Developing Climate Uncertainty Index and Analyzing its Association with CO2 Emissions in Pakistan

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Climate change is a global issue that existing studies are intensively examining its impact on several economies. Recently, a U.S. climate policy uncertainty index has been created by Gavriilidis, (2021) which led the focus of researchers to utilize it or develop country-specific indices by following a similar methodology of index creation. In the case of Pakistan, no specific index is yet created. Making the first attempt, we aim to create a climate uncertainty index (CUI) for Pakistan by using monthly Google trends data from April 2004 to June 2022. Reaching net zero is one way we can contribute to addressing climate change, which is high on the agenda. In this study, our index will capture important events related to climate policy. When we examine the nexus between climate uncertainty and current global issues like CO2 emissions, environmental degradation, global warming, and other climate-related web searched queries.

Keywords: Climate Change, Google trend, uncertainty, carbon emission (co2), web searched queries

1. Introduction

Climate Change is the major issue of our time and the effects of climate change are worldwide in scope ranging from changing weather patterns that endanger production of food to increasing sea levels that raise the risk of massive flooding. Future adaptation to these effects will be more costly and difficult if strong action is not taken today (United Nations, n.d.). We must drastically reduce global carbon emissions if we want to prevent the worst consequences of climate change by naturally absorbing carbon dioxide, forests act as nature's most effective climate change mitigation tool, lowering the emission intensity of this heat-trapping gas. Forests emit a lot of CO_2 into the atmosphere when they are not managed properly. After the use of fossil fuels, deforestation and degradation are the main causes of carbon dioxide emissions. According to scientists, deforestation is responsible for up to 13% of global CO_2 emissions. The significant and inevitable effects of carbon emissions, such as rising temperatures, changed rainfall patterns acidification of the oceans, rising sea levels, and an increase in the severity and frequency of natural disasters, must also be considered (*Climate | Initiatives | WWF*, n.d.). Climate change is a statistical change in the weather conditions over time such as changes in patterns of rainfalls, temperatures, etc with time further in the future this concept will keep gainingmore attention with globalization and high environmental awareness among the masses. The mainreason for this change is attributed to greenhouse gases which have significantly increased the atmospheric temperature since the start of the industrial revolution. These emissions are constantlyincreasing with more than a 5.5% increase in 2010, with Pakistan being no exception. This change does not only present itself in the form of weather changes but also the in form of economic and financial losses to the affected areas. According to a German watch report, Pakistan ranks as the eighth-most affected country in the world due to climate change despite only contributing 0.9% ofthe total share of global greenhouse gasses. The change has taken 0.3% of lives in one hundred thousand inhabitants and around $4 billion in economic losses because of forever increasing natural calamities (Pakistan among Top 10 Countries Affected due to Climate Change, 2021). The clearest phenomenon of climate change in Pakistan presents itself in the form of recurring floods (I. Khan et al. 2021).

The economy of Pakistan is expanding quickly, and it is anticipated that this trend will continue in the years to come. Agriculture is the country's most important and dominant sector, and it is the foundation of Pakistan's economy. Still,

agricultural land is deteriorating in Pakistan as a result of the country's explosive industrial boom. In addition, fast population expansion fuels deforestation, with Pakistan leading the list of Asian nations facing deforestation. Increased industrialization and economic growth use energy for expansion, which harms the environment. Along with ushering in a period of explosive economic growth, the industrial revolution also gave rise to the well-known phenomena of today, global warming and climate change (Aftab et al. 2021). More than doubt, advancements in the research of climate change observation and attribution during the past 20 years have demonstrated that human emissions of GHGs are mostly to blame for the observed variations in global temperature throughout the 20th century. (Stone et al. 2009). The climate will continue to change as long as we emit carbon dioxide (CO_2) and other GHGs into the atmosphere. How precisely and fast the atmosphere will alter in response to these changes in the composition is less certain. The relationship between future climate and GHG emissions has been attempted to be quantified by the scientific community, but it is still quite uncertain. A very basic indicator of the intensity of the climate challenge is climate sensitivity. It does not provide much information on its own regarding the times and locations where temperature changes are most likely to occur, which is essential knowledge for decision-makers (Heal and Milner 2014).

(Hawkins and Sutton 2009) divided the uncertainty in temperature projections into three categories: model uncertainty, emissions scenario uncertainty, and initial condition uncertainty. Initial condition uncertainty refers to variations in model predictions resulting from minor changes in how the models are initialized. Model uncertainty refers to uncertainty regarding which climate model best captures the dynamics of the climate system and uncertainty in the emissions scenario, such as uncertainty on the trend of future GHGs. As a developing country with limited resources, it is vital to take climate change mitigation measures before it is too late. There has been a significant increase in both internal and foreign tourism in recent years as a result of improved transportation services and infrastructure in o northern areas. But, the growth in human footprint in these places has resulted in unparalleled exploitation, putting millions of species, as well as our own survival, in danger. The melting of glaciers has been increased by rising temperatures, increasing the risk of glacial lake outburst flowand floods. This puts lives in danger in these places, which are already short on basic necessities. Pakistan as a country is highly reliant on its climate-sensitive land, which not only provides jobs but also a source of revenue through agricultural exports. As a result, natural calamities may have a negative impact on the country (Taj and Siddiqui 2022).

This study follows the idea of (Gavriilidis 2021) that developed a newspaper based index to measure the climate policy uncertainty. To create this index 8 major newspaper of USA containing climate related terms like climate risk, CO_2, GHGs, green house, carbon dioxide etc and their frequency in articles were used Number of articles were scaled related to these term and then from those 8 newspaper they created 8 series and then those series were normalized to create the index using the established methodology of (Baker et al. 2016). The finding of this newspaper based study showed that over the sample period, there are quite a few spikes that correspond with significant climate events. Further, another empirical analysis was done in this study in which author estimated the impact of CO_2 emissions on the index for that exercise VAR model was used. The result of that analysis showed that uncertainty in climate has a significant and detrimental impact on CO_2 emissions. Another study by (Lin et al. 2020) used textual analysis to create an index of climate policy uncertainty for four major economies UK, USA, China and India following (Baker et al., 2016) methodology in this study correlation between the climate uncertainty indexes of these four countries was estimated which shows that climate policy uncertainty index of these four economies are correlated with each other highly. Moreover in this study relationship of climate policy uncertainty with economic policy uncertainty and GDP of these economies was estimated through VAR model and according to the findings of this study climate uncertainty index and economic policy uncertainty have correlation but there is also a positive effects of EPU may leads to increase in CPU.

Our study is based on the idea of above mentioned studies (Gavriilidis, 2021) and (Lin et al. 2020) of creating climate uncertainty index for the case of Pakistan but our study is different from these studies in two major ways. Firstly, this present study creates the index in which monthly Google trends data is used for climate related queries helped in getting frequency of web searches keywords or number of times climate related terms are searched also this index is created through Generalized dynamic principal component (GDPC) technique and secondly, this study will show the association of climate uncertainty index with CO_2emissions and GDP of Pakistan.

2. Glimpses from previous Google trends based and Pakistan's climate change Literature

In the study conducted by (Lineman et al. 2015), they focused on public awareness of global warming (GW) and climate change (CC) using relative search volume (RSV) patterns and sentiment analysis on social media. The results indicated a strong correlation between information awareness and the amount of publicity surrounding these terms, with increased publicity playing a pivotal role in raising awareness. Additionally, the emotional associations with these phrases were found to be context-dependent. In another study. (Syed and Bouri 2021) investigated the impact of Economic Policy Uncertainty (EPU) on CO2 emissions in the US, considering both short-term and long-term effects. Using the ARDL bootstrap approach, they found that EPU intensifies CO2 emissions in the short term, contributing to environmental degradation. However, in the long term, EPU leads to a decrease in CO2 emissions, indicating a sustainable improvement in environmental quality. The study suggests that policymakers must act to reduce EPU in the short term to enhance environmental quality. For the long term, they should explore alternative measures, such as the use of renewable energy, to effectively control both EPU and CO2 emissions.

(Fahad and Wang 2019) examines that due to farming practices made in accordance to weather and climate variations, Pakistan is among the most vulnerable nations, particularly in Southeast Asia, to floods and storms. Additionally, research has shown that farmers who live in wetlands face less climatic change than farmers who live in some of the most vulnerable areas affected to these variations, with the farming industry being one of the most severely impacted sectors. The main risks associated with climate variation that have had a negative influence on the agricultural sector in the region recently are floods, droughts, rising temperatures, and fluctuations in rainfall.

(Gavriilidis 2021) develops a new climate policy uncertainty (CPU) indicator for the United States based on major newspaper article volumes, effectively capturing significant climate policy and event events. The study finds a link between lower CO2 emissions and shocks to climate policy uncertainty at both the aggregate level and in various sectors. (Bontempi et al. 2021) propose the economic uncertainty-related questions (EURQ) index, evaluating economic, political, and normative uncertainty through large-scale internet searches in the United States and Italy. The index reflects economic agents' demand for knowledge in the face of uncertainty shocks, indicating genuine interest in ambiguous topics rather than mere media coverage. (Ziabina et al. 2021) examine energy efficiency in the nation's economic development for carbon-free sources, using keyword co-occurrence analysis and Google Trends techniques. The study's sample comprises 48,888 publications from 2000-2022, and the authors find a lack of consensus among the scientific community on critical variables determining the country's economy transition to carbon-free development. The research results hold value for researchers studying factors influencing national economy's energy efficiency growth**.**

In their respective studies, (Qudrat-Ullah 2022) and (Rana et al. 2022) investigated crucial aspects of climate change and its impacts. Qudrat-Ullah's research analyzed the role of the electricity sector in greenhouse gas emissions and the effectiveness of government policies in achieving the Paris agreement target by 2030. The study emphasized the need for more robust measures, as financial incentive-based policies alone would not suffice to meet the target. Meanwhile, (Rana et al. 2022) explored urban temperature rise and heat wave vulnerability in Lahore, Pakistan. They proposed a localized heat wave vulnerability index (L-HVI) based on exposure, sensitivity, and capacity components, providing valuable insights for disaster risk mitigation and climate change adaptation in the Global South region**.**

(Aslam et al. 2022) conducted a study in Pakistan's Gilgit Baltistan region to assess glacial lake outburst flood (GLOF) and climate change risk perception. Household surveys and regression analyses revealed higher GLOF risk perception compared to climate change, with gender, education, lifespan, and previous hazard experiences influencing climate change perception, while fear played a significant role in GLOF perception. Effective policies are essential for raising awareness and building community resilience against GLOFs.

(S. Khan et al. 2022) estimated glaciological risks in Pakistan's mountainous regions due to climate-induced temperature and precipitation changes. Focusing on the Bindo Gol Valley glacier in the Hindukush area, the study analyzed meteorological and geophysical data to assess GLOF lake formation potential. Crevasses filled with moraines,

particularly in the south and center of the study area, may contribute to GLOF lake formation. Meteorological and geophysical data revealed factors influencing increased water accumulation and potential GLOF incidents**.**

3. Research Methodology and Data

To create CUI for Pakistan we have followed “New Web Search-based Uncertainty approach for economic uncertainty related queries (EURQ)” (Botempi et al. 2021). We have utilized Google Trends to assess the volume of searches for terms connected to climate uncertainty. Google Trendis a free internet service provided by the Google Corporation. It shows how often a single keywordphrase is typed in comparison to the total number of Google Search searches. Geographic locationand timelines can be used to refine the query. Google Trend provides an estimate of how manypeople are talking about a specific topic at any given time.

Previously climate policy uncertainty index was created by (Gavriilidis 2021) for US. To create the CPU index, he followed the established methodology of (Baker et al. 2016). This study is also relevant to the index created by (Gavriilidis 2021) for USA. But the major difference is that in our study we have used Google search instead of terms extracted from newspaper articles.This helps in extracting data direct from the person. It makes us observe the interest of an individual which avoids any third perception in the study. We have extracted terms similar or Closely linked to terms used in the newspaper version for measuring climate policy uncertainty of (Gavriilidis 2021) But, substituting the frequency of articles in newspaper containing specificterms with the intensity of Google searches for similar words. It changes focus from the press, the media to the individual.

To create this index we used monthly data from January 2004 to December 2021. Below mentioned table contains all the term/queries closely related to climate uncertainty and used by (Gavriilidis 2021) in his study about measuring climate policy uncertainty and also terms extracted from other climate-related articles and studies. Initially we extracted 58 keywords to create the index but after looking at the searched volume of few keywords some of the keywords were eradicated before creating index because of very low searched volume of those queries. So now we have 47 keywords left which we have used to create index.

Web scraping has been used to obtain Google Trends data. We constructed a Python formula basedon the Pytrends module that allowed us to download Google Trends data for a list of keywordsautomatically. We can also alter the time span and country characteristics using this way.

This table includes keywords extracted from existing climate-related studies and the studies in which climate uncertainty index has been developed already.

Table 4.1 List of the keywords/web searched queries for Climate Uncertainty Index.

Sr.No	Keywords	Sr.No	Keywords
1	Afforestation	30	Environmental Law
2	Atmospheric temperature	31	Environmental policy
3	Biodiversity	32	Environmental protection
4	Bioenergy	33	Environmental risk
5	Burning coal	34	Floods
6	Burning fuel	35	Forest fires
7	Carbon dioxide	36	Fossil fuel
8	Carbon footprint	37	Global environmental change
9	Carbon intensity	38	global warming
10	Chlorofluorocarbons	39	green energy
11	Climate	40	Greenhouse effect

12	climate change	41	Greenhouse gas emissions
13	Climate change adaptation	42	Heat stress
14	Climate change crisis	43	Heat wave
15	Climate change effects	44	Humidity
16	Climate change mitigation	45	Methane
17	Climate disaster	46	Natural disaster
18	Climate policy	47	Nitrous oxide
19	Climate risk	48	Ocean acidification
20	Cloud burst	49	Ozone depletion
21	CO2	50	Ozone layer
22	Combustion	51	Plantation
23	Cop26	52	renewable energy
24	Deforestation	53	Sea level rise
25	Drought	54	Smog
26	Ecosystem	55	Solar energy
27	Emissions	56	Temperature
28	Environment	57	Weather change
29	Environmental degradation	58	Wildfire

Further to achieve the secondary objective of the study in which we estimates the association between climate uncertainty index (CUI), CO2 emissions and GDP for the case of Pakistan. Secondary date for CO2 emissions per capita (t) and GDP per capita is extracted from (World Bank) for the year (2004-2021).This study creates the uncertainty index by using monthly data from (January 2004 to December 2021) but monthly data for CO2 emissions were not available so index is converted from monthly to annually and then VAR model is applied.

Vector Autoregressive Model (VAR)

The association between CUI of Pakistan and CO_2 emissions is analyzed using a Vector Autoregressive (VAR) model using the sectoral as well as aggregate data of CO2 emissions for Pakistan. Annual data of CO2 emissions (per capita) was collected from Word Bank for (2004-2021). To apply this model we converted our Climate uncertainty index to annually from monthly because monthly data was not available of CO2 emissions (per capita).

Let $W_t = \begin{bmatrix} CUI_t \\ CO_{2_t} \\ GDP_t \end{bmatrix}$ be a vector of order 3×1, then the $VAR(P)$ model relating to CUI_t, CO_{2_t} and GDP_t is:

$$\boldsymbol{W_t = A_0 + \sum_{i=1}^{P} A_i W_{t-i} + \varepsilon_t} \qquad (\mathbf{1})$$

$$\boldsymbol{W_t = [CUI_t\ CO_{2_t}\ GDP_t]}$$

$$\begin{bmatrix} \boldsymbol{CUI_t} \\ \boldsymbol{CO_{2_t}} \\ \boldsymbol{GDP_t} \end{bmatrix} = \begin{bmatrix} \boldsymbol{a_{01}} \\ \boldsymbol{a_{02}} \\ \boldsymbol{a_{03}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \boldsymbol{a_{13}} & \boldsymbol{a_{14}} \\ \boldsymbol{a_{21}} & \boldsymbol{a_{22}} & \boldsymbol{a_{23}} & \boldsymbol{a_{24}} \\ \boldsymbol{a_{31}} & \boldsymbol{a_{32}} & \boldsymbol{a_{33}} & \boldsymbol{a_{34}} \end{bmatrix} \begin{bmatrix} \boldsymbol{CUI_{t-1}} \\ \boldsymbol{CO_{2_{t-1}}} \\ \boldsymbol{GDP_{t-1}} \end{bmatrix} + \begin{bmatrix} \in_{1t} \\ \in_{2t} \\ \in_{3t} \end{bmatrix}$$

WhereA_i's (i= 0,12. . . . p) are coefficient matrices and ε_t is an error term with zero mean and constant variance. We

assume that there is no contemporaneous correlation between the error terms. P is an optimal log length chosen via Akaike Information Criteria (AIC).

$$CUI_t = a_{01} + a_{11}CUI_{t-1} + a_{12}CO_{2_{t-1}} + a_{13}\ GDP_{t-1} + \in_{1t}$$

$$CO_{2_t} = a_{02} + a_{21}CUI_{t-1} + a_{22}CO_{2_{t-1}} + a_{23}\ GDP_{t-1} + \in_{2t}$$

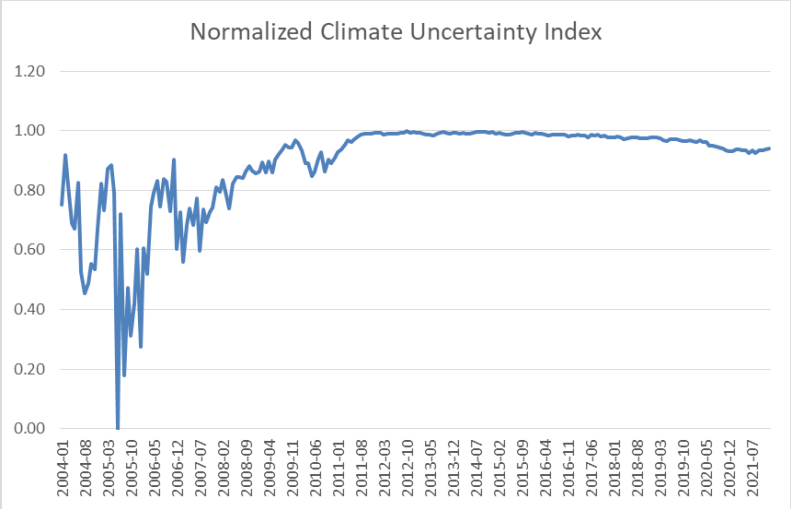
$$GDP_t = a_{03} + a_{31}CUI_{t-1} + a_{32}CO_{2_{t-1}} + a_{33}\ GDP_{t-1} + \in_{3t}$$

Time series data will be used to estimate VAR model for all variables and further impulse response will be generated by giving one standard deviation shock**.**

4. Result & Discussion

Climate Uncertainty Index by using GDPC

Below mentioned figure shows normalized monthly climate uncertainty index through using generalized dynamic principal component technique



ADF Unit root test

Variables	***t stat Level***	*Probability (Level)*	***t stat 1st diff***	*Probability (1st diff)*	***t stat 2nd diff***	*Probability (2nd diff)*
CO2 emissions	-0.611	0.8436	-2.636	0.1064	-4.00	0.0009
CUI	-6.71	0.0001	-3.59	0.0224	-4.99	0.010
GDP	-0.525	0.863	-3.361	0.029	-3.981	0.010

Vector Autoregressive (VAR)

	Dependent		
	CO_2	**CUI**	**GDP**
Constant	-0.0008 (0.01) [-0.04]	-0.12 (0.12) [-1.01]	-307.3 (1224.3) [-0.25]
CO_2(-1)	-0.12 (0.30) [-0.38]	-1.74 (2.25) [-0.77]	-1441.3 (21659.1) [-0.06]
CUI(-1)	0.009 (0.01) [0.58]	-0.56 (0.12) [-4.53]	85.04 (1191.2) [0.07]
GDP(-1)	-9.26 (6.30) [-0.14]	-5.45 (4.60) [-1.18]	0.58 (0.44) [-1.88]
Adj R-squared	-0.21	-0.56	-0.09
S.E. equation	0.06	0.47	4564.3
F-statistic	0.17	7.17	0.61
Log likelihood	22.04	-7.77	-145.3
Akaike AIC	-2.40	1.57	19.9

Note: standard errors in ( ) & t-statistics in [ ]

Impulse response

Response to cholesky one S.D. (d.f. adjusted) innovations ± 2 analytic asympotatic S.E.s

figure (a)

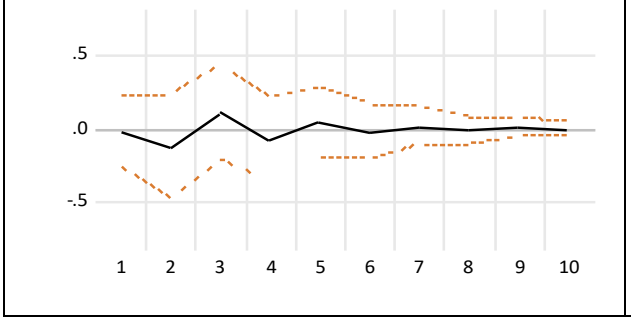
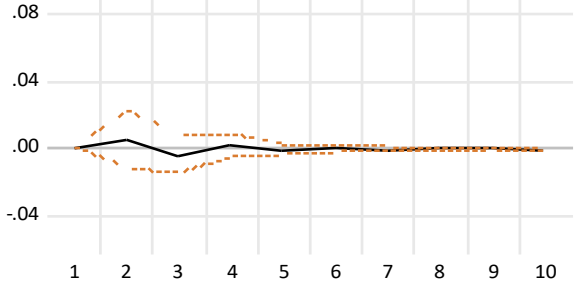
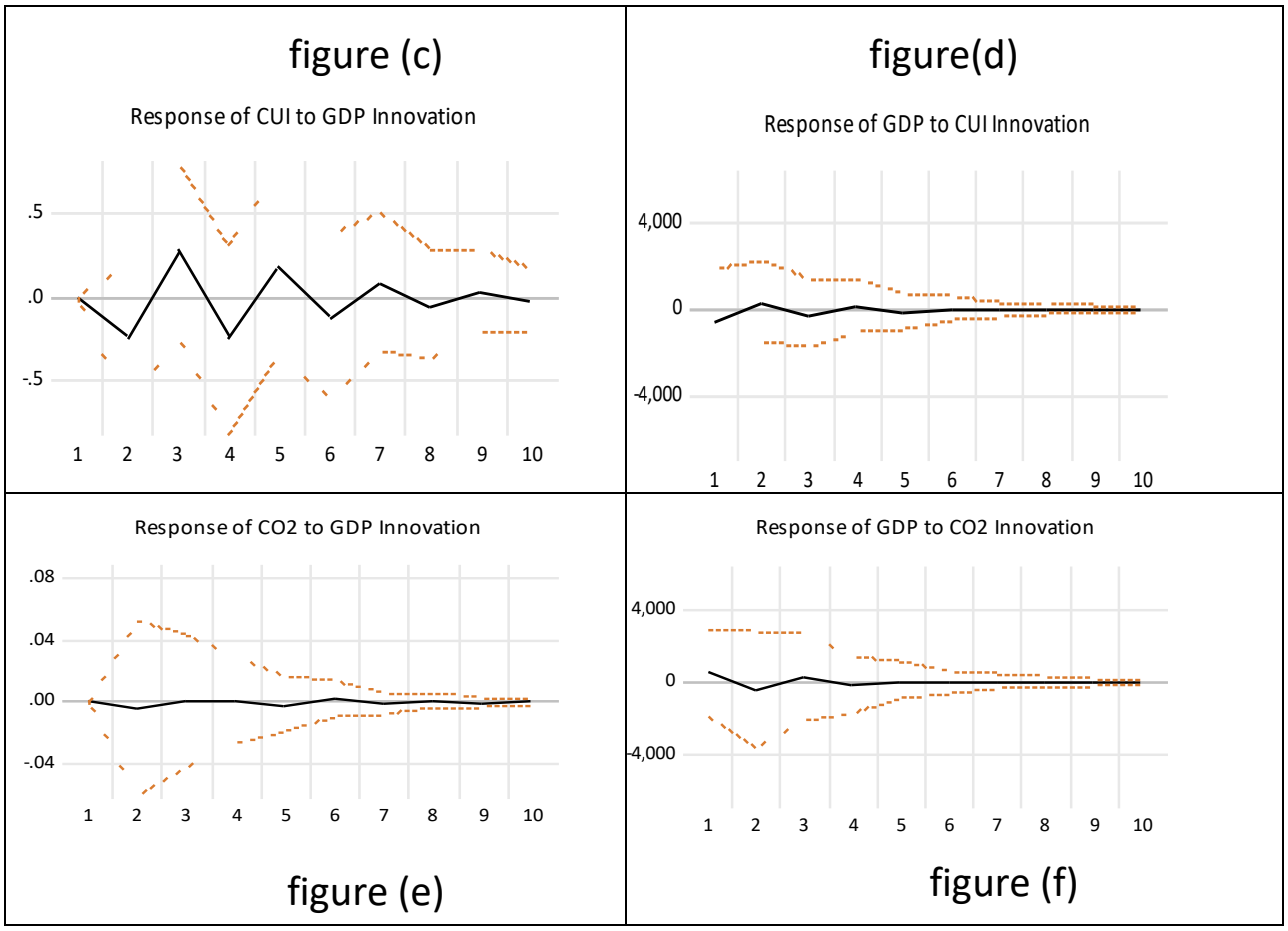


figure (b)





In figure (a) due to one standard deviation shock in CO_2 emissions there is a negative impact in climate uncertainty index from period 1 – period 2. After period 2 climate uncertainty index shows a spike from which means there is more uncertainty in period 2 – period 3. After period 3 there is decrease in the climate uncertainty index again till 4 period but after period 5 it converges back to 0 and the effect of a shock dies out. So this figure shows negative response to shock in CO_2 emissions in start but keeps fluctuating but eventually it converges back to 0.

In figure (b) no significant response in CO_2 emissions from period 1-period 2 has been shows in result of one standard deviation shock in climate uncertainty index of Pakistan. From period 2 to period 3 there is decrease in CO_2 emissions of Pakistan which shows a negative impact due to shock in climate uncertainty index and again there is an increase in period 3 to period 4. But after4 years of shock it started declining again and converges back to 0. So this graph shows that in the result of one shock in climate uncertainty index has no significant impact initially then it declined but after 4 periods it converges back to 0.

In figure (c) one standard deviation shock in GDP of Pakistan cause decline in climate uncertainty so it decreases in period 1 to period 2. But after 2 periods there is a spike in climate uncertainty index from period 2 to period 3 which shows that after one year of shock there is more uncertainty. But it decreased again from period 3 to period 4. For 5 periods there are fluctuations in climate uncertainty index of Pakistan due to shock in GDP of Pakistan but after 5 periods it converges back to 0.

In figure (d) the impact of one standard deviation shock in climate uncertainty index cause an increase in GDP of Pakistan. So initially climate uncertainty index will lead to increase in GDP for one period after that it will decrease between period 2 to period 3 but after period 3 the effect of one standard deviation shock will die out and start converging

back to 0 after period 4. There is no significant impact on GDP due to shock in climate uncertainty index and it disappears completely after period 4.

In figure (e) due to one standard deviation shock in GDP of Pakistan there is no significant change in CO_2 emissions. From period 1 to period 2 there is a slightest decrease in CO_2 emissions. But period 3 CO_2 emissions converges back to 0. For first 1- 2 period the response of shock was decreasing but very slight for one year and then it increases in and went back to 0 after 3 periods the effect of shock vanished and converges back to 0.

In figure (f) shows that one standard shock in CO_2 emissions cause significant decrease in GDP of Pakistan during period 1 to period 2. But after period 2 it increase significantly till period 3and after period 3 it starts to converge back to 0 and the effect of the shock CO_2 emissions disappears after period 3.

5. Conclusion

Currently Pakistan's climate uncertainty index is missing we have created this index for the case of Pakistan but our index is based on Google trend data or internet searches for the terms relatedto climate change instead of terms extracted from newspaper based articles. We have examined the nexus between climate uncertainly index, CO_2emissions and GDP through relative searchvolume (RSV) patterns for the phrases like global warming (GW) and climate change (CC) to see howwell people knew about them and also it will showed the changes in CUI due to increase or decreasein CO2 emissions and GDP for the case of Pakistan

So, this study concluded that shock in climate uncertainty index is associated to CO_2 emissions so that the availability of new uncertainty index aids researchers in their quest to understand the relationship not only between CO_2 and climate uncertainty also other variables and climate uncertainty. Any analysis of the effects of climate change on the global financial and economic markets should focus on the risk and uncertainty of climate change action as well as any potential physical risks. The decisions being made by governments and decision-makers around the world regarding climate change are risky and uncertain in terms of how, when, and what kind of an impact they will have so this index will help in estimating the impact of climate uncertainty on CO_2 emissions, GDP. The Climate uncertainty index could also be used in a variety of future academic studies, including those looking at the impact of climatic uncertainty on energy consumption and greenhouse gas emissions. The impact of climate policy uncertainty on businesses in climate-sensitive industries, is yet another potential research topic for example transportation, energy and mining.

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