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A STUDY ON GLOBAL CONNECTIVITY OF INTERESTS FOR CLIMATE CHANGE MITIGATION USING WEB SEARCH TREND DATA

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Abstract. *We investigated global connectivity of interests using Google trends data, especially about climate change mitigation which is a difficult problem to solve for just one country. Firstly, we studied whether global connectivity of interests exists through static correlation analysis with search query of 'CO_2' in 14 countries. Secondly, we examined whether the global connectivity has been enhanced through dynamic correlation analysis during the study period of Jan. 04, 2004∼Jun. 04, 2016. Thirdly, we analyzed how the global network of interests works among countries through Granger causality test and impulse-response function employing vector autoregressive model. In this study, authors could find the existence of global connectivity of interests and its growing trend during last 13 years. Authors could also find that the USA, Canada, and Japan have the leading position on influencing the interest of 'climate change mitigation' among the 14 countries. This result has an implication that these countries should be targeted with high priority that fosters global actions for climate change mitigation while establishing global policy strategies.*
Keywords: Global connectivity, Globalization, Google trends data, Dynamic correlation, Granger causality

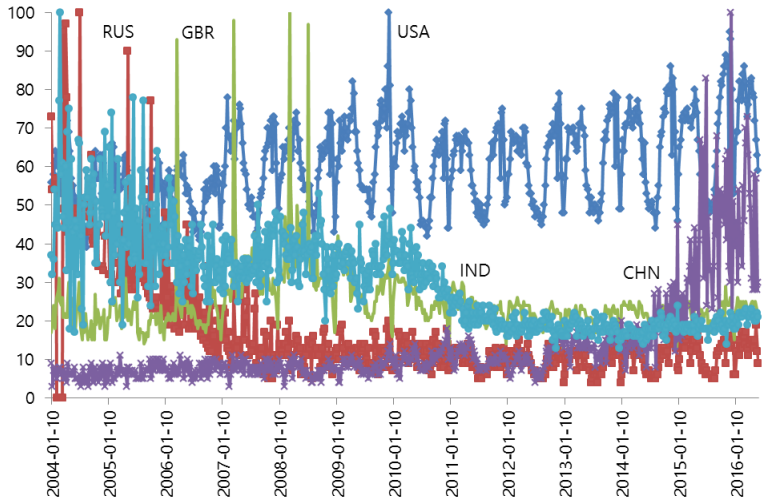
1. **Introduction.** Global connectivity (or globalization) has grown with the development of ICT (Information & Communication Technology) in almost all areas of our life including economy, culture and society. It is considered as a powerful engine for peace and prosperity. Cross-border flows of people, information, trade, and capital enhance intercultural understanding and tie countries together in sustainable economic relationships [1]. Global connectivity may be used to foster the cooperation of countries helping to solve global concerns such as climate change mitigation. Previous studies on global connectivity have been done to find some insights for global business [1-7] and policy strategy [8-17]. To provide such insights, they suggest several globalization-related indexes and apply network analysis for webpage hyperlinks [7-11], Internet traffics [12,13], and social media usages [14-17]. Few studies, however, have focused on the changing trends of interest which are more important to understand global dynamics of each nation. Recently, Google trend makes us observe people's interests globally. So it may be possible to investigate global connectivity using Google trend data, especially on global warming issues, and how it evolves over long time period. In this paper, authors investigate global connectivity of interests (or concerns) using Google trends data, especially about climate change mitigation which is a difficult problem to solve for just one country. Authors can find the existence of global connectivity of interests on climate change mitigation through static correlation analysis with search query of 'CO_2' in each country. Dynamic correlation analysis over 'CO_2' query between nations also shows growing global connectivity during last 13 years.

Influential and susceptible countries are further found by vector autoregressive model and Granger causality test.

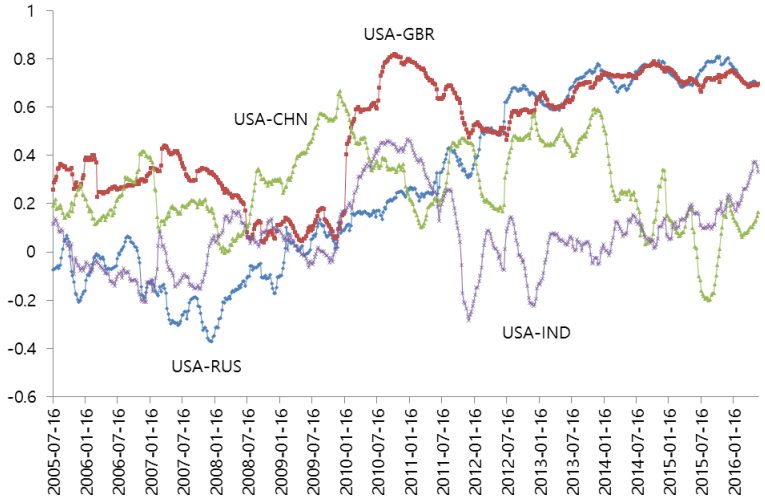
The rest of this paper is organized as follows. In Section 2, previous researches on global connectivity are briefly introduced. The details about the static and dynamic correlation analysis are explained with corresponding results in Section 3. Granger causality test results are given in Section 4. Finally in Section 5, discussion and conclusion are given with further study issues.

2. **Previous Researches on Global Connectivity.** Previous studies on global connectivity can be grouped into 2 broad categories. One is to provide the insights for global business strategy [1-7]. The other is to assess the effect of ICT on society to provide the insights for global policy strategy [8-17]. And those studies try to answer several different questions. One is how much we are globalized, where we are going and which countries are leading in terms of globalization. Another is which countries are closely related to each other and which countries have many relatives, which are referred to as betweenness and centrality, respectively. As for the answer to the first question, assessments to intensity, extensity, velocity and impact are mentioned [2]. Intensity (or depth) measures how much of an economy's activities (flows) are international compared to domestic activities (flows) by calculating the relative size of corresponding activities (flows). Extensity (or breadth) looks at how broadly such activities (flows) are distributed internationally [1]. High extensity refers to inter-regional or inter-continental networks and flows, and low extensity denotes localized networks and transactions. There are several indexes used to measure the degree of global connectivity, which include DHL Connectedness Index [1], KOF Index of Globalization [3], Ernst & Young Globalization Index [4], Maastricht Globalization Index [5], Huawei's Global Connectivity Index [6] and so on. These indexes employ multiple flow categories of their own and use various measures for each category. For example, DHL Connectedness Index uses 4 flow categories – trade, capital, information and people. It uses trade volumes of merchandise and services for trade flow, FDI and portfolio equity stocks for capital flow, Internet traffic and telephone calls for information flow, and finally, migrants, international students and tourists for people flow. The second question is related to network topology among countries, and network analysis is usually used to answer that. Some researchers used hyperlinks of web pages in different countries to analyze geographic topology among them [7-11]. Crovella and Krishnamurthy studied Internet traffic in terms of packets and bytes on a global scale [12]. Others applied network analysis on the Internet backbone [13], news websites and newspapers [14,15], Facebook [16], and Twitter [17]. However, few studies have focused on the changing trends of interest (or concerns) which are more important to understand global dynamics of each nation. Recently, Google trend makes us observe interest of people. So it may be possible to investigate global connectivity using Google trend data, especially on global warming issues. Global warming can be a good issue to apply authors' approach since it has long been a controversial and worldwide agenda that needs to be examined and needs global cooperation to tackle it. To remove variations affected by meanings and linguistic usage, authors have chosen the search term 'CO_2'. It can be language-neutrally used among all nations without any complex intervention from Google's search term extraction algorithm.

3. **Global Connectivity of Interests on Climate Change Mitigation.** Authors have tested whether Global Connectivity of Interests (GCOI) exists by static correlation analysis with search query of 'CO_2' during the study period of Jan. 04, 2004∼Jun. 04, 2016 in each country[1]. Among G20 countries, top 14 countries with the highest CO_2 emission indicator during 2001∼2012 have been selected[2]. Figure 1(a) shows the Google search trends for keyword 'CO_2' in USA, Russia (RUS), China (CHN), India (IND), and United Kingdom (GBR). Since each nation's search volume is independently normalized with the maximum value 100, the difference of index value does not directly infer the gap between each nation. Instead of search index value itself, authors have focused on fluctuations to find co-movements or deviations between nations.



(a) Google search trends for CO_2



(b) Dynamic correlations

FIGURE 1. Query trends and dynamic correlations results in each country for CO_2

[1]Search volume data is obtained from Google Trends service (http://www.google.com/trends). The service provides time series data computing how many searches have been done for specific terms, relative to the total number of searches done on Google over time in each country. Thus, the data reflect the change of interest of people for a specific topic. The time series data have weekly frequency.

[2]Sources: OECD (2016), Air and GHG emissions (indicator). doi: 10.1787/93d10cf7-en (Accessed on 07 June 2016).

TABLE 1. Correlations between search queries in each country for CO_2

	USA	**AUS**	**CAN**	**SAU**	**RUS**	**KOR**	**GER**	**JPN**	**GBR**	**FRA**	**CHN**	**IND**	**BRA**	**ITA**
USA	1.00													
AUS	**0.04**	1.00												
CAN	0.73	0.08	1.00											
	***	**												
SAU	−0.07	0.29	0.15	1.00										
	*	***	***											
RUS	−0.21	0.13	**0.02**	0.39	1.00									
	***	***		***										
KOR	**−0.04**	0.39	0.13	0.26	0.27	1.00								
		***	***	***	***									
GER	0.35	0.10	0.30	−0.12	−0.24	0.07	1.00							
	***	***	***	***	***	*								
JPN	**−0.04**	0.32	**0.02**	0.06	**−0.06**	0.61	0.25	1.00						
		***		*		***	***							
GBR	0.24	0.30	0.25	**0.00**	−0.11	0.29	0.37	0.51	1.00					
	***	***	***		***	***	***	***						
FRA	0.42	**0.03**	0.40	−0.11	−0.19	0.16	0.34	0.32	0.32	1.00				
	***		***	***	***	***	***	***	***					
CHN	0.39	−0.18	0.26	−0.15	−0.21	−0.34	**0.05**	−0.39	−0.12	**0.04**	1.00			
	***	***	***	***	***	***		***	***					
IND	−0.24	0.33	**0.01**	0.50	0.48	0.56	**−0.04**	0.43	0.16	**0.05**	−0.41	1.00		
	***	***		***	***	***		***	***		***			
BRA	0.30	0.33	0.22	**-0.04**	−0.18	**0.04**	0.10	**0.04**	0.09	**0.04**	0.27	−0.20	1.00	
	***	***	***		***		**		**		***	***		
ITA	0.32	0.19	0.42	0.17	0.07	0.34	0.33	0.35	0.35	0.41	**−0.06**	0.27	**−0.04**	1.00
	***	***	***	***	*	***	***	***	***	***		***		

Significance level: 1%***, 5%**, 10%*

Note: AUS (Australia), CAN (Canada), SAU (Saudi Arabia), RUS (Russia), KOR (Korea), GER (Germany), JPN (Japan), GBR (United Kingdom), FRA (France), CHN (China), IND (India), BRA (Brazil), ITA (Italy)

TABLE 2. The results of trend analysis on dynamic correlations (β values)

	USA	**AUS**	**CAN**	**SAU**	**RUS**	**KOR**	**GER**	**JPN**	**GBR**	**FRA**	**CHN**	**IND**	**BRA**	**ITA**
USA														
AUS	−0.27													
	***													
CAN	0.41	−0.41												
	***	***												
SAU	0.70	−0.76	0.41											
	***	***	***											
RUS	3.00	0.31	2.77	1.51										
	***	***	***	***										
KOR	0.65	0.54	0.52	0.42	0.77									
	***	***	***	***	***									
GER	0.45	−0.79	0.64	0.52	2.16	0.53								
	***	***	***	***	***	***								
JPN	−0.08	−0.34	0.10	0.12	0.59	−0.04	0.53							
		***			***		***							
GBR	1.54	0.19	1.66	0.76	1.87	0.79	1.34	0.03						
	***	***	***	***	***	***	***							
FRA	1.31	0.01	1.50	1.40	2.80	0.60	1.20	−0.28	1.86					
	***		***	***	***	***	***	***	***					
CHN	−0.08	0.03	0.21	0.89	0.89	0.23	0.63	−0.29	0.22	0.47				
			***	***	***	***	***	***	***	***				
IND	0.45	0.41	0.41	0.38	0.64	−0.11	0.31	−0.02	0.48	0.08	0.84			
	***	***	***	***	***		***		***		***			
BRA	−0.44	0.95	−0.38	−0.37	0.22	0.77	−0.67	−0.16	0.25	0.19	0.20	0.64		
	***	***	***	***	***	***	***	***	***	***	***	***		
ITA	0.97	−0.22	0.90	0.59	2.54	0.18	1.13	−0.02	1.75	1.28	0.08	0.20	−0.58	
	***	***	***	***	***	***	***		***	***	***	***	***	

Significance level: 1%***, 5%**, 10%*

Correlation coefficients for search queries between 14 countries are given in Table 1[3]. It shows that 79.1% (72 out of 91) of correlation coefficients are statistically significant including positive (76.4%) and negative correlation (23.6%). Considering the majority of countries (55 out of 72) shows positive significant correlation, we may possibly infer the existence of GCOI on climate change mitigation.

To find changing trends of GCOI on climate change mitigation, dynamic correlation analysis is done on data set estimating correlation coefficients with 80 weeks of moving time window for 13 years. Figure 1(b) shows dynamic correlations between the USA and the other 4 countries – Russia, China, India, and United Kingdom. Correlation between USA and the United Kingdom (USA-GBR) is higher than the others except the time period between 2008∼2009. Correlation between the USA and Russia (USA-RUS) has been increased while correlation between the USA and China (USA-CHN) shows no specific trend. To further investigate the significance and direction of trends, authors have regressed the dynamic correlation coefficients over time t ($t = 0{\sim}568$, for weekly data) with Equation (1). In this linear model, the value of coefficient β indicates whether there exist some trends or not. Table 2 shows the value of coefficient β, and its significance level. About 86.8% (= 79/91) of the coefficient β values are statistically significant including positive coefficient (82.3%) and negative coefficient (17.7%). Judging from this result, it makes sense that GCOI on climate change mitigation increases over study period.

$$\rho_{x,y}(t) = \alpha + \beta t \tag{1}$$

4. **Interactions between Countries.** Granger causality test and impulse-response function employing vector autoregressive model are applied to analyzing how the network for GCOI on climate change mitigation works. In Figure 2, Granger causality test results that are statistically significant at 1% or 5% level are depicted.

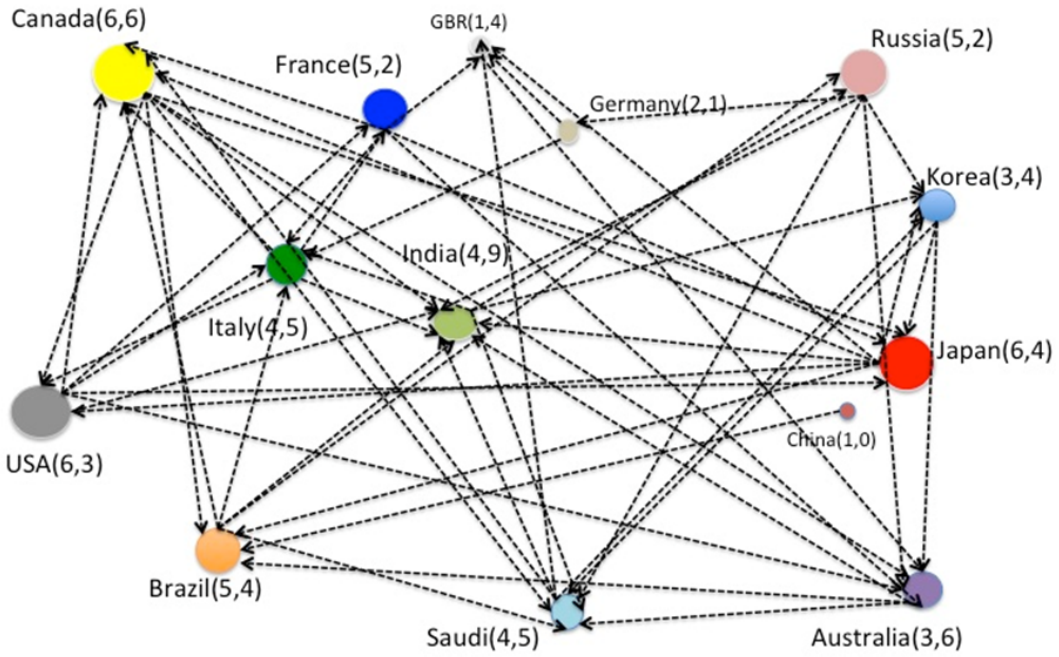
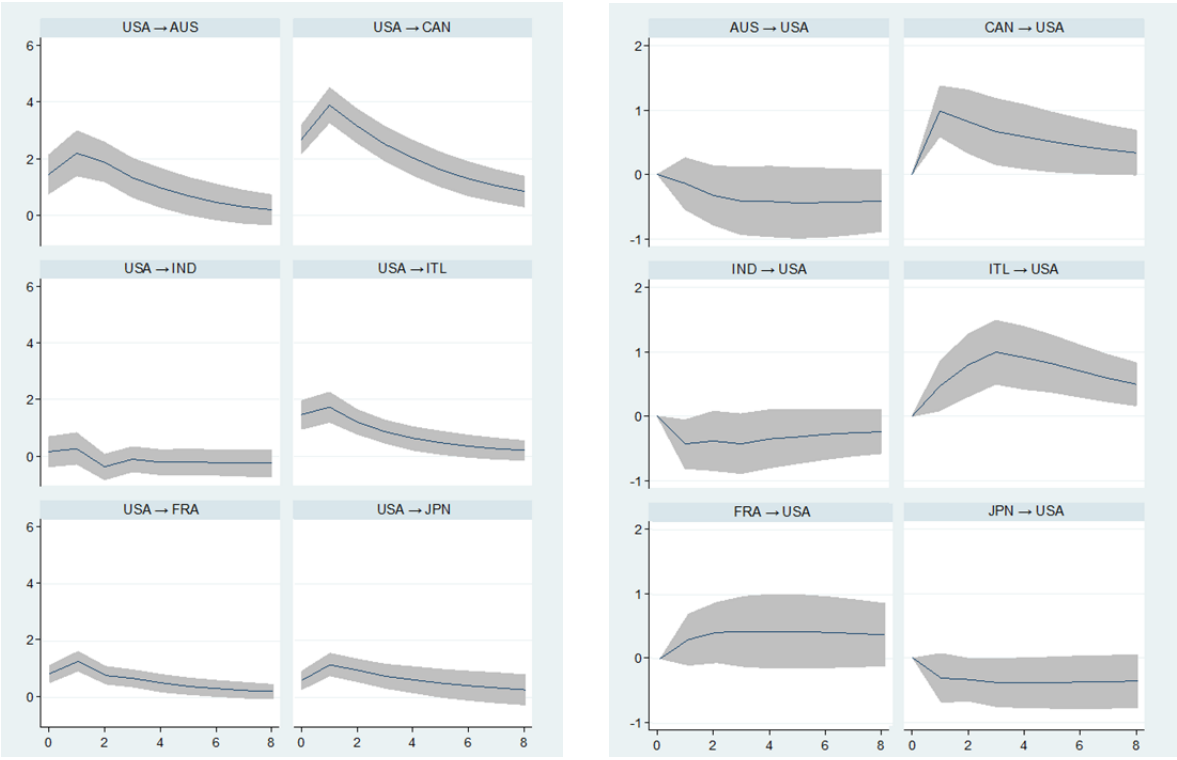


FIGURE 2. Visualization of Granger causality results

[3]Augmented Dickey-Fuller unit-root test is conducted to check stationarity of time series data, which is usually used to prevent spurious correlation and regression. The test shows no evidence for existing unit-root implying that time series data is stationary.



(a) Impulse variable: the USA (b) Response variable: the USA

FIGURE 3. Results of orthogonalized impulse-response function

The direction of arrow indicates the direction of influence between countries, which is usually expressed as Granger-causes[4]. The number of outgoing and incoming arrows is shown in the parenthesis next to that country's name. The size of node is proportional to the number of outgoing arrows from that node, which implies how much that country influences the other countries. The USA, Canada, and Japan with the most outgoing arrows (6) can be considered as the most influential leading countries for climate change mitigation. India with the most incoming arrows (9) seems to be the most susceptible country in our study. The next susceptible countries are Canada and Australia. It is interesting that Saudi Arabia shows the same strength of influence as that of Italy. China, however, shows the least connection with the other countries contrarily to its current status in global economy. China's ban on Google search may be a possible reason to this result.

Authors have investigated how much interest is transmitted from one country to another, and how long its effect lasts through impulse-response function. Figure 3 shows the results of orthogonalized impulse-response function for USA's case[5]. Figure 3(a) shows that Canada and Australia respond the most to USA, and its effect lasts longer than the

[4]A country Granger-causing another country means the country is influential to the other countries if the effect of latent variable on each country which might exist or could not be recognized is weak. Unless the effect of the latent variable is weak, a country X Granger-causing another country Y means the country X responses faster to the latent variable than another country Y. This paper assumes the effect of latent variable is weak following the approaches of previous studies. Actually, there was no discussion of latent variable in the previous studies. Additionally, the dates of United Nations Framework Convention on Climate Change (COP) are used as control variable to catch the effects of that event in each country. The search query for 'Financial Crisis 2007-08' is also used as control variable to remove the effect of regime change that seems strongly affects the search data.

[5]Authors use orthogonalized impulse-response function instead of ordinary one to remove the effect of contemporaneous correlation which might exist in the dataset although authors try to identify the effects of some events on the interests in each country using the date of COP as a control variable.

other countries that are Granger-caused by USA. Figure 3(b) shows that USA responds the most to Canada and Italy, and lasts longer than the other countries.

5. **Conclusions.** First of all, authors could find the existence of GCOI on climate change mitigation, and its growing trend over past 13 years. The interactions between countries are also identified, which shows that Canada, USA, Japan are the most influential among the 14 countries and India is the most susceptible one. It implies that Canada, USA and Japan can be the strategic target to leverage the effect of global policy-making on climate change mitigation with high priority. It is also notable that feeble connection of China from global network may be attributable to biased access to specific web search engine that this study uses for analysis. This implies that the preference of search engine between nations and within generations or peoples can be one of the most important factors that hugely affects the result of these kinds of study. Practitioners can obtain some insights from this study to develop their global policy by conducting preliminary connectivity analysis and thus globally exert their efforts. In this study, authors newly introduce analysis method for global connectivity of interest that incorporates web search data. Suggested method has some distinctions in that it incorporates dynamic network analysis over internationally classified web search data compared to conventional researches that only use limited geographical data and trends analysis [18-21]. Assumption for no latent variable needs further investigation to strengthen the findings of this study. If there exist some strong latent variables, the interpretation of result for Granger-causality should be changed since it just reflects the fact that a Granger-causing country responses to the latent variables faster than the other Granger-caused countries. To further enhance the accuracy of suggested method, a way to synthesize multiple search engines' results is needed. This will reveal China's real influence that appears weak in this study. Extension to keywords that are related to climate change mitigation is also encouraging to provide more detailed policy making for further research issues.

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