THE INVESTIGATION OF SOURCES AND ECONOMIC LOSSES OF $PM_{2.5}$ IN SELECTED SOUTH ASIAN COUNTRIES

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CERTIFICATE

This is to certify that this thesis entitled **"The Investigation of Sources and Economic Losses PM2.5-In Selected South Asian Countries"** submitted by **Ms. Duaa Nazir** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Environmental Economics.

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Author's Declaration

I Duaa Nazir hereby state that my MPhil thesis titled "Investigation of sources and Economic losses of $PM_{2.5}$ in selected South Asian countries" is my own work and has not been submitted previously by me for taking any degree from Pakistan Institute of Development Economics or anywhere else in the country/world. At any time if my statement is found to be incorrect even after my Graduation the university has the right to withdraw my MPhil degree.

Date: JANUARY 19, 2023

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ABSTRACT

Air pollution specifically the presence of $PM_{2.5}$ concentrations is a rising concern in south Asian countries. Along with health effects it has economic repercussions that cannot be ignored. This study estimates the source of $PM_{2.5}$ in Pakistan, India, and Bangladesh through panel regression and survey from MOCC and EPA officials. The study finds that fossil fuel usage and number of vehicles in a country have significant and positive influence on $PM_{2.5}$ concentrations and are considered the main sources of particulate pollution. Furthermore, the study calculates the economic loss due to $PM_{2.5}$ concentrations. It reveals that Pakistan's percentage increase in economic loss from the observed time of 1998-2019 is the highest (129%) compared to India (57%) and Bangladesh (122%). Also, the Cost-Benefit analysis of reducing $PM_{2.5}$ emissions shows that all the selected countries would have received more benefits than the costs used for emissions reduction. Hence, to avoid excessive usage of fossil fuels, public transportation should be encouraged. Moreover, financial investment and human resource training should be provided to EPA Pakistan employees for its capacity enhancement as it is the leading tool for monitoring air quality. This will also aid in shaping the air quality improvement policies. Lastly, public should be made aware of economic and health damages of air pollution through media advertisement.

Keywords: $PM_{2.5}$ emissions, panel regression, economic loss.

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AQLI	Air quality life index
FE	Fixed Effect Regression Model
FF	Fossil fuel consumption
GOP	Government of Pakistan
GOB	Government of Bangladesh
GOI	Government of India
GDP	Gross Domestic Product
IG	Industrial growth
MOCC	Ministry of Climate Change of Pakistan
NDC	Nationally Determined contributions
NRV	Number of registered Vehicles
PLS	Pooled least square regression
$PM_{2.5}$	Particulate matter of 2.5 micrometer in diameter
RE	Random Effect Regression Model
UP	Urban population growth
US EPA	United States Environmental Protection Agency
UNEP	United Nation Environmental Programme
WB	World Bank
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Introduction:

The high- risk air pollutant identified as Particulate matter ($PM_{2.5}$) is easily breathable due to its size (EPA, 2021). It contains mixture of minute solid and liquid droplets which is undetectable to the naked eye and is present both indoor and out (United Nations Environment Programme (UNEP), 2021). $PM_{2.5}$ infiltrates lungs carrying high toxins and permits harmful mixtures into the circulatory system and thus, induce adverse health effects (Xing et al., 2016).

Particulate matter can be separated into 3 main categories including "*coarse particles (PM_{10}), fine particles ($PM_{2.5}$), and ultrafine particles ($PM_{0.1}$)"*(Smith, 2020). Here the fine particles $PM_{2.5}$ are considered as its exposure is the most hazardous for health (Nations et al., 2018). Its emissions arise from both natural and anthropogenic sources. However, this study only focusses on human generated emissions. The $PM_{2.5}$ is released in the air directly from industrial processes and during the combustion of fossil fuels. Also, large portion of fine particles is attributed to chemical reactions between gaseous emissions in the atmosphere. So, in this way the main contributors of $PM_{2.5}$ formation either directly or indirectly can be taken as industrial processes and combustion of fuel (United Nations Environment Programme (UNEP), 2019).

Air pollution is a global issue but specifically in Asia and pacific 92 percent of the population is subjected to high concentrations of particle pollution which pose threat to their health (Nations et al., 2018). Thus, to improve the quality of air and save health of individuals the WHO has recently updated air quality guidelines with a value for $PM_{2.5}$ of 5 micrograms per cubic meter (μg/m3) as an annual mean concentration in ambient air(WHO, 2021a). Furthermore, South Asian region in the last years have emerged as the most polluted worldwide. More prominently countries including Pakistan, India, and Bangladesh suffer the worst air quality in this area. Such as Bangladesh, China, India, and Pakistan are sharing 49 of the 50 most polluted towns globally (IQAir, 2020). So, the importance of improving air quality of South Asia cannot be denied. Therefore, in this study three countries (Pakistan, India, and Bangladesh) are selected for comparison where their contribution to particulate pollution and influence on economic loss is explored. To investigate the matter, Pakistan particulate pollution has increased progressively with time. In such manner that almost all of Pakistan's population is now living in areas where the level of annual average particulate pollution is beyond the Pakistan's air quality standard of 15 $\mu g/m^3$ plus the WHO guideline (Air Quality Life Index, 2021). Consequently, Pakistan is ranked as the second most polluted country in the "*World Air Quality Report 2020''* (IQAir, 2020). The urbanization, industrialization and economic development can be accounted for higher particulate pollution in Pakistan. The key components include emissions from road transport and construction, domestic biomass burning, and industrial activity (Sánchez-Triana et al., 2014).

Furthermore, India air pollution has also been on the rise such as it consistently dominates annual $PM_{2.5}$ rankings by city. Like Pakistan the pollution sources of India are transport, burning biomass for cooking and episodic agricultural burning. Plus, the generation of electricity through fossil fuel, industries, construction, and waste burning. In particular, the prime source of $PM_{2.5}$ emissions in India is transportation (Molina, 2021). Similarly, Bangladesh is another developing country in South Asia which air quality has deteriorated over time. The air quality data of Bangladesh reveal that whole population of the country is living in levels of annual average particulate pollution that exceeds both the WHO guideline and own national standard. The sources of particulate emissions are identified as transportation, industrial processes, biomass burning and construction (Air Quality Life Index, 2020).

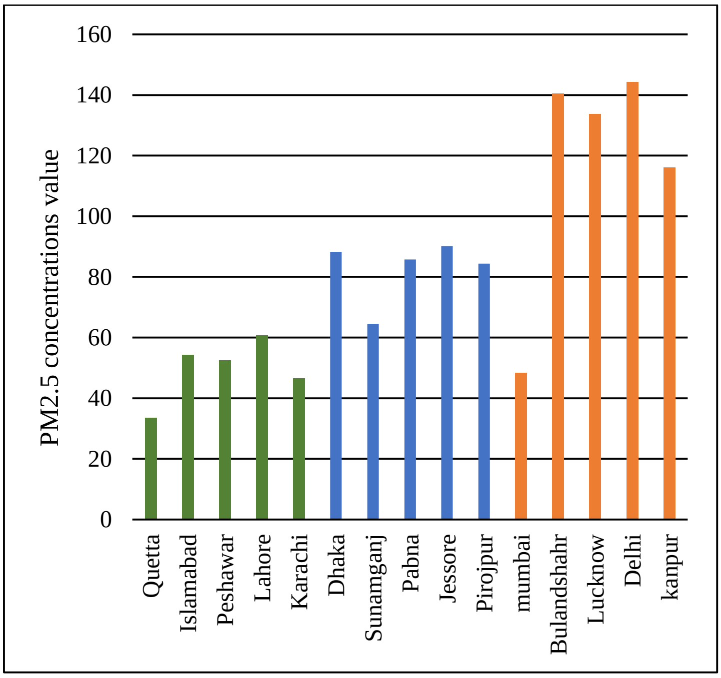

Figure 1 Annual average PM2.5 concentration for year 2018

Source: Air Quality Life Index (AQLI).

Figure 1 shows the annual average concentration of $PM_{2.5}$ in three selected countries for year 2018. The green bars represent $PM_{2.5}$ concentrations in main cities of Pakistan. The blue bars represent main cities of Bangladesh while orange bars show $PM_{2.5}$ values for main cities of India. All countries $PM_{2.5}$ levels are above the national and WHO recommended standards. This indicates that currently the air quality of these countries is harmful for their citizens.

This leads to health and economic costs. Historical review of economic costs caused by air pollution reveal that, Pakistan currently make up around 47 billion US dollars forecasted economic burden (Rafique et al., 2022). This has increased tremendously from 2006. Such as per (Abedullah, 2006), Pakistan was spending environmental cost of $1.8 billion. Similarly, (Qamar Uz Zaman, n.d.) summarized health costs for ten cities of Pakistan and suggested a monetary value of 583 to 1121 million US dollars in 2020. Moreover, exploring the India's economic costs to air pollution (Dalberg et al., 2021) revealed that air pollution every year costs Indian businesses USD 95 billion. In 2013, a World Bank study indicated that deaths caused by air pollution account for a loss of USD 55.4 billion. In 2019 the premature deaths form ambient particulate matter in India resulted in lost output and accounted for US$36.8 billion (Pandey et al., 2021). In case of Bangladesh, the monetary loss in 2017 due to loss of productivity was estimated to be 0.59% to 0.76% of GDP. While the cost from air pollution rose and was almost equal to 4.4 percent of country's GDP in 2019 which is calculated to be US$ 18.6 billion.

However, the countries have taken initiatives and made policies for reduction of particulate emissions. Such as Bangladesh has recently instigated inland water ways project from Dhaka to Chittagong(World Bank, n.d.). Similarly, other actions to be taken by the country includes widening of roads to reduce the congestion in traffic and introducing the electronic road pricing for congestion to discourage vehicles usage. While India has not yet updated its nationally determined contributions to UNFCC. But it is taking several initiatives to minimize country's air pollution. Which includes National clean air programme that has been launched in 2019 with assistance from World Bank. Further, SAMEER app has been introduced to provide masses of information regarding air quality. Pakistan has also taken several steps to tackle air pollution. Such as the Government of Pakistan consider emissions reduction from the transport sector a high priority in the updated NDCs. Considering which Pakistan has launched National electric vehicle policy in 2019.

Hence, it can be observed from the above discussion that the three South Asian countries have immense particulate pollution with similar sources of emissions and are experiencing monetary loss. Although, they have taken initiatives to reduce pollution the problem persists. According to World Health organization (WHO) about 91 percent of premature deaths in South Asia specifically in developing nations are a consequence of particulate pollution (WHO, 2021b). Furthermore, in lower-middle income countries of Asia high concentration of $PM_{2.5}$ in the air is mainly responsible for haze and smog which has tremendous health, economic and environmental repercussions. Thus, India and Bangladesh are being selected for analysis due to two reasons. First, both are lower-middle income countries like Pakistan. Secondly, cities like Dhaka (Mahmood et al., 2019), Delhi(Chowdhury et al., 2019) and Lahore have been consistently experiencing high levels of $PM_{2.5}$ concentrations compared to rest of South Asia.

1.2 Statement of the Problem:

Different studies have investigated the effect of air pollution on respiratory health symptoms (Kim et al., 2018) but it has been rarely explored that how higher intensity of $PM_{2.5}$ is affecting the economic activity. Therefore, the prime focus of this study is to investigate the source of pollution and estimate the economic loss due to emissions of particulate matter ($PM_{2.5}$). The sources of $PM_{2.5}$ in selected countries are identified through regression technique for time 1998-2019. To calculate the economic loss, the years of life lost from (EPIC, 2021) are translated into monetary value (named as economic loss). Such as, we assume that each labor is earning at least 2 US dollars per day. Earning 2US$ per day is a poverty baseline according to WHO and is taken here to avoid the fluctuations occurring in labor earnings of each country. This 2$ is then multiplied with years of life lost and the labor force of a country in same year. This display economic loss a country is incurring due to $PM_{2.5}$ pollution. Due to limitation of secondary data, the study is not considering other economic losses such as forgo labor earning, expenditure of hospitalization and cost of un-comforts facing during the sickness period. This implies that our economic losses are partial and indicate only lower bound estimates. Then, Cost-Benefit analysis is performed to estimate the benefits countries will receive if pollution is reduced. Further, pollution level in terms of $PM_{2.5}$ of Pakistan is compared with neighboring countries (India and Bangladesh) having similar cultural and economic situation and that how it has changed over time. Lastly, a short survey is conducted with the respondents being

Ministry of Climate Change and Environmental Protection Agency officials. The purpose is to identify pollution sources and evaluate the performance of Pakistan in reference to controlling air pollution.

1.3 Research Problem:

*Based on the narrative of SoP as stated in the preceding text, I am narrowing my research problem into "***The Investigation of Sources and Economic losses of $PM_{2.5}$ in selected South Asian Countries"** *and have operationalized my topic into following research questions and objectives.*

1.4 Research Questions:

1. What are the influencing factors of $PM_{2.5}$ in Pakistan, India, and Bangladesh?
2. Is Pakistan incurring more economic losses due to $PM_{2.5}$ pollution compared to selected countries.
3. Is the cost of reducing air pollution more than its benefits?

1.5 Research objectives:

The objectives of the study are to:

1. Identify major sources of $PM_{2.5}$ pollution.
2. Estimate the economic loses of increase in pollution ($PM_{2.5}$) and to make comparison of Pakistan with selected South Asian countries (India and Bangladesh).
3. Compare the costs and benefits of reducing $PM_{2.5.}$

1.6 Significance of the study:

This study aims to provide economic loss incurred due to $PM_{2.5.}$ through years of life lost. It identifies the factors contributing to $PM_{2.5}$ emissions. The country performance is also analyzed in controlling its air pollution**.** Hence, this study briefs the Ministry of Climate Change and Environmental Protection Agency, Pakistan on status of Pakistan with respect to air quality as compared to its South Asian neighbors India and Bangladesh.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction:

This segment of the study shows the literature review of previous studies to better understand the issue at hand. The literature review follows the narrative style.

2.2 Factors influencing $PM_{2.5}$ emissions:

The air quality of Pakistan, India and Bangladesh exceeds the World Health Organization's guidelines and is considered unsafe. The prime factors of worsening air quality in these countries include fossil fuel combustion, vehicular emissions, urbanization, and industrial emissions (IAMAT, 2020). The (MOCC, 2020) further describes PM_{25} emission sources in Pakistan which consists of marble cutting, construction activity, vehicular traffic, usage and dumping of building material. Additionally, brick kilns are another source of emissions with main pollutants being particulate matter (Ur Rehman et al., 2019). Although**,** the industrial sector in Pakistan contributes to air pollution it is the transport sector that produce major part of emissions. The available data of Pakistan air quality indicate that Peshawar, Karachi, Rawalpindi, Lahore and Islamabad had consistently been experiencing higher levels of air pollution (IAMAT, 2020). Where the main sources of $PM_{2.5}$ in Lahore and Karachi cover industrial emissions, vehicular emissions and fossil fuel based thermal plants (Lodhi et al., 2009).

Similarly, in India, the $PM_{2.5}$ sources are mainly transportation, industries and fossil fuel combustion (Molina, 2020). According to (Liu et al., 2020) rate of urbanization, population density, population of vehicles, the price of refined oil and intensity of energy are main influencing sources of $PM_{2.5}$ concentrations. The urban cities are comparatively more vulnerable to particulate pollution because there exist industries and greater number of vehicles which hamper the dispersion of pollutants (IAMAT, 2020). Such as, the India’s air quality data indicate that major cities including Ghaziabad, Lucknow, Kanpur and Bulandshahr continuously have greater concentrations of $PM_{2.5}$ as an outcome they experience smog throughout the year. In Delhi, emission sources are presence of cluster of small-scale industries and vehicle transportation. While Ghaziabad have major construction sites which emit air pollutants (Chatterji, 2020).

Exploring further, the key sources having impact on $PM_{2.5}$ concentration identified by (Kudrat-E-Khuda, 2020) in Bangladesh are vehicle emissions, industrial emissions and brick kilns**.** As in the last years construction activities in the Bangladesh experienced growth which led to high demand for the construction materials. However, the country does have alternative to bricks for the construction activities, so the number of brick kilns has been increased to about 8000 kilns in 2018 as reported by(Kirby, 2018). Besides, with expansion in urbanization the use of vehicles has supposedly increased in the country. Thus, the outcome being extreme levels of $PM_{2.5}$ concentrations.

2.3 Economic loss due to particulate pollution:

Along with health impacts particulate pollution also induce economic costs. Such as prolong exposure to air pollution increases the human's risk of premature death by developing respiratory or cardiovascular diseases. Thus, particulate pollution imposes costs on society in a way that individuals are no longer fit to work as their productivity is affected. Furthermore, the largest share of health damage costs is associated with premature mortality from long-term PM_{25} exposure (Kamp, 2017). As per prediction of (OECD, 2016a) report, at global level the health cost due to higher concentration of $PM_{2.5}$ is to be 176 billion USD by 2060. In addition to that, (Myllyvirta, 2020) reveal that the economic costs of air pollution caused by fossil fuels was estimated to be 3.3% of global GDP. While in 2018, $PM_{2.5}$ pollution of Fossil fuel was responsible for almost 1.8 billion days of work absence.

Therefore, air pollution not only reduces life expectancy but also impacts societal wellbeing. It creates economic costs by decreasing the productivity of human capital. Furthermore, the health repercussions of air pollution can lead to lower participation of labor force, more absence from work, lower productivity, loss of output and eventually premature death. The global economic cost from air pollution estimated by is US$2.9 trillion (World Economic Forum, n.d.)

The young and older population both are impacted by exposure to higher particulate matter pollutants. Although older people are considered more vulnerable. In 2016, the economic cost of deaths attributed to $PM_{2.5}$ was US $2.4 trillion globally for older population (Yin et al., 2021). This economic cost borne by the old due to $PM_{2.5}$ has increased tremendously since 2000. With demographics of countries changing, middle and lower-income countries now have greater population of old. So, developing nations have even more of a reason to curb air pollution to save economic costs.

Air pollution has severe health impacts however, its economic costs cannot be denied. India is also incurring economic costs because of air pollution in form of loss of output. In 2019, the premature deaths form ambient particulate matter resulted in lost output and accounted for US$36.8 billion (Pandey et al., 2021). Thus, the state is not only incurring additional losses but is unable to achieve its upcoming economic targets. However, in the light of current world scenario lockdown could be a temporary solution to save surging economic costs. As (Bherwani et al., n.d.) estimates that in different countries a collective of US$100.9 billion have been saved due to reduction in air pollution externalities during lockdown period.

Although, the health costs due to air pollution have been globally calculated and, in a way, they can be taken as the part of economic costs that a country bear. But, in Pakistan the economic costs as consequence to air pollution is not actually calculated and is said to be uncertain (Habib et al., 2021). One reason could be the non-availability of concrete air quality data. So, this study will be a step towards quantifying the air pollution costs.

2.4 Life expectancy loss due to particulate pollution:

Air pollution is a silent killer. According to WHO, air pollution account for 7 million deaths annually. The dominant air pollutants namely $PM_{2.5}$ and PM_{10} are emitted by the combustion of petrol, gasoline, coal, and other fossil fuels thus causing premature mortality. An example of China as observed by(Chen et al., 2013), coal combustion increased in accordance with "*China's Huai River policy*" of providing free coal boilers in winters. This was causing tenants of northern China (where the policy was implemented) to lose out on 2.5 billion life years of life expectancy due to prolonged exposure to particulate pollution. This is because when PM enter the bloodstream through the lungs not only respiratory but also cardiovascular and cerebrovascular problems arise consequently.

Moreover, across Asia the highest levels of $PM_{2.5}$ are observed in middle income countries particularly in India, China, Pakistan and Bangladesh (WHO, 2018). Although China has to a large extent reduced its particulate emissions, but the problem remains in Pakistan, India, and Bangladesh. Besides, (Waidyatillake et al., 2021) reported that exposure to ambient PM_{25} is linked with 253/million people premature deaths. Furthermore, loss in life expectancy due to air pollution exceeds that of HIV/AIDS and tobacco smoking. While smoking can be completely avoidable, the anthropogenic particulate emissions are only 25 to 80% avoidable (Lelieveld et al., 2020a). Also, backed on evidence provided by (Ebenstein et al., 2017) a " *10-$\mu g/m^3$*" increase in airborne particulate matter (PM_{10}) is predicted to reduce life expectancy by

0.64 years. That is individuals of the country are expected to lose approximately half year of their living life every year if WHO recommended guidelines for air quality are not followed.

Air pollution results in immense global mortality specifically through cardiovascular diseases. The loss in life expectancy from air pollution is estimated to be 2.9 years worldwide. Which exceeds that of violence of all forms. So, if all the controllable anthropogenic emissions along with the fossil fuel are removed or reduced to a large scale, the global mean life expectancy would increase by 1. 7 years. (Lelieveld et al., 2020b). This shows that life years loss from air pollution is to some extent avoidable and within human capability.

Further exploring the global scenario, air pollution is considered a fourth greatest risk for health. (Juginović et al., 123 C.E.) predicts that, an increase in 10 percent of $PM_{2.5}$ concentration causes 16.7 percent increase in years of life lost. Additionally, air pollution has been associated with seven million deaths worldwide. And has estimated global economic impact of $5 trillion annually. Although, air pollution is a serious health threat in developed nations it is even more severe in developing countries. The reason being rapidly growing population and expanding industrialization which is leading causes of poorer air quality in developing nations. According to (Balakrishnan et al., 2019), in middle and lower-income countries like India, the premature mortality due to air pollution is comparatively high. The major factor being ambient particulate matter from coal burning, construction activity, industries, and transport. In 2017, 51.4% of deaths attributed to air pollution in India were among people younger than 70 years. These are mainly active workforce thus, indicating that air pollution poses a risk to non-retired labor force.

In case of Pakistan, air pollution ranked as 6^{th} leading factor for mortality in 2017. Exposure to ambient particulate matter Pm2.5 and indoor air pollution has been associated with increased hospitalization and deaths from respiratory diseases. In 2017 alone, Pm2.5 exposure contributed to a loss of 1 year and 7 months in life expectancy of individuals (*Pakistan-State of Global Air*, 2019).

Long- and short-term disclosure to Pm2.5 has been identified to be linked with loss in life years. In terms of daily vulnerability to Pm2.5 (Qi et al., 2020) explore the influence of daily exposure to Pm2.5 on life expectancy in China. Which reveals that if WHO's recommended guideline for daily $PM_{2.5}$ concentrations are to be achieved, then 1.00% (168,065.18) of the total years of loss in life can be avoided. This indicates that long term exposure is not necessary as even daily exposure to high $PM_{2.5}$ can reduce life expectancy.

2.5 Benefits due to reduction of particulate pollution:

$PM_{2.5}$ emissions are a major health concerns which eventually turns to economic costs. According to (Yang et al., 2019), who performed the cost-benefit analysis of $PM_{2.5}$ if particulate emissions are reduced the economic benefits would increase by 560 Billion US dollars. With the additional benefits of clear air, lower cardiovascular and respiratory infections, less missing work, and school days. Furthermore, the higher benefits will be observed in urban areas where pollution is more. Also, economic assessment of health benefits by (Bjoren Larsen, 2014) provides that if $PM_{2.5}$ control goals are achieved it would generate US 1.4 trillion per year. Hence, control in air pollution is extremely important specifically in Asia as benefits by a large amount outweighs the costs. Moreover, a comparative analysis between costs and benefits of Taiwan Air pollution control action plan was carried out by (Lai et al., 2020). Which indicated that benefits of controlling air pollution are higher than costs through comparing benefits to costs ratio. Also, these pollution control measures would bring up to net benefit of 210.3 billion NTD per year. Specifically, the restriction on vehicles standards and control on dust from construction sites.

Furthermore, (Suhyoung & Chng, 2021) calculated the economic benefits and health impacts of $PM_{2.5}$ reduction by conducting costs benefits analysis. The outcomes were as such that economic benefits depending on the level of $PM_{2.5}$ concentration reduction ranged from USD 22 million to USD 79 million. This suggests that economic benefits of controlling and reducing air pollution specifically the $PM_{2.5}$ emissions has immense benefits.

In case of Bangladesh, Dhaka city has massive population and is one of the cities that experience highest concentrations of $PM_{2.5}$ in the world. Among many reasons, brick kilns can be termed as a main contributor to these particulate emissions. A cost benefit analysis of brick manufacturing sector with cleaner technologies has been performed by (Bjorn Larsen, 2016). Which indicated that new zigzag kilns technology will produce greater benefits as the benefits to costs ratio is positive. Furthermore, the new technological options have far the highest B-c ratio than traditional brick manufacturing. Particulate pollution is also a rising concern in India. The key factor being the excessive decency on coal. As in India's power sector coal is still one of the largest providers of energy. As per (Cropper et al., 2019), that assessed the coal power sector of India. If the scrubbers are installed in the coal power plants than benefits received would be more compared to the costs used to install theses scrubbers. Also, these benefits tend to be higher in lower income and densely populated cities.

For Pakistan, the air pollution is among the world's worst. (Mir et al., 2022) analyze the benefits of climate and air pollution control policies on health of individuals in Pakistan. The results of which reveal that air pollution control measures have several benefits. Such as, if sustainable development strategies are implemented, they would decrease $PM_{2.5}$ induced mortality by 24% and can save the emissions cost by 0.32% of GDP. Hence, when combined with national strategies for air pollution control Pakistan will have co-benefits in terms of health, social and economic.

2.6 Climate accords followed to reduce $PM_{2.5}$ emissions:

Aiming to control the threat of air pollution, an international climate accord namely Paris Agreement was established by United Nations in 2015(UNCC, 2015). Pakistan is a Party to the "*Paris Agreement of the United Nations Framework Convention on Climate Change"* (UNFCCC, 2021). It was also the one of the first country that adopted "*SDGs 2030*" with the help of parliament's resolution (Ministry of Planning Development & Reform, 2019). In efforts towards reducing harmful emissions and climate change risk, Pakistan has recently updated its Nationally determined contributions (NDC). It includes "*Ten Billion Tree Tsunami Programme (TBTTP), and Protected Areas Initiative (PAI)"* among others. Ten Billion Trees Tsunami Program (TBTTP) also comes under SDG13 and was launched in 2018 by the Prime minister. As of now, phase I (2019-23) is in progress (Shahid, 2020).

Furthermore, Pakistan has set the target of decreasing at least 50 percent of the estimated emissions at the end of 2030. For its attainment, Pakistan is planning a shift towards 60% renewable energy, and 30% electric vehicles. It has recently launched National Electric vehicle policy (Ministry of Climate Change, 2019). It also aims to completely ban imported coal. Thus, if implemented fully Pakistan will reduce its harmful emissions. But there are a lot of inefficiencies regarding targets attainment. Therefore, Pakistan needs to reinforce its technical and scientific capacities for emissions reduction and climate change (UNFCCC, 2021).

Similarly, Bangladesh which also follow Paris agreement has updated its NDC to tackle climate change. For reduction in emissions certain targets have been set by the Bangladesh Government. In case of reducing transport sector emissions, there will be 5% improvement in fuel efficiency, improvement in road quality and road traffic congestion. Plus, construction of bicycle lanes and introduction of congestion charging. To reduce industrial emissions specifically form brick kilns that is a major $PM_{2.5}$ emission contributor in Bangladesh. A target of 14% emission reduction is set by completely banning fixed chimney kiln (Ministry of

Environment, 2021). However, the country still needs to properly implement these actions for the $PM_{2.5}$ emissions to be controlled.

Although India is also a party to Paris Agreement it has not updated its NDC's recently. Based on the report of (UNFCCC, 2015) submitted in 2016, the renewable energy share has expanded to 13% from 2002-2015. However, coal remains the dominating tool of power generation in India. Still to reduce the emission from coal power plants, "*Renovation and Modernisation (R&M) and Life Extension (LE)"* of existing old power stations has been performed. These are not enough actions undertaken and results can be seen in form of higher concentrations of $PM_{2.5}$ emissions.

2.7 Air quality monitoring of selected countries:

In Pakistan the air quality is managed at national, provincial, and local levels (Aziz, 2006). "*Pakistan Environment Protection Agency (EPA)"* has the responsibility to set quality of air and emissions standard regulations at the national level. Similarly, at provincial level the Provincial EPAs manage the environment and air quality of the corresponding provinces. This includes implementation of guidelines under the *"Pakistan Environment Protection Act (PEPA) 1997".* According to EPA, the national standard for $PM_{2.5}$ annual concentration is set to 15 µg/m3 and 35 µg/m3 for 24 hrs (Khwaja & Shams, 2020). However, the current air quality data indicates that Pakistan is struggling to maintain its air quality. In case of reducing the emissions, technological assistance is required for shift towards less polluting options. Also, Environmental protection department (EPA) lacks budget to properly monitor air quality data (Habib et al., 2021). Furthermore, the power is divided among different departments such as transport, agriculture, and municipal authorities etc so coordination is needed for desired outcome.

The Government of India (GOI) initiated the "*National Clean Air Programme (NCAP)"* in 2019 (International trade administartion, 2020). Its purpose is to enhance air quality monitoring infrastructure. The program also aims to reduce 20-30% in $PM_{2.5}$ concentrations. It is led by "*Ministry of Environment, Forests and Climate Change with Central Pollution Control Board*" (CBCP). Moreover, India has set the annual average concentration value of $PM_{2.5}$ as 15 µg/m3 and 60 µg/m3 for 24hrs (Habib et al., 2021). Although, initiatives are taken by the GOI to improve air quality. There is lack of financial and infrastructural facilities. As per (Lin et al., 2018), the cost of monitoring air quality is quite high while India lacks adequate infrastructure for monitoring its air quality. This hinders the implementation and monitoring process of air quality management.

In 2005, Government of Bangladesh for enhancing the quality of air issued a set of values for air pollutants. This included 15 µg/m3 annual average concentration for $PM_{2.5}$ and 65 µg/m3 for 24 hours(Khwaja & Shams, 2020). In addition to that, GOB has taken certain measures during different times to improve the air quality. It covers; in 1999 the removal of lead from the gasoline, in 90's the initiation of cleaner fuel CNG to transport sector. Furthermore, in 20's the 2-stroke 3-wheeled baby taxis was discontinued from Dhaka. Also, in 2013 new brick burning and control law was adopted (Government of the People's Republic of Bangladesh, 2018). These measures at the time of implementation improved the air quality. However, in the coming years urban population increased along with excessive usage of fuel. This consequently cancelled out the benefits gained. Thus, Bangladesh continues to battle with monitoring and improving its poor air quality.

2.8 Exploring the policy options to reduce $PM_{2.5}$ emissions:

The main source of particulate matter emissions in selected south Asian countries has been identified as fossil fuel consumption specifically in road transportation. Through the years all the countries have taken initiatives and made policies for reduction of particulate emissions. Such as Bangladesh has recently instigated inland water ways project from Dhaka to Chittagong(World Bank, n.d.). With the purpose to reduce the vehicular emissions which is becoming a rising health concern for its residents. Although, inland water ways are a good substitute for road transport but developing the waterways for navigation have its own environmental consequences. Such that it impacts the water quality and ecological value (Ro et al., 2006). Similarly, other actions to be taken by the country includes widening of roads to reduce the congestion in traffic. And introducing the electronic road pricing for congestion to discourage vehicles usage. However, every action has its own drawbacks such as in some area's roads cannot be widened due to less space. While the congestion charging requires proper technology to be successful and it being regressive tax leads to more burden on poor (Economics Help, 2022).

India has not yet updated its nationally determined contributions to UNFCC. But it is taking several initiatives to minimize country's air pollution. Which includes National clean air programme that has been launched in 2019 with assistance from World Bank. This aim to reduce 20-30% of PM_{10} and $PM_{2.5}$ concentrations by 2024 in non-attainment cities. It also provides air quality management framework to cities. Further, SAMEER app has been introduced to provide masses of information regarding air quality. Also, the public can complaint against air polluting activities (World Bank, 2021a). NCAP is a good initiative; however, it requires the cities to reduce emissions within their boundaries. Which is not entirely possible as emissions comes from other cities as well. Moreover, to minimize the vehicular emissions GOI has implemented Bharat stage VI emissions standards on the new cars. But this is nearly unsuccessful as not everyone is buying new cars (Lou Del Bello, 2022).

Pakistan being a victim of air pollution is taking several steps to tackle it. Such as the Government of Pakistan consider emissions reduction from the transport sector a high priority in the updated NDCs. Pakistan has launched National electric vehicle policy in 2019. Which aims to sell 30% of all new vehicles to be electric vehicles in Pakistan by 2030. This is to lower vehicular emissions and improve air quality in the country. However, electric vehicles are comparatively expensive and there is a lack of meaningful governmental incentive for the masses to encourage the transition.

From the above discussion, it can be extracted that selected south Asian countries have factors influencing particulate emissions. Which includes fossil fuel combustion in transportation vehicles, industries, and rapid urbanization. These emissions are affecting the life expectancy and is leading to economic loss. That is in form of absence from work, reduction in the productivity levels, and eventually loss of output. However, it has been observed from the above literature review that if air pollution is reduced it will have immense health as well as economic benefits. Moreover, the selected countries are trying their best to curb air pollution. Such as Pakistan, India and Bangladesh are a party to "*Paris Agreement of the United Nations Framework Convention on Climate Change"* (UNFCCC, 2021). As a matter of fact, for reducing emissions several policies and initiatives have been undertaken by the countries. This consists of "*Ten Billion Tree Tsunami Programme (TBTTP), Protected Areas Initiative (PAI),* and *National Electric vehicles policy"* of Pakistan among others. Inland waterways and construction of bicycle lanes in Bangladesh. National clean air programme, "*Renovation and Modernisation (R&M) and Life Extension (LE)"* of existing old power stations for India. However, inefficiencies in the said policies are causing failure in achieving the targeted goals. Therefore, before policies are to be undertaken, the air quality monitoring capacity should be enhanced which is the main concern in selected SA countries. Furthermore, it is the leading indicator for evaluating the $PM_{2.5}$ emissions and aids in shaping the policies for minimizing air pollution.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction:

This part of the study consists of conceptual framework which is used for achieving the research objectives. The chapter includes mixed methodology and follows quantitative and qualitative approach.

3.2 Research Strategy

The quantitative research is mainly used to confirm or test theories and assumptions and can be expressed in numeric terms. While qualitative research is mainly focused on in depth analysis of concepts through interviews, surveys etc (Streefkerk, 2019). In this study, the relation between variables is explored through econometric techniques. While to analyze the country performance and provide better options regarding air pollution control a survey has been conducted from MOCC of Pakistan and EPA officials. Hence, mixed method is the most suitable.

3.3 Research Design

The study is based on descriptive research design. Which describes and explore the situation through utilizing existing data and collection of primary data. Thus, descriptive research can be defined as a research whose aim is to shed light on the current issues or existing problems through data collection in order to fully understand and explain the situation completely (Dudovskiy, 2022). The descriptive research design is appropriate for this study as here $PM_{2.5}$ impact on economic loss is investigated by using secondary data. While the primary data has been collected through survey from Ministry of climate change and Environmental protection Agency officials.

3.4 Methods of Data Collection

The study is secondary as well as primary data based so the method of collection is as such as; The data for each variable has been obtained from the authentic websites. While for primary data an electronic survey has been conducted from MOCC and EPA experts. The method for sampling used is convenience sampling with the respondents being officials of MOCC and EPA. This sampling technique choose participants that are convenient for the researcher and are available around the location (Stratton, 2021). Therefore, this method is appropriate due to environmental and economic limitations.

3.5 Units of Data Collection:

In this study, the statistics of $PM_{2.5}$ concentrations for the countries is obtained from Air quality Life index (AQLI) website. Further, the data for variables including Gross Domestic Product, Industrial growth, fossil fuel consumption and Urban population is collected from World Bank(World Bank, 2021b).While the variable namely Number of registered vehicles data is obtained from CEIC data(CEIC Data, 2020). In case of India for missing years (2014-2017) the data for registered vehicles has been taken from (Statista.com, 2021). Moreover, primary data is collected by survey from experts of MOCC and EPA of Pakistan.

3.6 Analysis

For the achievement of first objective, panel regression technique is applied which help identify the sources of $PM_{2.5}$ concentrations. The reason for assigning panel regression is because our data is panel which is collected for three different countries from time 1998-2019. Moreover, (Shi et al., 2021) used panel regression for analyzing the environmental protection expenditure on $PM_{2.5}$ reduction . While (Zhao et al., 2019) for quantifying the influence of economic progress, urbanization and number of vehicles on $PM_{2.5}$ levels utilized panel model analysis. Similarly, (Załuska & Gładyszewska-Fiedoruk, 2020) utilized panel regression for analyzing the influence of $PM_{2.5}$ emissions on a single family house. Also, Panel data is different from time series and cross sectional data as it consist of observations of multiple events gathered over different time period for the same entities or individuals (Adefemi, 2017). Thus, in panel data regression, there are pooled OLS, fixed effect (FE) and random effect (RE) model (Wooldridge, 2020). Therefore, regression is performed in three ways:

1. **Fixed Effect model (FE):**
   In FE model each cross section has different intercept such as heterogeneity is allowed. Although, the intercept is different for each cross section it is time invariant which means intercept is same over time (Adefemi, 2017). Such as FE model captures the differences across cross sectional units through differences in the constant term (Hiestand, 2011). The fixed effect regression is also referred to as Least Square Dummy

Variable technique as it is run with dummy variables. Hence, we first perform a country fixed effect regression, as countries are constant over time.

2. **Random Effect Model (RE):**
   Then Random effect regression is carried out. RE model captures the individual effects that are randomly distributed across the cross-sectional units. Like Fixed effect, Random effect model is also time invariant and allows for heterogeneity. It can also be referred to as variance component model (Adefemi, 2017). Now to choose between FE and RE model for analysis we apply Hausman test. The selection depends on the probability value of chi-square. If its value is greater than 5%, we reject null hypothesis and select RE model to be appropriate than FE model. But, if p-value is less than 0.05 we accept null hypothesis and fixed effect is selected.

3. **Pooled least square (PLS) or Common effect model:**
   If FE model is chosen, then the next step is to pool the data and run panel least square regression. In PLS all the sections of data are treated as single section of data that is homogeneity is assumed. Such as it does not consider time series and cross section nature of data and cannot differentiate between countries (Adefemi, 2017). Moreover, pooled least square model has constant intercepts and slopes (Hiestand, 2011)**.** Now to choose between FE and PLS, Wald test is carried out. If the p-value is greater than 5% we accept null hypothesis and select PLS model as the most suitable for our analysis otherwise FE model is used for regression analysis.

In case of variables for model, they are selected based on knowledge gathered from literature. According to (Antoine Dechezleprêtre, 2020), $PM_{2.5}$ is impacted by GDP. While fossil fuel consumption also contributes to increase in concentration of $PM_{2.5}$(Mcduffie et al., 2021). Moreover, industrial growth is considered as one of the major driver of particulate pollution (Q. Li et al., 2021). Similarly, Urban population influence the air pollution (Liu et al., 2020). Furthermore, transportation specifically road transportation produces greater amount of $PM_{2.5}$ emissions that can be indicated by vehicles on road(C. Li & Managi, 123 C.E.). Thus, **Table *1*** provides an outline of variables used in this study and their expected relation with $PM_{2.5}$ emissions based on previous literature.

Table 1 Summary of variables

variable	definition	Unit	Expected relation
GDP	GDP growth	percent	+
FF	Fossil fuel consumption	percent	+
IG	Industrial growth	percent	+
UP	Urban population	percent	+
NRV	Number of registered vehicles	thousand	+

Source: variables expected relation based on literature

Where PM2.5 is the particulate matter of size 2.5 in the air due to anthropogenic emissions, while Gross domestic product (GDP) is the annual growth rate for money value based on constant 2010 U.S. dollars of all goods and services produced in specific time in a country (world bank, 2020). Fossil fuel (FF) is the combination of coal, oil, petroleum, and natural gas products usage as the percentage of total energy consumption in the country (World Bank, 2021b). While industrial growth (IG) is annual growth rate for industries including construction. It consists of value added in mining, manufacturing construction, electricity, water, and gas (world bank, 2022a). Number of registered vehicles (NRV) is the total number of registered vehicles in the country. Lastly, urban population (UP) is defined as percentage of total population residing in urban areas of a country(world bank, 2022b).

Thus, the panel model is given as:

$$PM_{it} = \alpha_0 + \alpha_i + \beta FF_{it} + \gamma GDP_{it} + \delta IG_{it} + \zeta NRV_{it} + \eta UP_{it} + \mu_{it} \quad \text{Equation 1}$$

Variable Specification:

Dependent Variable:

PM_{it} = annual concentration of $PM_{2.5}$ of the country i in time t

Independent variables:

FF_{it}= fossil fuel consumption of the country i in time t

GDP_{it} = gross domestic product of the country i in time t

IG_i = industrial growth of the country i in time t

NRV_{it} = number of registered vehicles in the country i in time t

UP_{it} = urban population of the country i in time t

α_o = intercept

α_i = time invariant variable

μ_{it} = error term

Where 'i' represents Country which is 1= Pakistan, 2= India and 3= Bangladesh. While 't' represents time from 1998-2019 that equals 66 observations. Furthermore, before regression analysis the correlation matrix is generated to check for multicollinearity problem. Then the stationary of variables data is explored through unit root test. It is necessary as outcome is inefficient with nonstationary data. For the stationary test, if the data is balanced panel data, then levin-lin-chu test (Levin et al., 2002)is utilized. In case of unbalanced panel data Im-Pearson-shin (Im et al., 2003)is preferred.

Now to achieve the second objective of estimating economic loss, the years of life lost due to $PM_{2.5}$ exposure is converted into monetary value. Such as the economic cost incurred by a country is calculated by multiplying the life years lost (obtained from AQLI) with labor force of the country. Labor force is defined as people 15 years and older who can supply labor to produce goods and services during a specified period (world Bank, 2021). As we are estimating minimum economic cost, we assume that each labor is earning at least 2 US dollars per day. Earning 2US$ per day is a poverty baseline according to WHO and is taken here to avoid the fluctuations occurring in labor earnings of each country.

Thus, economic loss because of $PM_{2.5}$ exposure is calculated by the given equation as:

$$Economic\ loss = labor\ force\ x\ life\ years\ lost\ x\ 2\ x\ 365 \qquad \text{Equation 2}$$

Furthermore, for the attainment of third objective this economic loss when calculated for each country will be regarded as benefits gained by that country if air pollution is reduced. For the costs, the literature implies that sources of $PM_{2.5}$ is same worldwide (Lim et al., 2020). Thus, we assume that measures required to control air pollution is also similar. Therefore, as per (Cheng et al., 2019)the abatement cost of reducing 1μg/m^3 of $PM_{2.5}$ is 0.638 billion yuan. This value is converted to US dollar using exchange rate and is regarded as total cost. Then, Cost-Benefit analysis is executed which produce the benefits forgone or the costs incurred by each selected country if air pollution is not controlled. Also, Cost-Benefit analysis take discount rates when calculating future benefits. However, we are estimating benefits forgone so we assume a zero-discount rate. Another reason for assigning a zero-discount rate is to ensure equality between generations as all lives matter equally (CLOUTIER, 2022).

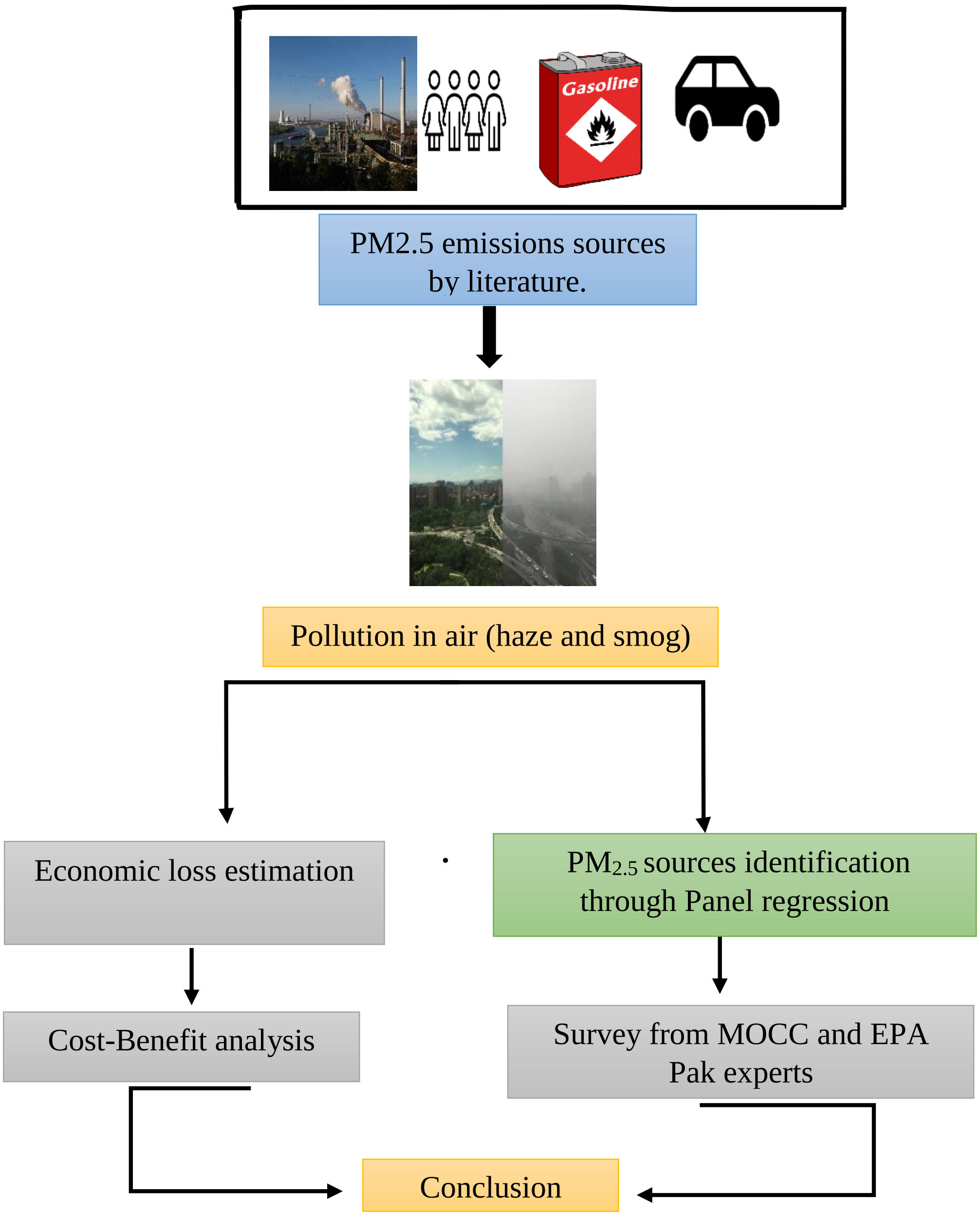

Figure 2 Conceptual framework

In the end, for countries comparison and analysis of Pakistan performance in accordance with air pollution control a short electronic survey is conducted. The respondents being EPA and MOCC experts. The survey cover issues of air quality and responsibilities of EPA and MOCC of Pakistan.

Figure 2 presents the conceptual framework based on literature. It shows different sources of particulate matter emissions. Which covers industrial growth, urban population growth, vehicular and fossil fuel emissions. These emissions contribute to air pollution that can be detected in form of haze and smog. Which is the cause of health, economic and environmental damages. It further indicates step by step process of how this research is carried out ending with conclusion.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction:

This section explains the key findings of our research. Which provides us with identification of $PM_{2.5}$ influencing factors, estimation of economic loss, and cost benefit analysis.

4.2 Econometric Analysis

To identify the sources of $PM_{2.5}$ emissions panel regression is applied through EViews software. Moreover, to choose the appropriate model for analysis three different panel regression models are utilized.

4.3 Correlation Matrix

Before regression analysis, the first and foremost step is to generate a correction matrix. The purpose of this is to identify any correlation between independent variables and drop any problematic variable to avoid multicollinearity problem. Multicollinearity is the high correlation between two independent variables. If the multicollinearity exists in the data, it can lead to inefficient outcomes. For the correlation coefficient value between 0.3 to 0.5 it is considered weakly correlated. When the correlation coefficient value is between 0.5-0.7 it is considered positive correlation. If the value ranges from -0.3 to -0.5 then it is weakly negative correlation. while +1 is considered strong positive correlation and -1 is considered strong negative correlation Hence, the correlation matrix in **Table *2*** is given as:

Table 2 Correlation matrix of dependent variables

	GDP	**IG**	**FF**	**UP**	**NRV**	
GDP	1.000000	0.623207	0.532130	-0.113356	0.342625	
IG	0.623207	1.000000	0.254296	-0.142843	-0.136282	
FF	0.532130	0.254296	1.000000	0.439410	0.390409	
UP	-0.113356	-0.142843	0.439410	1.000000	0.087884	
NRV	0.342625	-0.136282	0.390409	0.087884	1.000000	

Source: Correlation matrix using EViews.

GDP is strongly correlated with IG (0.6) and FF (0.532). This implies when GDP increases, fossil fuel consumption and industrial growth also goes up. This high correlation could raise the question of authenticity of coefficients.

Hence, including all variables in the regression could lead to multicollinearity problem. To solve this issue, we will run regression by including IG and FF and excluding GDP. Thus, equation 1 can be rewritten as:

$$PM_{it} = \alpha_0 + \alpha_i + \beta FF_{it} + \delta IG_{it} + \zeta NRV_{it} + \eta UP_{it} + \mu_{it} \qquad \text{Equation 3}$$

Furthermore, GDP is negatively correlated with urban population and weakly correlated with number of registered vehicles. While Industrial growth is weakly correlated with Fossil fuel consumption and negatively correlated with UP and NRV. Which means that when industrial growth goes up there is a slight increase in fossil fuel usage while urban population and number of registered vehicles declines. In case of fossil fuel consumption, it is moderately correlated with both UP and NRV. On the other hand, UP has a negative correlation with IG and GDP and is moderately correlated with fossil fuel usage and number of registered vehicles. Lastly, NRV is weakly correlated with GDP, FF, UP and is negatively correlated with IG.

4.4 Panel Unit root test:

To run the regression after correlation matrix another important step is to check the stationarity. It is required in panel data as nonstationary series of data gives biased and inefficient results. The method to detect the stationarity is unit root test. If a series has no unit root this means data is stationary. Incase unit root exists in the variable data, it is made stationary by taking log, first or second difference of variable depending on the test results. For the balanced panel data in this study, levin-lin-chu test is applied.

The hypothesis of Levin-lin-chu test is:

H0: null hypothesis: Unit root exists

Ha: alternate hypothesis: Unit root does not exist.

Table 3 Levin, Lin and Chu test results

variable	t-statistic		
	level	1st difference	2nd difference
$PM_{2.5}$	1.56664	-6.99756**	-10.0671
IG	0.55104	-7.83541**	-11.2951
FF	2.27949	-1.96292**	-5.29862
UP	2.35861	-1.54609**	-4.14293
NRV	2.08819	-1.16123**	-5.15647

** indicates null hypothesis is rejected and variable is significant at 5% level.

Source: unit root test using EViews.

If the LLC t-statistic is significantly less than zero where p< 0.5, the null hypothesis is rejected as no unit root exist. The alternate hypothesis is accepted as the variable is stationary. Thus, in the above **Table *3***, all the variables are stationary at first difference.

4.5 Panel Regression outcome:

The regression is first performed with fixed effects and then with random effects. To choose suitable model for analysis Hausman test is applied. The hypothesis of Hausman test is as:

Null hypothesis (Ho)is: Select Random Effect if P value is greater than 0.05.

Alternate hypothesis (Ha) is: Select Fixed Effect if P value is less than 0.05.

Table 4 Correlated Random effects-Hausman test outcome

Test summary	*Chi-square statistic*	*Chi sq D.f*	*Prob.*
Cross-sectional random	26.35164	4	0.0000

Source: Hausman test using EViews

Table *4* reveals the outcome of Hausman test. As shown, based on the probability value of chi-square, which is less than 0.05, the null hypothesis is rejected, and alternate is accepted. Thus, Fixed effect (FE) model is the most suitable for our panel regression. Now to choose between fixed effect and pooled least square regression we use Wald test. The fixed effect model is run with dummy variables and Wald test is run.

The hypothesis of Wald test is as:

Null hypothesis (Ho)is: Select PLS if P value is greater than 0.05.

Alternate hypothesis (Ha) is: Select Fixed effect if P value is less than 0.05.

Table 5 Wald test outcome

Test statistic	*value*	*d.f*	*Prob.*
F-statistic	32.08632	(2,59)	0.0000
Chi-square	64.17264	2	0.0000

Source: Wald test using EViews

Hence, from the above **Table *5***, it is observed that the probability value of chi-square is 0.00 which is less than 0.05. So, we reject Ho and accept alternate hypothesis and select fixed model for our panel regression.

Table 6 provide a detailed comparison of panel regression techniques used in this study. As Fixed effect model is selected through Hausman and Wald test only FE regression results is interpreted.

Table 6 Panel Fixed effect regression outcome

Variable	*Definition*	*FE*
C	Coefficient	1.368282** (0.0044)
IG	Industrial growth	0.004952** (0.9819)
FF	Fossil fuel consumption	1.090400** (0.0000)
UP	Urban population	-1.009828** (0.0000)
NRV	Number of registered vehicles	2.84E-08** (0.0006)
R-squared	Coefficient	0.92
Durbin Watson	statistic	1.7

- Dependent variable: $PM_{2.5}$, ** indicates parameter is significant at 5% level.

Source: author’s estimation using EViews

The dependent variable is annual average concentration of $PM_{2.5.}$ The R squared value is 0.92 which indicates model is a good fit. Also, there is no autocorrelation is the model as the Durban Watson statistic value is 1.7. Hence, it can be perceived form above table 6, that industrial growth has positive but insignificant influence on air quality measured as concentration of $PM_{2.5}$. This means an increase in industrial growth is leading to a slight increase in particulate matter emissions. However, this relation is contradictory to literature that indicates a positive significant influence of industries on particulate emissions. Moreover, fossil fuel consumption has significantly positive relationship with $PM_{2.5,}$ which indicates that, if fossil fuel usage is increased by 1 percent the particulate matter concentrations rises by 1.09 $\mu g/m^3$. This is in line with literature where, the main sources cover industrial emissions, vehicular emissions and fossil fuel based thermal plants (Lodhi et al., 2009).

Similarly, urban population show significantly negative relation with dependent variable. So, if urban population in a country goes up by 1 percent the concentrations of $PM_{2.5}$ declines by -1.009 $\mu g/m^3$. However, urban population can be indirectly linked to particulate emissions as increase in urban population leads to higher demand of transport vehicles. Lastly, the number of registered vehicles has significantly positive influence on particulate matter emissions. This is in accordance with the literature which suggests a positive impact of vehicles on $PM_{2.5}$ emissions (Molina, 2020). These answers our first research objective.

4.6 Economic Loss estimation:

Moving forward to achieve the second objective, we look at the Figure 3 which shows the annual average concentrations of particulate emissions in selected South Asian countries. Particulate matter ($PM_{2.5}$) of 5$\mu g/m^3$ concentration in the air is recommended by WHO. However, Bangladesh $PM_{2.5}$ level increased from 46.93$\mu g/m^3$ in 1998 to 55.12 $\mu g/m^3$ in 2019. While India and Pakistan $PM_{2.5}$ concentrations in the air in 1998 climbed from 51.02 $\mu g/m^3$ to 60.2 $\mu g/m^3$ and 34.69 $\mu g/m^3$ to 39.79 $\mu g/m^3$ in 2019 respectively. As seen from figure 3, all selected countries have $PM_{2.5}$ levels exceeding WHO guidelines. When $PM_{2.5}$ value exceeds the proposed guidelines, it not only poses a threat to human health but also cause economic damages. Therefore, the economic loss is calculated through equation 2.

The graphical representation of economic loss faced by selected countries because of $PM_{2.5}$ concentrations is shown by figure 4. While figure 5 display the labor force in each country as economic loss estimated here is dependent on labor force.

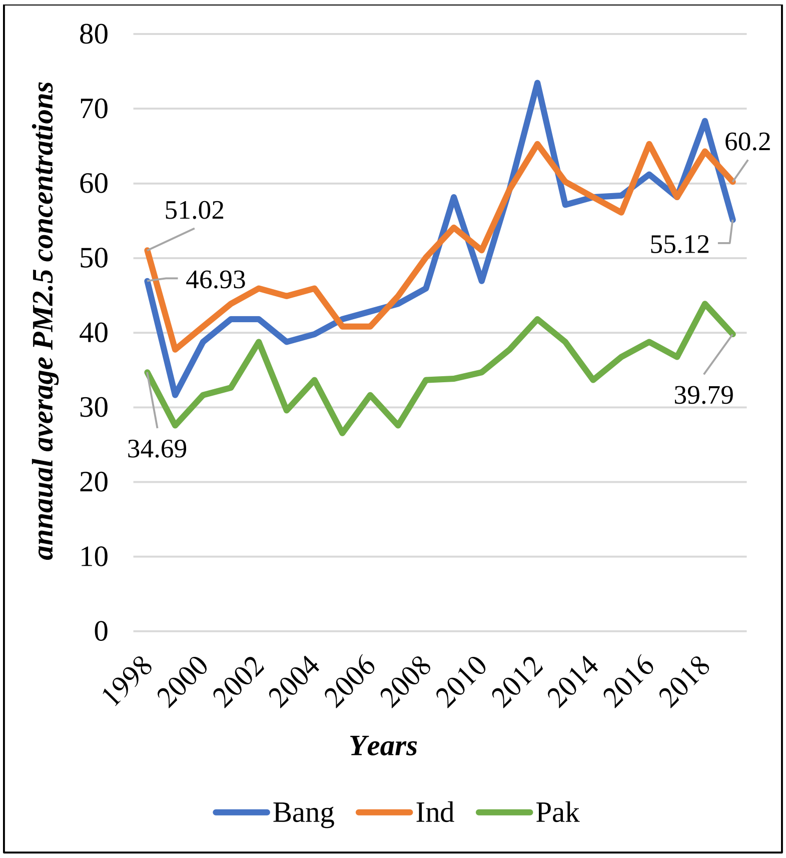

Figure 3 Annual average PM2.5 levels of selected SA countries

Source: Air quality life index (AQLI)

From below figure 4, it can be perceived that India experienced US $1378 billion loss in 1998 because of $PM_{2.5}$ exposure. While Bangladesh lost US $150 billion, and Pakistan incurred loss of US $96 billion in 1998 only. India shows an increasing trend of economic loss due to particulate pollution. In the observed time India experienced its greatest loss of US $2194 B in 2018. One reason is excessive fossil fuels usage, because fossil fuel consumption as a percentage of total energy consumption in India rose to 87% in 2018. Moreover, number of vehicles in the country also increased from 272 million in 2018 compared to 253 million of previous year.

Therefore, the $PM_{2.5}$ level of 64.28 µg/m^3 in the air were also high. Also, one component of economic loss which is labor force of the country expanded to 473 million. Hence, it can be concluded that greater levels of pollution along with more exposed labor force causes higher economic loss to the country (Pandey et al., 2021). This is since when labor force either low or high wage earner is open to hazardous air will experience decline in their life years. This decline in life years eventually contributes in loss to economy (Yin et al., 2021).

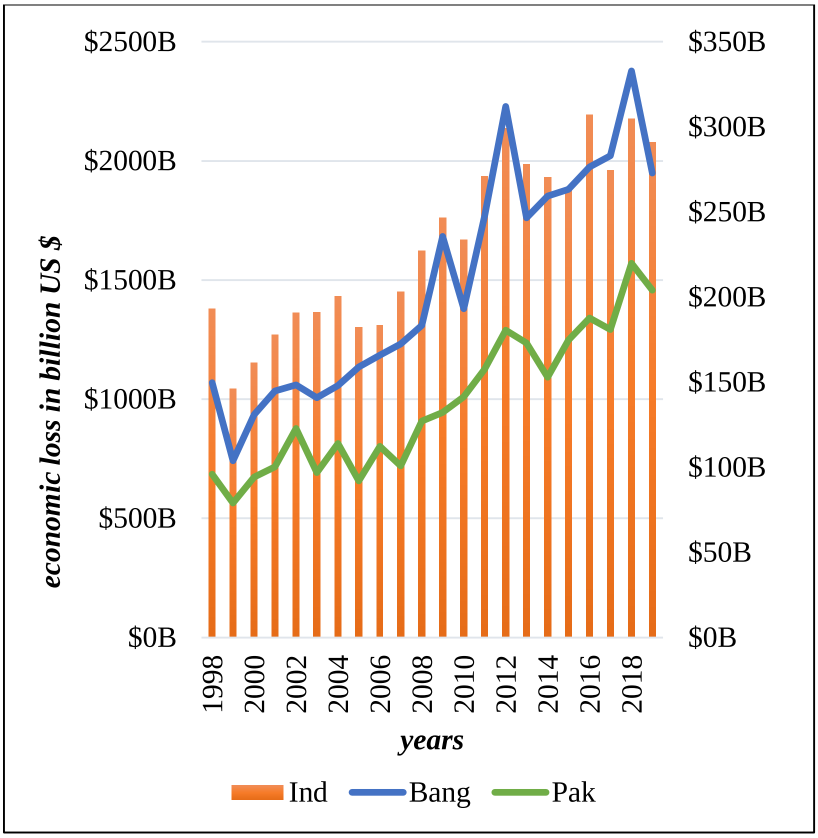

Figure 4 Economic loss from PM2.5 exposure in selected SA countries

Source: Author's own estimation from AQLI and World Bank data.

Similarly, in Bangladesh the increasing trend of economic loss can be owed to fossil fuel usage and expansion of industrial growth. Bangladesh has lower number of labor force compared to India and Pakistan as shown in figure 5 but a faster and steadier rate of industrial growth. This along with excessive usage of fossil fuel in the recent years is causing greater economic damages to the country. Such that industrial growth of Bangladesh shows a steady expansion as shown in figure 7 below. And was around 8-9% till 2014 while it exceeded 11% growth rate in 2016-19. Comparatively, India's and Pakistan industrial growth has a lot of fluctuations and both countries even experienced decline of -1.2% and -1.5% respectively in 2019. Bangladesh also has greater percentage of fossil fuel consumption than India and Pakistan. As seen from the figure 6 below, it has increased even more in the recent years. Thus, this higher industrial growth and fossil fuel consumption is resulting in higher amount of $PM_{2.5}$ emissions and eventually contributing to polluting the air (Kudrat-E-Khuda, 2020). Hence, as shown in above figure 4, Bangladesh is experiencing greater loss than Pakistan. However, loss compared to India is less, this is because Bangladesh has number of labor force and vehicles a great deal lower than India.

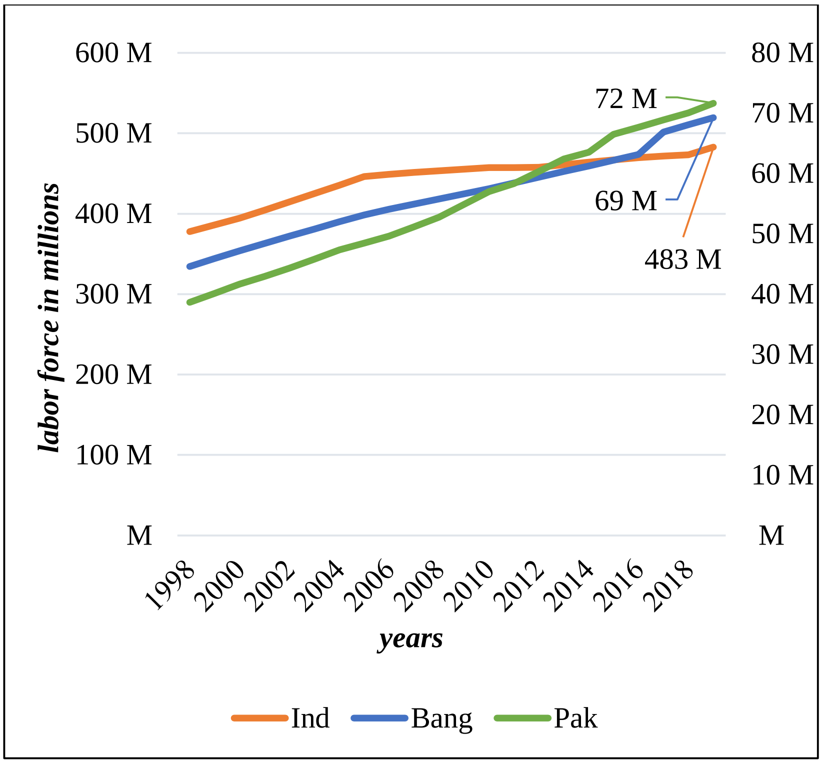

Figure 5 labor force of selected SA countries

Source: World Bank

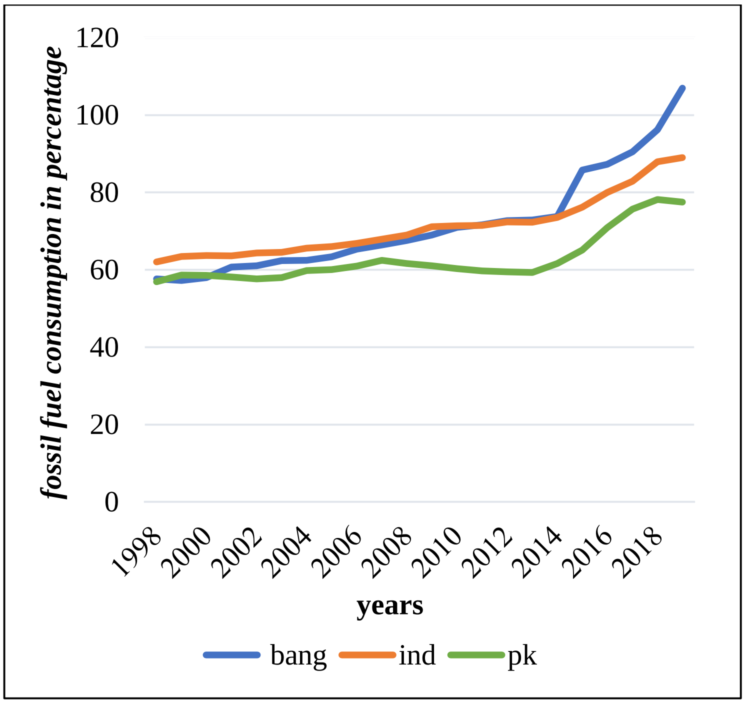

Figure 6 Fossil fuel consumption as percentage of total energy consumption

Source: World Bank

While looking at the statistics in figure 4, Pakistan is incurring less economic loss compared to other two countries. But it is also exhibiting increasing trend such that it experienced greatest loss of US$ 220 billion in 2018. This was because fossil fuel consumption reached to 78% as shown in figure 6. Industrial growth rate also rose to 4% in the same year. Consequently, Pakistan had 70 million labor force exposed to 43.8 µg/m^3 of $PM_{2.5}$ an all-time high value observed in the selected timespan. Comparatively, India and Bangladesh had labor force expose to higher concentrations of $PM_{2.5}$ of value 64.2 µg/m^3 and 68.3 µg/m^3 respectively in 2018.

In comparison to India, it is true that Pakistan has less labor force, but it also has lower annual average concentrations of particulate matter which has not exceeded 50 µg/m^3 in the observed period. While India has experienced as much as 60 µg/m^3 of $PM_{2.5}$ during the years. Similarly, compared to Bangladesh, a Pakistani resident was losing around 4 years of life in 2019 which was generating $204 US billion loss per year to the economy. Although, Pakistan has a greater number of the labor force exposed to particulate pollution. But the concentrations of $PM_{2.5}$ are very low as opposed to Bangladesh. This answers our second research question of economic loss due to particulate pollution.

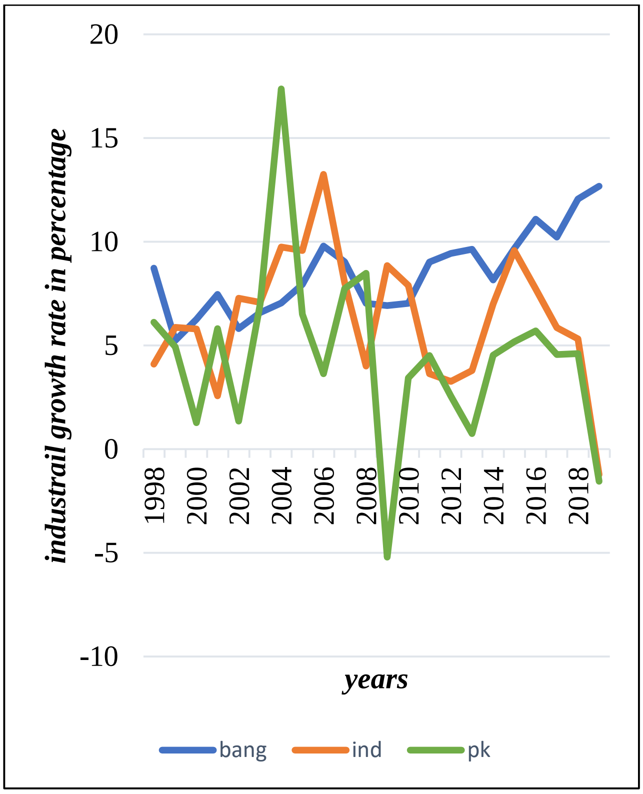

Figure 7 industrial growth rate in percentage of selected SA countries

Source: World Bank

A detailed comparison of countries is shown by **Table *7***. Pakistan throughout the time has lower concentrations of $PM_{2.5}$ compared to other two. While percentage increase in PM emissions for the observed time is lower than Bangladesh but slightly more than India. Consequently, the people of Pakistan are expected to live more years of life as they are exposed to lower $PM_{2.5}$ levels. In case of economic loss that considers labor force. The labor force of Pakistan has increased by 79% from 1998-2018. As compared to Bangladesh and India whose labor force saw a percentage increase of 51% and 55% respectively. Hence, Pakistan has experienced 129% increase in economic loss from 1998-2018. This is higher than 122% of Bangladesh and 57% of India. This indicates that although comparatively Pakistan has lower $PM_{2.5}$ levels, its increase in economic loss is higher than other two countries, Thus, the below **Table *7*** answers the second part of second research objective which is the performance of Pakistan as compared to India and Bangladesh with respect to air pollution impact.

Table 7 Comparison of Selected SA countries

countries	*unit*	*1998*	*2009*	*2018*	*% Increase from 1998 to 2018*
	PM2.5 level				
Bangladesh	µg/m³	46.93	58.16	68.36	45
India	µg/m³	51.02	54.08	64.28	25
Pakistan	µg/m³	34.69	33.82	43.87	26
	Life years loss				
Bangladesh	years	4.6	5.7	6.7	45
India	years	5	5.3	6.3	26
Pakistan	years	3.4	3.3	4.3	26
	Labor force				
Bangladesh	Million	45	57	68	51
India	Million	378	455	473	25
Pakistan	Million	39	55	70	79
	Economic loss				
Bangladesh	US $ Billion	150	236	333	122
India	US $ Billion	1378	1762	2177	57
Pakistan	US $ Billion	96	132	220	129

Source: $PM_{2.5}$ and life years loss from AQLI, Labor force from World Bank and Economic loss through author's estimation

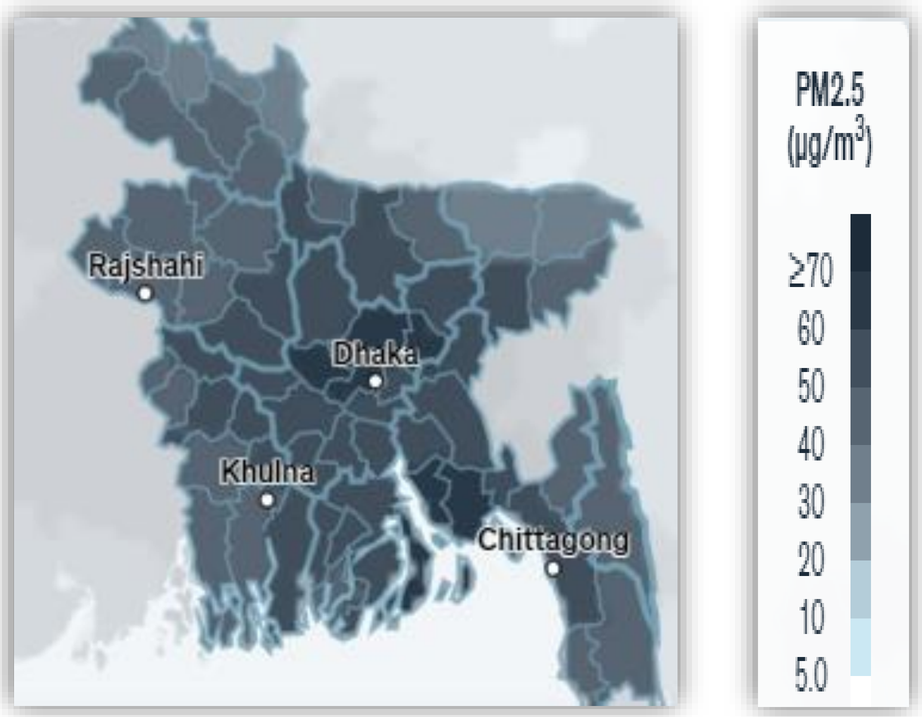

Figure 8 Bangladesh Pm2.5 concentrations in 2000

Source: AQLI

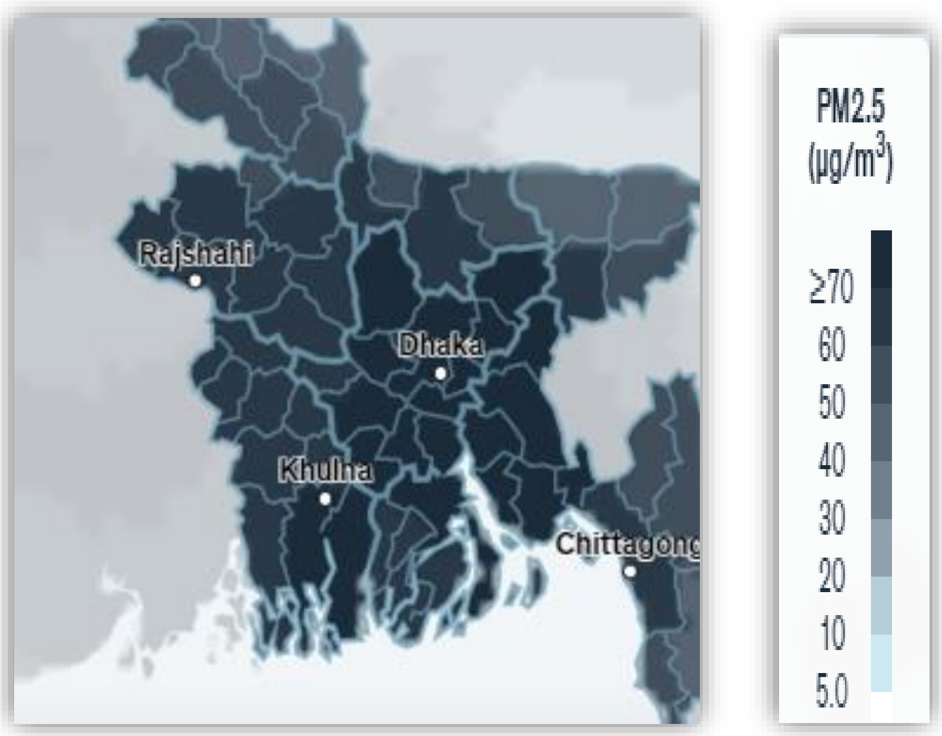

Figure 9 Bangladesh Pm2.5 concentrations in 2018

Source: AQLI

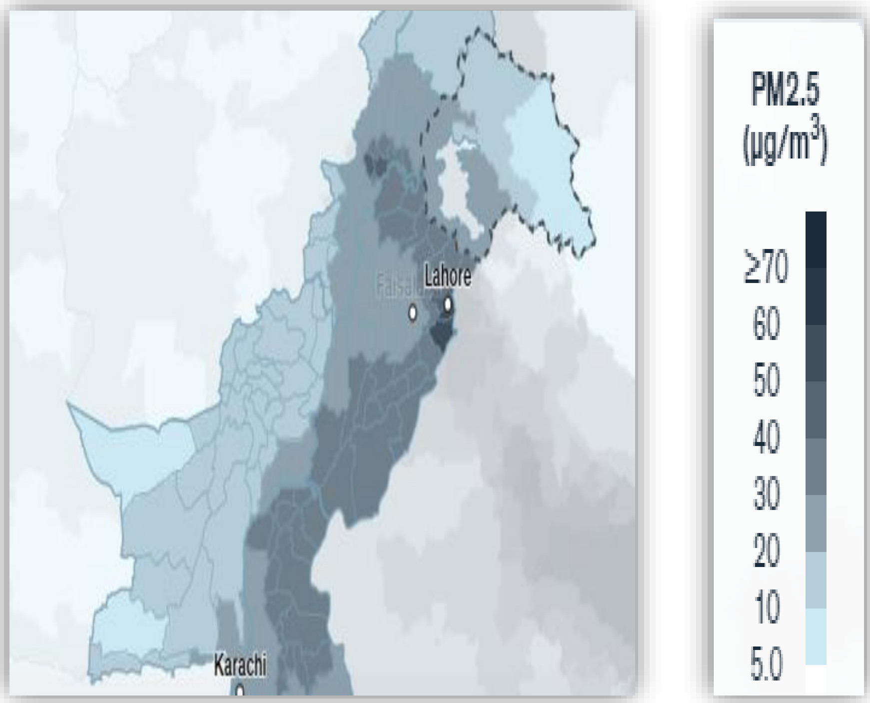

Figure 10 Pakistan Pm2.5 concentrations in 2000

Source: AQLI

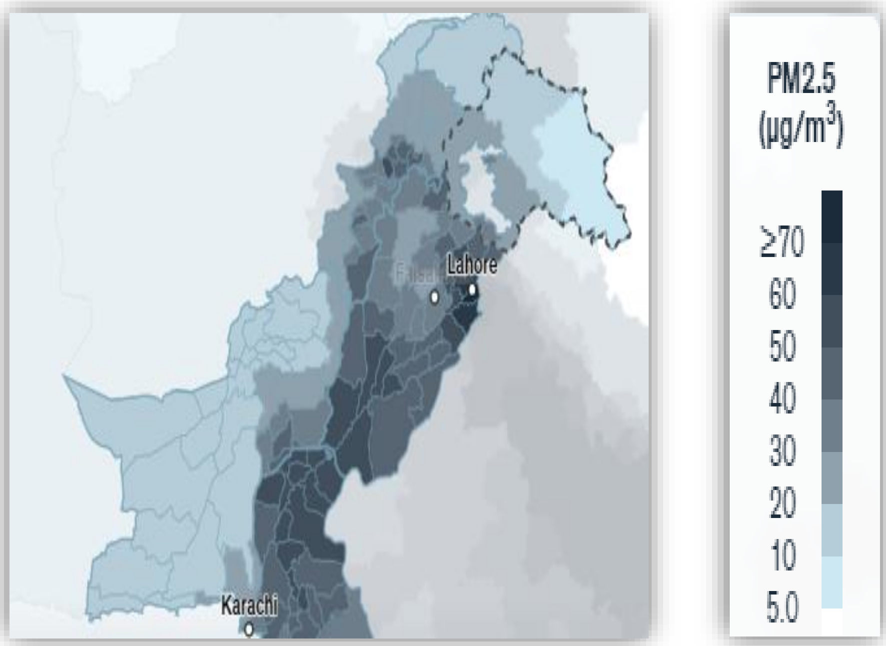

Figure 11 Pakistan Pm2.5 concentrations in 2018

Source: AQLI

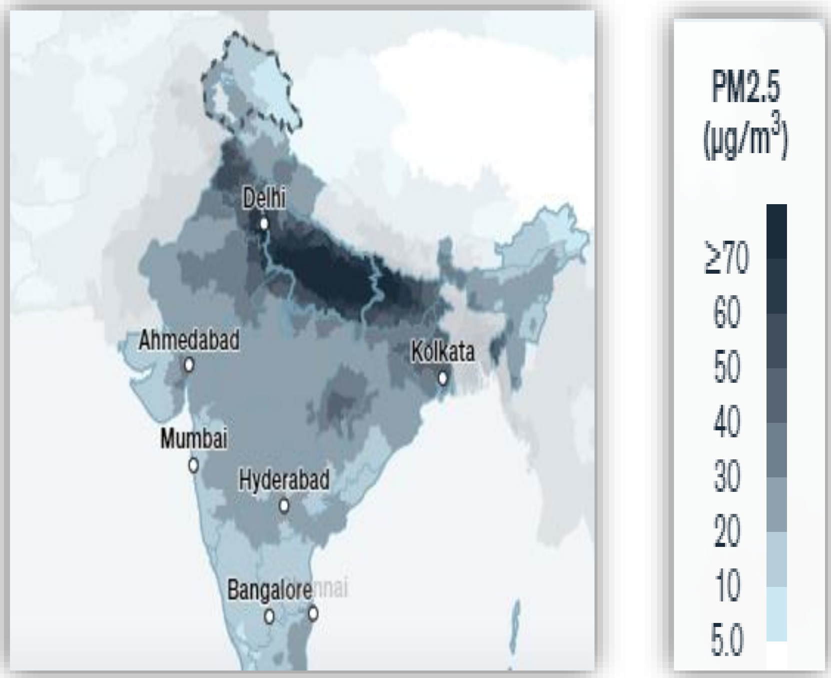

Figure 12 India Pm2.5 concentrations in 2000

Source: AQLI

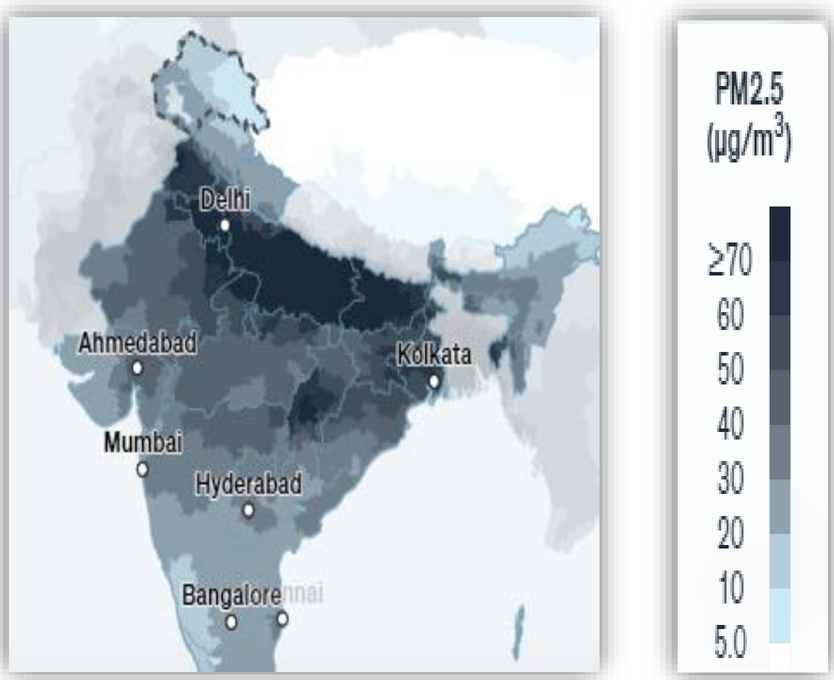

Figure 13 India Pm2.5 concentrations in 2018

Source: AQLI

The figures above show a visual presentation of changes in $PM_{2.5}$ concentrations of selected countries from 2000-2018. Bangladesh and India's $PM_{2.5}$ levels has increased while comparatively Pakistan has lower pollution levels.

4.7 Cost-Benefit analysis (CBA):

Now to achieve the third objective of our research we conduct Cost- Benefit analysis. For the measurement of losses or gains from an investment, Cost-Benefit analysis is considered a main tool (O'Mahony, 2021). Likewise, this evaluation method is also being used in decision making of environmental policies. Such that in case of environmental valuation and estimation of environmental damages CBA is utilized(Atkinson & Mourato, 2008a). Thus, environmental Cost-benefit analysis can be explained as the application of Cost-benefit analysis to the policies which goal is to improve environment (Hanley & Spash, 2018). As it provides a clear view of how much the society would be incurring costs or receiving benefits in place of a specific policy. This method also helps uncover the monetary value of environment and its related impacts (Atkinson & Mourato, 2008a).

CBA include discount rate when calculating the future benefits. This is giving lower weight to a far-off future benefit. However, it has been criticized recently due to many reasons. Firstly, Since the environmental events have longer time horizon so in CBA when they are discounted environmental problems disappear. This is referred to as tyranny of discounting (Atkinson & Mourato, 2008b). Secondly, taking an acceptable environmental discount rate is an issue itself. As discount rates applied for environmental projects have unsystematic range and have weak justification. Lastly, the discount rate based on marginal utility of consumption should not be applied to human lives and their loss as it is unethical. Hence, it is appropriate to have a zero-discount rate for our CBA analysis as it ensure equality between generations and life loss (CLOUTIER, 2022).

Moreover, we are calculating the costs incurred and only the benefits forgone from 1998-2019 because of high concentrations of $PM_{2.5.}$ Also, the literature suggests that sources of $PM_{2.5}$ are the same globally therefore the cost of reducing one unit of $PM_{2.5}$ is assumed to be the same for each country. As per (Cheng et al., 2019)the abatement cost of reducing $1\mu g/m^3$ of $PM_{2.5}$ is 0.638 billion yuan. This value is converted to US dollar using exchange rate and is regarded as total cost. For the benefits, they are estimated through equation (3.2). If the Benefits to costs ratio is above 1, it means the policy or project should be carried out as it benefits exceeds the costs. In case of Benefits costs ratio lower than 1, the policy or project should be dropped as now the costs exceeds the benefits.

The below figure 14 represents the benefits costs ratio of Pakistan, India, and Bangladesh for the abatement of $PM_{2.5}$ emissions from 1998-2019. It can be observed that all the countries have Benefits costs ratio above 1. Which concludes that if the air pollution had been reduced for these countries the monetary benefits would have been more than the costs.

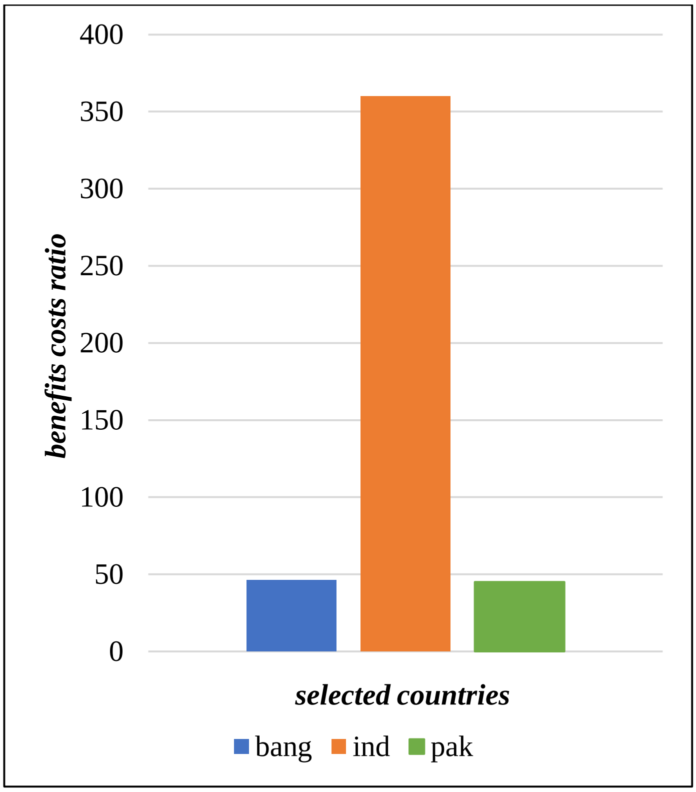

Figure 14 benefits costs ratio of selected SA countries

Source: Author's own estimation using AQLI and World Bank data.

India would have greater benefits than other two as its pollution levels are high. Moreover, Pakistan would have received less benefits as compared to India and Bangladesh. This is because Pakistan had lower pollution recorded in the period. However, the main concern is receiving the benefits from pollution reduction. Which would have been gained by all three countries either less or more than the other.

Hence, it answers our third research question that costs of reducing $PM_{2.5}$ emissions is less than its benefits. Therefore, concerned authorities should invest in controlling and abetment of particulate matter emissions.

CHAPTER 5

SURVEY ANALYSIS

5.1 Introduction:

This section of the study explores the views of MOCC and EPA Pakistan officials through electronic survey.

5.2 Survey analysis:

The data has also been collected through a short survey. The government officials in Ministry of Climate Change and Environmental Protection Agency were the respondents. The method of sampling used here is convenience sampling. This sampling technique choose participants that are convenient for the researcher and are available around the location (Stratton, 2021). Therefore, this method is appropriate due to environmental and economic limitations. Moreover, according to (Memon et al., 2020)the unit of analysis also influence the sample size. As here our respondents are high ranked officials at ministries hence sample size of 15 is accurate.

The outcome of the survey revealed that around 60% officials believe fossil fuel usage in transport is the main cause of $PM_{2.5}$ emissions. According to (Mcduffie et al., 2021), the outdoor particulate emissions comes from fuel combustion in transposrt. Thus, in figure 15, it can be seen that the main source of $PM_{2.5}$ emissions was selected to be fossil fuel in transport. While 40% chose that industrial emissions are the leading cause of particulate matter. Such as (Munsif et al., 2021) associated industrial emissions in air to be the reason of air pollution.

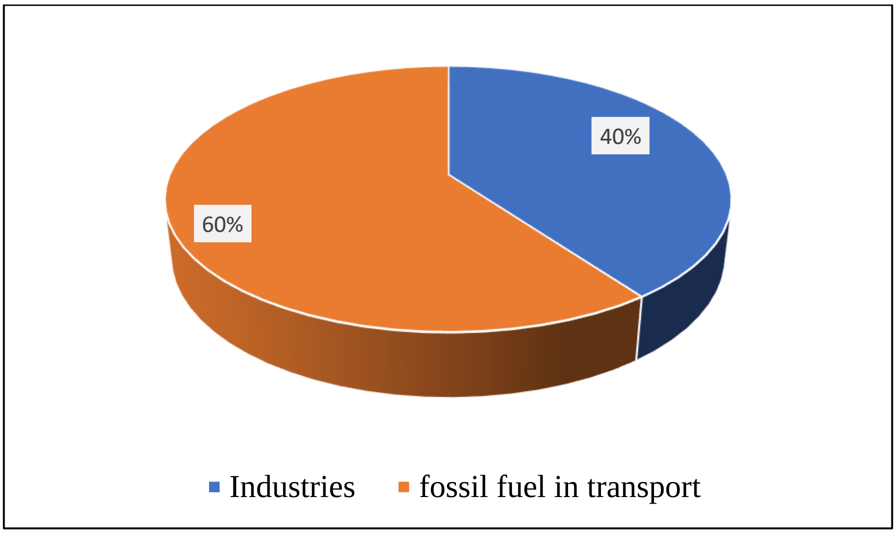

Figure 15 sources of pm2.5 emissions

When asked with the question as to why air pollution is neglected, around 50% officials are of the opinion that air pollution is mainly neglected because of unawareness of the damages. (Ramírez et al., 2019) also pointed put that on accurate timely information of air quality can reduce the repercussions of air pollution. While 40% respondents suspected lack of resources to be the cause and 10% credited it to the lack of will power. Figure 16 represents the opinion of officials regarding the reason of neglect of air pollution.

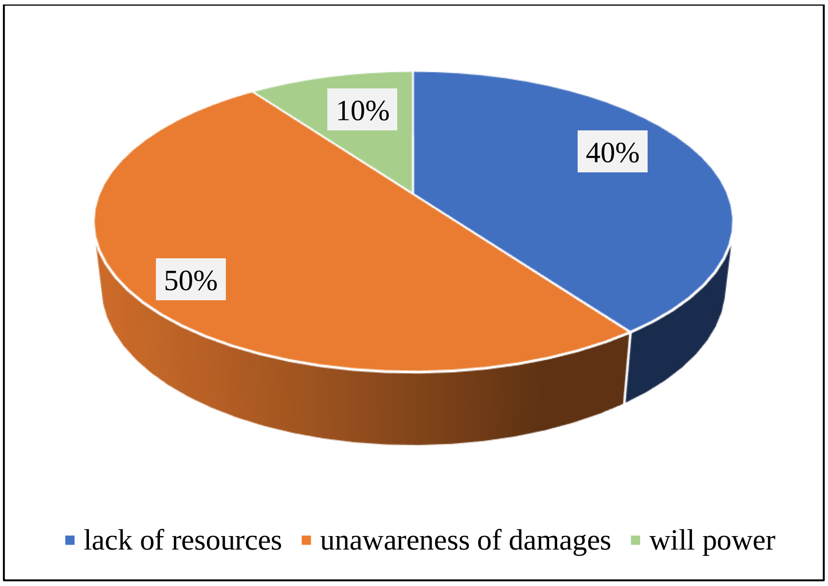

Figure 16 Reasons of air pollution neglect

Moreover, 60% agree that EPA has no capacity to provide desired air quality in the country. This can be recognized from literature as (Khwaja & Shams, 2020) focused on improving the air quality monitoring through building EPA capacity. In total, 50% respondents suggests that EPA can improve its capacity through investment in financial resources and 30% believe that human resources can be the way to improve the capacity of EPA. Remaining 20% are of the opinion that problem lies in the managerial ability of EPA workers. Thus, the capacity of EPA can be improved by financial aid, investment in human resources by training of EPA workers. Along with the improvement of management in the EPA.

When presented with the question about air pollution costs, 90% officials believe that air pollution impose costs in terms of health. According to (Chen et al., 2013; OECD, 2016b; Waidyatillake et al., 2021; Yin et al., 2021) air pollution impose major health costs. Figure 17 show the costs of air pollution.

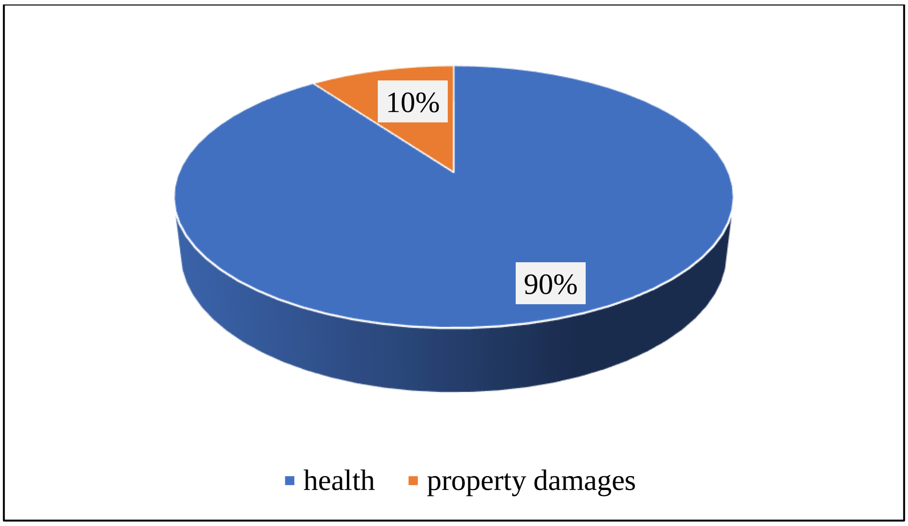

Figure 17 Air pollution costs

These costs eventually lead to economic costs. In case of Pakistan performance in controlling air pollution compared to the neighboring countries, 40% are of the view that Pakistan is performing worse than both India and Bangladesh. Where 30% officials think than Pakistan's performance is than both. While 20% believe that it is at least better than Bangladesh and 10% thinks that its performance in controlling air pollution is better than India. As a matter of fact, (AQLI, 2021) show that Pakistan and India has the world most polluted countries including Lahore and Delhi. Figure 18 represents the countries comparison regarding air pollution control.

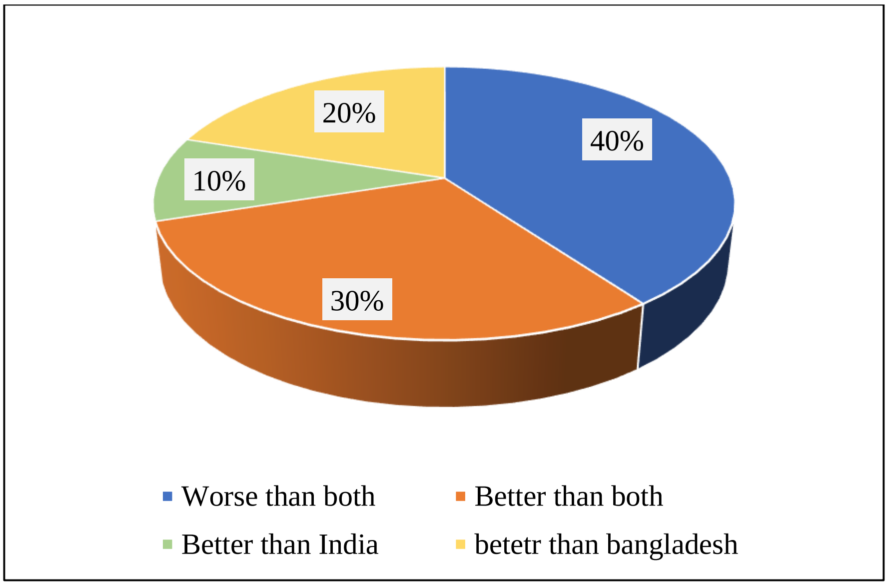

Figure 18 Pakistan's comparison with neighboring countries

Moreover, 80% believe that air pollution is deteriorating faster in Pakistan than neighboring countries. With 50% officials of the view that it is due to non-usage of abatement technology in Pakistan. As per (Nasim, 2021), Pakistan lacks a proper framework and technologies to decrease air pollution. The 37% respondents thinks that deterioration of air quality is due to non-usage of clean energy while 12% due to faster growth rate of Pakistan. Such as (Abbasi et al., 2020) specify that usage of nonrenewable energy impacts the air quality while clean energy can improve the environmental health.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

According to updated air quality guidelines of WHO, the annual average concentration of $PM_{2.5}$ should be below 5 ug/m^3. In the observed South Asian countries, it exceeded the recommended levels from 1998-2019. The key objectives were to identify the sources of these high levels of $PM_{2.5}$ emissions, economic loss and Pakistan's comparison with India and Bangladesh.

The sources were identified through fixed effect regression analysis. Which revealed that fossil fuel consumption and number of vehicles in a country has significantly positive influence on $PM_{2.5}$ emissions. While industrial growth has positive but insignificant impact on dependent variable. In case of economic damages incurred due to large concentrations of $PM_{2.5}$, and the life years loss of residents of selected countries. An economic loss of 273 USD, 2079 USD and 204 USD billion in Bangladesh, India, and Pakistan respectively for the year 2019 was generated. Furthermore, a detailed comparison of the countries revealed that Pakistan is comparatively suffering less economic losses than India and Bangladesh. This can be attributed to the excessive usage of fossil fuel and increasing industrial growth in Bangladesh. While a greater population exposure specifically labor force in India. However, the percentage increase in economic loss from 1998-2018 in Pakistan is the highest. Which suggests that with time Pakistan economic loss from $PM_{2.5}$ has increased the most as compared to India and Bangladesh. Also, the cost benefit analysis of economic costs and benefits due to $PM_{2.5}$ emissions of all the selected countries showed that benefits to costs ratio is above 1 for all. Which indicates that benefits of reducing particulate emissions is more than its costs.

Moreover, a survey was conducted to have the opinion of Ministry of climate change and Environmental protection Agency of Pakistan officials. The outcome showed that according to 60% of officials, fossil fuel usage in transport sector of a country is the main leading source of particulate emissions. This has also been observed from the literature and our findings where fossil fuel consumption significantly impacts particulate emissions. The survey also provided that over half of the officials agree EPA Pakistan has no capacity to provide the desired air quality. Furthermore, according to 50% officials the main reason of air pollution neglect is unawareness of damages.

To solve these issues, usage of public transport should be encouraged. One way is introduction of congestion charge. This has shown to reduce the car usage by 33% according to (Kimberly Nicholas, 2022). Also, the EPA capacity should be improved through financial investment and human resource training. This will lead to effective implementation of air quality reduction policies. Moreover, a uniform force should be introduced to ensure enforcement of air quality regulations at federal and provincial level. In case of unawareness of damages, media advertisement should be promoted to better inform the masses about the greater economic loss incurring due to air pollution. Lastly, as benefits are comparatively more than reduction costs of emissions so the concern authorities of these countries should invest in reducing the $PM_{2,5}$ concentrations in the air.

6.1 Limitations of the Study:

There are certain limitations of the study to be considered. Firstly, the electronic survey was conducted due to monetary and environmental considerations. Secondly, the number of registered vehicles data for India was missing for the years 2014-17. Which was then obtained from (Statista.com, 2021). Thirdly, all the exposed population might not be losing years of life due to PM2.5 emissions exposure. Some might be wearing masks while others could have a strong immune system. Lastly, considering other economic losses such as forgo labor earning, expenditure of hospitalization and cost of un-comforts facing during the sickness period are not undertaken. This implies that our economic losses are partial and indicate only lower bound estimates.

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Annex 1

Survey Form

The purpose of this survey is to identify the sources of particulate matter ($PM_{2.5}$). To evaluate the performance of Pakistan in controlling air pollution through comparison with neighboring countries. The information collected will be used for study purposes only.

Name: ________________ Department: ______________________

Designation: _______________

Questions from EPA and MOCC Pakistan officials:

1. In your opinion, main source of PM2.5 emissions is
   - fossil fuel burning in electricity production
   - fossil fuel in transport
   - Industries
   - Other
2. Is air pollution mainly neglected because of
   - lack of resources
   - unawareness of damages
   - lack of measurement technology
   - will power
3. Does EPA Pakistan have capacity to provide desired air quality?
   - Yes
   - No
4. EPA can improve its capacity by enhancing its
   - Human resources
   - Financial resources
   - Managerial ability
5. In your opinion, Air pollution impose costs in terms of
   - Health
   - trouble in mobility
   - property damages
   - life expectancy reduction

6. How is Pakistan performing to control air quality compared to neighboring countries?
    - Better than India
    - Better than Bangladesh
    - Better than both
    - Worse than both
7. Do you believe air quality is deteriorating in Pakistan faster than neighboring countries?
    - Yes
    - No
8. If yes, then because of Pakistan's
    - Faster growth rate
    - non usage of clean energy
    - non usage of abatement technology
9. Please recommend three short solutions to reduce $PM_{2.5}$ emissions in Pakistan.