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Asymmetric Effects of Inflation Instability and GDP Growth Volatility on Environmental Quality in the USA

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ABSTRACT

Historically, the USA economy has faced many ups and downs regarding the stability of GDP, growth rate, and exchange rate. We evaluated and analyzed the symmetric and asymmetric effects of macroeconomic volatility on environmental quality in the United States from 1970 to 2019. ARDL and NARDL are used to achieve this goal. By using the secondary data, the findings revealed that inflation uncertainty and GDP volatility have both short- and long-term effects on pollution emissions. When the effect of GDP volatility is captured, the negative shocks of GDP volatility and inflation instability have a positive and significant impact on environmental quality, however when the effect of GDP volatility is captured, severe outcomes are reached. The study also indicate that there were some negligible inflation instability and GDP growth rate volatility coefficients.

Keywords: ARDL, Asymmetric, NARDL, Environmental Quality

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Introduction

Historically, the USA economy has faced many ups and downs regarding the stability of GDP, growth rate, and exchange rate. As we have analyzed the evolutionary process of the USA economy, then we came to know that there were many contractions and recessions faced by the whole economy, since the 1970s. The country has faced macroeconomic instability[1] in the short run, but due to healthy fiscal and monetary policies, the impact was not so prolonged for the economy. The United States has credit limitations in the financial sector and a high debt-to-GDP ratio during the recession. As a result, the country experienced significant macroeconomic instability, high and variable inflation rates, significant output slowdowns, and low economic growth. According to the World Bank (WB), the United States had the highest inflation rate of 5 percent, followed by Canada at 4 percent and Europe at 3.89 percent. According to EKC, as money rises, so does environmental pollution, which rises at first and subsequently falls (Carson et al. 1997). The unit root test for carbon emissions, which are considered as a proxy for environmental quality, is shown in Tables 1 and 2.

[1] It is measured through the variation in macroeconomic indicators like inflation, GDP growth rate, and exchange rate

Table 1: *Defination of Variables*

Parameters	Symbol	Unit of Measure	Data source
Carbon dioxide emissions	CO_2	Kilotons	World Bank
Nitrous oxide emissions	N_2O	Thousand metric tons of CO_2 equivalent	World Bank
Methane emissions	CH_4	Kilotons of CO_2 equivalent	World Bank
Inflation Instability	INFinstab	Inflation variation from its mean values	Author's calculations
GDP growth rate volatility	GDPvolat	Standard deviation of GDP growth rate	Author's calculations
Financial development	FD	Domestic credit to private sector (% of GDP)	World Bank

Table 2: *ERS and PP test Statistics to check the Unit root*

	ERS test statistics			PP test statistics		
Parameters	**Level**	**1st difference**	**Decision**	**Level**	**1st difference**	**Decision**
CO_2	28.55	1.041**	I(1)	− 1.696**		I{0}
N_2O	10.49	1.331**	I(1)	− 0.985	− 6.107**	I{1}
CH_4	38.00	2.372**	I(1)	− 0.066	− 6.458**	I{1}
INFinstab	15.19	0.383	I(2)	− 1.604	-6.578**	I{1}
GDPvolat	1.981**		I(0)	− 4.718**		I{0}
FD	79.390	1.031**	I(1)	− 0.703	− 7.2185**	I{1}

In the last 50 years, the USA economy exhibited many shocks in the form of macroeconomic instability i.e. unstable inflation rate, while the country has adopted healthy policies to cope with the gap created due to unstable inflation. The Federal Reserve Bank was able to achieve this by lowering the discount rate in order to encourage domestic investment in the economy. The US government has neglected the policy's environmental impact by taking this step. Environmental pollution is inevitable, we could not eradicate it but we can mitigate it. USA is the fourth largest country of carbon emitter in the world with 14.6 tons per capita, according to the 2017 rankings by carbon emissions (WDI, 2019).

While there are plenty of publications examining the numerous factors of carbon emissions around the world, with the nexus between energy consumption and the environment having received a lot of attention. According to the findings, an economy's carbon emissions are caused by energy consumption(Ahn et al., 2010; Bilgen, 2014; CARSON et al., 1997). "Another assumption derived from these empirical research is that environmental quality improves as economic growth accelerates (Hakimi & Hamdi, 2016; Li et al., 2015; Orubu & Omotor, 2011). In addition, several research established several variables in the relevant link, such as corruption, industrialization, development, stock market rate, and governance. It goes without saying that these factors play a critical role in the economy and are required for macroeconomic stability. It's also worth noting that the financial industry has a huge impact on environmental quality preservation. According to the theoretical framework, a robust financial sector promotes economic growth by attracting foreign direct investment (FDI) into the local market. Carbon emissions are strongly influenced by the level of financial development. The analysis shows that there is an inverted U-shaped association between carbon emissions and financial development, which maintains even as economic growth increases. Empirical studies also show that the stock market provides a gateway to environmentally friendly technology that have a significant impact on energy consumption and carbon emissions, implying that the financial sector is critical to the energy sector's survival(Li et al., 2015)."

However, there is another school of thought that argues macroeconomic stability has a two-way impact on carbon pollution reduction. In this method, macroeconomic growth variables and ecological resources can be improved. For example, a stable macroeconomic system can reduce the use of nonrenewable energy by businesses that generate more pollution in the country(Hanif & Gago-de-Santos, 2017). An unstable macroeconomic system, on the other hand, restricts the entrance of new businesses, resulting in fewer carbon emissions(Rousseau & Wachtel, 2002). As a result, neither public nor private investors have any motivation to invest in clean and green technologies. Macroeconomic instability, on the other hand, discourages consumer and producer behaviour while improving environmental quality(Ullah et al., 2020).

However, there is significant debate about whether macroeconomic stability has a beneficial or detrimental impact on environmental degradation. The non-linear relationship between these variables is not addressed in the current study. There are many empirical studies to answer this issue i.e. inflation uncertainty (Hossain & Arwatchanakarn, 2016), financial uncertainty(Li et al., 2015), and economic vagueness (Hanif & Gago-de-Santos, 2017); all these studies have worked on ARDL[2] approach that gives rise to the biased problem in the analysis. Inflation instability has symmetric effects on the US economy, according to Hossain's findings, suggesting that an X percent rise in inflation instability leads to a Y percent increase in pollution, and vice versa. However, because this is not the case, this is the first study to take into account the unequal effects of inflation instability and GDP volatility on the US economy's environmental quality from 1970 to 1990. This research examines the environmental literature in a variety of ways. It uses a non-linear or asymmetric ARDL technique to account for the asymmetric effects of inflation and GDP growth rate. Some evidence on the impact of inflation instability on the American economy are also known, but this study takes into account the asymmetric effects of inflation instability on environmental quality in the United States. Finally, from an environmental standpoint, the study indicates some policy implications for industrialised countries.

The literature review is covered in the second section, while the model and technique are discussed in the third. The fourth section will explain the data, while the fifth section will give the results.

Literature Review

The association between macroeconomic instability and pollution emissions is highlighted in the literature. As macroeconomic variables become more volatile, investors procrastinate their decisions, obstructing the transition from renewable to non-renewable energy use (Carson *et al.* 1997). In this way, there is a direct association between economic instability and environmental quality.

There is plenty of empirical data available to study the first half of the literature, namely the bidirectional relationship between economic expansion and environmental degradation. For the United States and Canada, Ahn and Lee (2010) highlight that economic expansion requires sustainable development in the industrial sector through the use of energy consumption, which results in carbon dioxide emissions. As a result, the greater the usage of energy, the greater the development or growth, and the greater the carbon dioxide emission(Ahn *et al.*, 2010). Bilgen (2014) also looked at global energy usage and found that there is a strong link between energy consumption and economic growth. He also mentioned that a lot of work is being done to reduce carbon dioxide emissions as a result of the Kyoto Protocol (Bilgen, 2014). Soyatas and Sori (2007) looked at the effect of the bidirectional relationship between energy consumption and output on carbon emissions. They discovered that, in the long run, income does not drive carbon emissions in the United States, but energy usage does(Soytas et al., 2007). They also determined that income increase is not a concern for carbon emissions in and of itself; many other factors influence carbon emissions. Baek (2016) evaluated the impact of nuclear and renewable energy usage on carbon

[2] Auto regressive distributed lag

dioxide emissions in a dynamic relationship. He used the ARDL approach to capture the short- and long-run effects of nuclear and renewable energy on carbon emissions, and discovered that nuclear energy decreases carbon dioxide emissions in both the long and short runs, whereas renewable energy reduces them in the short run (Baek, 2016). For the G7 countries, Ajmi (2013) discovered a bidirectional causation between energy consumption and carbon emissions, as well as their impact on income (Ajmi et al., 2013). In conclusion, all of the evidence suggests that increasing energy use increases carbon emissions and other pollutants, which create acid rain and the greenhouse effect.

Many other markets, such as the financial sector, are accountable for carbon emissions. “The inverted U-shaped relationship between financial development and carbon emissions was studied by Li (2015). They also mentioned that the level of financial development could help to reduce carbon emissions. Through the financial sector, macroeconomic stability contributes to environmental improvement. According to Haas (2019), financial development and financial structure can reduce carbon emissions in two ways: first, stock market investment reallocates capital to cleaner industries, and second, they allow carbon-intensive firms to produce green patents and reduce their energy intensity (De Haas & Popov, 2019). We can identify the majority of empirical work on both uncertain inflation and economic growth on both theoretical and empirical backgrounds by focusing on the economic growth literature. Lucas (1973) assumes that price instability causes production elements to become less efficient, resulting in shocks in macroeconomic variables and thus improved environmental quality (Lucas, 1973). Similarly, Pindyck and Solimano (1993) found that investment projects are associated with many types of uncertainty, such as inflation and political uncertainty, causing investors to demand a greater rate of return, resulting in slowed economic growth and improved environmental quality (Pindyck et al., 1993). Certain studies also support the idea that inflation uncertainty and capital formation have a negative relationship. Byre and Davis (2004), for example, looked into the dynamic relationship between inflation instability and foreign investments. They discovered that when inflation is unclear, capital accumulation decreases (Pindyck et al., 1993).” Grier (2005) finds that unstable inflation has a negative impact on the physical capital formation in 21 Sub-Saharan African nations (Grier, 2005). According to Friedman (1977), unexpected inflation causes an undesirable distortion in the resource allocation process, reducing the rate of economic growth (Friedman, 1977).

In summary, the previous discussion shows that macroeconomic instability affects environmental pollution through the channels of GDP growth volatility and inflation volatility, although this effect has never been investigated in an asymmetric framework for the United States.

Model Specification

This section constructs a model based on the prior literature. The goal is to figure out what effect inflation and GDP growth rate fluctuation have on environmental quality. Environmental quality is determined by a variety of variables such as carbon and nitrogen emissions, whereas inflation uncertainty, GDP growth volatility, and financial development are among the independent variables.

$$EQ = \alpha 0 + \alpha 1 \text{INFinsbt} + \alpha 2 \text{GDPvolat} + \alpha 3 \text{FD} + \text{V} \tag{1}$$

The environmental quality and white noise error terms are represented by EQ and V, respectively. Because this equation only represents the long-run impact of inflation volatility and GDP growth rate volatility, we will include the following short-run variables, as recommended by Paerson (2001):

$$\Delta EQ_t = \alpha_0 + \sum_{i=0}^{n} \square \Delta EQ_{t-i} + \sum_{i=0}^{n} \beta_0 \Delta INFinstab_{t-i} + \sum_{i=0}^{n} \beta_1 \Delta GDPvolatt_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta FD_{t-i} + \eta_1 EQ_{t-1} + \eta_2\, INFinstab_{t-1} + \eta_3\, GDPvolatt_{t-1} + \eta_4 \Delta FD_{t-1} + u(t) \tag{2}$$

This is the ARDL equation, which has several advantages because it captures both short- and long-term effects at the same time. The multiplicative constant associated with "is the short-run proxy, whereas" signifies the long-run coefficients. As a result, integrating variables are not an issue for this model, and we may utilise it because the integrating order in our data differs from that in Table 1. We will employ the sum procedure method to split GDP volatility and inflation instability into positive and negative components to address the issue of nonlinear ARDL.

$$INFinstab(t)+ = \sum_{i=1}^{n} \Delta \ INFinstab+= \sum_{i=1}^{n} \max(\ INFinstab + (t), 0) \qquad (a)$$

$$INFinstab(t)- = \sum_{i=1}^{n} \Delta \ INFinstab-= \sum_{i=1}^{n} \min(\ INFinstab - (t), 0) \qquad (b)$$

$$GDPvolat(t)+ = \sum_{i=1}^{n} \Delta \ GDPvolat+= \sum_{i=1}^{n} \max(\ GDPvolat + (t), 0) \qquad (c)$$

$$GDPvolat(t)- = \sum_{i=1}^{n} \Delta \ GDPvolat-= \sum_{i=1}^{n} \min(\ GDPvolat - (t), 0) \qquad (d)$$

$$\Delta EQ(t) = \alpha 0 \ + \ \sum_{i=0}^{n} \square \Delta EQ(t-i) + \ \sum_{i=0}^{n} \beta 0 \Delta INFinstab(t-i) + \ \sum_{i=0}^{n} \beta 1 \Delta GDPvolatt(t-i) + \sum_{i=0}^{n} \beta 2 \Delta FD(t-i) + \ \eta 1 EQ \ (t-1) + \ \ \eta 2 \ INFinstab(t-1) + \ \ \eta 3 \ GDPvolat(t-1) + \eta 4 \ FD(t-1) \sum_{i=1}^{n} \max(\ INFinstab + (t), 0) + \sum_{i=1}^{n} \min(\ INFinstab - (t), 0) \ + \sum_{i=1}^{n} \max(\ GDPvolat + (t), 0) \ + \sum_{i=1}^{n} \min(\ GDPvolat - (t), 0) \ + u(t) \ \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \qquad (3)$$

When we add positive and negative limits to the ARDL equation 2 to represent the asymmetric information, we get equation 3 (NARDL) .

The study uses annual data for the United States from 1970 through 2019. Carbon dioxide, methane, and dinitrogen oxide emissions are dependent variables, while inflation instability, or the difference between inflation and its mean value, GDP volatility, which is a proxy for GDP growth rate standard deviation, and financial development, or domestic credit to the private sector, are independent variables (percent of GDP). The information is taken from the World Development Indicator.

Results and Discussion

Using the ARDL approach, we can get both the short and long runs. First, the Akaike Information Criteria are used to make the lag selection decision (AIC). Second, all unit root tests such as Elliot, Rothenberg, and Stock (ERS) and, last but not least, Phillips Peron are used to integrate inflation instability into 2nd order (PP). In contrast, in both tests, all variables are integrated at the same level or first difference.

The model is then linearly estimated, and the results are summarised in Table 3. It summarises both short- and long-term data. The carbon dioxide model is the first in the line. It means that the inflation instability coefficient is insignificant, but the GDP volatility coefficient is statistically significant at 5%. It shows that a 1% rise in GDP volatility results in 423 kilotons of carbon emissions and the discharge of environmentally harmful pollutants into the atmosphere. According to the FD coefficient, a 1% increase in financial development results in 734 kilotons of carbon emissions. This is the evidence to back up the claim that financial development improves the environment for economic activity. As a result, the environment produces fewer contaminants. Sadorsky also agrees with this statement (2011). All coefficients produce beneficial consequences in the long run. INFinstab, GDPvolat, and FD estimations suggest that a 1% increase in each increases carbon emissions by 5509 kilotons, 18978 kilotons, and 14423 kilotons, respectively. The dependent variable in the following model is nitrogen oxide. GDPvoalt and FD have no substantial impact on nitrogen emissions, but inflation instability has a 0.003 percent positive impact on nitrous oxide emissions, implying that a 1% increase in inflation instability corresponds to a 93 thousand metric tonne increase in nitrous oxide emissions. The coefficients in the long run are not significant.

Methane is used as the dependent variable in the last model. Methane emissions are reduced by 670 kilotons and 771 kilotons, respectively, when INFinstab and GDPvolat are increased by 1%. However, the financial boom results in a 445 kiloton rise in methane emissions. The long-run coefficients have no bearing on the situation.

The diagnostic tests are listed in Panel C of the table. First, there are bound F statistics, which validate the long-run estimates' combined importance. The co-integration in the first model was validated by the critical values. The remaining models don't pass the F test or the error correction model test, thus they can't prove it. The LM test reveals that the aforementioned three models have no serial correlation. The RESET is used to double-check the specification. Last but not least, the analysis runs both CUSUM and CUSUMQ tests to ensure that the model is stable, with "S" indicating stability and "US" suggesting unstable behaviour.

The non-linear ARDL approach in Table 4 is then used to capture the asymmetric effects. Panels A and B describe short-run and long-run estimates, respectively. Starting with carbon dioxide, the document shows that positive inflation instability has no effect on carbon dioxide emissions, but negative inflation instability has a considerable impact, meaning that a 1% rise in inflation instability results in a 2000 kiloton increase in carbon emissions. Long-term data shows that a 1% decrease in inflation instability increases carbon emissions. Financial development aids in the reduction of carbon emissions.

Table 3: *ARDL estimation*

	CO_2		N_2O		CH_4	
	Co-efficient Value	S.E	Co-efficient Value	S.E	Co-efficient Value	S.E
Panel A: Short-run Results						
$\Delta INFinstab_t$	0.003	0.001	0.003**	0.001	− 0.060**	0.002
$\Delta GDPvolat_t$	0.012**	0.009	0.004	0.004	− 0.006**	0.002
$\Delta GDPvolat_{t-1}$	− 0.012**	0.001				
ΔFD	0.001**	0.0002				
ΔFD_{t-1}	0.006**	0.001	0.005	0.006	0.008**	0.009
Panel B: Long-run Results						
INFinstab	0.0487*	0.069	0.567	0.170	− 2.891	4.500
GDPvolat	0.175*	0.110	0.0871	0.145	− 2.094	3.079
FD	0.184**	0.0452	− 0.078	0.089	4.097	4.010
Intercept	9.0975**	0.992	12.805**	2.016	− 9.649	9.025
Panel C: Diagnostic tests						
F-Statistic	6.192**		2.692		2.784	
ECM_{t-1}	− 0.458**	0.019	− 0.046	0.064	− 0.041	0.129
LM	0.345		0.031		0.031	
RESET	2.174		0.231		0.612	
CUSUM	S		S		US	
CUSUMSQ	S		S		US	
Adjusted R2	0.1		0.1		0.1	

A. *"Due to the application of annual data, we have a limited number of observations, i.e., 50 hence, the Pesaran (2001) critical values for F tests are not appropriate for a small sample like ours. Therefore, we have picked critical values (4.15 and 5.01 at 10% and 5% significance levels respectively) proposed by Narayan (2005) which are suitable for small samples*(Ullah et al., 2020).*"*

B. *"The test of serial correlation, i.e., LM and the test of misspecification, i.e., RESET have the same $\chi 2$ distribution with one degree of freedom with critical values 2.71 at 10% level of significance and 3.84 at 5% level of significance*(Ullah et al., 2020).*"*

The negative shock of inflation instability has a beneficial impact on pollution levels, meaning that in a stable economic zone, consumers engage in more economic activities, which leads to increased energy consumption by automobiles. Similarly, GDP volatility shocks have a positive influence on pollution, implying that economic stability promotes economic growth and financial development in the United States. The findings also imply that in industrialised countries, GDP volatility is based on fossil fuels. The next model includes nitrous oxide as a dependent variable, implying that a short-run positive shock at the third lag has a positive impact on environmental pollution, and these results are risky for economic activity. Reduced inflation volatility, on the other hand, has a considerable positive influence on nitrous oxide emissions. Furthermore, during the third lag, the GDP volatility coefficient is statistically significant. However, with a scale of 754 metric tonnes as indicated in table 4, this result is not significant for the first lag. Financial development, on the other hand, reduces nitrous oxide emissions by 689 metric tons.

Finally, the macroeconomic model considered environmental quality as a dependent variable by using methane emissions. Increased inflation fluctuation has a short-term detrimental impact on methane gas emissions. The negative coefficient of inflation instability is negative, implying that inflation has a negative impact on environmental quality. Financial development has a big and positive impact on pollution levels. In the long run, however, many variables have no effect on methane emissions.

The different methods to assess the stability of NARDL are discussed in Panel C of Table 4. We confirmed the co-integration of carbon dioxide and nitrous oxide by observing that the long-run results are genuine, based on the F-statistic. The LM, RESET, and CUSUM & CUSUMQ tests were used to verify serial correlation, accurate specification, and model stability. The degree of fit is determined and modified. All models fit quite well, according to R square. The Wald test was used to see if macro indicators have a symmetric or asymmetric effect. The Wald test's short-run results indicated that the environmental quality and our model's independent variables have an unbalanced relationship, since we get insignificant results in the short run. However, in the instance of carbon dioxide emissions, the long-run results for the variable of inflation instability are substantial, demonstrating that positive and negative results have differing effects on pollution. Table 4 and the CUSUM and CUSUMQ graph following demonstrate that the results for nitrous oxide and methane are substantial.

Conclusion

The objective of this research was to assess the symmetric and asymmetric effects of macroeconomic changes on environmental quality in the United States from 1970 to 2019. ARDL and NARDL are used to solve this problem. The findings revealed that inflation uncertainty and GDP volatility have both short- and long-term effects on pollution emissions. When the effect of GDP volatility is captured, the negative shocks of GDP volatility and inflation instability have a positive and significant impact on environmental quality, however when the effect of GDP volatility is captured, severe outcomes are reached. The findings also revealed that there were some negligible inflation instability and GDP growth rate volatility coefficients. Finally, the study discovers that macroeconomic volatility has a short- and long-term impact on environmental pollution. Many important conclusions of the study have been recognised by the empirics. For example, stable inflation can reduce pollution, therefore we can limit pollution emissions by imposing taxes. As a result, the environment's quality can be increased. Another rationale is that stable inflation lowers fossil fuel usage, reducing entropy and improving environmental quality. The government should invest in infrastructure to track the benefits and drawbacks of inflation on environmental quality. We must implement clean and green energy as well as environmentally friendly policies and technologies because GDP growth is the primary goal of every government. To improve environmental quality, the US government should consider the gaps described in this paper. Future research will focus on the various factors that influence pollution levels in the environment. The ARDL approach captures asymmetric impacts, allowing us to obtain reliable and distinct results for macroeconomic instability and pollution. The research added asymmetric effects to the ecological literature, which will be useful in the future.

The purpose of this study was to estimate the symmetric and asymmetric effects of macroeconomic variations on the environmental quality in the USA, over the period 1970-2019. This purpose is achieved by applying ARDL and NARDL. The outcome of these confirmed the short-run and long-run effects of inflation uncertainty and GDP volatility on pollution emissions. The negative shocks of GDP volatility and inflation instability have a positive and significant impact on the environmental quality, while the drastic results are obtained when the effect of GDP volatility is captured. The results also discussed that there were some insignificant coefficients of inflation instability and GDP growth rate volatility. At last, the study finds that macroeconomic instability affects environmental pollution both in the short run and long run. The empirics have identified many key implications of the study. For instance, stable inflation can reduce pollution, so by applying taxes we can minimize the pollution emissions as a result quality of the environment can be improved. Another reason is that stable inflation reduces fossil fuels consumption so that entropy will be mitigated and it upsurges the environmental quality. Government should provide good infrastructure to monitor the pros and cons of inflation on the environmental quality. As GDP growth is the prime objective of every country, so we have to adopt clean and green energy and environmentally friendly policies and technologies. The USA government should consider the loopholes i.e. discussed in this study to flourish the environmental quality. Future studies will look at the different variables that influence environmental pollution. The ARDL technique is useful to capture the asymmetric effects and enable us to get robust results and different results of macroeconomic instability on environmental pollution. The study inserted the asymmetric effects in the ecological literature that will be fruitful in the future.

Table 4: *NON Linear ARDL Estimates*

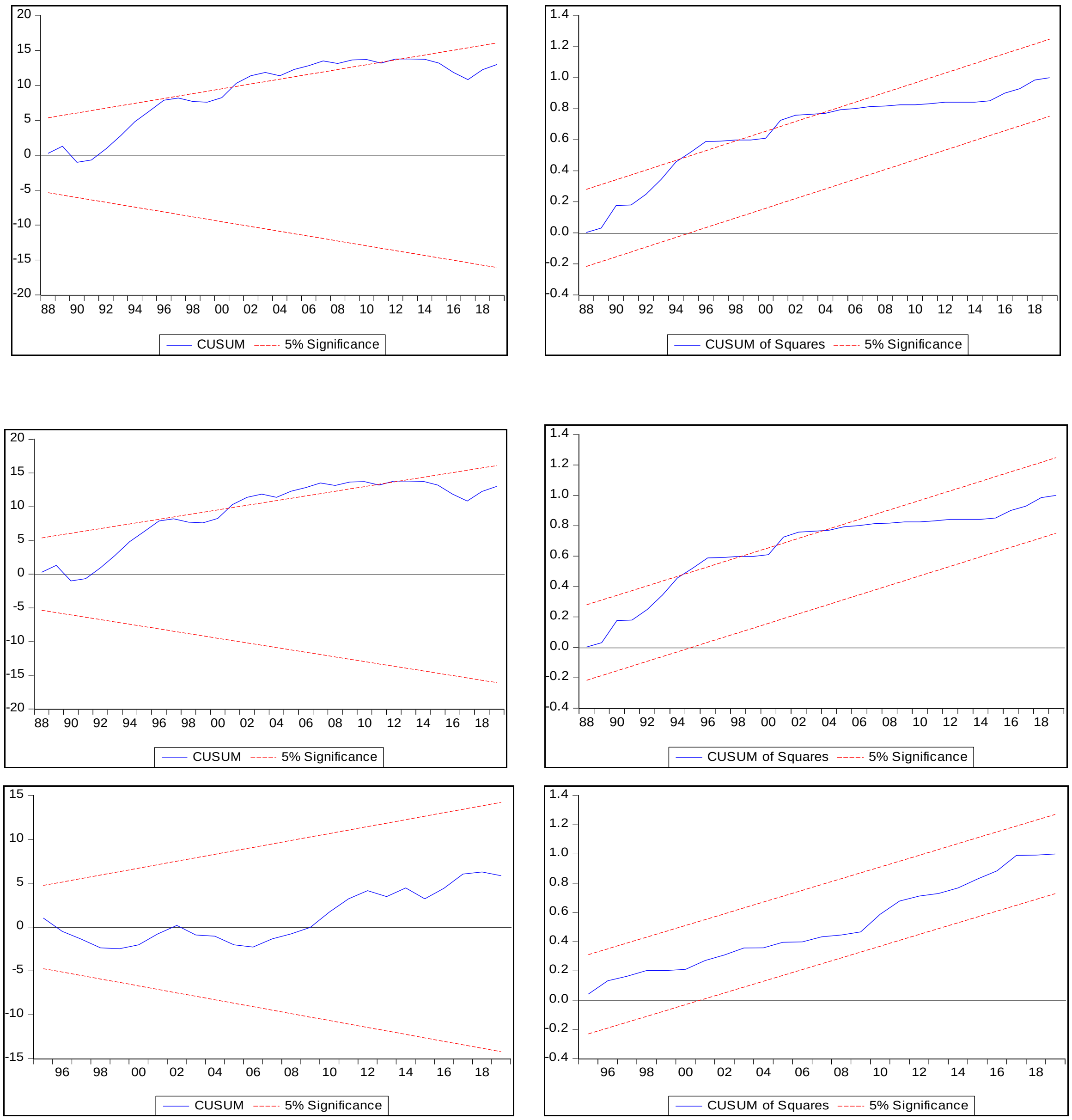
	CO_2		N_2O		CH_4	
	Coefficients	**S.E**	**Coefficients**	**S.E**	**Coefficients**	**S.E**
Panel A: Short-run Results						
$\Delta INFinstab_t^+$	0.000	0.002	0.003	0.004	− 0.001**	0.002
$\Delta INFinstab_{t-1}^+$			0.004	0.007		
			− 0.002	0.005		
$\Delta INFinstab_{t-2}^+$			0.006*	0.003		
$\Delta INFinstab_{t-3}^+$	0.022**	0.006	0.003**	0.003	− 0.003**	0.003
$\Delta INFinstab_t^-$			− 0.005**	0.007		
			0.001	0.006		
$\Delta INFinstab_{t-1}^-$			− 0.013**	0.005		
$\Delta INFinstab_{t-2}^-$	0.004	0.004	0.012*	0.019	0.003**	0.003
			− 0.002	0.007	− 0.003**	0.004
$\Delta INFinstab_{t-3}^-$			0.003	0.005		
$\Delta GDPvolat_t^+$			− 0.023**	0.009		
$\Delta GDPvolat_{t-1}^+$	0.004**	0.007	0.003*	0.018	− 0.004**	0.004
	− 0.025**	0.009	− 0.017**	0.015		
$\Delta GDPvolat_{t-2}^+$	0.027**	0.005				
$\Delta GDPvolat_{t-3}^+$	0.004	0.004	0.003	0.003	0.004	0.003
	0.008	0.009	0.006	0.063	0.064	0.033
$\Delta GDPvolat_t^-$	0.012	0.001	0.002	0.001	0.002	0.001
	0.005	0.003	0.007	0.007	0.008	0.004
$\Delta GDPvolat_{t-1}^-$	0.007	0.006	0.005	0.004	0.002	0.001
$\Delta GDPvolat_{t-2}^-$						
ΔFD_t	0.006**	0.001	− 0.003	0.003	0.009**	0.001
ΔFD_{t-1}			0.002	0.006		
ΔFD_{t-2}			0.008*	0.003		
ΔFD_{t-3}			0.004*	0.002		
Panel B: Long-run Resul						
$INFinstab^+$	0.002	0.011	− 0.001	0.011	0.001	0.014
$INFinstab^-$	0.073*	0.038	0.130**	0.065	− 0.021	0.075
$GDPvolat^+$	0.151*	0.111	0.128*	0.320	− 0.246	0.176
$GDPvolat^-$	0.074	0.071	0.067*	0.086	− 0.043	0.098
FD	0.080*	0.018	− 0.174*	0.077	− 0.054	0.089
Intercept	15.919**	1.12	13.70**	2.262	0.072***	0.127
Panel C: Diagnostic tests						
F	20.001**		14.300**		2.961	
ECM_{t-1}	− 0.072*	0.061	− 1.257**	0.219	− 1.044	0.093
LM	0.29		0.861		3.874*	
RESET	0.36		1.967		2.937	
CUSUM	S		S		S	
CUSUMSQ	S		S		US	
ADJ.R2	0.998		0.978		0.999	
WALD SR-INFinstab	0.677		0.326		0.821	
WALD LR-INFinstab	23.45**		0.312		0.846	
WALD SR-GDPvolat	0.036		0.422		1.535	
Wald LR-GDPvolat	0.054		36.07**		23.78**	

A* “.Due to the application of annual data, we have a limited number of observations, i.e., 50 hence, the Pesaran (2001) critical values for F tests are not appropriate for a small sample like ours. Therefore, we have picked critical values (4.15 and 5.01 at 10% and 5% significance levels respectively) proposed by Narayan (2005) which are suitable for small samples*(Ullah et al., 2020)*.”*

B. *“The test of serial correlation, i.e., LM and the test of misspecification, i.e., RESET have the same* $\chi2$ *distribution with one degree of freedom with critical values 2.71 at 10% level of significance and 3.84 at 5% level of significance*(Ullah et al., 2020)*.”*

C. *“Just like LM and RESET tests the tests of short-run and long-run Wald tests are distributed at* $\chi2$ *with one degree of freedom. So their critical values are also the as we have mentioned in note “B*(Ullah et al., 2020).”

CUSUM & CUSUMQ for CO2, N2O, and CH4



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Conflict of Interest

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