

Quantitative Analysis of Petroleum Consumption and CO₂ Emission of Mining and Quarrying Industry of Pakistan

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Abstract

Energy is playing dynamic role in the development of national economy of Pakistan. The country's economy is supported by different industries, such as mining and quarrying is one of the leading industry of the country. The industry is producing different artefacts, for each artefact the industry consumes energy. Fossil fuels are instant sources of energy, burning of fossil fuels are the main factor of the climate change. Hence energy is directly and indirectly used in every sector of the country and petroleum sector is considered the main driving force of the energy. This work derives measures of petroleum consumption and CO₂ emissions related to fuel consumption activities in Mining and quarrying industry of Pakistan from the year 1970 to 2016. Results of the study have been calculated by using Wassily Leontief input-output analysis. Results demonstrated that total petroleum consumption of mining and quarrying industry reached at the peak level from year 1994 to 1998, in 2014 1.58E+7 metric barrels were consumed by the sector. Similarly, in 2015 and 2016, 1.62E+6 metric barrels and 1.72E+6 metric barrels of petroleum respectively consumed in the sector.

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Petroleum consumption caused of emissions of greenhouse gases around 1.01E+7 metric tons of CO₂ was released in 1998. Respectively in 2015, 6.98E+6 and in 2016, 7.42E+6 metric tons CO₂ was released. By analysis outcomes of the study, petroleum demand and its consumption will raise and the relevant emission will also increase in the future.

Keywords: Mining and quarrying industry; Leontief input-output analysis; Petroleum consumption, and CO₂ emissions.

1. Introduction

Pakistan is bestowed with all kinds of resources including mineral, a number of precious minerals and useful crystals are available in Pakistan and countless sides are still forbidden to explore. Mining and Quarrying sector grew by 3.8 percent in 2014-15 as against 1.6 percent last year (2017). Soap stone, Crude oil, Gypsum, Coal and Lime Stone posted a positive growth rate of 41.68 percent, 14.03 percent, 8.11 percent, 4.12 percent and 3.73 percent respectively. However, that was considered a gradual level of improvement during the period, such as Sulphur 42.06 Dolomite 46.87 percent, percent, Bauxite 25.69 percent Phosphate 47.75 percent, and Magnesite 7.44 percent [1]. Assessing life cycle of minerals and it's made products, it has been investigated that each product or service consume some amount of energy directly or indirectly. For each process, some amount of energy is needed and that amount of energy contributes directly to progress of national economy and devastation of environment. Although energy is the main component of the economy, for a smooth and progressive development of the economy enough energy is needed and it is considered as unavoidable element of the economy, energy is a particular component of the economy which is used in every sector of the economy, similarly, its importance can not be denied. Energy and economy have a positive and significant relationship investigated [2,3]. Energy can be produced in different ways; only sophisticated and reliable source of energy has contributed to the development of national economy. Since long time petroleum is a key driver of energy production [4]. Energy is consumed in every sector of the economy, it is studied that the processing sector consume more energy as compared to other sectors. However, the quest to meet the demand of energy, the world has hiked the use of environment degradable energy generation sources. Non-renewable energy sources are the cause of environmental degradation. By using Granger's causality test, economic growth, environmental pollution and energy consumption has been tested, the corresponding factors become sweeping interest [5,4]. Current energy policy of Pakistan is not sophisticated which may not able reform energy crises, [6] implementation of integrated Energy Planning (IEP) can be carried out at different stages, the process is expected to compensate for existing policies and practices in a rational direction. Energy is the basic need of today's humans but it also put a long time adverse effects on the planet. Usage of energy in different stages of life releases a large amount of the carbon dioxide (CO₂). The rapid growth of CO₂ is seen in the last 29 years 1979-2014 [7]. Production and operations of different industries are totally reliant on the supply of energy. Mining and quarrying is one of the processing industries which produce refine and purify different minerals and precious element including digging and extractions etc. Mining and quarrying industry in the country has boasted in last few decades and will grow even more in upcoming years. Alike other industries Mining and quarrying industry also consumes a large amount of energy that directly release CO₂ by burning of fusil fuel and degrade the environment. In order to meet the accurate results of CO₂ emission of mining and quarrying

industry, the Input-Output (IO) approach is used by the integration of Pakistan statistics board data. IO approach is widely used to investigate the impacts of one sector on another sector of the economy. Due to the simplicity of model its usage was found in multiple disciplines. Developed model optimize closed and accurate results of CO₂ emission of mining and quarrying industry, this model is used mostly short-term analysis [8]. By using data of petroleum consumption of mining and quarrying, CO₂ emissions of mining and quarrying sector is counted. In IO table study mining and quarrying has been considered a single sector, similarly in this study mining and quarrying sector is considered as single unite.

2. Status analysis of Petroleum consumption and CO₂ emission of Pakistan

Pakistan is counted amongs developing countries, for its progressive development many industries donating its large portion of production. Fossil fuels are the main sources of generating a dynamic form of energy, can be used anywhere at any time without any interpretation. According to the report of BP Statistical Review of World Energy 2010, United States of America oil demand dropped by 4.9% in 2009 compared to 2008. In underdeveloped nations consumption decreased censoriously and this was the lowest level of consumption ever recorded since 1997. Beside this, oil consumption of China increased 6.7% in 2009 [9]. In 2010 oil prices decrease it was the first downfall of oil prices since 1982, this downfall proved beneficial at some extent for underdeveloped countries including Pakistan was pointed. [10,11]. Pakistan's oil production is not enough to extinguish the country's thirst its large portion is imported by gulf countries. It is documented that in July 2016 Pakistan has imported 35.57 million barrels of compared to the previous year, import was 34.35 million barrels, 3.4% import of oil was increased in the year 2016. While in values US \$ 3.59 billion oil was imported comparing to the US \$ 1.97 billion. Every year demand of energy is growing, simultaneously demand of petroleum products will also rise. Thus, it has been proven in several studies that increase of burning degrades environment, burning of fossil fuels are in proportion to the degradation of the environment and ecosystem of the planet.

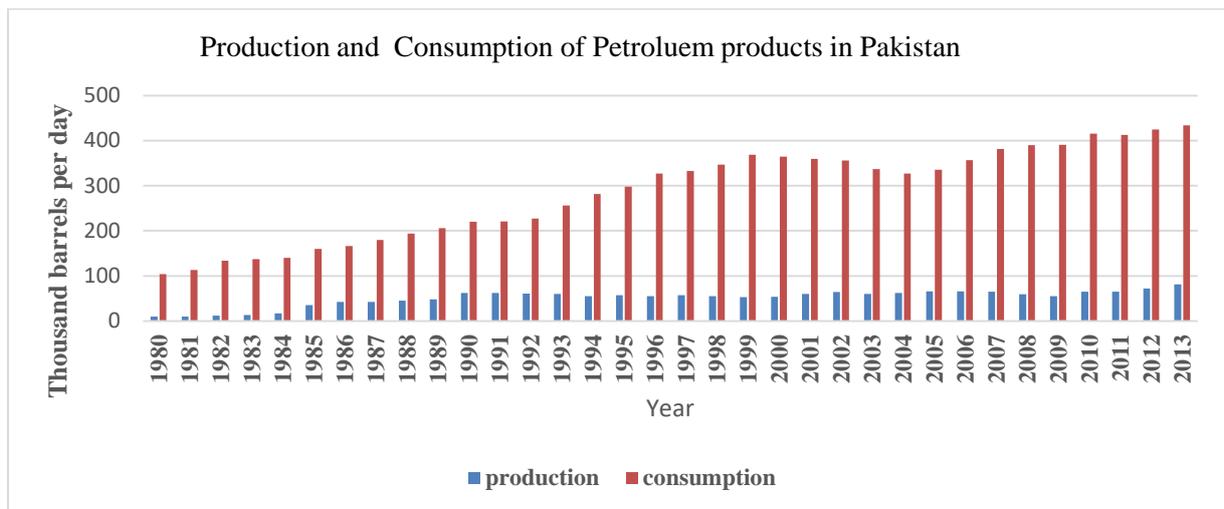


Figure 1: United State Energy Information administration 2016.

Fuel consumption in transport sector clearly defined the cargo carriage and masses transportation mode.

Practically it is very hard to stop fuel consumption of transport system but it can be reduced by using advanced technology and switched of the old system into new advance transportation mode, like as fuel cell, solar storage system or hydrogen vehicle. Hence energy consumption in the form of fossil fuel is greater compared to other sector of the economy. The mobility of masses and goods directs the growth of production of the country and development of the economy. It can be seen that fuel consumption increased 62.64% from 2001 to 2016 shown in figure 2. Usage of transportation is not limited for any specific sector but this sector directly and indirectly contributes in other sectors, including construction, electricity generation, mining and quarrying etc.

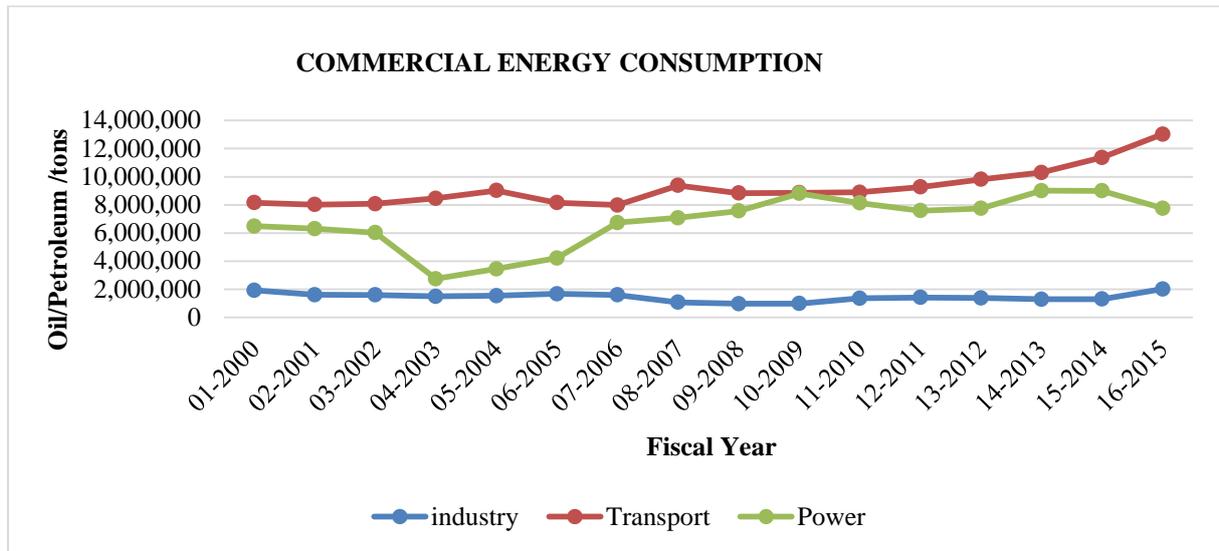


Figure 2: Pakistan economic survey 2015-2016

Lack of the energy not only reduces the production of industries but also put adverse effects on Gross Domestic Product (GDP) growth of the country. It was verified through literature that about 62 % and 64% electricity generated from thermal power plants in the fiscal year 2016 and 2017 respectively [12]. Thermal power plants and transport are major burners of oil. The share of oil consumption of both sectors was 91% in 2016 and 90% 2017 and a 1% reduction recorded in the electricity sector due to the provision of renewable electricity generation [13]. Electricity production and fuel consumption directly consumed by industries, if production of electricity increase, production of industries also increases as shown in figure 2. The energy (fossils fuel) consumed by the power sector appears to have declined in the fiscal year 2003-2004, as consumption gradually increased and reached the maximum level in 2009-2010, during this year the country faced major load shedding. The shortage of power supply has direct impact on GDP. Climate change is reality, the internal energy of planted is converting into heat which warm atmosphere, form water vapor, melts glaciers and destroy the environment. Internal energy could be anything that burns and produce CO₂, like as fossil fuels biomass etc. Human activities are also responsible of CO₂ emission and CO₂ is 90% contributor of global warming [14]. Useful product come to cross to individual processing units similarly different processes are used to obtained useful products, in each process some amount of energy directly indirectly used, it is easy to calculate direct consumption of energy but indirect used of energy for those processes are still forbidden. Xu Tang has used the method of calculating indirect use of petroleum and energy embodied in different useful products, before the

study it hard to optimize the energy embodied in different products in detail and combined effects of those products on the environment were not confirmed [15]. Through dematerialization, the large amount of metal can be saved and the demand of materials can be reduced. Different metals and materials are under the use of human being and most of them can be recycled because metals are not biodegradable they have good recycling capabilities, metal can be recycled many time and its properties may change by adding small amount of impurities. Due to the recycling efficiency of the metals a large amount of energy can be saved in future, such as copper 85% zinc 75 nickel 90% lead 65% Aluminum 95% and steel 74%. The recycling of metals reduces mining and mineral processing activities that continually consuming energy and destroying environment [12]. Emissions of different nature of fossil fuels are shown in figure 3. It is shown that total emission of CO₂ release by the country. In the report of CDIAC collective emission of solid fuel, gas fuel and liquid fuel. It is difficult to distinguish the release of CO₂ from the given data how much a sector is contributing to destruction, once energy consumption or petroleum consumption is analyzed then it will become easy to predict emission of any sector.

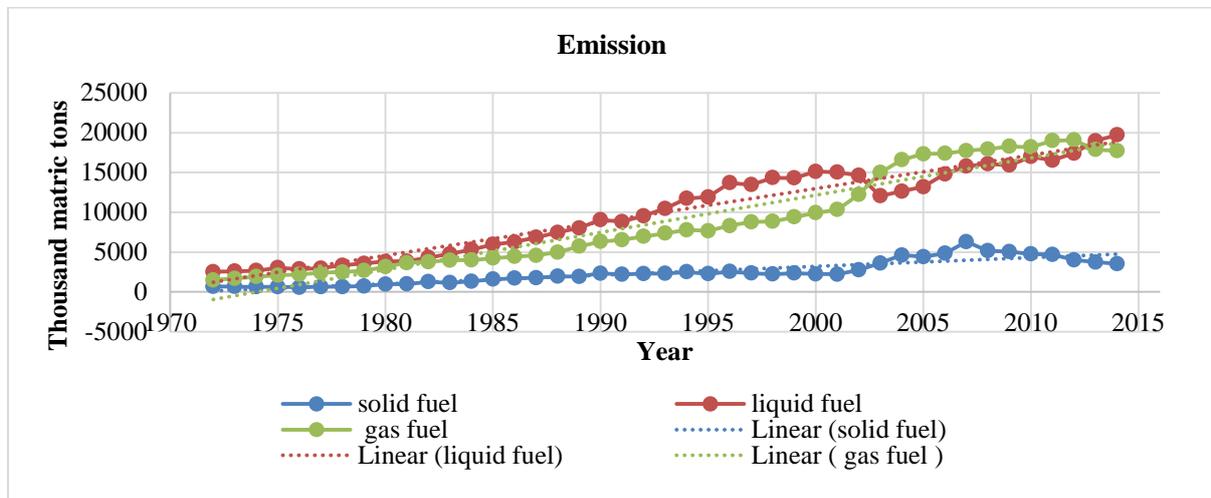


Figure 3: Pakistan's CO₂ Emission from different energy sources. (CDIAC)

Over the past 200 years, measurable effects of carbon were initiated by the human being. However, an even bigger change to the cycle has occurred as a result of the widespread use of fossil fuels. Burning fossil fuel releases CO₂ into the atmosphere. This adds carbon that has been out of circulation of millions of years directly to the atmosphere. The instant outcome of these people activities is that in the past 200 years, the concentration of carbon dioxide in the atmosphere has dramatically increased. In 1800 the carbon dioxide concentration in the atmosphere was about 280 parts per million, but recent readings from June of 2012 measure the concentration at 395 parts per million. It was compulsory to know how much CO₂ exist every million molecules of the air. In 1958, scientists took direct measurements of atmospheric CO₂ continuously. From this direct measurement, we know that the concentration of carbon dioxide has been steadily increasing year after year for past 54 years in a remarkable regular seasonal pattern. The outcome shows that CO₂ reached at the peak level, In May of 2013 CO₂ levels has raised to a new peak level of 398.6 ppm plus 0r minus one part per million. The burning of fossil fuels has added extra carbon dioxide to the atmosphere and it can be seen how this leads to climate change. Human-induced climate change or global warming, fossil fuels like oil coal and natural gas, these fuel are buried inside the earth at different levels of depth from millions of years, these fossil products are usually composed of

carbon and changeable amount of hydrogen. Before the world became industrialized, by burning of fossil fuel CO₂ concentration in the atmosphere was 0.28% tiny compared with oxygen at 21% and nitrogen at 78% is enough to keep human warm this concentration provides natural blanket to the planted that warm earth, that natural blanket provide heat to support life. Combustion of fossil fuel adds extra CO₂ to existing level. The carbon in fossil fuels has remained trapped underground for hundreds of million years so it is extra carbon that's been added to the natural cycle. The raise of CO₂ raises temperature of the planet similarly that could be cause of climate change as well as there is extra trapped energy in the form of heat on earth initiating glaciers and ice caps to melt similarly weather becomes extreme, nowadays nearly 50% higher than pre-industrial time. As humanity adds carbon dioxide to the atmosphere and is putting a tricot around the plane. The extra layer isolates the heat and it cannot escape as easily whilst it's easy to take off the sweater. The earth cannot lose its green gases as quickly and keep adding to them by putting the planet in a sweatbox and causing wide-ranging.

3. Methodology and data preparation

The data used in the study taken by Input-Output (IO) table, IO model is developed by Noblier economist Wassily Leontief [13]. The model can be used to investigate co-relation of one sector to another sector within the economy. Pakistan's IO is extracted from World Multiregional Input-Output (MRIO), Pakistan Bureau of Statistic (PBS) and World Input-Output Database (WIOD). IO data is available up to 2013. The data of corresponding four years are counted by using Leontief IO approach. Emissions of fuel have been counted by multiple of heat content times with the carbon coefficient time the fraction oxidized times the ratio of the molecular weight of carbon dioxide to that of carbon (44/12). 5.80 mmbtu heat can be generated from one barrel of crude oil [15] The fraction oxidized is 100 percent [13] and average carbon coefficient of crude oil is 20.31 kg carbon per mmbtu (EPA 2017). Further, per barrels emission of crude oil can expressed as 5.80 mmbtu/barrel × 20.31 kg C/mm btu × 44 kg CO₂/12 kg C × 1 metric ton/1,000 kg = 0.43 metric tons CO₂/barrel. Based on IPCC and EPA, monetary data of the IO table and PBS is converted into barrels at the standard given rates. The required IO data is obtained by using Leontief IO approach than calculated data is compared and converted at suggested standard. Suppose an industry produces some kind of product, for that product some kind of raw material is required as input. The industry which is producing some output it is also consuming some amount of input in order to maintain its production.

Table 1: General format of Input-Output.

Input / Output	Industry 1	Industry2	Industry3	Final demand
Industry 1	α_{11}	α_{12}	α_{13}	Y_1
Industry 2	α_{22}	α_{22}	α_{23}	Y_2
Industry 3	α_{31}	α_{32}	α_{33}	Y_3
Value Added	V_1	V_2	V_3	GDP

It is not necessary that the industry which gives some kind of output will consume same nature of the input, it is also possible industry can consume multiple inputs have different nature than the final product. Above statement can be described into following equation (1)

$$X_i = x_{i1} + x_{i2} \dots x_{ij} \dots x_{in} + y_i \tag{1}$$

X_i is total output, x_{ij} is production of sector i purchased by sector j and y_i is final demand

$$\alpha_{ij} = x_{ij} / X_j \tag{2}$$

Equation (1) (2) and general term of table (1) further expressed as follows

Similarly, Eq. (3)

$$\begin{aligned} \alpha_{11}X_1 + \alpha_{12}X_2 + \alpha_{1j}X_j \dots \alpha_{1n}X_n \dots y_1 &= X_1 \\ \alpha_{21}X_1 + \alpha_{22}X_2 + \alpha_{2j}X_j \dots \alpha_{2n}X_n \dots y_2 &= X_2 \\ \alpha_{31}X_1 + \alpha_{32}X_2 + \alpha_{3j}X_j \dots \alpha_{3n}X_n \dots y_3 &= X_3 \\ \alpha_{n1}X_1 + \alpha_{n2}X_2 + \alpha_{nj}X_j \dots \alpha_{nn}X_n \dots y_n &= X_n \end{aligned} \tag{3}$$

term α_{ij} is called technical co-efficient X_j is total output of sector j

Matrix notation is given as below, similarly Eq. (5)

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1j} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2j} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{i1} & a_{i2} & \dots & a_{ij} & \dots & a_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nj} & \dots & a_{nn} \end{bmatrix} X \begin{bmatrix} Y_1 \\ Y_2 \\ \dots \\ Y_i \\ \dots \\ Y_n \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \\ \dots \\ X_i \\ \dots \\ X_n \end{bmatrix} \tag{5}$$

$$AX + Y = X \tag{6}$$

Eq. (6) is basic matrix equation which is transformed into the basic formula of the IO model as given below in Eq. (7) and (8). The term I is known as identity matrix and $(I - A)^{-1}$ is known as Leontief inverse matrix.

$$(I - A) X = Y \tag{7}$$

$$Y = (I - A)^{-1} X \tag{8}$$

Required data has been calculated by using Eq. (8) and Eq. (6) IO data is accessible up to 2013. remaining data of the year 2014, 2015, and 2016 has been calculated by the Eq. (6) that data finally converted by using IPCC method which one is previously discussed.

4. Results and discussions

Progressive development of the Mining and quarrying sector can be investigated by Analyzing consumption of energy in the sector. The sector which consumes more energy and their consumption does not overlap production and profitability that consumption cannot be denied that consumption counted as a gainful. Findings have ensured the role of energy generation sectors is dominant on all other sectors.

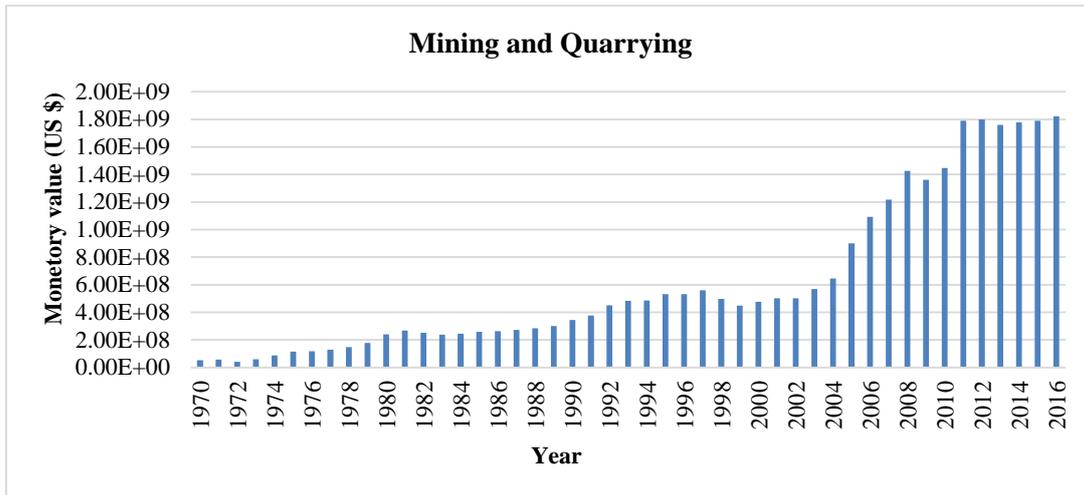


Figure 4: Consumption of petroleum energy in the Mining and Quarrying

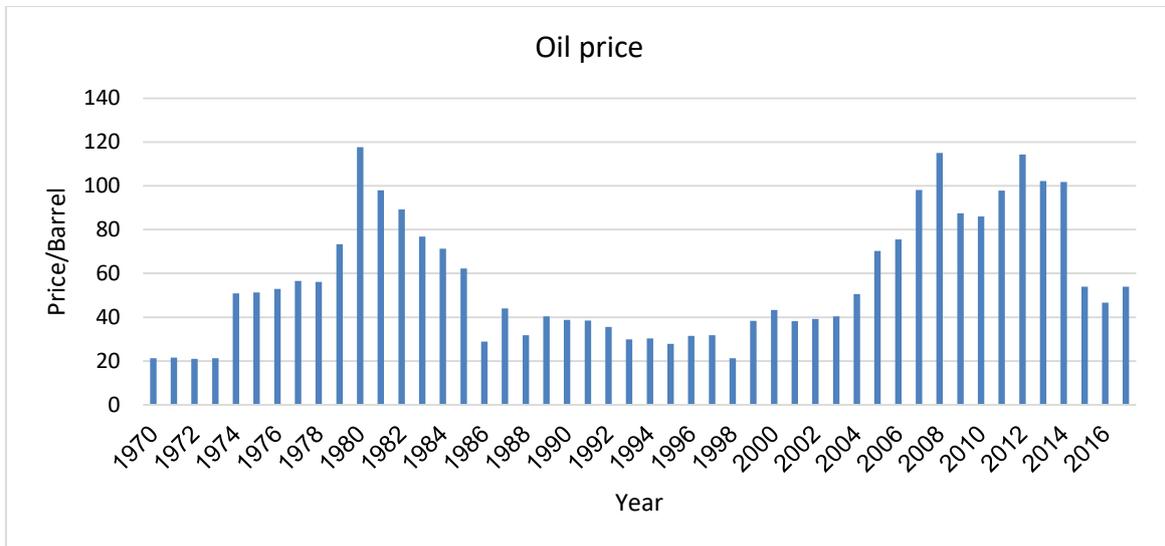


Figure 5: Rate of Crude oil in different years

The petroleum consumption has been calculated by using Eq.1 in which different inputs are shown; these inputs are contributing in different sectors of the economy. Input contribution of petroleum is extracted from the table of year 1970 to 2016. In year 2004 contribution of petroleum in the term of monetary units was stable and gradually increase, it did not show any rapid progress as shown in the figure 4. Since year 2005 consumption of petroleum energy rapidly increased similarly growth in mining and quarrying was also noted as shown in figure

6. Similarly, in the year 2004 growth was recorded near 15.6%. By analysis figure 5 & 6 it can be observed that, as prices of the petroleum increased, consumption of the petroleum products was declined. It has been indicated that price changes have a direct effect on the national economy. Surplus changes in prices were recorded from year 1979 to 1984. After that petroleum prices dramatically decrease and that have become stable until 2004, in this duration fuel consumption was recorded in the peak as shown in figure 7.

Petroleum consumption was recorded in the sector was much higher compared to other years as shown in figure 7, at same time petroleum prices were decreased compared to other corresponding year shown in figure 5. Similarly, industrial sector, particularly mining and quarrying sector's growth was recorded positive, as price of petroleum decreased production of industrial sector increased, sub-department of the industrial sectors' growth were also increased, but other hand constraint is also employed like as infrastructure, power supply availability of raw material, and work personnel also counted major developer of any productivity. The growth rate of three factors are shown in figure 6, the industry sector represents collective definition of mining & Quarrying, Manufacturing of large scale and small scale, Construction and Electricity & Gas Distribution. The highest growth was recorded in year 1986 22.7% and the lowest regress was recorded in year 1995, 1989 and 2011. Similarly industrial growth was also affected due the mining and quarrying sector because the sector is sub-sector of the industrial sector. It is shown in figure 6 that GDP and industry are directly interconnected, the progress and regression has direct effect on one another. In 2016 growth rate of GDP was 5.12% and growth of mining and quarrying was 3.94%.

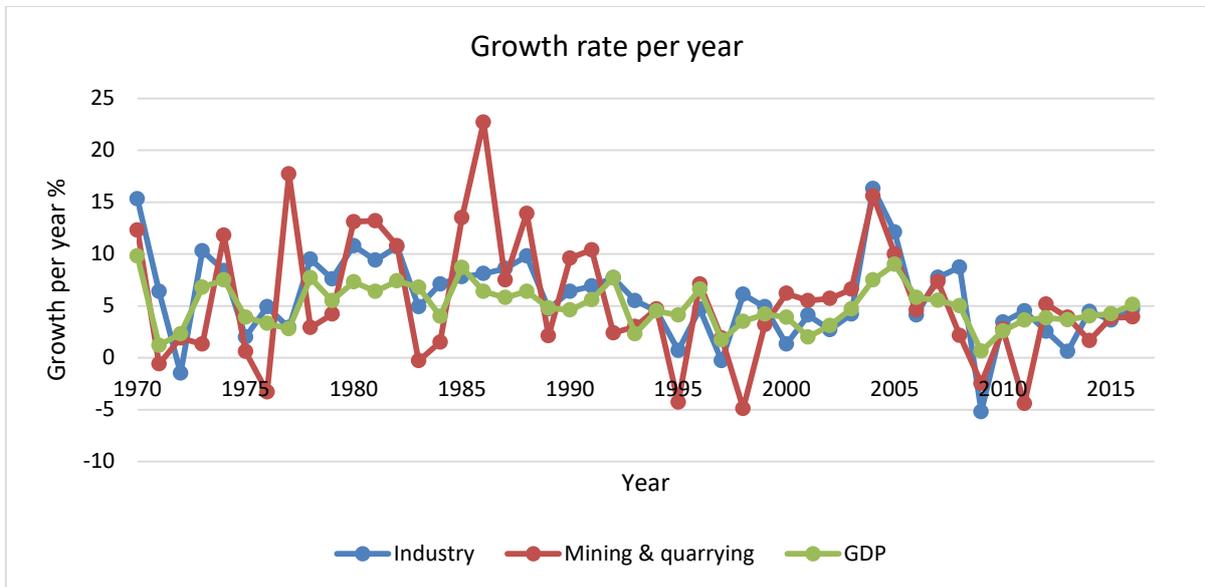


Figure 6: Per Year Growth in Industry Mining & Quarrying and GDP (PBS)

The growth rate of GDP of the country was recorded in year 1985 8.7%, in year 2005 growth of GDP and industry were recorded 9 % and 10% respectively. Once industrial production increased GDP of the country is also increased. Thus, it is justified by figure 6, numerous studies that GDP and industry are directly related to one another. Results of the study indicate that large portion of the petroleum product was consumed by mining and quarrying sector. Total petroleum product consumed by the sector in year 1970 were 2.48E+6 barrels, in

year 1985 first progress was recorded about to $4.15 \text{ E}+6$ and 67% consumption of petroleum products increased in 15 years from 1970 to 1985, after it rapid consumption was recorded. In 1996 about $9.12\text{E}+6$ barrels were consumed, and this growth of consumption was the highest ever recorded before. After 1996 oil consumption increased rapidly, from 1992 to 1998 consumption crossed linear limit and reach the peak level. From 1999 fuel consumption was declined slowly and reached $1.17\text{E}+7$, it was first declined after 1992 the consumption was below the linear limit shown in figure 7. Overall consumption of petroleum products is shown in the figure 7.

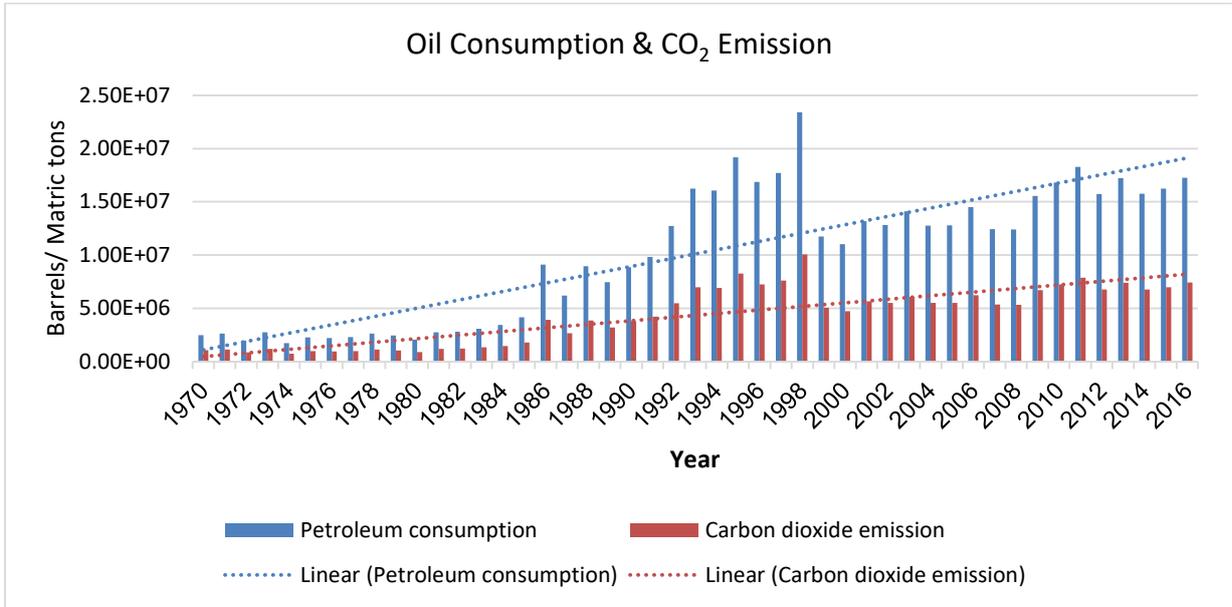


Figure 6: Petroleum consumption and CO₂ Emission of Mining & Quarrying sector.

Once the consumption of petroleum products is calculated then it becomes easy to calculate CO₂ emissions. The burning of fossil fuel produces CO₂ and petroleum products are considered as a major burner. Once petroleum consumption is investigated it becomes easy to investigate CO₂ emission. Based on the calculated results of petroleum consumption of the mining and quarrying sector, emissions of CO₂ are achieved as shown in figure 7. In 1970 mining and quarrying sector has released $5.95\text{E}+5$ metric tons of CO₂ into the atmosphere by burning petroleum energy. After it massive amount of CO₂ released in 1996 about $3.92\text{E}+6$ metric tons, this was initiative of CO₂ emission in the atmosphere. The second massive release of CO₂ was recorded in 1992 near about $5.47\text{E}+6$ metric tons; this amount was greater than suggested linear limit as shown in figure 7. The release of CO₂ increased continuously till 1998, as consumption of petroleum increase emission of CO₂ also increases. Emission reached at the peak from 1994 to 1998 at that time consumption petroleum products in the sector was also increased.

5. Conclusion

Energy is considered as backbone of national economy; petroleum energy has played a major role in the development of the national economy. The economy is supported by deferent sector or different industries which directly indirectly participate in the progress of national economy of Pakistan. In the country the number of industries are installed and produce different products and consume energy. In this study consumption of

petroleum energy in mining and quarrying industry is investigated, outcomes of the study direct that the oil consumption reaches at a peak level in 1998, the reason behind higher consumption of petroleum products in the sectors was that the petroleum prices were the lowest level and per barrel price was 21.2 dollars. Findings show that consumption is influenced by the oil prices. Similarly, increased of petroleum consumption also increase the emission of greenhouse gases. Cheap prices of petroleum products and emissions are reciprocally related to each other, in 1998 prices were cheap at that time petroleum consumption was higher, similarly, at that time emissions were also recorded at the peak. It can be estimated by analysis current consumption rate and demand of petroleum products, in future demand will increase, similarly CO₂ and global warming will increase, consumption of petroleum energy and CO₂ cannot be constrained but these can be reduced at some extent by using renewable energy resources.

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