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-RESEARCH ARTICLE-

ACCOUNTING FOR AIR POLLUTION FROM MANUFACTURING INDUSTRY IN IRAQ

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─Abstract─

The present study attempts to evaluate the economic costs involved in mitigating air pollution in urban areas when deterioration of environmental quality has been a critical factor affecting ecological results and enhancing global warming. This is despite the importance of the topic being poorly debated in recent scholarly literature. This study investigates the impact that investment in environmental capital and physical environmental expenses has on air pollution levels in Iraq. Data for the study are from World Development Indicators and financial reports for the manufacturing sector, running from 1991 to 2022. The approach employed to study the relationship between variables is the Dynamic Independent Distribution Lag. From the results, real capital and environmental costs have a negative relationship with air pollution in Iraq. These results may serve as inputs for policymakers in setting the level of regulations on mitigating air pollution through increased investment in current capital and environmental costs.

Keywords: Air and Population Accounting, CO2 Emissions, Capital Environmental Cost Accounting, Current Environmental Cost Accounting

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INTRODUCTION

Iraq is amongst the world leaders regarding oil production and has experienced fast economic growth in the last couple of decades. As such, social measures of this economic growth clearly followed the same line of fast industrialization and urbanization which, while on one side accelerating the economic development at very high tempos, on another side they resulted in incredible environmental degradation. (Ahmed et al., 2020). Air pollution is a major large-scale problem among public health and quality of life environmental problems with substantial significance to the integrity of the natural environment. Major sources of contamination are particulate matter, fine particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds that result from combustion of fossil fuel together with electricity used for lighting and industrial processes, plus many other chemical pollutants. When these substances interact with sunlight, they form smog, which can cause significant respiratory problems. (Anwar et al., 2020; Hormazábal, 2022). Additionally, the manufacturing industry, a key driver of Iraq's economy, significantly contributes to CO2 emissions. This sector encompasses a wide range of industries, from steel production to electronics manufacturing, with varying levels of energy intensity and pollution across different industries.

Environmental accounting activities, particularly those addressing air pollution, are essential for both society and individuals, as air is a fundamental resource for all living organisms. For humans, an individual's lungs process approximately 16 kilograms of atmospheric air daily, highlighting the critical need to maintain air quality. Air pollution has a direct and significant impact on human health, either positively or negatively, depending on air quality (Duval, 2022; falih Chichan & Alabdullah, 2021). Clean air is vital for sustaining life, and its influence on human health is well-documented. Studies indicate that air pollution is responsible for approximately seven million deaths annually worldwide, in addition to the numerous health, economic, social, and psychological consequences, including the rising costs of medical treatment. Alarmingly, recent research shows that urban centres are among the most polluted areas globally (Scarpellini et al., 2020). These results point to the fact that intervention is immediately called for, as with every passing day or hour human suffering increases, and so do economic losses. Other specific impacts of this crisis include deteriorating public health, massive losses in productivity, huge increases in health care expenditure, and large losses in tourism. This is more so discouraging because a vast percentage of these pollutants are locally generated-they mainly emanate from anthropogenic activities. (Giang et al., 2020).

Air pollution is a undoubtedly very serious condition that calls for effective and prudent management. Besides huge deficiencies in public awareness, there are many and varied sources of pollution, including means of transportation and industrial activities. In addition to all the above, the legal frameworks in Iraq that would have been exploited

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to regulate these sources are very restrictive, making the case much worse. This is due to the poor enforcement of laws on road traffic, energy generation, and indiscriminate waste combustion and industrial production from especially high-petroleum dependent factories in this state. This presents a dire need and urgent necessity for the establishment of other government agencies that shall be specially concerned with roads and traffic matters, more especially because of the now rapid increase in vehicle population as well as energy production within this country since the year 2003.(Korabayev et al., 2024). In addition, making a fully dedicated ministry for the environment, as well as the review and implementation of stricter environmental regulations, is urgent. To effectively combat pollution and the risks associated with it, it is necessary to develop a very comprehensive strategy, like those successfully implemented in Germany and many other EU countries. Such strategies include, for example, the serious introduction of "polluter pays" laws, which constitutes a fundamental step to effectively combat and mitigate pollution. (Shmarova & Ignatova, 2023).

This tough task is aggravated by increasing population, which definitely increases consumption of energy and demand for goods and services, causing greater pollution levels (Yang et al., 2021). Population growth in Iraq also drives urbanization, resulting in concentrated economic activities and greater energy use, often associated with air pollution episodes (Chenet et al., 2021). The shift from rural to urban areas has led to significant urban expansion, which has significantly increased vehicle emissions and further contributed to the deterioration of air quality. This study specifically aims to assess the capital and ongoing environmental costs associated with reducing air pollution, particularly carbon dioxide (CO2) emissions. The study also seeks to accurately determine the contribution of different industries to total CO2 emissions in Iraq.

This study largely addresses the major research gaps in the current literature on air pollution in Iraq. The growing global interest in environmental pollution has made this area a crucial topic for accounting studies, because the costs of pollution abatement are costs that are borne and paid by polluters. To stakeholders directly. Accountants are increasingly trying to measure and disclose these costs associated with polluting activities. The study specifically aims to assess the contribution of different units to pollution abatement and their financial obligations towards organizations working in the field of environmental protection. Efforts are also being made to develop effective methods. It is very important that these costs are disclosed in clear and useful reports for the decision-making process. The importance of the study lies primarily in proposing a comprehensive framework for measuring and reporting pollution abatement costs, carefully tailored specifically for Iraq. In the next section of this article, a comprehensive literature review, a clearly defined research methodology, and an empirical analysis conducted to systematically test the proposed hypotheses will be presented.

LITERATURE REVIEW

Carbon dioxide (CO2) emissions directly from fuel combustion are a major contributor to air pollution, with many harmful substances released as by-products during this process. CO2 is released every time fossil fuels are used to produce energy. (Rehman et al., 2019). These emissions can possibly be reduced by intentionally investing in capital environmental costs, like acquiring equipment and machinery designed to reduce CO2 emissions (Gola et al., 2022). For example, PM can harshly go deeper into the lungs and freely enter the circulatory system, unwillingly causing respiratory and cardiovascular diseases, which can be reduced by similar investments (Maama, 2021). Volatile organic compounds (VOCs) and nitrogen oxides (NOx) contribute to the formation of increased surface ozone, which aggravates respiratory problems such as asthma and bronchitis. In addition, nitrogen oxides and sulfur dioxide (SO2) contribute to the formation of acid rain, which is harmful to the natural environment and infrastructure. These problems can be solved by investing money in environmental investment costs. (Asiaei et al., 2022). Rehman et al. (2019), further stress that high temperatures arisen from increased CO2 levels can undoubtedly boost the formation of smog and ground-level ozone, which can also be administered through capital environmental investments. Moreover, climate change intensifies the frequency and severity of fires, which release substantial pollutants into the air—another issue that can be addressed by increasing capital environmental costs (Popov, 2020). Addressing these environmental challenges requires a systemic approach, emphasizing the need for investments in equipment and technology to reduce emissions. Therefore, we propose that,

H1: *The capital environmental cost such as purchasing the equipment and machinery can reduce the CO2 emissions in Iraq.*

Air pollution also affects the amount of CO2 released to the atmosphere particularly from the manufacturing industry through the utilization of fossil energies and processes and can be reduced using capital environmental cost such as application of mandatory legislation and standards. The manufacturing sector somehow is a major contributor to CO2 emission since it still utilizes a lot of energy, especially by burning coal, oil and natural gas that is the reason they must apply high capital environmental cost such as application of mandatory legislation and standards to reduce CO2 emission severe effects on environment (Hatane et al., 2021). This actually involves the emission of CO2, a potent greenhouse gas that is notorious in climate change while at the same time emitting other pollutants and such pollutants negatively impact the quality of air by pollution and

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potential health effects, including respiratory and cardiovascular diseases and controlled by applying high capital environmental cost such as cost on the application of mandatory legislation and standards (Sicard et al., 2019). Also, according to Yoro and Daramola (2020), carbon emissions in the atmosphere due to manufacturing processes enhance global warming, and subsequently escalate effects of air pollution and being controlled by applying high capital environmental cost such as application cost of mandatory legislation and standards. According to Singh and Yadav (2021) climate change has an impact on raising the temperatures that enhance the generation of smog and Ground level Ozone. Others are floods and droughts, which may enhance the occurrence of wildfires that emit significant amounts of smoke and other particulate matters to the atmosphere and managed by applying extensive capital environmental cost such as cost on the application of mandatory legislation and standards. Therefore, we make a hypothesis that,

H2: *The capital environmental cost such as application of mandatory legislation and standards can reduce the CO2 emissions in Iraq.*

Several activities directly contribute to air pollution, including CO2 emissions from fossil fuel combustion in electricity and heat production, as well as from coal, oil, and natural gas. These emissions can be mitigated by implementing high current environmental costs, such as expenses associated with filtering air emissions. While CO2 itself is a greenhouse gas rather than a traditional air pollutant, its production releases PM, NOx, SOx, and VOCs, all of which are harmful pollutants. These pollutants may possibly be managed by filtering costs (Y.-S. Chen & Chang, 2013). According to Bălă et al. (2021), air pollution exacerbates respiratory illnesses and impairs lung function, while SO2 emissions lead to acid rain that damages forests, crops, and water bodies, which can also be mitigated by emission filtering. Higher temperatures further contribute to smog and ground-level ozone formation. Additionally, climate change, driven by elevated CO2 concentrations, can intensify weather events such as wildfires, which release large amounts of smoke and particulate matter, further aggravating air pollution and health risks (D'Evelyn et al., 2022). These impacts extend beyond health, affecting the broader natural environment, but can be controlled through environmental costs for emission filtering (Cho et al., 2022). i.e, Singh and Yadav (2021), found that high temperatures can boost up methane emissions from land sources such as swamps. This creates a cyclical effect where climate change, fueled by CO2 emissions, continues to degrade air quality and the environment, which could be managed through high current environmental costs, including filtering emissions. Therefore, we say that,

H3: *The current environmental cost such as cost of filtering emissions in the air can reduce the CO2 emissions in Iraq.*

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A well-documented relationship exists between air pollution and economic growth, as economic development often drives industrialization, transportation, and energy consumption. However, these activities degrade air quality and negatively affect human health, necessitating the implementation of high current environmental costs, such as the expense of sanitary waste burial, to mitigate these impacts (Asiri et al., 2020; Gunarathne et al., 2021). According to (Liang & Yang, 2019), Rapid industrialization and urbanization, closely linked to economic growth, are worsening air pollution levels. Despite progress, factories, power plants and vehicles continue to release significant pollutants into the atmosphere, necessitating strict control measures such as sanitary waste disposal. (Abu Afifa & Saleh, 2022; Hussein & Mahmood, 2022). In addition, human-induced economic activities, such as deforestation and land degradation, reduce the capacity of natural ecosystems to sequester carbon dioxide and other greenhouse gases, underscoring the need to reduce the current high environmental costs of controlling these problems. (Jebur, 2021). In the economy, it is important to achieve growth without sacrificing environmental safety, which makes it necessary to apply the current high environmental costs to address these challenges. Therefore, we propose that,

H4: *The current environmental cost like cost of sanitary burial of waste can undoubtedly mitigate the CO2 emissions in Iraq.*

RESEARCH METHODS

The research examines the dire effects of capital and current environmental costs on air pollution in Iraq. Data were sourced from the World Development Indicators (WDI) and financial statements of the manufacturing industry, covering the period from 1991 to 2022. The study developed the following equation:

$$AP_t = \alpha_0 + \beta_1 CEM_t + \beta_2 CAMLS_t + \beta_3 CFE_t + \beta_4 CSBW_t + \beta_5 PG_t + e_t \quad \textbf{(1)}$$

Where;
AP = Air Pollution
t = Time Period
CEM = Cost of Equipment and Machinery
CAMLS = Cost of Application of Mandatory Legislation and Standards
CFE = Cost of Filtering Emission
CSBW = Cost of Sanitary Burial of Waste

The study focused on air pollution, measured by PM2.5 concentrations (mean annual exposure in micrograms per cubic meter), as the primary variable. It considered two predictors of interest: capital environmental cost and current environmental cost. Capital environmental cost was assessed through the ratio of the cost of equipment and machinery to total cost, as well as the ratio of the cost of implementing mandatory

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legislation and standards to total cost. The actual environmental cost was accurately estimated using the ratio of the cost of filtration of emissions to the total cost, as well as the ratio of the cost of disposal of sanitary waste to the total cost. These measurements are presented in Table 1.

Table 1: Measurements of Variables

S#	Variables	Measurement	Sources
01	Air Pollution	PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)	WDI
02	Capital Environmental Cost	The ratio of cost of equipment and machinery and total cost. The ratio of cost of application of mandatory legislation and standards and total cost.	Financial Statements
03	Current Environmental Cost	The ratio of cost of filtering emissions and total cost. The ratio of cost of sanitary burial waste and total cost.	Financial Statements

The analysis of these variables employs the use of descriptive statistics, whereby it calculates the mean, number of observations, mediation effects, and range between minimum and maximum values. A correlation matrix has been employed to check possible relationships among the variables. This paper also investigates the unit root of the variables by using the PP and ADF tests, which is very critical in ascertaining the kind of model to be used in analysis. The equation used in the analysis is shown below:

$$d(Y_t) = \alpha_0 + \beta t + \Upsilon Y_{t-1} + d(Y_t(-1)) + \mathcal{E}_t \quad \textbf{(2)}$$

Furthermore, the research meticulously assessed co-integration to identify the appropriate model, adopting the approach outlined by (Westerlund & Edgerton, 2008). The equations for this approach are provided below:

$$\mathrm{LM}_{\varphi}(\mathrm{i}) = \mathrm{T}\hat{\varphi}_{\mathrm{i}}\,(\hat{\mathrm{r}}_{\mathrm{i}}/\hat{\sigma}_{\mathrm{i}}) \quad \textbf{(3)}$$
$$\mathrm{LM}_{\tau}(\mathrm{i}) = \hat{\varphi}_{\mathrm{i}}/\mathrm{SE}(\hat{\varphi}_{\mathrm{i}}) \quad \textbf{(4)}$$

Nonetheless, when notably certain constructs obviously exhibit no unit root at the level but do at the first difference, the ARDL approach is undoubtedly most suitable for examining the relationships among variables (Zaidi & Saidi, 2018). The ARDL model is also advantageous because it mitigates the adverse effects of heteroscedasticity and autocorrelation on the results (Nazir et al., 2018). The equation of ARDL model with understudy variables are given below:

$$\Delta AP_t = \alpha_0 + \sum\delta_1\Delta AP_{t-1} + \sum\delta_2\Delta CEM_{t-1} + \sum\delta_3\Delta CAMLS_{t-1} + \sum\delta_4\Delta CFE_{t-1} + \sum\delta_5\Delta CSBW_{t-1} + \varphi_1 AP_{t-1} + \varphi_2 CEM_{t-1} + \varphi_3 CAMLS_{t-1} + \varphi_4 CFE_{t-1} + \varphi_5 CSBW_{t-1} + \mathcal{E}_t$$
(5)

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Lastly, the study estimated the relationships among the variables by using the DARDL approach, as specified by (Jordan & Philips, 2018). This method addresses limitations not covered by the standard ARDL approach. The equation for the DARDL model, including the variables under investigation, is provided below:

$$\Delta AP_t = \alpha_0 + \sum\delta_1 \Delta AP_{t-1} + \sum\delta_2 \Delta CEM_t + \sum\delta_3 \Delta CEM_{t-1} + \sum\delta_4 \Delta CAMLS_t + \sum\delta_5 \Delta CAMLS_{t-1} + \sum\delta_6 \Delta CFE_t + \sum\delta_7 \Delta CFE_{t-1} + \sum\delta_8 \Delta CSBW_t + \sum\delta_9 \Delta CSBW_{t-1} + \varepsilon_t \quad \textbf{(6)}$$

RESEARCH FINDINGS

Descriptive statistical techniques, the mean, number of observations, mediation effects, and range, minimum and maximum, made up the variables that were evaluated. The results showed that the mean air pollution (AP) tallied to 159,372.760, average capital environmental costs (CEM) measured a mean of 20.080, and chemical waste index (CAMLS) mean was recorded at 4.322. More concretely, the average of the environmental costs as presently calculated amounted to 2.082, while for the health wastes index or CSBW, the mean value was 2.888. The values are tabulated in Table 2.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
AP	32	159372.760	901264.480	45.901	5098372
CEM	32	20.080	6.338	5.200	26.930
CAMLS	32	4.322	7.071	2.261	6.719
CFE	32	2.082	2.066	1.047	3.382
CSBW	32	2.888	1.147	1.850	3.832

Furthermore, the relationship of variables was analyzed with the correlation matrix where the negative relationship of air pollution (AP) was found with capital environmental costs (CEM), chemical waste index (CAMLS), current environmental costs (CFE), health waste index (CSBW), and they are reflected in Table 3.

Table 3: Matrix of Correlations

Variables	AP	CO2FC	CO2MI	EG	PG
AP	1.000				
CEM	-0.063	1.000			
CAMLS	-0.053	0.136	1.000		
CFE	-0.004	-0.066	-0.080	1.000	
CSBW	-0.345	0.018	-0.046	0.310	1.000

For a unit root analysis, all variables were profoundly tested using both PP and ADF tests to exactly determine the proper model that should meticulously be used in estimation. The results of this study, at the level of air pollution AP, current

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environmental cost CFE, and health care waste index CSBW, there was no unit root shown in these variables. At the first difference, capital environmental cost CEM and chemicals index CAMLS were not showing any unit root. These results are presented in Table 4.

Table 4: Unit Root Test

	ADF		**PP**	
Series	Level	First Difference	Level	First Difference
AP	-3.242***	------	-4.382***	------
CEM	------	-3.903***	------	-3.907***
CAMLS	------	-3.829***	------	-3.646***
CFE	-2.918***	------	-3.434***	------
CSBW	-2.766***	------	-3.278***	------

Nonetheless, the paper interestingly examined co-integration to specify the appropriate model by using the approach developed by (Westerlund & Edgerton, 2008). The obtained results were less than 0.05 levels of p-values and had greater than 1.96 levels of t-values. These gave an indication that there might be the presence of co-integration among the variables as shown in Table 5.

Table 5: Co-integration Test

Model	**No Shift**		**Mean Shift**		**Regime Shift**	
	Test Stat	**p-value**	**Test Stat**	**p-value**	**Test Stat**	**p-value**
LM_τ	-4.657	0.000	-5.463	0.000	-5.666	0.000
LM_φ	-4.775	0.000	-5.546	0.000	-5.857	0.000

The last part applied the use of DARDL approach to estimate the relationship among the variables. These findings suggested that capital environmental costs-investments in plant and machinery-and those related to the fulfilment of mandatory legislation and standards, and ongoing environment costs related to emission filtration, as well as those for sanitary waste landfills, are inversely linked with air pollution within Iraq. These relationships are illustrated in Table 6.

Table 6: Dynamic ARDL Model

Variable	**Coefficient**	**t-Statistic**	**Prob.**
ECT	-0.664***	-5.784	0.000
CEM_{t-1}	-0.473***	-5.940	0.000
CEM	-1.875**	-2.133	0.020
$CAMLS_{t-1}$	-0.804***	-5.750	0.000
CAMLS	-0.453***	-3.997	0.002
CFE_{t-1}	-1.272**	-2.674	0.005
CFE	-1.275**	-2.018	0.038
$CSBW_{t-1}$	-0.564***	-5.482	0.000

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CSBW	-0.641***	-5.682	0.000
Cons	-3.741***	-5.009	0.000

R square = 61.846 Stimulation = 5000

DISCUSSION

The contribution of carbon dioxide emissions by this present study brings into focus air pollution in Iraq, and it is well indicated herein how such emissions can be minimized by capital environmental costs-such as investments in equipment and machinery, and implementation of obligatory legislation and standards-and ongoing environmental costs-including filtration of emissions and landfilling of health wastes. According to the research, capital environmental costs include mainly equipment and machinery, which are effective measures in air pollution control. Supporting this, Saud et al. (2020), note that investments in such capital can significantly reduce CO2 emissions from transportation. Although Iraq uses very little in terms of fuel sources such as coal, oil, and natural gas, which would make the CO2 and pollutant emissions high, considerable capital environmental costs in use could alleviate such issues. (F. Chen & Zhao, 2022; Irwansyah & Hudayah, 2022). These pollutants are known to cause serious health issues, such as respiratory and cardiovascular diseases, and contribute to environmental problems like acid rain and smog. Lodhia et al. (2021), prove that even though efforts to improve the adoption of cleaner sources of energy gradually gain pace, investment in capital environmental expenses like equipment and machinery has a quicker and far greater effect on emissions reduction.

The manufacturing sector, which plays a significant role in driving economic growth in Iraq, is also a major source of air pollution. This industry relies heavily on large amounts of fossil fuels for energy production, as seen in steelmaking, cement production, and chemical manufacturing, resulting in significant emissions of carbon dioxide and other greenhouse gases. These emissions can be effectively mitigated by investing in high environmental capital costs, including implementing mandatory legislation and standards. (Parkinson & Chew, 2022). Despite technological advances and improvements in environmental laws, controlling industrial emissions remains a persistent challenge. Government agencies need to encourage the use of clean production technologies, improve energy efficiency in industrial processes, and enforce environmental laws more stringently. (Yulong Chen et al., 2019). The study highly focuses that at the time the manufacturing industry plays an instrumental role to greenhouse gas emissions and deteriorates air pollution in urban territories, such entangled issues can definitely be addressed by substantial capital environmental investments, like enforcing stringent legislation and standards (Rosa et al., 2023; Xiong & Wu, 2021).

The results suggest that air pollution can be mitigated by applying ongoing environmental costs, such as those associated with emissions mitigation. Despite the increasing potential of renewable energy sources such as wind and solar, their contribution to total energy production remains relatively limited. Decarbonization of the energy sector represents both a challenge and an opportunity for developed and developing countries. This needs substantial investments in renewable energy infrastructure, improved grid systems, and supportive policies to promote efficient and low-carbon energy systems. (Usman et al., 2020). While air pollution is being immensely exacerbated by economic development and population growth, the application of high current environmental cost applications can definitely offset this problem. As obviously revealed, at the beginning of most development phases, environmental degradation often increases but may decrease with technological advancement, underpinning how important high current environmental cost applications, including emission filtration are in managing pollution effectively. (Yuqing Chen et al., 2023). In Iraq, the balance between growth and enhanced quality of development is delicate, where effective mitigation in the future will largely involve policy steps to support green technologies, undoubtedly improve urban practices, and increase funding for environmental protection, supported by high ongoing environmental costs. Besides, demographic factors and extension of cities greatly contribute a lot to the increase in the level of pollution, as the intensely growing demands for energy, transportation, and industrial activities result in very high emissions that could effectively be mitigated by the high ongoing costs to the environment and health through waste management, among others.. (Brunelli, 2020; Salami & Bhatti, 2022).

IMPLICATIONS

As one of the most important air pollutants, carbon dioxide has significantly a great effect on the environment and presents a major challenge for Iraq. High reduction costs of carbon dioxide emissions indicate the urgent need for the adoption of effective strategies in this respect. The methods of forestation and increasing green spaces are highly economically effective. These results are of great importance to policy franchisers, industrial stakeholders, and environmental organizations in Iraq because the results have clearly brought into view the need for carbon dioxide emissions controls. The study seriously calls for the conservation of natural resources by means of adopting clean production technologies and enhances public awareness campaigns. However, combating air pollution requires an integrated strategy and a firm legal framework. The study, therefore, contributes to the policymakers for articulating a balanced policy between economic growth and environmental conservation and also helps regulators in implementing measures for controlling air pollution through capital and ongoing environmental cost.

LIMITATIONS

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Although this research interestingly gave insight into CO2 emissions and their contribution to air pollution in Iraq, there were a few limitations that have to be considered. The major basis of the research was mainly secondary data from government sources and international organizations. Therein lies the point at which some flaws may have regluarily happened and produce incomplete results. Additionally, the present study focuses on CO2 emission only, leaving other very important pollutants such as CH4 and black carbon, thus being another limitation in air quality and climate change. The analysis of the relationship of economic growth, population, and pollution may also be limited by the fact that the overly simplified complex socio-economic environment was considered in the study. It is to be noted that this inference has been made in light of the existing technological and political contexts, which may change with time, and its effect with regard to results and implications will differ totally.

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