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CHINESE REGION AIR POLLUTION SPILLOVER'S SPATIAL AND SEASON CHARACTERISTIC

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ABSTRACT

China is a country which has different regions development and has distinct seasonal characteristic. The air pollution spillover's characteristic in different regions and seasons have different feature. To analyze how to distinguish the regions of air pollution, we used complex network algorithm to discover the topological features of Chinese cities air pollution spillover system. We divided the cities which have synchronization to same region. Then we analyzed the air pollution's spillover between regions in different seasons by motif algorithm. In this research, we divided the cities to different regions easy to control air pollution spillover between cities. After that we analyzed the air pollution's spillover between regions and found that there is a core region in every season and different have different core regions. This region could influence most other regions in this season. Therefore, we could control air pollution's spillover between regions by control the air pollution in core region.

Keywords: Air pollution; regional spillover effect; motif; seasonal; complex network

NONMENCLATURE

Abbreviations	
APEN	Applied Energy
Symbols	
n	Year

1. INTRODUCTION

From 2016 Chinese government begin to claim that the serious polluted regions should be treated more seriously. And the joint pollution control between the regions through China should be done. However, China is a country which has different development level in different spatial, and different seasons in China also have different air pollution characteristic (Ting Gan，2020). Our paper will research air pollution's spillover construction between regions in four seasons through China, to identify the characters of air pollution's spillover in different seasons, and give advice how to joint control the air pollution's contagion between regions.

Air pollution could be transported through long distance has already be proved in numerous studies. These researches proved that there must be different characteristic of air pollution contagion in different seasons and regions. Through research of air pollution's spillover efficient we found that we could identify the construct of air pollution contagion by air pollution's spillover (Wu,2019). The GARCH-BEKK model could be used to calculate the air pollution's spillover efficient. GARCH-BEKK model is a kindle of GARCH model, it's a financial time series developed from Baba; Engle; Kraft and Kroner's research result (Robert F Engle，2000). It could be used in different subject include the research of air pollution (Qi,2019).

In this paper we used AQI (Air Quality Index) as the air pollution data, and used air pollution's spillover efficient to research how the air pollution contagion between regions through all China and the different of air pollution's contagion construct in different seasons.

Because there are lot of cites in China, the air pollution's spillover is a very complex system (Gong, 2014), use complex network could find hidden topological relationship in this system, and the algorithm of modularity could divide regions better. These papers

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showed that the algorithm of modularity could help us to divide the air pollution's regions.

To analyze the contagion of air pollution spillover between regions deeper, we used algorithm in complex network—motif to dig the three pattern of air pollution spillover between regions. Motif is the subgraph of complex network, it's a kind of basic construct of complex network between nodes and modularity. Through research the motif of air pollution network, we could know how the air pollution transport between aeras (Liu,2019).

Our paper's purpose is divided the more synchronizer cities to same region and analyzed the air pollution's contagion between different regions in different seasons.

2. DATA AND METHOD

2.1 Data

We used Chinses 366 cities AQI data in 2019 and the data came from the Chinese Ministry of Ecology and Environment's official web(*https://www.mee.gov.cn/*). The data included a complete change of seasons, from spring to winter. To make the compare of season's different more convenience.

2.2 Method

Frist, our paper used GARCH-BEKK model to extract the air pollution spillover between cities. This model could analyze time series more flexible. Then we used complex network modularity algorithm divide cities to different by analyzed the air pollution spillover cities. Finally, we used motif analyzed the construct of air pollution spillover between regions.

3. RESULT

3.1 The divide of air pollution region

In this part we used GARCH-BEKK model divided cities which have same synchronization spillover to same region. And we used ArcGIS visualized it. In Fig1 the red color means the *a*verage clustering coefficient of cities air pollution spillover. The red means the average clustering coefficient in this region is not 0. The red deeper means the air pollution spillover connection between cities in this region stronger. Gray means the average clustering coefficient in this region is 0. White means there is no data in this city.

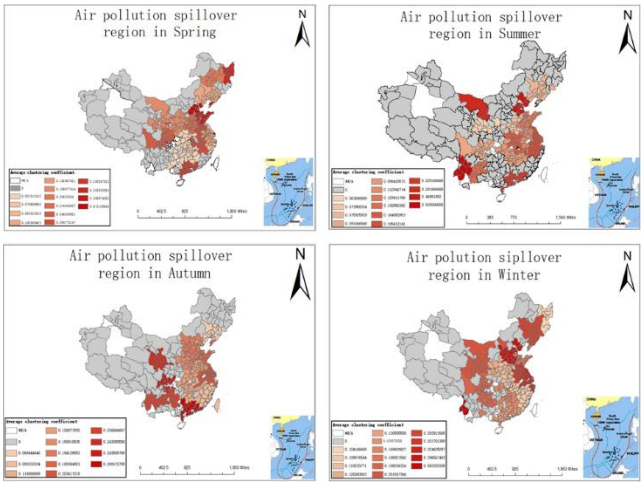

Fig1 air pollution spillover region in all year

Fig 1 showed the region of air pollution spillover in all year. We could see in Fig 1 that in spring and winter the air pollution spillover in all China stronger than summer and winter. In west of China the phenomenon of air pollution spillover is stronger than east of China, but the region in west of China could not connect with each other. The air pollution spillover in east of China could connect regions in all year.

In summary, The cause of this phenomenon perhaps there is spring there is strong abnormal of north east wind through South China Sea and the region of North Pacific Ocean; the influences typhoon stronger, and the South Asian summer monsoon and East Asian Summer Monsoon's cross influences are stronger in summer; on Northern Hemisphere the atmospheric migration from west to east active in autumn; and centralized heating in north China in winter.

3.2 The contagion of air pollution between regions

This paper used the quantity of cities between regions which has spillover relationship to construct complex network. The nodes of complex network are air pollution regions we divided in 3.1. The color of nodes is the strength of the regions output air pollution. The edges of complex network are the quantity of cities which has spillover relationship between regions. The edges wider the quantity of cities which have relationship more, the edges narrow means the quantity less.

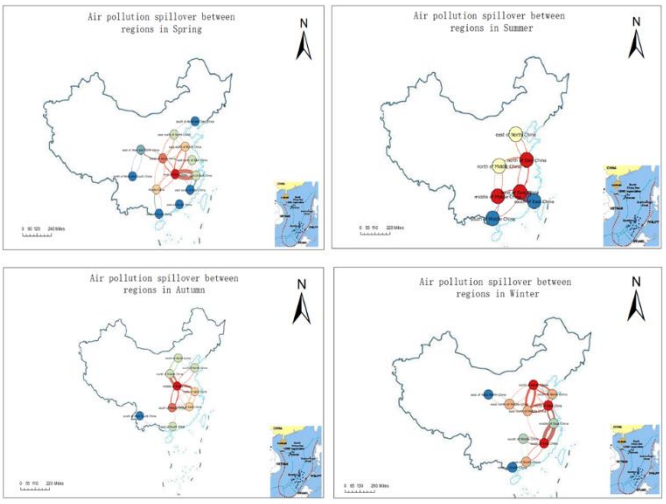

Fig2 air pollution spillover between regions in all year

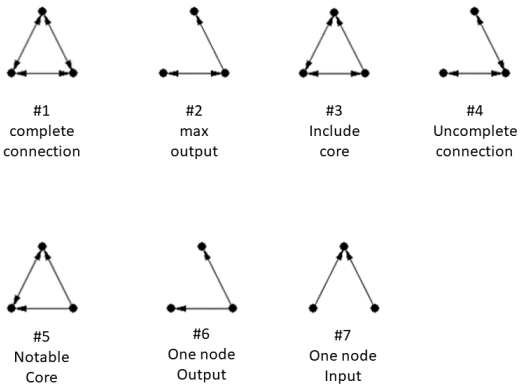

Fig3 motif construct of air pollution spillover between regions

From the Fig2 we could see that the air pollution spillover relationship between regions are stronger in spring and winter, weaker in summer and autumn. In summer, spring and autumn the East China and Middle China have stronger air pollution output to other regions. In winter the East China, Middle China and North China have stronger influence to other aeras. In four seasons the aeras which have relationship of air pollution spillover concentrated on Middle of China and East of China. Although in West of China the cities in aera's air pollution spillover relationship stronger than Middle and East of China, but the air pollution spillover relationship between aeras weaker than Middle and East of China. The reason perhaps is in East of China cities are dense, the development higher, terrain flat, easy to spread air pollutants. In West of China terrain complex, hard to transport air pollutants between regions.

3.3 Motif construct of air pollution spillover between regions

Fig 3 showed the motif of air pollution spillover between regions all year. The nodes of motif are the regions we divided in 3.1. From left to right the nodes are region1, region2 and region3. The edges are the connect between regions. The arrays show the direction of air pollution spillover between regions.

In 2019 there were 7 motif construct of air pollution spillover between regions. Motif #1 is the construct of completely connection. In this construction air pollution spillover in 3 regions could influences each other. Motif #2 is max output construct. Region3 send air pollution to region1 and region2, so the region3 is the max output region. In motif #3 node1 received air pollution spillover from region1 and region2, is the notable core of the motif. In motif #4 region3 received the air pollution spillover from region1 and region2. Region1 and region2 didn't connect. So that the motif #3 is uncomplete connection construct. In motif #5 region1 and region2 air pollution spillover influenced each other, region3 send air pollution spillover influence to region1 and region2, so region3 is motif #5's notable core. In motif #6 region3 send air pollution spillover to region1 and region2. It's the construct of one node output. In motif #7 region2 send air pollution spillover to region1 and region3, it's the construct of one node received.

Through the result of motif analysis, we found there is a core region in every season. In spring the core of motif #1 is west of East China. It could connect with south of North China, east north of East China, middle east of East China, east south of North China and Middle China and the air pollution spillover could influences each other. In summer the core of motif #4 is north of East China. It could connect with north of Middle China, middle of Middle China, west of East China, south of Middle China, south of East China, east of North China. In autumn the core of motif #1 is north of East China. It could connect with south of East China, middle od Middle China, south of Middle China. In winter the core

of motif #1 is north of North China. It could connect with east of South China, south of East China, south of Middle China, south of North China, north of East China, east north of Middle China and west north of Middle China.

From that we could see, there is a core of air pollution contagion in four seasons. Through the core aera other regions could connect each other. The different season has different core aera. From control the air pollution in core region we could stop air pollution contagion between regions better.

4. CONCLUTION

In this paper we analyzed the air pollution region divide and air pollution spillover between regions of all China. We got conclusion like this:

Frist, the overall situation average clustering coefficient regions in China is spring and winter stronger than winter. And in west of China regions couldn't connect with each other. In east of China the situation is opposite to west.

Next, the phenomenon of air pollution transport always appeared in East China, South China and Middle China.

Finally, we analyzed the motif construct of air pollution. We found there is a core region in every season. We could stop the phenomenon of air pollution spillover in region by weak the air pollution in the core region.

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