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National wealth, cultural moderators and pollution mortality: a panel analysis of 170 countries

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Abstract

Global concerns have arisen due to pollution-related mortality, and scholars studying the Environmental Kuznets Curve (EKC) have explored the impact of economic growth on carbon emissions, yielding conflicting findings. Considering these opposing perspectives on whether wealth exacerbates or mitigates the negative consequences of environmental pollution, we aim to assess the influence of economic growth on pollution-related mortality and investigate whether national culture moderates its impact. To gain insights into the effects of economic growth on pollution-related mortality, we utilized panel data covering 170 countries over a span of 23 years (1996–2017). Initially, we examined the relationship between GDP per capita and pollution-related mortality, finding support for the theory of a curvilinear correlation but not for the concept of a bell-shaped curve. Upon introducing cultural moderators, the curve shifts in different directions along various dimensions. High power distance and masculinity cultures are associated with increased pollution-related mortality, whereas individualist and long-term orientation cultures are linked to reduced pollution-related mortality. The directions of these moderators align with both linear and nonlinear analyses, except for uncertainty avoidance. This study makes significant contributions to the critical issue of pollution-related mortality, extending beyond traditional sustainability analyses. Additionally, it provides a robust examination of the intertwining of economic wealth and culture, challenging the dominance of either type of logic. Lastly, our study draws attention to policy-driven solutions.

Keywords Pollution mortalities, Economic growth (GDP), Environmental Kuznets Curve, National culture, Moderating effects

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1 Introduction

Economic growth has significantly increased in some parts of the world over the last decades; concurrently, environmental sustainability has deteriorated in those economies (Xiang et al. 2022). The resulting ecological hazard of increasing greenhouse gas emissions has contributed to pollution mortalities.¹ Recent evidence shows that 8 million people die of pollution each year, which amounts to 1 in 5 mortalities globally (Vohra et al. 2021). Theoretically, the Environmental Kuznets Curve (EKC) explains the relationship between the level of economic development and variation in environmental hazards. The EKC posits that economic growth relates to environmental degradation in an inverted U-shaped relationship. The increase in economic growth in the earlier stages of the development timeline increases ecological degradation, and a further increase in the national wealth of countries begins to decrease greenhouse gases as affluent societies demand a higher quality of life (Grossman and Krueger 1995; Kuznets 1955). In line with the EKC, we expect the inverted U-shaped curve to hold for the relationship between pollution mortalities and economic growth.

While the focus of our research, the role of national cultural variation in the EKC analysis, is missing from the earlier EKC literature; recent studies have taken the effects of national culture into account in predicting the correlation between economic growth (wealth of nations) and environmental hazards. Based on the dimensional approach to national cultural differences (Hofstede 1980; Hofstede et al. 2010), these authors show that power distance and masculinity shift the EKC to the left, increasing pollution. Individualism, uncertainty, and long-term orientation cultures move the EKC to the right, implying a mitigated effect of the moderators on pollution (Disli et al. 2016). This insight from cultural moderation between economic factors and environmental outputs stimulates new questions regarding the interaction between national culture, economic growth, and its environmental consequences. This research concentrates on one such consequence, the pollution mortalities in the world which are highlighted in recent research (Vohra et al. 2021).

Motivated by the cultural moderators on the one hand and pollution mortality on the other, both of which are studied in isolation but not in integration, we focus on pollution mortality associated with GDP per capita growth and moderated by national culture to address the aforementioned gap. Several developments in the literature support this line of inquiry and the rationale behind it, without implementing them. Firstly, the increase in pollution mortalities is a clear and present threat, far more severe than previously estimated (Vohra

et al. 2021). Secondly, pollution mortality, directly and indirectly, relates to economic growth (wealth of nations) and national culture, norms, and behaviors (Malik 2023). Thirdly, pollution mortality correlates with economic activity and behavioral conditioning. Lastly, the cultural context influences the motives and capabilities to develop preventive and curing (health care) systems in nations across different levels of economic development. These variegated pollution mortalities, levels of economic development, and cultural variety between the two sides of the equation merit our attention to a cross-country study. Hence, we used 170 countries in 23 years to fill the gap in the literature and answer the following research question.

Main question: *Does national culture moderate the link between economic growth and pollution mortality?*

- a) *Does economic growth predict pollution mortality?*
- b) *Do cultural factors predict pollution mortality?*
- c) *How does cultural variation moderate the effects of economic growth on pollution mortality?*

Drawing upon Hofstede's well-established cultural dimensions and associated measurements in the form of cultural indices (Hofstede et al. 2010), we examined the moderating effects of various cultural dimensions on the relationship between GDP per capita and pollution mortality. Using a multilevel mixed-method approach, we extrapolated the direct effects and interaction effects, contributing in three keyways to the literature.

Firstly, our research addresses the critical concern of pollution mortalities and their socio-economic costs. Secondly, it investigates cultural moderations, elucidating their positive or negative implications for public health, both directly and indirectly. Thirdly, this investigation considers policy implications regarding the education and enculturation of society, emphasizing the importance of societal factors alongside scientific considerations (Malik 2023).

2 Literature review

Economic theories posit that national wealth, and its associated mechanisms enhance socio-economic well-being, including the improvement of environmental quality and prevention of pollution-related mortality. The underlying assumption of these theories is that developed economies, through wealth creation, reduce carbon emissions, enhance healthcare systems, and mitigate the adverse effects of economic development on societal welfare. The Kuznets Curve elucidates the relationship between national wealth and its implications for socio-economic well-being (Kuznets 1955), suggesting that economic prosperity decreases societal inequalities. As national wealth reaches a certain threshold, further increases contribute to diminishing wealth disparities (Kuznets 1955), resulting in

¹ Global Carbon Project (www.globalcarbonproject.org).

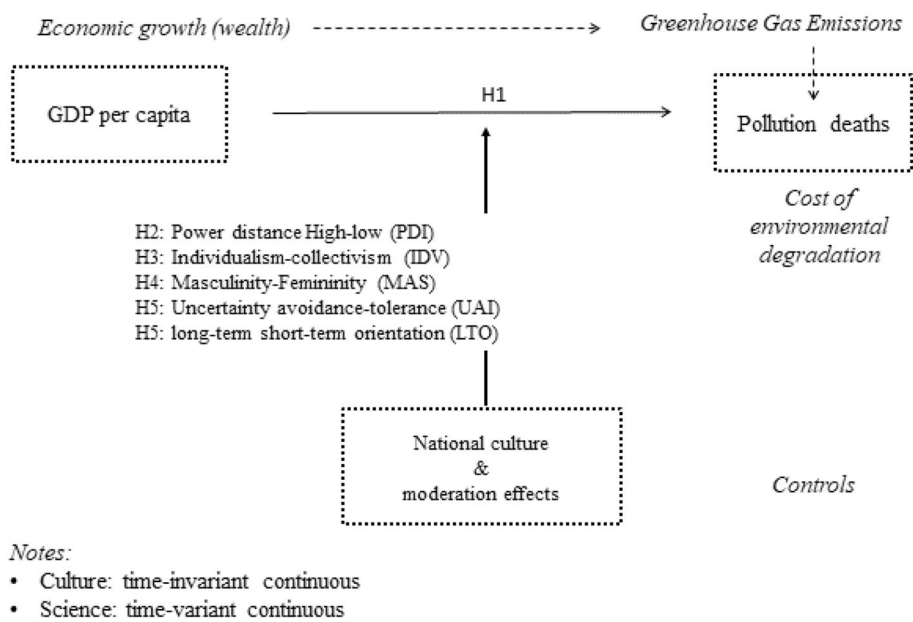
a nonlinear correlation between national wealth and socio-economic well-being. This nonlinear relationship, particularly regarding consequences like inequality management, gave rise to the Environmental Kuznets Curve (EKC), which posits that national wealth initially increases pollution up to a threshold, beyond which further increases in wealth lead to a reduction in environmental pollution (Grossman and Krueger 1995). According to EKC assumptions, the application of science and technology leads to desirable outcomes, such as the reduction in pollution mortality, as national wealth and scientific advancement are highly correlated. However, while the economic hypothesis suggests that national wealth initially exacerbates pollution mortality until a midpoint is reached, after which further wealth accumulation decreases pollution mortality, the scientific understanding only partially explains environmental quality (Malik 2023).

Conversely, institutional theory (Schotter 1981; Veblen 1899) and its various iterations (Douglas 1986; March and Olsen 1989; Nelson 1986) contend that informal norms (cultural variations) shape collective behavior, influencing both economic growth (wealth) and pollution mortality. These informal structures and normative behaviors attract societal attention, imbue significance, and elicit responses affecting both aspects of the equation (Abramovitz 1952; Beyer and Lodahl 1976; Hall 1976; Kroeber and Kluckhohn 1952; Rogers and Shoemaker 1971). These mechanisms of meaning evaluation and transformation translate policy into practice and knowledge into artifacts (Malik et al. 2021). For example, cultural factors influence environmental hazards

and their health implications (Cupples et al. 2007; Dangelico et al. 2020; Husted 2005; Lahuerta-Otero and González-Bravo 2018). By integrating economic and cultural theories within an institutional framework, we propose that national culture moderates the relationship between national wealth and pollution mortality. Based on this moderation proposition, we formulate baseline hypotheses followed by cultural moderators. Figure 1 encapsulates the essence of this proposition for analytical purposes.

2.1 Pollution mortality

Pollution mortality refers to deaths directly or indirectly influenced by carbon emissions in the air, resulting in health hazards. While the conceptual development of sustainability began in the 1970s (Meadowset al. 1972), it has gained legitimacy and prominence across countries in recent decades (Sen et al. 2010). Pollution mortality has transitioned from contentious debates to concrete evidence. Current research demonstrates a direct link between pollution and mortality rates worldwide (Vohra et al. 2021). Perceived pollution also impacts the mental health of middle-aged and older citizens across three East Asian countries (Yamashita et al. 2021). Increasing pesticide rates in developed countries (Hedlund et al. 2020) and rising fertilizer usage evidently contribute to health hazards (Lam et al. 2013; Xiang et al. 2020). Excessive waste in the environment creates an imbalanced metabolism, implying health hazards and pollution mortality (Gabrys 2009). This link between pollution and mortality also prompts questions about the social structure and behavior of societies that generate such outcomes,



- Notes:
- Culture: time-invariant continuous
 - Science: time-variant continuous

Fig. 1 Conceptual model. Note: The dark line shows the proposed correlation; the dotted line refers to the context of wealth creation and its environmental implications

with economic growth (wealth creation) emerging as a crucial antecedent to this phenomenon.

2.2 Economic growth and pollution mortality

The relationship between economic growth and pollution mortality is rooted in the Environmental Kuznets Curve (EKC) argument. The EKC posits that economic growth exhibits an inverted U-shape correlation with carbon emissions (Grossman and Krueger 1995), which consequently affects pollution mortality. Expanding upon this correlation between economic growth and pollution mortality, we extend the EKC to the mortality curve through the conceptual model depicted in Fig. 1. On the right side, pollution mortality in the country is illustrated. Evidence indicates that carbon emissions adversely impact mental and physical health (BJM 2019; Yamashita et al. 2021), leading to increased levels of pollution mortalities (Vohra et al. 2021). The association between pollution and health hazards occurs through metabolic operations via sink wastes (Gabrys 2009), in the food chain through fertilizers (Xiang et al. 2020), and in mental health anxiety (Downey and Van Willigen 2005). Therefore, economic growth directly correlates with carbon emissions and, subsequently, to pollution mortality until a threshold of economic growth is reached.

The EKC hypothesis (Grossman and Krueger 1993) explains that economic growth and pollution form a U-shape pattern: environmental pollution increases in the early stages of GDP per capita, stabilizes when the country reaches a middle-income stage, and then decreases after the country becomes an affluent society. Beyond that threshold of affluence, citizens demand a high-quality environment, can afford it, and are willing to pay for it. The EKC hypothesis suggests a similar nonlinear correlation between GDP per capita and pollution mortality. This analogy between the EKC in the literature and pollution mortality, developed in the current study, has strong foundations. Firstly, economic growth generates pollution through industrial activity based on fossil fuel energy consumption and industrial wastes. Secondly, economic development is correlated with the development of the healthcare system: wealthy nations are better equipped to attend to the primary healthcare needs of their citizens than developing nations. Moreover, economic growth contributes to new technological developments and shifts industries from more pollutant to less pollutant modes of operation. Therefore, in line with the EKC forming an inverted U-shape curve, we expect a nonlinear correlation between economic growth and pollution mortalities.

Hypothesis 1: GDP per capita (economic growth) predicts a non-linear negative correlation with pollution mortality.

2.3 National culture moderation

The social and institutional theories argue that cultural structures within and between countries moderate collective action by providing mechanisms of meaning-making. The role of the meaning-making system of national culture in cross-cultural studies has evolved through three stages since the early 1960s. Initially, research on culture gained prominence with conceptual development (Kroeber and Kluckhohn 1952), followed by an exploration of its religious context (Eliot 1960). In the second stage, the focus shifted to the meaning of symbols and the context of cultural structures, leading to the emergence of the analytical spectrum of high versus low context cultures in cross-cultural communication (Geertz et al. 1970; Hall 1976). The third stage, marked by increased international interaction, the dimensional approach to cultural analysis, and the proliferation of cross-cultural studies across multiple fields, began in the 1980s.

Hofstede (1980) initially identified four dimensions of national culture, with the development of a fifth dimension related to temporality (long-term orientation) in the 1990s. Recently, the application of cultural moderation based on this dimensional approach has entered environmental studies. One study applied national cultural dimensions to the Environmental Kuznets Curve (EKC) and found that national culture moderates the EKC, suggesting that cultural context alters its dynamics (Park et al. 2007). Another study proposed that cultural context shapes concepts and values that influence environmental behaviors and responses (Cupples 2009). Although it focuses on individuals' ecological behavior, it argues that wealth alone does not fully explain collective behavior. Empirical literature closely related to this topic indicates that national culture plays a role in explaining responses to environmental issues across countries, particularly regarding eco-efficiency practices (Halkos and Tzeremes 2013). In the context of the EKC, the dimensional approach to national culture assumes that cultural variations are reflected in carbon emissions at similar levels of economic growth. Outside the EKC research context, a recent study utilizes the dimensional approach to argue that cultural variation explains some of the variance in the transformation of science into economic products, specifically high-technology exports (Malik et al. 2021). These studies reflect on cultural moderation on carbon emissions directly and indirectly, consistently supporting its significance.

To extend cultural moderation to pollution mortality from the perspective of economic growth, we adopt Hofstede's dimensional view of cross-country analysis due to its stability, consistency, and widespread support across disciplines (Hofstede et al. 2010). These dimensions include power distance-proximity (PDI), individualism-collectivism (IDV), masculinity-femininity (MAS),

uncertainty avoidance-tolerance (UAI), and long-term vs. short-term orientation (LTO). In the following section, we develop cultural moderators for the correlation between GDP per capita and pollution mortality.

2.4 Power Distance Index (PDI)

The first moderating argument suggests that power distance influences the correlation between economic growth (GDP per capita) and pollution mortalities due to varying perceptions of power across cultural contexts. Analytically, the interaction between national wealth and power distance shifts the curvilinear correlation with pollution mortality to the left. In this moderating context, power distance refers to the perceptual gap between two ranks or positions on the hierarchy across cultures. Formal ranks within organizations differ between countries, leading to varied implications of power distance. Similarly, informal hierarchies within family structures also vary across cultures. Hofstede (1980) explains that the perceptual gap in power between two positions originates from the less powerful strata of the group. If the powerful individual rejects the senior position, the notion of power distance diminishes. High power distance in society adheres to established assumptions about unequal distributions of authority, status, and wealth (Hofstede et al. 2010). Thus, a high Power Distance Index (PDI) implies a perceptual gap larger than the actual gap between two positions, with inequality being a key concept in social or economic settings.

While high power distances tolerate inequalities in wealth, health, social status, and justice compared to low power distances in other research contexts, we anticipate a negative moderating effect of power distance inequalities on physical and mental health problems. In other words, high PDI exacerbates pollution mortalities for several reasons. Firstly, PDI increases inequality between groups, hindering access to information, diagnostics, and management of health problems (Mansyur et al. 2009). Secondly, inequalities reduce opportunities for the lower strata of the population to access education, healthcare, and mental security. Thirdly, inequalities contribute to disparities in healthy and unhealthy lifestyles and diets within groups. Fourthly, socio-economic imbalances lead to risky behaviors in everyday activities (Pascoe and Smart-Richman 2009). Lastly, inequalities breed corruption and other socio-economic anomalies, further exacerbating pollution mortalities (Vohra et al. 2021). The foregoing discussion suggests that power distance contributes to pollution mortalities, while low power distance discourages them.

Hypothesis 2: The Power Distance Index (PDI) positively moderates the relationship between GDP growth and pollution mortalities.

2.5 Individualism-Collectivism (IDV)

Individualism positively moderates the relationship between economic growth and pollution mortality, implying that collectivism negatively moderates this relationship. Individualism and collectivism represent opposite ends of the spectrum in terms of person-societal interdependence, and this level of interdependence moderates the association between GDP per capita and pollution mortality. Differences between individualist and collectivist cultures have been consistently addressed in cross-cultural studies since the inception of this dimension in the 1980s (Hofstede et al. 2010). High individualism reflects the independence of the individual or organization from society, while high collectivism denotes interdependence between the individual and society. For example, the USA scores higher than average on independence, while China scores higher than average on interdependence. These levels of integration-disintegration between the individual and society shape norms and behaviors.

According to cultural theories (Hofstede et al. 2010), individuals in high individualism cultures tend to prioritize self-interest. Such cultures promote autonomy in decision-making processes, thereby increasing individual discretion within the environment. Conversely, collectivist cultures shift discretionary power from individuals to collectives in decision-making processes, resource allocation, and distribution of wealth, health, economy, and institutions. Regardless of the cultural spectrum, meaning drives attention, values, and decisions for action. While theories point in both directions, evidence suggests support for individualism and environmental management.

Theoretically, individualist countries (e.g., the USA) tend to lag in working towards collective goals (Karau and Williams 1993). These cultures often overlook collective participation unless it directly impacts their economy, wealth, health, or subjective well-being. Conversely, individuals in collectivist cultures increase attention, participation, and efforts for the benefit of the group, irrespective of direct individual benefits (Schultz 2002). A study comparing American and Japanese respondents concluded that Japanese (collectivists) exhibit greater support for pro-environmental behavior than their American (individualist) counterparts (Eom et al. 2012). Given this related evidence and our focus on the effects of pollution, we propose a negative moderation of individualism-collectivism between GDP growth and pollution mortalities. Individualist countries tend to be wealthier, and wealth predicts a decrease in pollution and increased resources for its management.

Hypothesis 3: The individualist culture (IDV) negatively moderates the relationship between GDP growth and pollution mortalities.

2.6 Masculinity-Femininity (MAS)

Masculinity versus femininity cultures differently moderate the relationship between economic growth and pollution mortalities, with high Masculinity (MAS) countries tending to produce more carbon emissions. The behavior exhibited on each end of this dimension of national culture stems from assertive versus caring attitudes towards the environment. Hofstede introduced the masculinity-femininity dimension, borrowing from anthropological literature to delineate "manlike" versus "womanlike" roles in social and economic settings (Hofstede et al. 2010). He explains that masculine and feminine-like business decisions can be made by individuals of any gender. For example, a female executive can exhibit challenging, assertive, and material-oriented behaviors in a masculine culture, while a male executive can demonstrate caring, cooperative, and humanistic behaviors in a feminine culture. Both types of cultures exist in industrialized and non-industrialized countries. Masculine cultures prioritize output performance, while feminine cultures emphasize process (Hofstede et al. 2010). Masculine cultures foster competition, performance, and material values for objective well-being, while feminine cultures prioritize consensus, employee care, and subjective well-being (Diener et al. 2003; Li et al. 2019).

Empirical literature suggests that masculine cultures tend to prioritize objective performance over subjective well-being. On one hand, masculine cultures possess social and institutional capacities to manage environmental sustainability effectively (Husted 2005). On the other hand, gender difference studies indicate that females tend to be less polluting than males (Zelezny et al. 2000). Nevertheless, evidence in the literature suggests that masculine cultures shift the pollution curve to the left, indicating an increase in carbon emissions with rising GDP growth (Disli et al. 2016). This shift in the masculine moderator implies that masculine cultures positively moderate economic growth and pollution mortality.

Hypothesis 4: The masculinity culture (MAS) positively moderates the relationship between GDP growth and pollution mortalities.

2.7 Uncertainty Avoidance Index (UAI)

The high Uncertainty Avoidance (UAI) culture moderates the relationship between national economic growth and pollution mortality. Uncertainty avoidance refers to the tolerance of ambiguities in unknown situations by individuals, organizations, or nations (Hofstede et al. 2010). In high UAI cultures, organizations prefer clear structures, formal laws and rules, and bureaucratic systems of information exchange (Hofstede et al. 2010). In response to uncertainties, such cultures rely on the prestige of experts who reflect stable and consistent histories. This reliance on

experience implies that older rules, actors, and structures reduce uncertainty. Older organizations develop industry standards and rules, influencing structural and procedural legitimacies for followers. Similarly, incentives in high UAI cultures are based on known business models.

Shareholders in high uncertainty avoidance cultures prefer immediate returns, suggesting the exploitation of existing resources and known production functions. Similarly, such cultures are slower to adopt innovations in processes and products to maintain job stability for management and employees. Both management and employees avoid the perceived danger of innovation, and when the external environment changes, stress and anxiety further reinforce the practice of known business activities (Hofstede et al. 2010). Furthermore, uncertainty avoidance induces short-termism at individual, organizational, and institutional levels, leading to inaction on climate change in business enterprises and societies (Slawinski et al. 2015). This suggests that uncertainty avoidance tends to maintain the status quo and existing technologies in dealing with environmental issues, thereby predicting a positive correlation with environmental pollution.

However, the moderating effects of uncertainty avoidance suggest an opposite outcome regarding economic growth. High uncertainty avoidance cultures mobilize resources to improve environmental quality by shifting the Environmental Kuznets Curve (EKC) downwards (Disli et al. 2016). Uncertainty reduction theories explain the negative correlation between uncertainty and ecological hazard, positing that high uncertainty is undesirable and requires reduction mechanisms through exploration and exploitation of information and knowledge (Berger 1986; Kramer 1994). Applying these ideas to uncertainty avoidance, recent studies show that high uncertainty avoidance cultures shift the pollution curve to the right (Disli et al. 2016). Hence, based on the pollution reduction effects of uncertainty stemming from high GDP growth, we expect a negative moderation of high UAI culture between GDP growth and pollution mortalities.

Hypothesis 5: The uncertainty avoidance culture (UAI) negatively moderates the relationship between GDP growth and pollution mortalities.

2.8 Long-Term Orientation (LOT)

A long-term versus short-term orientation (LTO) negatively moderates between economic growth and pollution mortality. The LTO dimension in national culture has roots in anthropology, natural sciences, and cross-cultural studies (Malik 2023). Pierre Bourdieu (Bourdieu 1963) explored the notion of temporality, its meaning, and society's response to the timeline. From a scientific

perspective, the late physicist Stephen Hawking (1988) wrote about the history of time values, meaning, and responses to the timeline, which depend on the experience of time—thus, the past and present differ across spaces. Hofstede developed this fifth dimension in cross-cultural research in 1991, which shows that attention to the past and future, the relevance values of the past and future, and the coping capabilities in interpreting the timeline affect behavior differently. For instance, future reward orientation rests on perseverance, thrift, and adaptive attitudes towards the changing environment (Hofstede et al. 2010). This temporality view of time lies at the two ends of the spectrum: long-term orientation (LTO) versus short-term orientation (STO).

However, in theory, the LTO dimension of national culture has generated some confusion regarding the long term in the past or the distant future's long vision. While some writers and readers see long-term orientation about the future, others view it about the past. Both sides have different implications. The long-term orientation aligned with the future vision reflects the person's risk-taking, innovation planning, and patience for rewards far into the distal future. It implies that LTO culture expects rewards from far into the future, and society is willing to take a higher risk for a higher reward in the distal future. The short-term culture prefers lower risk and lower rewards on the timeline into the future.

Regarding the timeline into the past, the past reverses this argument. LTO cultures in the past tend to be stable, consistent, and path-dependent. They highlight past achievements, national pride, and social obligations (Hofstede et al. 2010). The past decides the present and future. In the current argument on the analysis of pollution mortality, the LTO refers to the distal future, and STO refers to the near future in supporting the negative moderation of temporality. Firstly, LTO cultures believe in their control over their destiny, hence thinking in the distant future (Bourdieu 2005). Secondly, high LTOs use policies and procedures favoring sustainability compared to the short-term orientation cultures in environmental sustainability. Thirdly, high LTO cultures invest in new technologies at the cost of short-term benefits favoring conventional technologies (Malik et al. 2021). Fourthly, the LTO influences social responsibility, and the related evidence suggests that the LTO moves the EKC curve to the right (Disli et al. 2016), indicating negative moderation. Therefore, we propose the negative moderation of the temporal dimension of national culture on pollution mortalities.

Hypothesis 6: The long-term orientation culture (LTO) negatively moderates GDP growth and pollution mortalities.

3 Methods

3.1 Research setting

The research question guiding the comparative analysis of pollution mortalities and national culture sets the research setting and design at a macro level. In this setting, an aggregated national unit of analysis is based on secondary data encompassing three dimensions: pollution mortalities, economic growth, and national culture. Pollution mortality measures the share of overall mortalities in the country annually, while economic growth (development) is measured by per capita GDP, both of which vary between years and countries. These components of the research setting lend themselves to panel data analysis for examining causal relationships. The panel data comprises 170 countries over 21 years, although missing data in some countries or variables has slightly reduced the sample size. Nevertheless, the large sample size, panel data structure, and robust analysis offer advantages over cross-sectional data or case studies.

The study design operates on several assumptions. First, GDP per capita contributes to carbon emissions. Second, culture moderates between economic development (GDP) and carbon emissions, meaning that national culture influences both GDP per capita and carbon emissions. Third, carbon emissions increase health hazards, resulting in pollution mortalities. Fourth, given that carbon emissions originate from GDP per capita and lead to pollution mortalities, the role of culture between GDP per capita and pollution mortality parallels the role of national culture in the relationship between economic development and carbon emissions. Thus, our design encompasses the Environmental Kuznets Curve (EKC) and its response to pollution in the cultural context.

We utilized multiple data sources for pollution mortality, national wealth (GDP per capita), and national culture across five dimensions. Pollution mortality data were obtained from the World Health Organization (WHO), while aggregated data on national wealth came from the World Bank. Measures for the five dimensions of national culture were adopted from established literature (Hofstede et al. 2010). Data on control variables, such as corruption ranking and suicide rates, were sourced from Oxford University's database. Together, these data sources provided a rich dataset for our study to analyze both the direct effects of GDP per capita and national culture on pollution mortalities and the indirect effects (interaction) between GDP per capita and national culture on pollution mortalities. Specific variables elucidate the nuances of the measurements and analysis.

3.2 Variables

3.2.1 Dependent variable

The dependent variable measures the percentage of mortalities associated with pollution in the country. Recent evidence confirms with precision that 1 in 5 mortalities worldwide is associated with pollution (Vohra et al. 2021). Data on pollution mortalities were obtained from the World Health Organization (WHO),² and we transformed the dependent variable using the natural logarithm. Therefore, the dependent variable is "log pollution mortalities," which is a normally distributed continuous variable.

3.2.2 Independent variables

The independent variables consist of two sets: main variables and controlled variables. The main variables comprise national economic development (GDP per capita) and five dimensions of national culture. GDP per capita measures the economic performance of the economy, and the data were obtained from the World Bank. The five dimensions of national culture represent the norms and behaviors of the nation, and the data for these dimensions were sourced from the database.³ These five dimensions of national culture are measured on a 100-point scale. With the interaction between culture and GDP per capita, the product variables become continuous variables: (culture)*(GDP per capita).

3.2.3 Control variables

The control variables include:

- (i) Suicide rate (mortalities per 100,000)
- (ii) Taxes as a percentage of revenue generated.
- (iii) Population of the country in millions (pressure on the environment)

3.2.4 Model and analysis

The multilevel mixed-effects model employed in our analysis is advantageous for handling both within-group and between-group variations simultaneously. This is particularly beneficial when dealing with heterogeneous data like ours, as it allows us to evaluate how entities change over time while also capturing common patterns across all entities.

$$Y_{ij} = \beta_0j + \beta_1jX_{ij} + \epsilon_{ij}$$

Y_{ij} = the dependent variable for the i th observation in the j th country.

X_{ij} = the independent variable(s) for the i th observation in the j th country.

β_0j and β_1j = the country-specific intercept and slope coefficients, respectively.

ϵ_{ij} is the error term for the i th observation in the j th country.

The equation comprises both fixed effects (the coefficients β_0j and β_1j) and random effects at the country level. The variability between countries, in addition to within-country variability, is captured by the varying intercept and slope coefficients across different countries. This equation embodies the hierarchical structure of the data, with observations (level 1) nested within countries (level 2), facilitating the estimation of both within-country and between-country effects. The model accounts for individual-level variation within countries and the disparities between countries in the relationship between the dependent and independent variables.

4 Results

In Table 1, summary statistics are presented, with each variable exhibiting a log distribution. The dependent variable represents the mortality rate, while the independent variables consist of GDP per capita and five cultural dimensions. Prior to applying the log distribution, pollution mortality ranged from 2 to 15% of total deaths in the country, while the GDP per capita of the country ranged from \$103 to \$119,000.

In Table 2, inter-variable correlations are presented, with two correlations exhibiting high values. One correlation is between wealthy countries and low corruption, while the other is between GDP per capita and GDP per capita squared, which is expected.

Table 3 presents the results from Multilevel Methods (Mixed Effects). Model 1 serves as the base model, Model 2 introduces two control variables, and Model 3

Table 1 Summary statistics

Variable	Mean	Std. Dev	Min	Max
Log Pollution deaths	1.94	.33	.71	2.73
Corruption	60.25	22.78	1	101
Suicides	11.52	6.94	2.02	44.78
GDP per capita	10,911.44	16,749.11	102.64	119,225.38
PDI	65.38	21.24	11	100
IDV	38.74	21.38	6	91
MAS	46.6	18.13	5	100
UAI	63.97	22.1	8	99
LTO	45.49	22.57	7	100

The dependent variable is log distribution

N = 170

Timeline = 1996 to 2017

Data = Panel

² https://www.who.int/health-topics/air-pollution#tab=tab_1

³ <https://www.hofstede-insights.com/product/compare-countries/> (accessed: March, 2021).

Table 2 Inter-variable correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Pollution mortality	1									
Corruption	0.579*	1								
Suicide	-0.170*	-0.062*	1							
GDP	-0.562*	-0.696*	-0.132*	1						
GDP2	-0.581*	-0.727*	-0.121*	0.995*	1					
PDI	0.559*	0.627*	-0.113*	-0.474*	-0.502*	1				
IDV	-0.446*	-0.547*	0.160*	0.530*	0.549*	-0.543*	1			
MAS	0.177*	0.234*	-0.281*	-0.051*	-0.056*	0.148*	-0.087*	1		
UAI	-0.029	0.246*	0.097*	0.055*	0.036	0.098*	-0.110*	0.107*	1	
LTO	-0.026	-0.152*	0.263*	0.262*	0.264*	-0.041	0.240*	-0.028	0.031	1

* $p < 0.05$

Table 3 Direct effects of GDP per capita and national culture on pollution mortalities

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	1.9401*** (.02481)	1.5155*** (.04854)	2.2321*** (.0591)	.50754 (.65995)	1.1592** (.56228)	.3291 (.52684)
Corruption		-.01268 (.00772)	-.02162*** (.00735)	-.01935** (.00925)	-.02945*** (.00842)	-.02164*** (.00818)
Suicide		.20623*** (.01043)	.10346*** (.01122)	.2668*** (.01238)	.16191*** (.01307)	.12204*** (.01306)
GDP			-.05514*** (.00305)		-.0585*** (.00384)	.21548*** (.02423)
GDP ²						-.01697*** (.00148)
PDI				.31838*** (.09822)	.25813*** (.08356)	.20546*** (.07767)
IDV				-.23389*** (.07815)	-.1626** (.06654)	-.13463** (.06179)
MAS				.17263*** (.05985)	.14405*** (.05088)	.12959*** (.04723)
UAI				-.06142 (.08187)	-.03824 (.06957)	-.05443 (.06456)
LTO				-.01781 (.05729)	.02263 (.04874)	.04088 (.04525)
L2 Var (Const.)	-1.1363*** (.05474)	-.9984*** (.05587)	-1.1721*** (.05696)	-1.1814*** (.0766)	-1.3449*** (.07733)	-1.4203*** (.07742)
L1 Var (Residual)	-2.4254*** (.0119)	-2.5048*** (.01244)	-2.5632*** (.01255)	-2.5294*** (.0165)	-2.6259*** (.0166)	-2.6570*** (.0166)
N	3696	3405	3348	1928	1908	1908

Dependent variable: Pollution mortality = share of mortalities from air pollution (%)

Standard errors are in parenthesis

[L2 Var(const.)] = estimated log of between-countries standard deviation

[L1 Var (residual)] = estimated log of residual (within-countries) standard deviation

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

adds the main predictor (GDP per capita). In this direct effect, GDP per capita negatively correlates (-0.055, $p < 0.01$) with pollution mortality. Model 4 includes

the five dimensions of national culture in the analysis, excluding GDP per capita, and encompasses all variables. Among the cultural predictors, high power

distance positively correlates (0.26, $p < 0.01$) with pollution mortality, while high individualism negatively correlates (-0.16, $p < 0.01$) with pollution mortality, and high masculinity positively correlates (0.14, $p < 0.01$). Uncertainty avoidance shows a negative correlation, albeit not significant ((-0.04, $p < 0.10$), and high long-term orientation is positive but not significant (0.02, $p < 0.10$).

The final model compares GDP per capita and its squared values to demonstrate curvilinearity. As expected, GDP per capita becomes positive (0.22, $p < 0.01$), and GDP per capita squared becomes negative (-0.02, $p < 0.01$). Thus, Hypothesis 1 confirms the negative correlation of GDP growth and pollution mortality, and the curvilinear correlation forms an inverted U-shaped curve (consistent with the EKC).

Table 4 tests the interaction effects between GDP per capita and national culture across five dimensions. The results from Mixed Methods (multilevel models) are presented in five interaction models.

Model 1 exhibits a negative coefficient for power distance interaction (-0.039, $p < 0.01$), indicating a shift of the interaction line to the right. This contradicts the hypothesis, which predicted a positive coefficient and an expected shift of the interaction line to the left.

In Model 2, individualism shows a negative coefficient (-0.08, $p < 0.01$), aligning with the predicted correlation of the interaction and resulting in a shift of the interaction line to the right.

Masculinity in Model 3 presents a positive coefficient (0.19, $p < 0.01$) and a shift of the interaction line to the left.

Model 4, focusing on uncertainty avoidance, reports a negative coefficient (-0.06, $p < 0.01$).

Similarly, Model 5, examining long-term orientation, reports a negative coefficient for the interaction (-0.19, $p < 0.01$).

The graphical representation of these shifting interactions is provided in Figs. 2, 3, 4, 5, 6 and 7 below.

Table 5 presents the results from Mixed Methods (multilevel models) on the interactions between GDP squared and cultural predictors.

In Model 1, power distance shows a positive interaction effect. Unlike the linear prediction in the earlier analysis, the squared values of GDP per capita have changed the correlation from negative to positive at the same level of power distance.

Model 2 reveals a negative interaction effect of individualism on pollution mortality, aligning with the hypothesis.

Masculinity in Model 3 exhibits a positive interaction effect on pollution mortality, confirming its hypothesis.

Model 4, focusing on uncertainty avoidance, reports a negative but not significant ($p > 0.10$) interaction

Table 4 Multilevel Models (Mixed Effects)

Variables	(1)	(2)	(3)	(4)	(5)
Constant	.417 (.558)	.109 (.215)	2.878*** (.28)	-.193 (.352)	1.527*** (.222)
Corruption	.153*** (.012)	.108*** (.012)	.139*** (.012)	.163*** (.012)	.143*** (.012)
Suicide rates	-.112*** (.009)	-.128*** (.009)	-.124*** (.009)	-.108*** (.009)	-.112*** (.009)
GDP linear	.065 (.054)	.165*** (.025)	-.175*** (.026)	.14*** (.035)	-.033 (.023)
PDI	.458*** (.126)	.023 (.016)	.066*** (.016)	.056*** (.016)	.07*** (.016)
IDV	-.031** (.013)	.683*** (.068)	-.032** (.013)	-.026** (.012)	-.03** (.013)
MAS	.034*** (.009)	.036*** (.009)	-.151** (.065)	.039*** (.009)	.034*** (.009)
UAI	-.088*** (.013)	-.088*** (.013)	-.09*** (.013)	.462*** (.081)	-.089*** (.013)
LTO	.112*** (.009)	.121*** (.008)	.115*** (.009)	.114*** (.009)	.273*** (.052)
GDP*PDI	-.039*** (.013)				
GDP*IDV		-.08*** (.007)			
GDP*MAS			.019*** (.007)		
GDP*UAI				-.06*** (.009)	
GDP*LTO					-.019*** (.006)
L1 Var (residual)	-1.588*** (.016)	-1.615*** (.016)	-1.588*** (.016)	-1.598*** (.016)	-1.588*** (.016)

Dependent variable: Pollution mortalities = % of total death in the country

GDP per capita = loglinear

N = 1908

L1 Var (residual) = estimated log of residual (within-countries) standard deviation; Variance of the means entities

Based on interclass correlation test (ICC) and Likelihood ratio test

*** $p < .01$, ** $p < .05$, * $p < .1$

effect with GDP squared on pollution mortality. This shift from a significant to non-significant coefficient deviates from the previous literature and the predicted hypothesis.

Lastly, in Model 5, long-term orientation shows a negative interaction effect on pollution mortality, consistent with the prediction in the hypothesis.

Overall, except for uncertainty avoidance, which has changed from significant to not significant between linear and quadratic functions, the results provide consistent support for the predicted correlations.

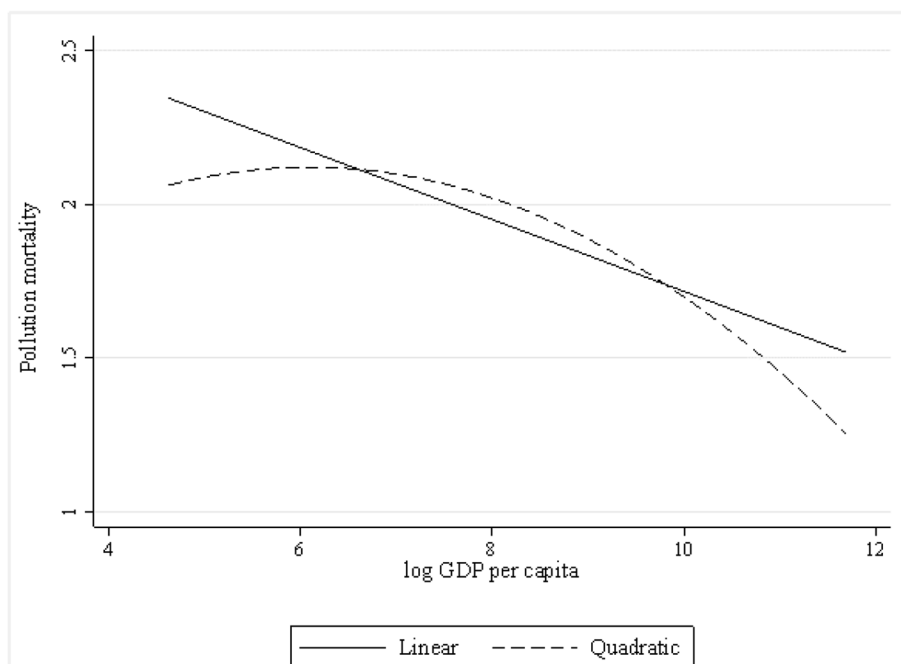


Fig. 2 GDP per capita and pollution mortality. Note: Concave curvilinear curve but not an inverted U-shape

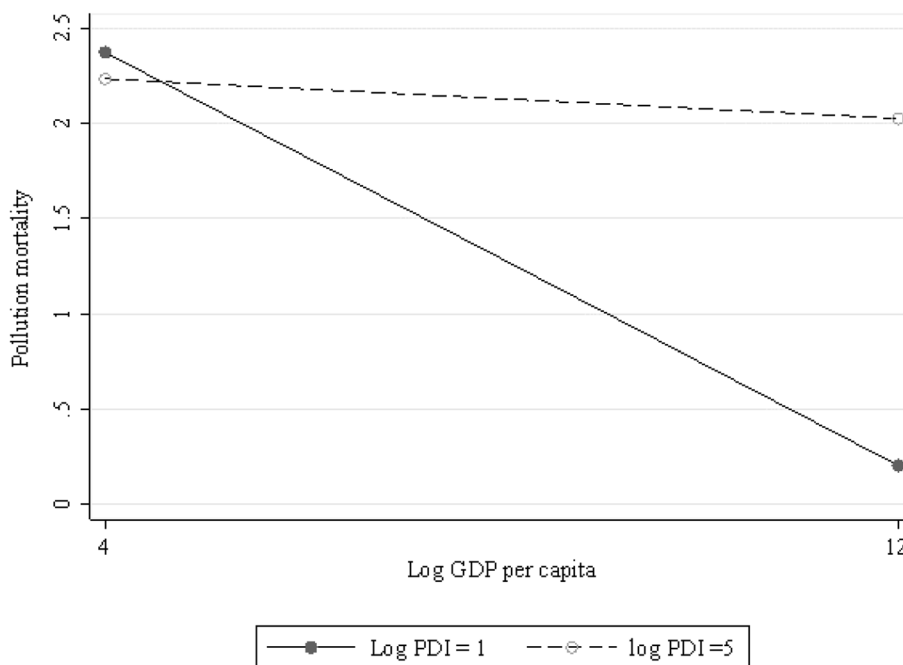


Fig. 3 Interaction plot: GDP & PDI. Note: The interaction of PDI shifts the line to the left, implying that the post-interaction effect (high power distance) increases the pollution mortality rates

Table 6 provides a summary of the findings from previous tables regarding the direct effects, linear interactions, and quadratic interactions.

- High power distance increases pollution mortality at low and high levels of GDP but decreases it at moderate income levels.

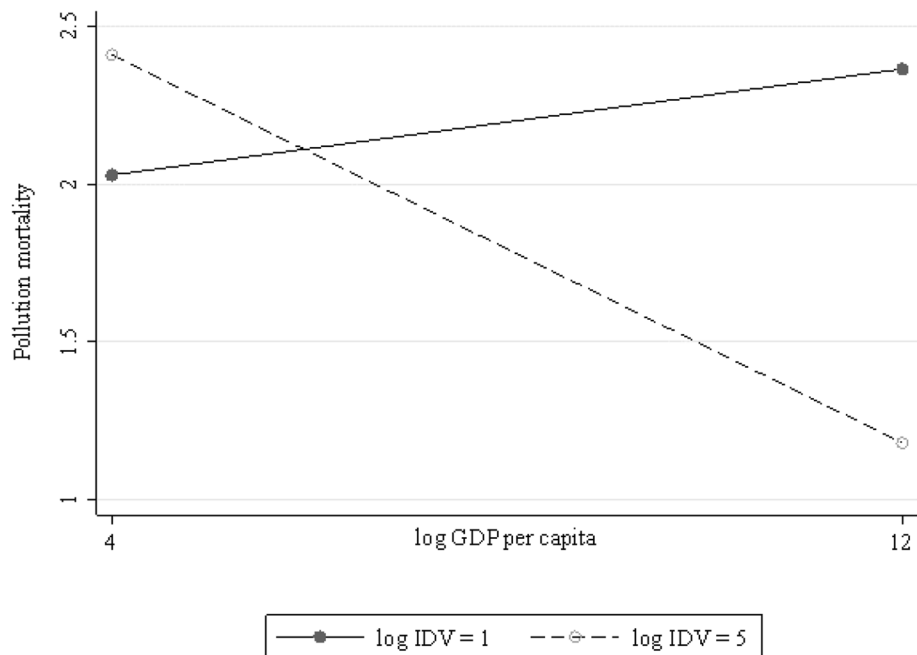


Fig. 4 Interaction plot: GDP & IDV. *Note:* The interaction of IDV shifts the dashed line to the right, implying that the post-interaction (high individualism) effect decreases the pollution mortality rates

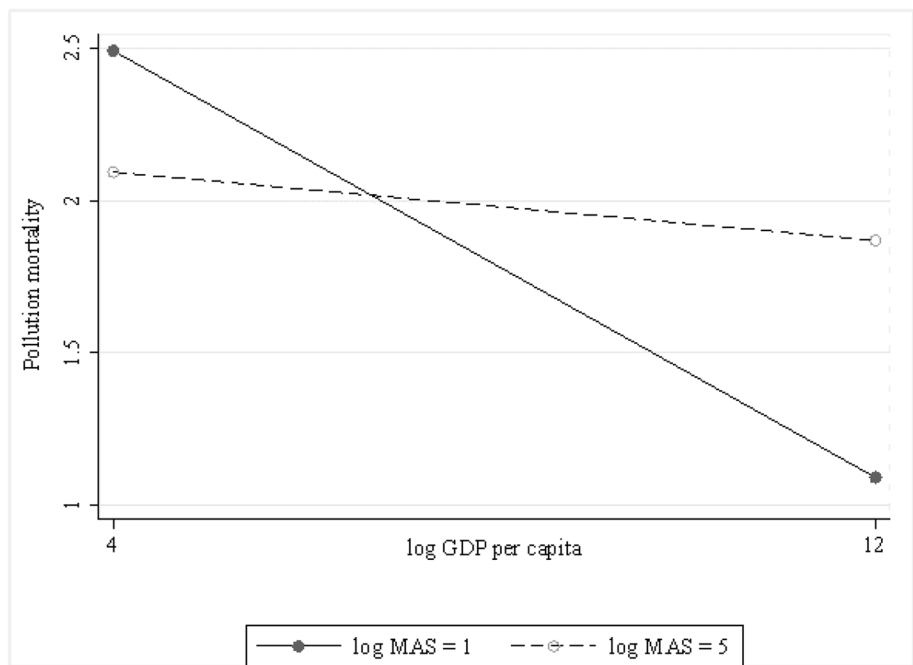


Fig. 5 Interaction plot: GDP & MAS. *Note:* The interaction of MAS shifts the dashed line to the left, implying that the post-interaction effect (high masculinity) increases the pollution mortality rates

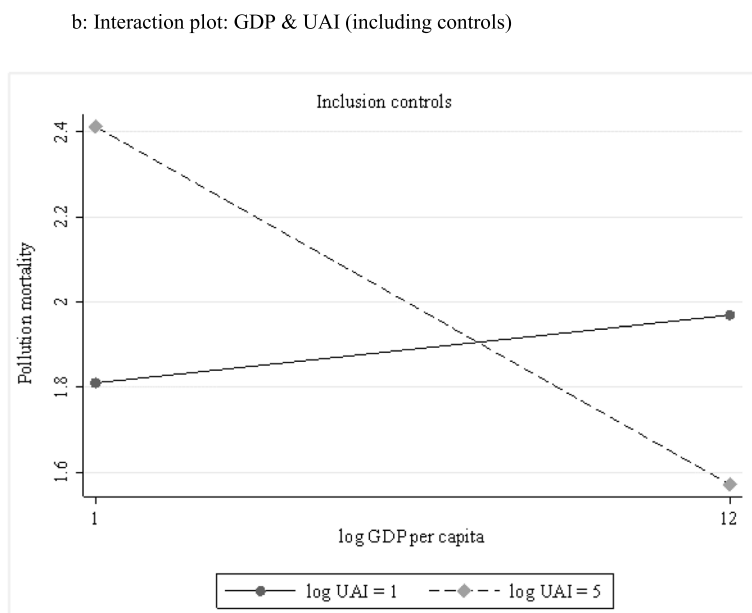
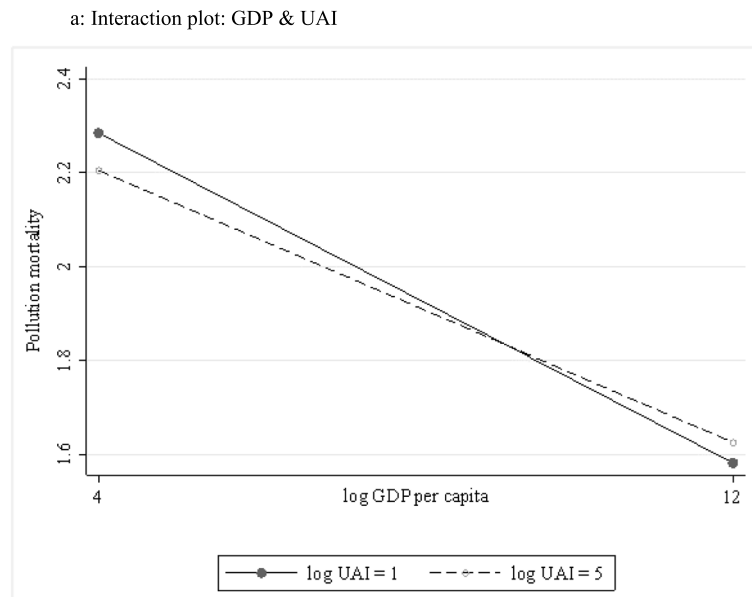


Fig. 6 **a** Interaction plot: GDP & UAI. Note: The interaction of UAI shifts the line to the left, implying that the post-interaction effect increases the pollution mortality rates. The proximity between the two lines shows a small difference. After adding the control variables changes the direction of UAI. **b** Interaction plot: GDP & UAI (including controls). Note: With the inclusion of controls, the UAI interaction shifts the dashed line from the left to the right, indicating decreased pollution mortality

- High individualism reduces pollution mortality across all levels of GDP.
- High masculinity increases pollution mortality across all levels of GDP.
- Uncertainty avoidance reduces pollution mortality at moderate GDP levels but has a neutral effect at extremes.

- High long-term orientation reduces pollution mortality at moderate and high levels of GDP.

While these directional correlations support the moderation hypotheses, additional insights can be gleaned from plots of these interactions.

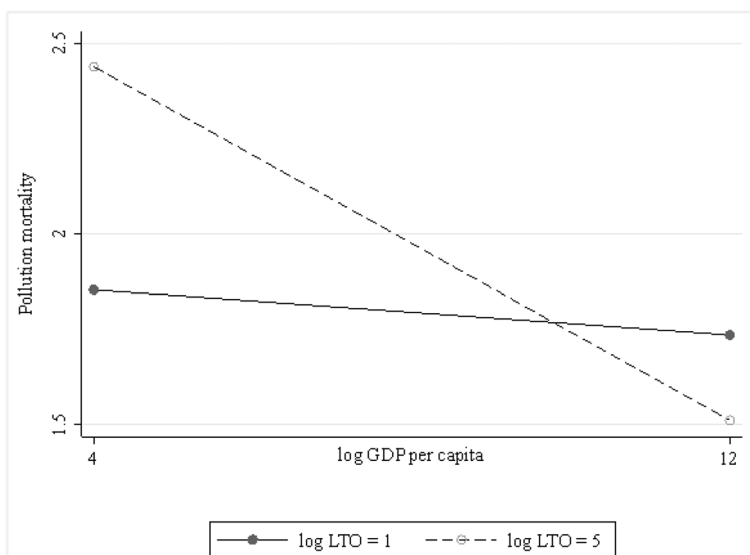


Fig. 7 Interaction plot: GDP & LTO. *Note:* The interaction of LTO shifts the line to the right, implying that the post-interaction effect decreases the pollution mortality rates

Figure 2 presents the plot of GDP per capita linear versus quadratic fitted lines. The quadratic curve indicates concavity, suggesting that an increase in the wealth of low-income countries increases pollution mortality, while pollution decreases as countries become richer. This overall trend supports the Environmental Kuznets Curve (EKC), wherein economic growth initially leads to increased pollution mortality, followed by a subsequent decrease.

Figure 3 illustrates the interaction plot between wealth (log GDP) and power distance (log PDI). The dashed interaction line shifts to the left, indicating that the post-interaction effect leads to an increase in pollution mortality rates.

Figure 4 displays the interaction line between individualism-collectivism and log GDP per capita. The interaction of IDV shifts the dashed line to the right, indicating that the post-interaction effect (high individualism) decreases the pollution mortality rates.

Figure 5 displays the interaction between masculinity-femininity and log GDP per capita. The interaction of MAS shifts the dashed line to the left, implying that the post-interaction effect (high masculinity) increases the pollution mortality rates.

Figure 6 displays the interaction plot between log GDP and log UAI, where the post-interaction (dashed line) of the UAI shifts to the left, implying that the post-interaction effect increases the pollution mortality rates. However, the proximity between the two lines suggests a slight difference. After adding the control variables, these

differences shift the dashed line from left to right, indicating that high UAI levels decrease pollution mortality.

Figure 7 illustrates the interaction between log GDP and log LTO. The interaction (dashed line) of LTO shifts to the right, implying that the post-interaction effect decreases the pollution mortality rates.

5 Discussion

Following extensive research on the EKC and recent developments on cultural moderation between economic growth and pollution, some authors have shown that environmental hazards lead to high pollution mortality rates (Vohra et al. 2021). We explored pollution mortality from the perspective of national wealth creation (economic growth) and cultural moderation. This research question motivated answers in two steps.

First, the direct formulation of the question enabled us to draw the EKC curve as the baseline model for comparison. Second, the indirect formulation of the question helped us assess whether the post-interaction curvilinear correlations differed from the pre-integration (GDP growth alone). Our findings answer both questions systematically and robustly.

The direct correlation between economic growth (GPD per capita) and pollution mortality shows a curvilinear shape. While the literature reports that the EKC forms an inverted U-shape, our mortality EKC forms an arch-shape. This concavity in the arch-shaped curve suggests that the increase in economic growth initially increases pollution mortality, and then it begins to decrease. This

Table 5 Multilevel Models (Mixed Methods); log GDP²

Variables	(1)	(2)	(3)	(4)	(5)
Constant	3.2179*** (.5829)	.4214 (.5261)	1.3478** (.5603)	.7935 (.5816)	.6605 (.547)
Corruption	-.0212*** (.0082)	-.0242*** (.0082)	-.0284*** (.0083)	-.0291*** (.0083)	-.0308*** (.0083)
Suicide	.1139*** (.0132)	.1225*** (.0131)	.1376*** (.0134)	.1475*** (.0134)	.1386*** (.0131)
GDP ²	-.0243*** (.0022)	.0069*** (.0013)	-.007*** (.0014)	-.0015 (.0021)	.001 (.0012)
PDI	-.2571*** (.0956)	.1939** (.0778)	.2375*** (.0807)	.2431*** (.0813)	.2462*** (.0803)
IDV	-.1452** (.0633)	.1112 (.0692)	-.1493** (.0643)	-.1526** (.0647)	-.149** (.064)
MAS	.1237** (.0484)	.1306*** (.0472)	.0603 (.06)	.1408*** (.0495)	.1378*** (.0489)
UAI	-.0506 (.0661)	-.0503 (.0646)	-.0423 (.0672)	.0116 (.0812)	-.0391 (.0668)
LTO	.0407 (.0463)	.0371 (.0453)	.0311 (.0471)	.0293 (.0474)	.1267** (.0526)
GDP ² *PDI	.0048*** (.0005)				
GDP ² *IDV		-.0032*** (.0004)			
GDP ² *MAS			.0008** (.0004)		
GDP ² *UAI				-.0006 (.0005)	
GDP ² *LTO					-.0013*** (.0003)
L2 Var(const.)	-1.396*** (.0771)	-1.420*** (.0775)	-1.381*** (.0774)	-1.373*** (.0775)	-1.385*** (.0774)
L1 Var (residual)	-2.660*** (.0166)	-2.655*** (.0166)	-2.639*** (.0166)	-2.638*** (.0166)	-2.642*** (.0166)

Dependent variable: Pollution mortalities = % of total death in the country
 GDP per capita = log-squared
 N = 1908
 L2 Var(const.) = estimated log of between-countries standard deviation: Variance of the means of intercepts
 L1 Var (residual) = estimated log of residual (within-countries) standard deviation; Variance of the means entities
 Based on interclass correlation test (ICC) and Likelihood ratio test
 *** $p < .01$, ** $p < .05$, * $p < .1$

arch-shaped curve of economic growth and pollution mortality answers the first question.

The second question associated with national cultural moderation draws on prior research, which suggests that rich countries tend to reduce pollution (Grossman and Krueger 1995), and national culture shifts the EKC (Disli et al. 2016). We tested five cultural moderators; except for the uncertainty avoidance interaction, four of them

Table 6 Preview of the findings

Variables	Direct effects	Moderation GDP	Moderation GDP ²
GDP per capita	-		
PDI (power distance)	+	-	+
IDV (Individualism)	-	-	-
MAS (masculinity)	+	+	+
UAI (Uncertainty avoidance)		-	
LTO (long-term orientation)		-	-

Power distance shifts from negative (-) to positive (+) correlation; Individualism (-), Masculinity (+) and Long-term orientation (-) are consistent

support the proposed direction of the correlation after the interaction effects.

The preview in Table 6 reveals the support and consistency of that support for the hypothesis. First, high power distance and high GDP growth increase pollution mortality rates, suggesting that high GDP and low power distance reduce pollution mortality rates. Individualist countries decrease pollution mortality, and collectivist countries increase pollution mortality. Masculinity increases pollution mortality, and femininity decreases it. Uncertainty avoidance-tolerance culture shows indifference to high or low pollution mortality. Lastly, long-term orientation decreases pollution mortality, and short-term orientation increases it. Thus, high PDI and MAS cultures behave similarly to increase pollution mortality, and high IDV and LTO cultures behave similarly to reduce pollution mortality.

Several explanations support the moderating effect of power distance on pollution mortality through wealth creation. Power distance generates inequality in wealth, health, and social integration. A recent example comes to the fore from the health crisis in India and the suffering of the lower strata. In the face of the COVID pandemic in 2021, inequalities have exposed the suffering of the lower strata of the population (Saxegaard et al. 2023). Power distance compromises integrity and fosters corruption (Ariely and Uslaner 2017; Bapuji et al. 2018; Jong-sung and Khagram 2005; Katic and Ingram 2018). High power distance culture is notorious for the flow of information towards innovation, environmental management, and response to a health crisis. In addition, high power distance adversely affects subjective well-being (Bochner and Hesketh 1994; Summereder et al. 2014), which translates into morbidities and mortalities. Thus, power distance has a negative influence on both sides of the equation—wealth and health.

Likewise, high masculinity culture increases pollution mortalities directly, and at the same time, high

masculinity increases wealth creation. On the one hand, the high masculinity culture increases economic growth, and on the other hand, high masculinity increases pollution mortality. Compared to the power distance cultural differences, the masculine culture increases national wealth through economic growth, but high masculine cultures also increase pollution morbidities and mortalities. The prior literature finds that power distance and masculinity shift the interaction line to the left, suggesting an increase in carbon emissions (Disli et al. 2016). Compared to the analysis in this literature, we show a nuanced analysis of the cultural moderators' pollution mortalities.

On the opposite, individualism (IDV) and long-term orientation (LTO) show positive implications for wealth creation; however, high IDV and LTO cultures increase pollution mortalities. Appendices B and C show a positive correlation with wealth creation and pollution mortality. The literature on the EKC analysis shows similar findings of carbon emissions from individualism and long-term orientation (Disli et al. 2016). Individualist countries support economic growth, which translates into reduced pollution mortality. Likewise, long-term oriented countries support economic growth, which translates into R&D investment, infrastructure development, and pollution control mechanisms.

While the above-listed findings agree with the literature, the uncertainty avoidance dimension differs from the previous literature. The prior literature indicates that high uncertainty avoidance shifts the interaction line to the right, implying a decrease in carbon emissions (Disli et al. 2016). Instead, our findings show conditional support to this literature, depending on the other cultural dimensions. Without the controlled effects of different cultural dimensions, the uncertainty avoidance culture shifts the pollution mortality curve to the left, suggesting an increase in mortality rates. With the control variables introduced in the analysis, the higher uncertainty avoidance line shifts to the right, implying a decrease in pollution mortality. Hence, uncertainty avoidance varies due to other cultural and institutional factors.

The study makes a threefold contribution to the literature. Firstly, this study attends to pollution morbidities and mortalities in the world. Pollution mortality has become a much more severe threat to human life than previously thought (Vohra et al. 2021). Secondly, this study contributes to the cultural perspective in shaping economic and natural phenomena. National culture influences natural phenomena through climate change and an evolutionary pattern in human biology, morbidities, mortalities, and adaptation. National culture influences the attention structure, setting the direction of people's behavior. Thirdly, this study implies that

economic dynamics are inevitable for human progress; morbidities and mortalities are preventable. The broader level of education needs to align with cultural change to achieve behavioral change at the prevention and curing stages in the wealth-pollution relationship.

While this investigation concludes a robust analysis, we list some limitations for future studies. Firstly, formal institutions (law and regulations) influence both sides of the equation. Neither the earlier literature has explored, nor has this study addressed these issues. Secondly, the wealth creation of nations comes from STEM (science, technology, engineering, and mathematics), but arts and humanities are absent from the literature and this study. Thirdly, the pollution effect and mortality follow two roots in the food chain—the economic wealth root and the pollution root. The economic wealth root refers to intentional food safety and security issues, and the pollution root refers to the climatic conditions in the natural evolution. Lastly, more data analysis is required to strengthen the findings for theoretical and practical purposes elaborated in this study.

Authors' contributions

All the authors read and approved the final manuscript.

Declarations

Competing interests

The author has no conflict of interest of any kind related to this review article.

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