Pakistan Journal of Commerce and Social Sciences
2019, Vol. 13 (1), 180-208
Pak J Commer Soc Sci

Environmental Degradation and Output Volatility: A Global Perspective

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Abstract

This study examines the link between environmental indicators and output volatility unlike the previous literature that mainly emphasized the importance of carbon emissions and economic growth nexus. Output uncertainty is considered a serious global issue as it undermines economic gains and quality of life. This study scrutinizes the impact of greenhouse gas emissions on output volatility in 155 countries over the period 1971-2017. The empirical analysis is based on Pooled Ordinary Least Squares, Random and Fixed Effects Models. The empirical results confirm that carbon dioxide (CO_2), nitrogen oxide (NO_X), methane (CH_4), and total greenhouse gas (GHG) emissions are positively contributing to amplify global output volatility. Moreover, the Principal Component Analysis (PCA) of pollutant indicators also confirms the main results. Comparatively carbon emissions are contributing more to augment output volatility. A comparative analysis also reveals that all pollutants augment output volatility more in agricultural economies. The results of Granger causality confirm the bidirectional causality between environmental degradation and output volatility providing an evidence of endogeneity problem. To address it, the system GMM estimator is used by incorporating the instruments in output volatility model and the results of system GMM are also consistent with main findings. Findings of the study imply that a promising path of sustainable growth can be achieved by adopting the alternative ways of energy resources that produce less pollutant relative to greenhouse gasses.

Keywords: output volatility, environmental degradation, greenhouse gases, GDP per capita, CO_2 emissions, NO_X emissions, CH_4 emissions.

1. Introduction

Economic history of the world is full of macroeconomic fluctuations providing the evidence of ups and down in growth rates. In this perspective, the outlook of British South Sea Bubble in 1711, the oil price shock of 1973 (Kindleberger, 2000), the global financial crisis (2007-2008), and African low-income debt crisis of 2018 present some evidence of macroeconomic cycles which put devastating effects on respective economies by dampening growth rates.

Major changes in output growth make the economic environment riskier. Recent work has shown that vulnerability in growth rate hampered the growth of economic indicators and led to huge social costs (Turan and Iyidogan, 2017) by increasing the risk for the poor and uncertainty in economic policy; worsening institutional quality, level of investment, consumption, and total factor productivity (Cariolle, 2012). Therefore, achieving high growth rates as well as maintaining stable growth rates have become the fundamental policy objectives of the economies (Majeed, 2017; Majeed and Ayub, 2018).

Particularly, output volatility is higher in poor countries (Hakura, 2009) and they are more often exposed to external shocks (Cariolle, 2012). Other factors like country's risk sharing mechanism, and supportive financial system also play an important role in affecting growth volatility. Thus, a nation's exposure to economic uncertainty is motivated by numerous factors, which depend on structural changes as well as the level of economic expansion in an economy (Hnatkovska and Loayza, 2003).

Many studies have explored several causes of output volatility. The studies have linked output volatility with economic growth (Badinger, 2010), terms of trade uncertainty (Hakura, 2009), trade openness (Briguglio, 2018; Mohey-ud-Din and Siddiqi, 2018), financial development (Hakura, 2009; Majeed and Noreen, 2018), and inflation volatility (Hart, 2008; Majeed and Noreen, 2018). Moreover, the literature also distinguishes population (Popov, 2011; Mobarak, 2004), government expenditures (Moradbeigi and Law, 2014) and government type (Mobarak, 2004) as determinants of output volatility.

Output volatility also depends on changes in ecosystem. The literature recognizes that environmental degradation has a negative impact on economy's growth (Hu, 2017) and environmental risk increases growth uncertainty. However, surprisingly, the links of climate changes with output volatility have received little attention in applied environmental sciences. Generally, studies focus on growth effects of environmental changes and provide diverse evidence on the links of environment changes with economic growth and development.

Some studies do point out that high volatility is linked with natural disaster which is aggravated by climatic variations and rising sea level (Briguglio, 1995; Commonwealth Secretariat, 2000; Gounder and Xayavong, 2002). However, these studies do not present any empirical support to untangle the links of climate change with output fluctuations.

Recently, some research reports highlighted the production uncertainties in agrarian economies as a consequence of climate changes. For example, Food and Agriculture Organization of the United Nations (FAO) (2016) stated that climate change is a key driver of severe food crises as hunger arose significantly in agriculture dependent economies where drought caused more than 80 percent of the losses in agriculture sector. In addition, theses climate shocks contribute to environmental degradation in the form of deforestation, reduction of quantity and quality of ecosystem services, and biodiversity loss.

Similarly, some research reports highlighted the issue of unsustainable development as a consequence of environmental degradation. According to World Economic and Social Survey (2013), unsound production and consumption structure in developing countries create a challenge regarding sustainable development. The effect on agriculture sector in developing economies becomes more critical with extreme weather conditions, droughts, and reduction of arable land. The loss of major crops, such as wheat and maize, in this regard is considered a huge cutback to the agriculture sector development (Lobell et al., 2011).

Air pollution like dust, fumes, gases, and smoke are harmful not only for humans, but for plants, animals, and property as well. Consequently, economic opportunities shrink, and huge losses are observed in physical and natural capital along with the long lasting deterioration of human capital. Despite the essence of this critical issue the impact of environmental degradation on output volatility remains a neglected area in economic research. Therefore, the purpose of this study is to estimate the possible impact of environmental degradation on output volatility.

This study contributes to the literature by exploring the links between environmental degradation and output volatility unlike previous literature that mainly emphasized the importance of environmental degradation and economic growth nexus. Secondly, to the best of our knowledge, this is the first study of its kind that empirically determines the output volatility effect of environmental degradation using a large panel data set of 155 countries from 1971 to 2017. Thirdly, this study employs different measures of environmental degradation that are carbon dioxide, nitrogen oxide, methane, and total greenhouse gas emissions. Finally, this study also takes care of the problem of endogeneity.

The study endeavors to test the following two hypotheses: (i) environmental degradation tends to increase output volatility (ii) the impact of environmental degradation varies depending upon the determinants used to measure environmental degradation. The study finds that pollutant emissions contribute significantly in increasing output volatility. Findings of the study imply that pollutant emissions need to be controlled by investing in alternative sources of energy consumption (i.e. renewable energy), providing a business-friendly environment and supporting those industries which are adopting environmental-friendly technology.

The remaining paper is organized as follows: Section 2 presents the survey of relevant studies. Section 3 delineates data, methodology and statistical analysis. Section 4 presents the estimated results and a detailed discussion on empirical findings. Finally, Section 5 concludes the study with some policy implications.

2. Literature Review

The theoretical foundation of this study draws on three strands of the literature. The first strand identifies the causes of business cycle fluctuations with the perspective of different school of thoughts. According to classical school of thought, an economy always remains in equilibrium and no disequilibrium exists because of market forces. However, the event of ‘Great Depression’ revealed the flaws in classical thinking and Keynesian school of thought emerged. Keynesian argued that wages and prices are sticky and fluctuations in business cycles comes from the changes in demand side factors such as changes in consumption, investment, government spending and net exports.

Following the stagflation of 1970s, however, real business cycle (RBC) theory appeared as alternative to Keynesian’s theory of business cycles. The RBC models suggest that an economy experiences macroeconomic fluctuations due to technological shocks that is random fluctuations in productivity level. Examples of such shocks include innovations, bad weather, changes in raw material prices, and stricter environmental rules and regulations.

The second strand of the literature relates the environment with economic growth and output volatility. In this regard the Sun-spot theory was proposed by Stanley Jevons in 1875. The Sun-spots (created by extreme atomic explosion on the surface of the sun) affect weather conditions on earth and create uncertainty in the agriculture output as well as in the industrial output through its input-output association with agriculture sector. Hence, fluctuations in weather conditions first affect agriculture output and then spread the uncertainty in the whole economy.

According to ecological modernization theory moving towards environmentalism can increase overall economy's gain. The theory was developed in the early 1980s by the group of scholars at Free University and the Social Science Research Centre in Berlin who argued that just like capital and labor productivity environmental productivity (efficient use of natural resources) can be regarded as an important source of future economic growth. The core of the theory revolved around the environmental preservation by the use of environmental-friendly energy resources and green technologies that also help in controlling for greenhouse gas emissions.

Moreover, in the theoretical context an inverted U-shaped relationship exists between environmental degradation and economic development represented by Environmental Kuznets Curve (EKC). The empirical literature regarding the validity and significance of the EKC remains functional since the beginning of the 1990s. This comply with the influential works of Grossman and Krueger (1995), Shafik and Bandypadhyay (1992), Panayotou (1993) and Selden and Song (1994).

Lastly, theoretical foundations of this study are also based on some other theoretical arguments. Armstrong and Read (2002) and Gounder and Xayavong (2002) argue that rising issue of climate change and rising sea level are the major causes of environmental degradation that create economic uncertainty. The effects of global warming are also alarming in the case of agriculture economies. Global warming increases the crops optimum temperature and decreases the crops yield. The loss in crop yield negatively affects the famer's earning and leads to overall uncertainty in the agriculture output (International Monetary Fund, 2008). Similarly, variations in export earnings caused by natural disaster hamper growth of economics by increasing the economic dependence and output volatility.

Deforestation also puts huge cost on economy by worsening the ecosystem, environmental services, individual's earnings and livelihood. Losses in forest area and biodiversity contribute to macroeconomic volatility by creating uncertainty in tourism industry. Moreover, land and water degradation is also related with the loss of agriculture productivity (Jouanjean et al., 2014). Aggravation in soil quality also generates uncertainty in agriculture production and total factor productivity by lessening the income and consumption level along with increasing the earning risks and production cost (Moser and Barrett, 2006). Moreover, tropical cyclone creates vulnerability in agriculture, forestry, and fishery sector output (Kunze, 2018).

The third strand of the literature relates output uncertainty with economic indicators such as financial development, diversification opportunities, terms of trade, uncertainty in economic policy and trade openness. For example, Acemoglu and Zilibotti (1997) identify the role of diversification opportunities in affecting output volatility. They argue that in the initial stages of development of an economy diversification opportunities are very limited with undividable risky investment projects, slowing down the capital accumulation and creating high economic uncertainties in the growth process of poorer countries. Secondly, the large part of saving is invested in safer and unproductive projects which make the growth process random. In contrast, countries that grasp "good draws" in the initial stages are capable to diversify risk associated with remarkable projects and accumulate capital, thereby achieving stable growth.

Rodrik (1999) postulates a model in which exogenous shocks such as terms of trade shock increase domestic social conflicts, and as a result nations with weaker institutional quality of conflict management experience growth collapse. Moreover, author also shed light on the significance of government regimes in affecting the growth process that is an autocratic regime output may be more volatile than democratic regime due to the mediating effect of discretionary power regarding policy alteration. Similarly, uncertainty in economic policies is also considered as an important determinant of output volatility (Clarida et al., 2000; Cecchetti et al., 2006). Some studies distinguish the probable channels through which policy uncertainty affects growth and its volatility. At micro level, firm related unpredictability adds to the cost of capital and manager's risk aversion level (Panousi and Papanikolaou, 2012) which lead to the disfigurement in overall financing and investment policies and increase moral hazard problems. On the whole, consumption, saving and investment decisions are sensitive to policy uncertainty and these decisions alter resource allocation system leading to higher growth instability (Levine and Glover, 2017).

Theoretical affiliation between trade openness and output volatility is not well clear in the existing literature. Higher openness results in higher financial fragility and increases growth volatility in poor countries (Tornell et al., 2003). However, it may offset the effect of country specific shocks and mitigate the output fluctuations (Krebs et al., 2010). Empirical studies identify openness (Agenor et al., 2000; Easterly et al., 2001; Bejan 2006), structural reforms in labor market regulations (Kent et al., 2005), structural, institutional, and policy variations (Agenor et al., (2000); Malik and Temple, 2009) as determinants of growth volatility in developing countries. In contrast, Burger (2008) shows that reduction in household consumption, lowers vulnerability in investment in the industrial sector and well-defined monetary policy is linked with higher growth stability.

On the empirical ground, there is no empirical study about environmental degradation-output volatility nexus and most of the studies covered the economic growth-environmental degradation dimension along with few studies that focused on natural disasters as a source of economic fluctuations. Regarding the studies related to growth, until recently, there have been three research groups looking economic growth-environmental degradation nexus. The first group found the unidirectional causal relationship between growth and environmental degradation. Largely, these studies supported the validity of EKC and detect one way causality between CO_2 emission and economic growth (Isik et al., 2017; Majeed, 2018). The second group of the studies observed the bidirectional relationship between economic growth and environmental degradation. For France, Germany and USA Kum et al. (2012), for Malaysia Saboori and Sulaiman (2013) find the evidence of two-way causal relationship between economic growth and environmental degradation. These studies conclude that environmental degradation such as resource depletion slows down the growth process and puts negative consequences on economy's growth. Finally, the third group of the studies found no causality between environmental degradation and economic growth. In this perspective, the neutrality hypothesis is confirmed by Ocal et al. (2013) and Alvarado and Toledo (2017) for the case of Turkey and Ecuador, respectively.

Some studies identify natural disaster as a determinant of growth uncertainty. Using a panel data of South Pacific Island economies from 1971 to 2003, Gounder and Saha (2007) concluded that natural disasters, openness, export dependence, debt and narrow export basket tend to reduce economic growth. They found out that higher fluctuations in GDP per capita are caused by production uncertainty in agriculture as well as in manufacturing sectors. Similarly, using panel VAR model and the data of Latin American countries over the period 1974-2004, Raddatz (2008) concluded that external shocks including natural disasters are the main causes of macroeconomic fluctuations.

In sum, the theoretical literature illustrates the negative effects of environmental degradation on macroeconomic volatility. Mainly, the Sun-spot theory and RBC theory consider that environmental degradation caused by weather variations is a key source of output fluctuations. The empirical literature predominantly emphasizes the negative growth effects of environmental degradation and concluded that environmental deterioration hampers the growth of the economies. However, few research reports and studies on natural disaster highlight the role of environmental degradation in macroeconomic fluctuations. But, the systematic research on environmental degradation-output volatility relationship is ignored in the literature. The present study adds to the existing literature by analytically exploring and empirically determining the links of environmental indicators with output volatility.

3. Data and Methodology

We have developed a model to find the impact of environmental degradation on output volatility based on the literature. The literature provides evidence that not only volatility of terms of trade and inflation, trade openness, country size, and government consumption affect output volatility rather we need to incorporate the effect of environmental degradation that also plays an important role in affecting output volatility. Following the study of Bhoola and Kollamparambil (2011) and output volatility literature we have developed following regression model for the empirical investigation:

$$\mathrm{LOV_{it}} = \beta_0 + \beta_1 \mathrm{ED_{it}} + \beta_i \mathrm{X_{it}} + \mathrm{v_i} + \mu_t + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots (1)$$

Where, t represents the time period from 1971 to 2017. β_0 represents the intercept term. LOV represents the log of output volatility measured through the five years standard deviation of the annual GDP per capita based on constant 2010 US dollar (see Ramey and Ramey, 1995; Hakura, 2009; Malik and Temple, 2009; Majeed and Noreen, 2018, Briguglio, 2018). ED represents the environmental degradation. β1 is the slope coefficient, measuring the impact of change in environmental degradation on output volatility. The term X_{it} represents the row matrix including all other variables other than the focused variables that can cause change in output volatility. The term v_i is a country specific unobservable effect, and μ_t is a time specific factor. The term ε_{it} is the error term that captures the effect of all omitted variables. The subscripts i and t denote country and time period, respectively.

We exploit the dynamic panel data model by introducing the lag of dependent variable as independent variable because output volatility depends on the effect of economic uncertainty of the lag period (see Dabla-Norris and Srivisal, 2013). In the case of output volatility, the effect is long lasting and current output volatility depends on the effect of lag period (Piper, 2015). To account the role of monetary sector and real sector uncertainties, inflation and terms of trade volatility are incorporated in the model. The effect of terms of trade shock varies depending on the nature of economy. Economies with higher trade liberalization suffer more from terms of trade shock as it has direct effect on trade sector which is transmitted to the whole economy (Beck et al., 2006). Rumler and Scharler (2011) identify positive relationship between terms of trade shocks and output volatility in economies with high trade union density while a negative association in economies having managed and coordinated labor markets. The nature of relationship also depends on the flexibility of exchange rate as the flexibility of exchange rate helps to offset the effect of external shocks.

Regarding monetary sector shocks literature demonstrates both positive and negative relationship between inflation volatility and output volatility. Higher output volatility is associated with high inflation in the case of aggregate demand shocks while inverse relationship holds in the case of aggregate supply shocks (Hart, 2008). However, the broader view is that high fluctuations in inflation lead to higher output volatility in the economies. Trade openness increases the output volatility by putting the economy into external shocks (Tornell et al., 2003). On the other hand, high product diversification may help to stabilize the growth of an economy (Haddad et al., 2013).

The effect of country size is also controlled using the proxy of population growth. A large economy having large resource base tends to mitigate the output volatility (Furceri and Poplawski, 2008). The effect of fiscal policy is also controlled using the proxy of government consumption. The discretionary fiscal policy causes higher output uncertainty in an economy (Hakura, 2009). Equation 2 represents all variables included in the row matrix (X_{it}).

$$X_{it} = \beta_2 LOV_{it-1} + \beta_3 VTOT_{it} + \beta_4 LVINF_{it} + \beta_5 TO_{it} + \beta_6 POPG_{it} + \beta_7 GC_{it} \ldots.. (2)$$

Here, LOV (t-1) is the lag of output volatility; VTOT is the volatility of terms of trade. VINF is the volatility of inflation and TO is the trade openness. POPG is the population growth used as a proxy of country size and finally GC is the general government final consumption.

To scrutinize the empirical relationship between environmental degradation and output volatility we incorporated the various measures of environmental degradation. Most studies have used traditional measure of environmental degradation as CO_2 emission (see Isik *et al.*, 2017; Majeed, 2018). We have estimated the following five regression models incorporating four measures of environmental degradation and the index of CO_2 emissions, nitrogen oxide emissions and methane emissions represented by term PCA in equation 1.5.

$$LOV_{it} = \beta_0 + \beta_1 LCO2_{it} + \beta_i X_{it} + v_i + \mu_t + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots (1.1)$$

$$LOV_{it} = \beta_0 + \beta_1 LNO_{it} + \beta_i X_{it} + v_i + \mu_t + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots (1.2)$$

$$LOV_{it} = \beta_0 + \beta_1 LME_{it} + \beta_i X_{it} + v_i + \mu_t + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots (1.3)$$

$$LOV_{it} = \beta_0 + \beta_1 LGGE_{it} + \beta_i X_{it} + v_i + \mu_t + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots (1.4)$$

$$LOV_{it} = \beta_0 + \beta_1 PCA_{it} + \beta_i X_{it} + v_i + \mu_t + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots (1.5)$$

Where LCO_2 is the log of emissions of carbon dioxide measured in metric ton per capita, LNO is the log of nitrogen oxide emissions equivalent to thousand metric ton of CO_2, LME represents the log of the emissions of methane which are equivalent to kt of CO_2 and LGGE shows the log of total greenhouse gas emissions. Lastly, we have incorporated the PCA of three measures of environmental degradation namely, CO_2 emissions, nitrogen oxide emissions and methane emissions.

3.1. Econometric Methodology

This study covers the sample of 155 countries over the time period 1971-2017 using the data of World Bank (2018). The sample size is limited to 155 countries because of data limitations. We have used OLS, fixed effects, random effects and panel Granger causality test for assessing the relationship between environmental degradation and output volatility. Furthermore, the system GMM is also used to address the endogeneity problem. Table 1 provides the description of data utilized for empirical analysis.

Table 1: Variable Description, Transformation and Data Sources

Var.	Description	Definition of Variables	Source
Dependent Variable			
OV	Five year SD of GDP per capita (Constant 2010 US$)	"GDP per capita is gross domestic product divided by midyear population. It is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets."	World Bank (2018)
Independent Variables (Control Variables)			
VTOT	Five year SD of TOT calculated using export and import values.	"Export/Import values are the current value of exports/imports (f.o.b.) converted to U.S. dollars and expressed as a percentage of the average for the base period (2000)."	World Bank (2018)
VINF	Five year SD of inflation, consumer prices (annual %)	"Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly."	World Bank (2018)
TO	Trade (% of GDP)	"Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product."	World Bank (2018)
POPG	Population growth (annual %)	"Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage."	World Bank (2018)
GC	General government final consumption expenditure	"Annual percentage growth of general government final consumption expenditure based on constant local currency. Aggregates are based on constant 2010 U.S. dollars."	World Bank (2018)
Different Measures of Focused Variables (Environmental Degradation)			
CO_2	CO_2 Emission (metric tons per capita)	"Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring."	World Bank (2018)
NO	Nitrous oxide emissions	"Nitrous oxide emissions are emissions from agricultural biomass burning, industrial activities, and livestock management."	World Bank (2018)

ME	Methane emissions	"Methane emissions are those stemming from human activities such as agriculture and from industrial methane production."	World Bank (2018)
GGE	Total greenhouse gas emissions	"Total greenhouse gas emissions in kt of CO2 equivalent are composed of CO2 totals excluding short-cycle biomass burning (such as agricultural waste burning and Savannah burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peat lands), all anthropogenic CH4 sources, N2O sources and F-gases (HFCs, PFCs and SF6)."	World Bank (2018)

3.2. Descriptive Statistics

Table 2 reports the results of descriptive statistics. The minimum value of output volatility is 10.42 for Burundi while maximum value is 4818.3 for UAE. The maximum value of CO2 emissions is 52.83 for Qatar while a minimum value is 0.033 for Burundi. Likewise, the minimum values for NOx and methane are 0.844 and 17.209 for the case of Macao and Seychelles while maximum value is 340422.3 and 581102.67 for USA, respectively. The GGE takes the maximum value of 6287868.8 for USA whereas the minimum value is 249.56 for Cabo Verde.

Table 2: Descriptive Statistics

Variables	Obs.	Mean	Median	Max	Min	S.D
Volatility of Output	3290	475.11	165.13	4818.3 (UAE)	10.42 (Burundi)	740.05
CO_2	3290	4.167	1.803	52.83 (Qatar)	0.03 (Burundi)	5.715
NO_x	3290	19243.86	5135.08	340422.3 (USA)	0.844 (Macao)	46934.8
Methane	3290	44413.68	11569.6	581102.67 (USA)	17.209 (Seychelles)	102766.6
Greenhouse Gases	3290	269689.2	54218	6287868.8 (USA)	249.56 (Cabo Verde)	777688.4
Volatility of TOT	3290	13.78	9.116	209.91 (Sierra Leone)	1.072 (Netherland)	18.663
Volatility of Inflation	3290	50.80	2.777	1315.13 (Congo, Dem. Rep)	0.949 (Tunisia)	502.15
Trade	3290	81.47	69.85	343.24 (Singapore)	20.565 (Brazil)	52.704
Population	3290	1.716	1.759	7.84 (UAE)	-0.41 (Latvia)	1.431
Govt. Consumption	3290	4.712	3.031	87.09 (Zimbabwe)	-3.48 (Tajikistan)	19.000

3.3. Correlation Matrix

Table 3 presents of variables used for empirical analysis. All measures of environmental degradation have positive correlation with output volatility. Comparatively, CO_2 has the highest correlation (0.62) while methane has the lowest correlation (0.008).

Table 3: Correlation Matrix

	OV	CO2	NO	GGE	ME	VTOT	VINF	TO	POPG	GC
OV	1									
CO_2	0.61	1								
NO	0.03	0.19	1							
ME	0.008	0.17	0.93	1						
GGE	0.10	0.30	0.92	0.86	1					
VTOT	-0.15	-0.17	-0.07	-0.08	-0.07	1				
VINF	-0.04	-0.04	0.048	0.02	0.043	0.11	1			
TO	0.36	0.17	-0.27	-0.27	-0.22	-0.05	-0.05	1		
POPG	-0.14	-0.02	-0.08	-0.08	-0.12	0.23	0.005	-0.03	1	
GC	-0.02	-0.04	-0.01	-0.008	-0.02	-0.002	-0.06	0.04	0.10	1

4. Results and Discussion

4.1. Results of Pooled OLS

Table 4 reports the results using Pooled OLS technique. The results show that CO_2 emissions, nitrogen oxide, methane emissions, and greenhouse gas emissions have positive sign, indicating that an increase in these pollutant emissions augments output volatility. The effect of CO2 emissions is relatively stronger (0.0591) than the effects of methane emissions (0.0120) and total greenhouse gas emissions (0.0162). Moreover, nitrogen oxide has a minute effect (0.0067) on output volatility. This signifies that higher pollutant emissions are associated with higher climate change and global warming. Consequently, environmental degradation triggers that, in turn, augments growth uncertainty by exposing economies to natural shocks. Environmental degradation increases output volatility by increasing household's poverty level, creating loss of production and assets, and inducing food price shocks (Hallegatte et al., 2015, 2016).

The positive impact of environmental degradation on output transmitted through the loss of human and natural capital. Environmental degradation deteriorates the resource productivity that is spread of garbage, pollution of ground water resources and blocked drains result in poor health. In the same way, depleted soils can lead to risks of malnutrition for farmers and productivity losses mainly due to transportation channels, siltation of reservoirs, and other hydrologic investments. Air pollution like dust, fumes, gases, and smoke are harmful not only for humans, but also for plants, animals, and property (Gwangndi et al., 2016).

Environmental degradation increases the unpredictability in production due to the loss in land productivity or the direct damage of land as the result of floods and hurricanes. In some regions the issues of water shortages and extreme drought also arise. Such changes increase the overall growth volatility in the economy (FAO, 2016).

The lag of output volatility shows that 1 percent increase in volatility of previous year increases growth uncertainty by more than 90 percent in all estimated models. The parameter estimates on volatility of TOT show that one percent rise in VTOT increases OV by 0.001 percent. This result is consistent with the findings of Gavin and Hausmann (1996) and Andrews and Rees (2009). The terms of trade variations have a noticeable effect on investment and trade through the relative prices of import and export. This shock largely depends on the international shocks which are uncontrollable and have an effect on domestic demand, investment and growth and finally on growth fluctuations.

Table 4: Results of Pooled OLS Regression

Dependent Variable: Volatility of Output (1971-2017)					
Variables	(1)	(2)	(3)	(4)	(5)
CO_2	0.0591***				
	(0.000)				
NO_X		0.0067*			
		(0.071)			
Methane			0.0120***		
			(0.002)		
Greenhouse Gases				0.0162***	
				(0.000)	
PCA					0.0123**
					(0.048)
Volatility of Output t-1	0.9100***	0.9576***	0.9563***	0.9509***	0.9564***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of TOT	0.0009***	0.0007**	0.0008**	0.0009***	0.0006*
	(0.003)	(0.043)	(0.022)	(0.008)	(0.070)
Volatility of Inflation	-0.0209***	-0.0281***	-0.0289***	-0.0292***	-0.0277***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0004***	0.0005***	0.0006***	0.0007***	0.0005***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population	-0.0197***	-0.0269***	-0.0277***	-0.0298***	-0.0277***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Govt. Consumption	0.0012***	0.0010***	0.0010***	0.0010***	0.0010***
	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)
Constant	0.4414***	0.1834***	0.1302***	0.0884***	0.2493***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Observations	3283	2968	2968	2849	2967
R-squared	0.9543	0.9544	0.9545	0.9542	0.9545
Adjusted R-squared	0.9542	0.9543	0.9544	0.9540	0.9544
F-Statistics	9738.79***	8866.5***	8866.2***	8457.2***	8878.2***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Link Test	-0.0022	0.0028	0.0028	0.0015	0.0026
	(0.304)	(0.226)	(0.216)	(0.514)	(0.260)
VIF	1.40	1.25	1.25	1.25	1.19
Wooldridge's Test	656.95***	551.92***	549.58***	492.65***	548.50***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
BPG Test	87.92***	101.44***	100.99***	97.90***	101.34***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1)					

The results show that one percent increase in VINF decreases OV by 0.02 percent. This is because of the central bank's commitment towards minimum inflation volatility that leads to lower growth uncertainty. Therefore, countries that use monetary policy more often and more insistently experience a plunge in growth uncertainty. Inflation and output move in the similar direction as a result of aggregate demand shocks, while they follow opposite path in the case of aggregate supply shocks. Thus, depending on the type of uncertainty/shock, central bank faces different trade-offs (Hart, 2008). This finding is consistent with the findings of Lee (1999) and Majeed and Noreen (2018).

The impact of trade on output volatility is positive and statistically significant at one percent level of significance. This finding is in line with the conclusion drawn by Easterly et al. (2001) and Giovanni and Levchenko (2009). They argued that trade openness augments volatility by exposing the country to external shocks. Tornell et al. (2003) argued that trade openness leads to higher financial vulnerability which increases growth uncertainty.

Shocks in economy also depend on the size of economy. Most common measure of economy size is population (Tamirisa, 1999; Mobarak, 2004). The result reveals that higher population growth tends to reduce output volatility. This result favors the findings of Furceri and Poplawski (2008) who argued that larger country size signifies a large endowment and resource base that help to sustain growth.

Regarding the role of government consumption Keynes considers fiscal policy as an effective tool for economic stabilization whereas New Classical Economists regard fiscal policy as source of destabilizing the economy. Our results confirm positive and significant impact of government consumption on output volatility. This finding is consistent with the empirical findings of Hakura (2009) who also concluded that discretionary fiscal policy plays a role in increasing the output volatility in emerging economies.

Furthermore, the results show that R^2 take the value of 0.95 indicating that 95 percent variation in output volatility is explained by the independent variables. The Link test concludes that functional form is correctly specified in all models as P values of hat square are greater than the significance level. Moreover, the problem of multicollinearity is not detected as VIF is less than 10 in all models. The results of Wooldridge's test show the presence of first order autocorrelation in all models. The Breusch-Pagan-Godfrey (BPG) test shows that the problem of heteroskedasticity is present which is addressed using robust regressions and system GMM.

4.2. Results of Fixed Effects Model

OLS is based on very restrictive assumptions and disregard the significant country and temporal effects. The problem of unobserved country specific fixed and random effects is addressed using fixed effects and random effects models. Table 5 provides the empirical results of the fixed effects model which assumes that each cross section differs in its intercept term. The results show that all measures of environmental degradation tend to augment output volatility. Overall, main results are not much sensitive to fixed effects and variables carry the correct signs. Note that the volatility effect of all environmental turns out to larger in the case of fixed effects indicating that OLS underestimated the impact of environmental degradation on output volatility. Regarding the choice of model we have applied the Hausman test assuming the null hypothesis of fixed effects model is appropriate. In all models P<0.1 leading to the conclusion that fixed effects model is preferred over random effects model.

Table 5: Results of Fixed Effects Model

Dependent Variable: Volatility of Output (1971-2017)					
Variables	(1)	(2)	(3)	(4)	(5)
CO_2	0.0606***				
	(0.005)				
NO_X		0.0223			
		(0.422)			
Methane			0.0533***		
			(0.086)		
Greenhouse Gases				0.0453***	
				(0.019)	
PCA					0.0409
					(0.160)
Volatility of Output t-1	0.7840***	0.7844***	0.7821***	0.7776***	0.7841***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of TOT	0.0018***	0.0020***	0.0020***	0.0021***	0.0020***
	(0.008)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of Inflation	-0.0322***	-0.0379***	-0.0367***	-0.0367***	-0.0378***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0007**	0.0008***	0.0008***	0.0008***	0.0008***
	(0.010)	(0.004)	(0.000)	(0.008)	(0.004)
Population	-0.0329***	-0.0452***	-0.0441***	-0.0465***	-0.0437***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Govt. Consumption	0.0009***	0.0010***	0.0010***	0.0010***	0.0010***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.000)
Constant	1.0890***	0.9432***	0.6495***	0.6630***	1.1242***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Observations	3283	2968	2968	2849	2967
R-squared	0.9593	0.9610	0.9610	0.9608	0.9611
Adjusted R-squared	0.9572	0.9588	0.9588	0.9585	0.9588
F-Statistics	457.81***	432.8***	433.1***	423.3***	433.3***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1)					

4.3. Results of Random Effects

Table 6 reports the empirical results of the random effects model which assumes that each cross section differs in its error term. The results show that all measures of environmental degradation including their combined effect (PCA) tend to enhance output volatility.

Table 6: Results of Random Effects Model

Dependent Variable: Volatility of Output (1971-2017)					
Variables	(1)	(2)	(3)	(4)	(5)
CO_2	0.0591***				
	(0.000)				
NO_X		0.0067*			
		(0.057)			
Methane			0.0120***		
			(0.001)		
Greenhouse Gases				0.0162***	
				(0.000)	
PCA					0.0123**
					(0.037)
Volatility of Output t-1	0.9100***	0.9576***	0.9563***	0.9509***	0.9564***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of TOT	0.0009***	0.0007**	0.0008**	0.0009***	0.0006*
	(0.003)	(0.033)	(0.016)	(0.005)	(0.057)
Volatility of Inflation	-0.0209***	-0.0281***	-0.0289***	-0.0292***	-0.0277***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0004***	0.0005***	0.0006***	0.0007***	0.0005***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population	-0.0197***	-0.0269***	-0.0277***	-0.0298***	-0.0277***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Govt. Consumption	0.0012***	0.0010***	0.0010***	0.0010***	0.0010***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Constant	0.4414***	0.1834***	0.1302***	0.0884***	0.2493***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Observations	3283	2968	2968	2849	2967
R-squared	0.9543	0.9544	0.9545	0.9542	0.9545
Adjusted R-squared	0.9542	0.9543	0.9544	0.9540	0.9544
F-Statistics	9770.79***	7381.9***	8866.2***	8457.2***	8878.2***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hausman Test	267.077***	350.832***	347.378***	338.341***	348.94***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1)					

4.4. Results of Penal Granger Causality Test

To detect the direction of causality between environmental degradation and output volatility, stacked causality test of Granger (1969) is applied. The results are presented in

Table 7. The null hypothesis of panel Granger causality test is that CO_2, NO, ME, and GGE do not cause OV which is rejected at 1, 5, 10 and 1 percent level of significance, respectively. All indicators of environmental degradation significantly lead to variation in output growth. In addition, fluctuations in output also cause environmental degradation. Thus, bidirectional causality exists between different indicators of environmental degradation and output volatility.

Table7: Results of Penal Granger Causality Test

Null Hypothesis	F-Statistic	Probability	Decision	Conclusion
LCO_2 does not Granger Cause LOV	154.105	0.0000	LCO_2→LOV	**LCO_2↔LOV**
LOV does not Granger Cause LCO_2	17.2214	0.0000	LOV→LCO_2	
LNO does not Granger Cause LOV	3.30684	0.0367	LNO→LOV	**LNO↔LOV**
LOV does not Granger Cause LNO	6.99414	0.0009	LOV→LNO	
LME does not Granger Cause LOV	2.53944	0.0790	LME→LOV	**LME↔LOV**
LOV does not Granger Cause LME	10.2024	0.0000	LOV→LME	
LGGE does not Granger Cause LOV	5.75036	0.0032	LGGE→LOV	**LGGE↔LOV**
LOV does not Granger Cause LGGE	6.40793	0.0017	LOV→LGGE	

4.5. Results of System GMM

The system GMM is applied to resolve the problem of endogeneity. The results are presented in Table 8. The effect of CO_2 emissions remains stronger in all estimated models relative to other pollutant emissions. The results show that one percent increase in CO_2 emissions, total greenhouse gas emissions and methane emissions increase output volatility by 0.0591 percent, 0.0165 percent and 0.0139 percent, respectively. The volatility effect of nitrogen oxide is relatively small (0.008) as compared to other pollutants. Overall, empirical findings support the Sun-spot and RBC theories.

Table 8: Results of System GMM

Dependent Variable: Volatility of Output (1971-2017)					
Variables	(1)	(2)	(3)	(4)	(5)
CO_2	0.0591***				
	(0.000)				
NO_X		0.0080**			
		(0.055)			
Methane			0.0139***		
			(0.000)		
Greenhouse Gases				0.0165***	
				(0.000)	
PCA					0.0121**
					(0.061)
Volatility of Output $_{t-1}$	0.9088***	0.9352***	0.9337***	0.9495***	0.9564***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of TOT	0.0009***	0.0006**	0.0007**	0.0010***	0.0006*
	(0.003)	(0.080)	(0.041)	(0.006)	(0.070)
Volatility of Inflation	-0.0194***	-0.0329***	-0.0340***	-0.0270***	-0.0254***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0004***	0.0007***	0.0008***	0.0006***	0.0005***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.006)
Population	-0.0237***	-0.0379***	-0.0389***	-0.0343***	-0.0314***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Govt. Consumption	0.0012***	0.0010***	0.0010***	0.0010***	0.0011***
	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)
Constant	0.4522***	0.2952***	0.2352***	0.0983***	0.2582***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Observations	3250	2928	2928	2797	2935
R-squared	0.9543	0.9548	0.9549	0.9544	0.9545
Adjusted R-squared	0.9542	0.9547	0.9548	0.9543	0.9544
Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1)					

4.6. Sensitivity Analysis

To check the robustness of empirical findings, sensitivity analysis is conducted using additional four control variables namely broad money, foreign direct investment, personal remittances and official exchange rate. Table 9 shows that the impact of CO_2 emissions remains same, highly significant across all sensitivity variables. Similarly, the positive impact of nitrogen oxide and methane emissions on output volatility remains intact in all estimation, respectively. Likewise, greenhouse gasses continue to increase output volatility significantly. Overall, the results of sensitivity analysis suggest that the variables of study are robust and not sensitive to additional control variables.

Table 9: Sensitivity Analysis of Variables

Sensitivity Variables				
Variables	**Broad Money**	**Foreign Direct Investment**	**Personal Remittances**	**Official Exchange Rate**
Dependent Variable: Volatility of Output (1971-2017)				
CO_2	0.0580***	0.0590***	0.0524***	0.0596***
	(0.000)	(0.000)	(0.000)	(0.000)
R-Squared	0.9481	0.9536	0.9548	0.9515
NO_x	0.0081*	0.0065*	0.0070*	0.0074*
	(0.051)	(0.084)	(0.096)	(0.055)
R-Squared	0.9480	0.9537	0.9552	0.9512
Methane	0.0142***	0.0118***	0.0086**	0.0127***
	(0.000)	(0.002)	(0.043)	(0.001)
R-Squared	0.9481	0.9538	0.9552	0.9513
Greenhouse Gases	0.0019***	0.0161***	0.0014***	0.0017***
	(0.000)	(0.000)	(0.000)	(0.000)
R-Squared	0.9465	0.9534	0.9556	0.9504
PCA	0.0162**	0.0122*	0.0121*	0.0124*
	(0.013)	(0.051)	(0.053)	(0.052)
R-Squared	0.9481	0.9538	0.9552	0.9513
Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1) The data for all sensitivity variables is extracted from world Bank (2018).				

4.7. Comparison across Agriculture and Industrial Economies

The literature exerts that macroeconomic volatility in developing (agriculture) counties is much larger than the developed (industrial) economies (Loayza et al., 2007; Easterly et al., 2001; Hakura, 2009). To assess the heterogeneity of volatility effect of greenhouse gases, we have used agriculture value addition and manufacturing value addition as interactive variables for environmental indicators. The results show that output volatility caused by environmental degradation is relatively higher in agriculture economies than industrial economies (see Table 10 &11). The parameter estimates on CO_2 emissions imply that one percent increase in CO_2 emissions leads to 0.009 percent and 0.003 percent increase in output volatility in agriculture and industrial economies, respectively.

The effects of greenhouse gas emissions and methane emissions also remain stronger and significant relative to nitrogen oxide that has a minute effect on output volatility in both economies. However, the coefficient of NO becomes larger in the case of agrarian economies. The results show that agriculture economies are much sensitive to external, domestic, and natural shocks as compared to industrial economies. The agriculture countries are more often prone to external/exogenous shocks that may come from terms of trade shocks, weather variations and fluctuations in financial markets. Therefore, agrarian economies often experienced higher fluctuations in economic growth as compared to industrial countries (Loayza et al., 2007). Agrarian economies largely depend on the environmental sensitive sectors such as forestry, agriculture, and tourism. Thus, variations in environmental quality directly impact these sector and lead to higher macroeconomic uncertainly (International Monetary Fund, 2008). Moreover, trade openness in the presence of weak financial markets in developing economies makes the economy highly volatile.

In contrast, industrial economies have strong institutions including well-established and well-developed financial markets that provide a better risk-sharing mechanism and raise the welfare and offset the negative effect of trade openness (Broner and Ventura, 2011). In addition, the problem of moral hazard is much severe in agrarian economies that creates biasness in debt contracts and increases the risk of liquidity crisis and macroeconomic uncertainty (Kharroubi, 2006).

Table 10: Analysis of Agrarian Economies

Dependent Variable: Volatility of Output (1971-2017)					
Variables	(1)	(2)	(3)	(4)	(5)
CO_2*Agriculture	0.0090***				
	(0.000)				
NO_X*Agriculture		0.0022***			
		(0.000)			
Methane*Agriculture			0.0028***		
			(0.000)		
GHG* Agriculture				0.0028***	
				(0.000)	
PCA* Agriculture					0.0010
					(0.212)
Volatility of Output t-1	0.8931***	0.9525***	0.9351***	0.9290***	0.9564***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of TOT	0.0009***	0.0007	0.0008	0.0009**	0.0002
	(0.000)	(0.165)	(0.107)	(0.057)	(0.576)
Volatility of Inflation	-0.0190**	-0.0252***	-0.0250***	-0.0232***	-0.0276***
	(0.012)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0002**	0.0006***	0.0007***	0.0007***	0.0003***
	(0.043)	(0.004)	(0.000)	(0.008)	(0.013)
Population	-0.0232***	-0.0242***	-0.0271***	-0.0272***	-0.0285***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Govt. Consumption	0.0012***	0.0011***	0.0011***	0.0011***	0.0010***
	(0.000)	(0.002)	(0.001)	(0.003)	(0.002)
Constant	0.5162***	0.1434***	0.1118***	0.1096***	0.2693***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Observations	2634	2326	2326	2259	2326
R-squared	0.9572	0.9581	0.9584	0.9586	0.9578
Adjusted R-squared	0.9571	0.9580	0.9582	0.9584	0.9576
F-Statistics	8400.5***	7587.7***	7631.4***	7449.6***	7519.1***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)

Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1)
The data for all agriculture value addition is extracted from world Bank (2018).

Table 11: Analysis of Industrial Economies

Dependent Variable: Volatility of Output (1971-2017)					
Variables	(1)	(2)	(3)	(4)	(5)
CO_2*Industry	0.0028***				
	(0.000)				
NO_X*Industry		0.0002***			
		(0.041)			
Methane*Industry			0.0003***		
			(0.004)		
GHG*Industry				0.0004***	
				(0.000)	
PCA* Industry					0.0003
					(0.270)
Volatility of Output t-1	0.9051***	0.9534***	0.9320***	0.9483***	0.9545***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Volatility of TOT	0.0006**	0.0004	0.0005	0.0007*	0.0003
	(0.046)	(0.202)	(0.144)	(0.068)	(0.372)
Volatility of Inflation	-0.0169***	-0.0245***	-0.0247***	-0.0248***	-0.0244***
	(0.012)	(0.000)	(0.004)	(0.000)	(0.000)
Trade	0.0003***	0.0004***	0.0005***	0.0005***	0.0003***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.004)
Population	-0.0229***	-0.0291***	-0.0297***	-0.0315***	-0.0303***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Govt. Consumption	0.0010***	0.0008***	0.0008**	0.0008**	0.0008***
	(0.000)	(0.010)	(0.011)	(0.012)	(0.009)
Constant	0.4779***	0.2262***	0.2035***	0.1956***	0.2832***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Observations	2940	2639	2639	2542	2638
R-squared	0.9540	0.9545	0.9546	0.9544	0.9545
Adjusted R-squared	0.9539	0.9544	0.9544	0.9543	0.9544
F-Statistics	8695.5***	7891.3***	7903.3***	7589.8***	7892.1***
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
Probability values are in parentheses (*** p<0.01, ** p<0.05, * p<0.1) The data for all manufacturing value addition is extracted from world Bank (2018).					

5. Conclusion

Output volatility has always been a concern for policymakers as it creates financial, social and economic hazards in the economy that can badly affect economic development of a nation. The concern of output volatility stems not only from the requirement to maintain overall macroeconomic steadiness, but also from the fact that it further creates many economic and social problems. The present study investigates the impact of environmental degradation on output volatility using the penal data set of 155 countries over the period 1971-2017. The output volatility has been used as dependent variable. Environmental degradation is proxied using CO_2 emissions, nitrogen oxide emissions, methane emissions and total greenhouse gas emissions.

The findings of pooled ordinary least squares, random effects and fixed effects models show that all incorporated measures of environmental degradation tend to magnify output volatility. CO_2 emissions play more prominent role in enhancing output volatility as compared to other pollutant emissions. Moreover, bidirectional causality is detected between all environmental indicators and output volatility giving rise to the endogeneity problem. To address this issue, system GMM is applied which provides robust estimates and deals with the issue of endogeneity, heteroskedasticity and autocorrelation. The results of system GMM also confirm the main findings of the present study.

5.1 Contribution of the Study

The systematic research on environmental degradation and output volatility remains the neglected area in economic literature. To the best of our knowledge, this study is the first attempt in this field that fulfills this research gap. The existing literature generally considers CO_2 emission as an indicator of environmental degradation (Alvarado and Toledo, 2017, Majeed and Mumtaz, 2017). This study incorporates other measures of environmental degradation such as nitrogen oxide, methane emissions, and greenhouse gas emissions, thereby providing a broader view of the relationship. Moreover, this study employs the large panel data set of 155 countries and presents a broader view of relationship in a panel across agrarian and industrial economies. In addition, the present study utilizes the advance technique of system GMM and caters the issue of endogeneity.

5.2 Difference in Agricultural and Industrial Economies

The empirical results confirm that environmental degradation affects output volatility in a different way in the economies having different economic characteristics. The study found out that fluctuations in output are much higher in agrarian economies as compared to industrial economies. It implies that poor countries are more prone to uncertainties relative to advanced countries. The poor countries often lack the funds to adopt new technology (i.e. environmental-friendly technology). Moreover, they also have less capability to absorb the effects of external/global shocks. On the other hand, advanced economies are more powerful to absorb the effect of global shocks as well as have enough resources to adopt new technology which is more efficient and energy saving.

5.3 Theoretical/Policy Implications

This study is motivated by the rising issue of environmental degradation and its worsening impact on the economies. Our findings are consistent with the previous literature (Hallegatte et al., 2015, 2016) and theoretical viewpoints (RBCs Theory, Sun-spot theory) that environmental degradation enhances overall output fluctuations by negatively affecting the weather conditions, crop production, environmental productivity, and human health. This study also supports ecological modernization theory suggesting future sustained growth requires environmental protection. All pollutant emissions enhance output volatility and create an alarming situation for the economies.

The empirical findings of the study suggest following policy recommendations: Overall, reducing harmful emission and protecting the environment is not only the task of government but every individual in a society must play a role in protecting the environment. For this education and information regarding environmental protection need to be provided. Secondly, investment in alternative energy resources such as renewable energy needs to be increased. For this government may provide relaxation to industries which are adopting the alternative ways of energy resources. Thirdly, government may charge a price or fine in polluted area so that individuals become more conscious about environmental protection.

5.4 Limitations of the Study

This study consists of certain limitations. First, it incorporates only pollutant emissions to measure environmental degradation. Second, the study is restricted to the use of lag values as instrument variables. Third, findings of the study provide global perspective while regional perspective is not provided.

5.5 Directions for Future Research

Future research can extend this analysis by incorporating other measures of environmental degradation such as ecological footprint, biodiversity, and land degradation. Moreover, the future research may improve empirical analysis by identifying and analyzing other instruments of environmental degradation.

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Appendix

Table A1: List of Countries

No	Country	No	Country	No	Country	No	Country
1	Afghanistan	40	Czech Republic	79	Kuwait	118	Poland
2	Albania	41	Denmark	80	Kyrgyz Rep.	119	Portugal
3	Algeria	42	Dom. Republic	81	Lao PDR	120	Qatar
4	Angola	43	Ecuador	82	Latvia	121	Romania
5	Armenia	44	Egypt	83	Lebanon	122	Russian
6	Australia	45	El Salvador	84	Lesotho	123	Rwanda
7	Austria	46	Equator. Guinea	85	Liberia	124	Saudi Arabia
8	Azerbaijan	47	Estonia	86	Lithuania	125	Senegal
9	Bahamas	48	Eswatini	87	Luxembourg	126	Serbia
10	Bahrain	49	Ethiopia	88	Macao	127	Seychelles
11	Bangladesh	50	Fiji	89	Macedonia	128	Sierra Leone
12	Belarus	51	Finland	90	Madagascar	129	Singapore
13	Belgium	52	France	91	Malawi	130	Slovak Rep.
14	Belize	53	Gabon	92	Malaysia	131	Slovenia
15	Benin	54	Gambia	93	Mali	132	South Africa
16	Bhutan	55	Georgia	94	Malta	133	Spain
17	Bolivia	56	Germany	95	Mauritania	134	Sri Lanka
18	Bosnia	57	Ghana	96	Mauritius	135	Sudan
19	Botswana	58	Greece	97	Mexico	136	Sweden
20	Brazil	59	Guatemala	98	Moldova	137	Switzerland
21	Brunei	60	Guinea	99	Mongolia	138	Tajikistan
22	Bulgaria	61	Guinea-Bissau	100	Morocco	139	Tanzania
23	Burkina Faso	62	Haiti	101	Mozambique	140	Thailand
24	Burundi	63	Honduras	102	Namibia	141	Togo
25	Cabo Verde	64	Hong Kong	103	Nepal	142	Tunisia
26	Cambodia	65	Hungary	104	Netherlands	143	Turkey
27	Cameroon	66	Iceland	105	New Zealand	144	Uganda
28	Canada	67	India	106	Nicaragua	145	Ukraine
29	Cen. African Rep	68	Indonesia	107	Niger	146	UAE
30	Chad	69	Iran	108	Nigeria	147	UK
31	Chile	70	Ireland	109	Norway	148	USA
32	Colombia	71	Israel	110	Oman	149	Uruguay
33	Comoros	72	Italy	111	Pakistan	150	Vanuatu
34	Congo, Dem.	73	Jamaica	112	Palau	151	Venezuela
35	Congo, Rep.	74	Japan	113	Panama	152	Vietnam
36	Costa Rica	75	Jordan	114	Papua N Guinea	153	West Bank
37	Cote d'Ivoire	76	Kazakhstan	115	Paraguay	154	Yemen
38	Croatia	77	Kenya	116	Peru	155	Zimbabwe
39	Cyprus	78	Korea, Rep.	117	Philippines		