. The insufficiency of energy not only diminishes industrial output but also impedes the nation's Gross Domestic Product (GDP) expansion. According to a report, thermal power plants accounted for approximately 62% and 64% of electricity generation in Pakistan during the fiscal years 2016 and 2017, respectively [12].Oil is consumed at significant levels by thermal power plants and the transport sector. In 2016, the combined contribution of these two sectors constituted 91% of the overall oil consumption. Subsequently, in the year 2017, their proportion decreased slightly to 90%. Nevertheless, it is worth noting that the electricity sector experienced a marginal decline of 1% in its oil consumption, primarily attributed to the growing adoption of renewable energy sources for the purpose of electricity generation [13]. To enhance industrial production, it is imperative to concurrently augment the generation of electricity, as illustrated in Figure 2. The power sector experienced a decline in energy consumption (specifically fossil fuels) during the fiscal year 2003–2004. However, this trend gradually reversed, leading to a subsequent increase in consumption that peaked in 2009–2010. It is worth noting that this peak coincided with a period of significant power outages within the country. The insufficiency of electricity provision exerts a direct influence on the gross domestic product (GDP) of the nation. Climate change is an established phenomenon characterized by the conversion of the Earth's internal energy into thermal energy, resulting in the warming of the atmosphere, the generation of water vapor, the melting of glaciers, and consequential environmental degradation. Internal energy can be derived from various sources that undergo combustion and generate carbon dioxide, including fossil fuels, biomass, and other similar substances. Human activities are also accountable for the release of carbon dioxide (CO2) into the atmosphere, with CO2 being the primary factor contributing to the phenomenon of global warming. In fact, CO2 emissions are responsible for approximately 90% of the overall impact [14].

DATA DESCRIPTION AND METHODOLOGY:

The usage of oil and petroleum is subject to the impact of various factors, such as the economic conditions, temperature fluctuations, and population size in a given country. In order to explore this phenomenon, we obtained data on both the gross domestic product (GDP) [15] and population [16] figures spanning from 1970 to 2020, which were sourced from the World Bank's 2022 Open Data. In addition, we procured the relevant statistics pertaining to oil and petroleum consumption for various categories including households, commercial enterprises, industries, power generation, and fertilizers, which were obtained from the Federal Bureau of Statistics (FBS) [17].

Figure [1] shows the total amount of oil and petroleum consumption in the Pakistan from various sectors from 1972 to 2020. The fig is divided into five columns representing different sectors: industry, transport, power, other, and total. The "industry" shows the oil and petroleum consumption by the industrial sector, which includes manufacturing, mining, and construction. The "transport" shows oil and petroleum consumed by the transportation sector, which includes cars, trucks, trains, and airplanes. The "power" shows oil and petroleum consumption by the electric power sector, which generates and distributes electricity. The "other" shows oil and petroleum consumption by other sectors such as commercial and residential buildings. Finally, the "total" shows the overall energy consumption in the Pakistan across all sectors. The data shows that oil and petroleum consumption in the Pakistan has steadily increased over the years, with occasional fluctuations due to economic and political factors. The industrial sector has consistently been the largest energy consumer, followed by the transportation and power sectors. In recent years, the power sector has decreased its energy consumption due to the shift towards renewable energy sources such as wind and solar power. It is also interesting to note that the data for 2020 only includes the first few months of the year before the COVID-19 pandemic significantly impacted energy consumption patterns.

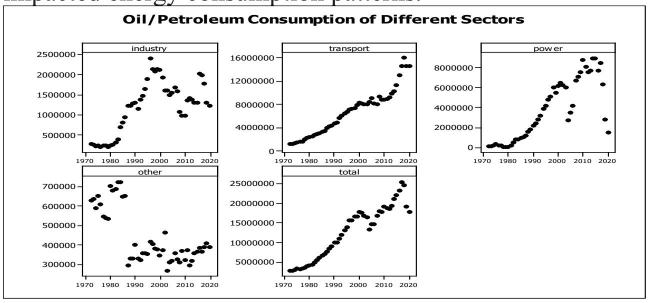

Fig.1: Represent historical data for oil/petroleum consumption of different sectors

The population data for the same period are related to Fig. 2, and it has a growing trend throughout the period considered.

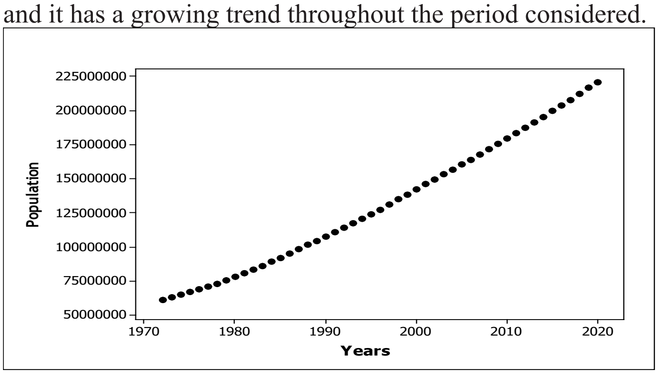

Fig.2: Represent historical data for the population 1972-2020.

The figure labeled as Fig 3 displays the demographic variables, specifically GDP per capita. The data was obtained from the World Bank and shows an interesting pattern of slight increase up until the year 2002. However, the years 2003 to 2018 exhibit a significant increase in GDP per capita, indicating a growing economic activity in the country, and consequently, an increase in demand for gas. The sudden changes in GDP per capita in the year 2018, when it reached its maximum value, can be attributed to the fluctuation in oil and gas prices. On the other hand, the rapid decrease in GDP per capita in the years 2019 and 2020 is likely due to the economic slowdown caused by the COVID-19 pandemic and the resulting lockdown measures. This emphasizes the impact of economic developments and shocks on the demand for oil and petroleum.

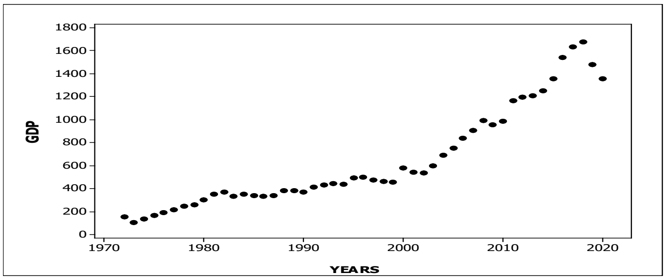

Fig.3: Represent historical data for the GDP 1972-2020.

Prediction Methods:

The proposed models have been developed with the objective of enhancing our comprehension of the impact of various factors, such as population, GDP per capita, and others, on oil/petroleum consumption across different sectors. These models facilitate a thorough examination of the relationships between the factors and oil/petroleum consumption, thus providing a more comprehensive perspective of the dynamics involved. To predict the population and GDP, several models were utilized, including linear, exponential, quadratic, and logarithmic models, as reported by several studies such as [18, 19, 20]. Through a careful selection process, the best model was identified and utilized to improve the accuracy of the forecasts.

Software uses for this research:

This article discusses two statistical laboratories – on descriptive statistics, and regression – for introductory statistics courses. They are presented in Minitab and Excel; two packages widely used in statistics education, and are available from the Web.

We have conducted regression analysis and created graphs as part of my research paper. I have utilized the appropriate tools and techniques to analyze and visualize my data. In that case, Minitab and Excel were likely used to perform these tasks.

Regression Analysis: Regression analysis helps in understanding the relationship between a dependent variable and one or more independent variables. It allows you to model and predict the behavior of the dependent variable based on the independent variables. Minitab and Excel both provide tools for regression analysis.

In Minitab, We can use the Regression tool to perform various types of regression, such as simple linear regression, multiple linear regression, logistic regression, and nonlinear regression. Minitab offers options for model selection, significance testing, model diagnostics, and interpretation of results. Minitab may provide more advanced statistical analysis features compared to Excel that I have use Minitab in this article.

Multiple linear regressions:

Multiple linear regressions are a statistical technique used to analyze the relationship between a dependent variable and two or more independent variables. Generally, the longer the data set, the more accurate the final result [21, 22].

The multiple linear regression trend models are generally expressed as follows:

$y=\alpha+b_1 x_1+b_2 x_2$

y: Dependent variable

a Constant parameter of model

b_1 Coefficient of independent variables

x Independent variables

Correlation between different sectors of oil/petroleum consumption with population and GDP:

The correlation between oil/petroleum consumption in different sectors [Household, commercial, industrial, power and fertilizer] with population and GDP are given below in table.

Correlation	Transport	Industrial	Power	Other	Total
Population	0.974	0.646	0.826	-0.680	0.953
Gdp	0.934	0.474	0.740	-0.520	0.876

Table 1: correlation b/w Gas consumptions with population and GDP

Model of Different Parameters:

The models of electricity consumption in different sectors (Household, commercial, industrial, Agriculture streetlight and others are given below in table.

Model	Equation	Parameters
Transport	C(P)= - 3445110 + 0.0718 pop + 931 GDP	A=-34445110, B_2=0.0718 ,β_2=931
Industrial	I(P)= - 964198 + 0.0265 pop - 2065 GDP	A=-964198, B_2=0.0265, β _2=-2065
Power	P(P)= - 4623197 + 0.0784 pop - 3039 GDP	A=-4623197, B_2=0.0784 ,β_2=-3039
Other	O(P)=897559 - 0.00542 pop + 401 GDP	A=897559, B_2=-0.00542, β_2=401

Table 2: mathematical model different sectors

Goodness of fit tests:

Models of different sectors check by using of different goodness of test such as Adj R2, SSR, SSE, MSE, F Value and RMSE.

Model	Adj-R2	SSR	SSE	MSE	F values
Household	98.4%	2.45764E+12	1.52391E+12	33128561260	37.09
Transport	94.7%	7.20138E+14	7.58529E+14	8.34596E+11	431.43
industrial	59.5%	1.24439E+13	7.89657E+12	1.71664E+11	36.24
agriculture	80.7%	4.19588E+11	94990141357	2065003073	101.59
Power	68.7%	3.16319E+14	1.35249E+14	2.94019E+12	53.79
other	60.4%	5.85416E+11	3.57734E+11	7776824903	37.64
Population	98.8%	47035952352	557436492	12118185	1940.72
GDP	95.05%	2619396	14201539	55731.83	254.819175

Table 3: goodness of fit test of different sectors

Best fitted model for GDP:

To forecast population different mathematical model have been applied to data (linear, exponential, polynomial and logarithmic model) (Kerry, 2017, Oscar Mario, 2018. Jeffrey K.2003, Naizhuo Zhao 2017). Based on goodness of fit test polynomial is the best fitted model as shown in table 4.

	Model	Adj-R2	SSR	SSE	MSE	F values	RMSE
polynomial	y=0.751656143x^2 - 2971.97612x + 2937949.971	95.69	8920546	401638.9	8196.712	1088.308	90.53569
Exponential	y = 2E-39e^0.0479x	95.05	15845073	2619396	53457.06	296.4075	231.2078
Linear	y= - 56510 + 28.6x	85.9	8259322	1529764	31219.67407	264.555	176.6909
Logarithmic	y = 57094ln(x) - 433201	86.02	7.44613E+14	7.44613E+14	1.58428E+13	47.00001116	3980304.833

Table 4: checking of model by different goodness of test for GDP.

Best fitted model for population:

To forecast GDP different mathematical model have been applied to data (linear, exponential, polynomial and logarithmic model). Based on goodness of fit test polynomial is the best fitted model as shown in table 5.

	Model	Adj-R2	SSR	SSE	MSE	F values	RMSE
polyno-mial	y=0.751656143x^2 - 2971.97612x + 2937949.971	99.98	1.129E+17	2.54396E+13	5.19176E+11	217471.7218	720538.9906
Exponen-tial	y = 2E-39e^0.0479x	0.9934	1.59384E+17	3.20517E+13	6.54117E+11	171420.112	808774.777
Linear	y= - 56510 + 28.6x	99.3	1.121E+17	8.52882E+14	1.74058E+13	6442.996184	4172020.224
Logarith-mic	y = 57094ln(x) - 433201	0.9922	4.59037E+20	5.00678E+20	1.02179E+19	44.92	3060219612

Table 5: checking of model by different goodness of test for population.

Forecasted result:

years	GDP	Pop	Transport	Industrial	Power	Other	Total
2024	1886.82	239762179	15526978.93	1493413.922	8440696.09	354622.42	25815711.36
2025	1958.299	244428310	15928554.66	1469462.47	8589296.707	357995.0256	26345308.86
2026	2031.282	249139488	16334764.91	1443598.978	8736858.274	361726.5859	26876948.75
2027	2105.769	253895713	16745609.84	1415823.497	8883380.948	365817.09	27410631.37
2028	2181.758	258696985	17161087.36	1386140.079	9028870.572	370265.7523	27946363.76
2029	2259.251	263543303	17581199.55	1354544.673	9173321.304	375073.3584	28484138.88
2030	2338.247	268434668	18005945.33	1321039.291	9316736.025	380239.5181	29023960.17
2031	2418.747	273371079	18435325.72	1285621.895	9459111.774	385764.6271	29565824.01
2032	2500.749	278352537	18869338.77	1248296.587	9600454.552	391647.8888	30109737.79
2033	2584.255	283379042	19307986.41	1209059.265	9740758.359	397890.0998	30655694.14
2034	2669.265	288450593	19751268.66	1167909.929	9880023.195	404491.26	31203693.04
2035	2755.778	293567191	20199184.5	1124850.616	10018252.02	411450.9739	31753738.11
2036	2843.794	298728835	20651734.01	1079881.354	10155444.91	418769.2361	32305829.51
2037	2933.313	303935526	21108917.12	1033002.116	10291601.79	426446.0519	32859967.08
2038	3024.336	309187264	21570734.89	984210.89	10426719.78	434481.8116	33416147.38
2039	3116.862	314484048	22037186.19	933509.6615	10560801.68	442876.1304	33974373.67
2040	3210.891	319825879	22508271.23	880898.51	10693847.73	451628.992	34534646.46

Forecasted results of different sectors are given below in table 6.

RESULTS AND DISCUSSION:

According to this equation in table 2, the predicted value of the transport sector is positively related to both population and GDP. An increase in population or GDP will lead to an increase in the predicted value of the transport sector. The coefficient for population (0.0718) suggests that a 1% increase in population will result in a 0.0718% increase in the predicted value of the transport sector, all other factors being constant. Similarly, a 1% increase in GDP will result in a 931 unit increase in the predicted value of the transport sector, all other factors being constant. According to this equation in table 2, the predicted value of the industrial sector is positively related to population but negatively related to GDP. An increase in population will lead to an increase in the predicted value of the industrial sector, while an increase in GDP will lead to a decrease in the predicted value of the industrial sector. The coefficient for population (0.0265) suggests that a 1% increase in population will result in a 0.0265% increase in the predicted value of the industrial sector, all other factors being constant. Similarly, a 1% increase in GDP will result in a 2065 unit decrease in the predicted value of the industrial sector, all other factors being constant. According to this equation in table 2, the predicted value of the power sector is positively related to population but negatively related to GDP. An increase in population will lead to an increase in the predicted value of the power sector, while an increase in GDP will lead to a decrease in the predicted value of the power sector. The coefficient for population (0.0784) suggests that a 1% increase in population will result in a 0.0784% increase in the predicted value of the power sector, all other factors being constant. Similarly, a 1% increase in GDP will result in a 3039 unit decrease in the predicted value of the power sector, all other factors being constant. According to this equation in table 2, the predicted value of the other sector is negatively related to population but positively related to GDP. An increase in population will lead to a decrease in the predicted value of the other sector, while an increase in GDP will lead to an increase in the predicted value of the other sector. The coefficient for population (-0.00542) suggests that a 1% increase in population will result in a 0.00542% decrease in the predicted value of the other sector, all other factors being constant. Similarly, a 1% increase in GDP will result in a 401 unit increase in the predicted value of the other sector, all other factors being constant. Overall, these equations can be used to predict the future values of each sector based on changes in population and GDP. They can also help policymakers make decisions about where to allocate resources and investments in different sectors based on their predicted values. However, it is important to note that these equations are based on assumptions and may not always accurately predict the actual values of each sector. Other factors, such as technological advancements, government policies, and natural disasters, can also have a significant.

CONCLUSION

Additionally, we also analyzed the relationship between population, GDP, and various sectors such as transportation, industrial, power, and other. The regression models showed that population and GDP are significant factors in determining the levels of development in each sector. Based on our results, we found that the transportation and power sectors are expected to grow rapidly in the future, indicating the need for investment in these sectors to meet the demand.

Overall, our study highlights the importance of understanding the relationship between oil/petroleum use and economic growth, as well as the impact of population and GDP on various sectors. The findings suggest that policymakers in Pakistan should focus on developing and diversifying the energy sector to ensure energy security and promote sustainable economic growth.

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Declaration of Competing Interest:
The authors have no relevant financial or non-financial interests to disclose.

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