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三重大学大学院　生物資源学研究科

修士論文

北太平洋の海水温と世界の経済格差の共変動

Global Connectivity between GDP Growth Rates and North Pacific Sea Surface Temperature and Global Economic Disparity

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Abstract

Weather and climate affect the economy. Weather in one region can affect weather in another region, such as the El Niño phenomenon. Similarly, the economy of one country can affect the economy of another. Therefore, it is necessary to study the relationship between economy and weather / climate from a global perspective. Although there are studies investigated the relationship between the El Niño / Southern Oscillation (ENSO) and the economy, the relationship between teleconnections other than ENSO and the economy is uncertain. It is also unclear how the relationship with teleconnection change depending on the economic situation of the country and industry. The purpose of this study is to investigate the relationship between teleconnections other than ENSO and economy of individual countries from a global viewpoint by using GDP. In addition, we examine GDP of developing countries, and GDP by industry. Result show that Pacific Decadal Oscillation (PDO) has the relation with GDP growth rates and developing countries tend to make profits whereas developed countries loss profits in La Niña years. Furthermore, for the level 1 countries, the service sector tends to be made more profits in the La Nina summer than in the El Nino winter. Our findings highlight the importance of the relationship between GDP growth rates and PDO. In addition, our paper shows that it is important to consider the relationship with the teleconnection index by economic situation and industry.

Keywords

Gross Domestic Product (GDP), Teleconnection, Pacific Decadal Oscillation (PDO), Southern Oscillation (SO), Correlation coefficient

1. Introduction

It is widely known that the economic activity of a country depends on domestic weather and climate as well as on government policy and diplomatic relations. For example, Jeffrey et al., (2011) showed that the gross domestic product (GDP) fluctuates significantly linking with the number of summer / winter days and precipitation variation in the United States of America. Florian Badorf et al., (2020) also indicated that the effect of weather on daily sales can be as high as 23.1% based on the store location and as high as 40.7% based on the sales theme in Germany.

These studies investigated the relationship of the economy of a single specific country with the weather of the same country. It is important to investigate from a global perspective in considering the relationship between weather / climate and the economy, because both weather / climate and the economy have the characteristics that local phenomena have wide-range and remote effects. The economic condition of one country can affect those of others. For example, a financial crisis triggered by the bankruptcy of Lehman Brothers Holdings, a major American bank in 2008, stagnated the economies of Japan, Europe, Africa, and other countries around the world. A similar remote influence can be seen in the weather and climate. For instance, It is widely known that EL Niño Southern Oscillation (ENSO), which originates in the tropical Pacific Ocean. ENSO affects global weather and climate. This kind of atmospheric remote influence is referred to as a teleconnection. We should therefore consider teleconnections when we investigate the relationship between weather / climate and economy. Dufrenot et al., (2021) investigated the effect of ENSO on global commodity prices and indicated the existence of a direct link between weather anomalies and commodity inflation. Moreover, Iizumi et al., (2014) showed that El Niño likely improves the global-mean soybean yield by 2.1 to 5.4%, but appears to change the yields of maize, rice and wheat by -4.3 to 0.8%. They also indicated that the global-mean yields of all four crops during La Niña years tend to be below normal (-4.5 to 0.0%). However, further investigations are needed. First, teleconnections other than ENSO might also affect the global-scale economy because global weather and climate is never determined by ENSO only. Second, the relationship of the economy with weather and climate might depends on the sectors of industry. i.e., agriculture, industry, and service. As mentioned above, there are studies focusing on specific industries, but they did not view from a global scale. Because the data and analysis methods are different in each study, it is difficult to summarize the global influence if we pick up the previous studies only. Third, developing countries might have different linkages with weather/climate from those of developed countries, because economic vulnerability on the extreme weather depends on the countries. Global North-South divide might be amplified by extreme weather and climate. We thus need to take these factors into consideration in order to globally understand the relationship between economy and weather / climate.

The purpose of this study is to reveal the existence of linkage between climatic teleconnection patterns and the economies of individual countries from a global viewpoint by using GDP. Since the climatic effect may depend on the economic level, we classify countries by using GDP. We also investigate the dependency on the sectors of industries because the response of the agriculture sector to the climate may differ from the other sectors. Present study uses GDP because it is widely used as an economic indicator. Obviously, climate alone does not determine the economy. Climatic effect is usually hidden by other primary factors. Thus, present study focuses only on listing the significantly correlated countries with climate, without taking account of the degrees of climatic effect compared with those of other factors.

2. Data and analysis methods

As economic indicators, we used 179-country GDP per capita spanning 57 years (1960 - 2017). The data are available at the website of the World Bank: https://data.worldbank.org/indicator/NY.GDP.PCAP.KD. GDP data are in constant 2010 U.S. dollars. We can calculate total GDP from Eq. (1).

$$Y = \mathrm{C} + \mathrm{I} + \mathrm{G} + (\mathrm{X} - \mathrm{M}) \qquad (1)$$

where Y is total GDP, C denotes private consumption, I describes private investment, G is government expenditure, X is export value, and M is import value. GDP per capita is calculated by dividing the total GDP by the population of a country. The total GDP tends to increase as the population increases, so even if the value is large, the people are not necessarily wealthy. Accordingly, we can consider the GDP per capita to be more suitable as an index showing the standard of living of the people than the total GDP. This study thus used the GDP per capita.

We calculated GDP growth rates of each country by the Eq. (2).

$$g = \frac{\mathrm{y_t} - \mathrm{y_{t-1}}}{\mathrm{y_{t-1}}} \qquad (2)$$

where g is GDP growth rate, y_t denotes GDP per capita in a specific year, t, and y_{t-1} describes GDP per capita in a year earlier. Year-to-year variations of the GDP growth rate in Brazil and South Africa are shown in Figs. 1a and 1b as examples.

Additionally, we used data of percentage of individual sectors of industries, agriculture, industry, and services in GDP per capita. Agriculture includes forestry, hunting, fishing, crops, and livestock production. Industry includes mining, manufacturing, construction, electricity, water, and gas. Services include value added in wholesale, retail trade (including hotels and restaurants), transport, government, financial, professional and personal services for example, education, health care, and real estate. The World Bank supplies the GDP percentage of individual sectors of industries. We calculated the value of the three sectors of GDP of each country (1960 - 2017) using Eq. (3).

$$y_A = \frac{y_t \times P_A}{100} \qquad (3)$$

where y_A is GDP per capita of one field, y_t denotes one country's GDP per capita and P_A describes the rate of one sector of the three industry fields. After that, we calculated GDP growth rate by (1). We classified all the countries into 4 levels by 2017 GDP. The classification method was based on Hans Rosling et al. (2019). The countries with GDP 0 to less than 1460 dollars belong to Level 1(Fig. 2a). These countries are mainly on the African continent from latitude 30 degrees north to latitude 30 degrees south. The countries with GDP 1460 to less than 5840 dollars belong to Level 2 (Fig. 2b). The countries of this group are mainly distributed on the African Continent and Southeast Asia. The countries with GDP 5840 to less than 11680 dollars belong to Level 3 (Fig. 2c). They are mainly located on the African continent and Eurasia Continent. The countries with GDP of 11680 dollars or more dollars belong to Level 4 (Fig. 2d). This group's countries are mainly on the Europa and the North America Continent and are subject to developed countries. Some oil-producing countries belong to this group.

As for climatic teleconnection indexes, we used Pacific Decadal Oscillation (PDO) index (Nathan J. Mantua et al., 1997) and Southern Oscillation Index (SOI) (Zhang. Y. et al., 1997). We focused on these teleconnections because they are known to have global climatic effects. PDO is PDO is a major sea surface temperature fluctuation found in the North Pacific Ocean, with a pattern of inverse sign deviations near the central region and along the North American coast. When PDO index is positive in winter, it is known that the northwestern part of North America tends to be warmer, and the southeastern United States tend to cooler than normal (Japan Meteorological Agency at https://www.data.jma.go.jp/gmd/kaiyou/data/db/climate/knowledge/pac/pacific_impact.html). SOI is well known to as an ENSO signature; positive SOI indicates La Niña, and the negative is

EL Niño. The analysis period is from 1960-2017. Both indices were averaged over the three months of June, July, and August (JJA) and January, February and December (JFD) (Fig. 3 - 4). From a climatological point of view, it is natural to use DJF mean value that is average from December of a previous calendar year, January and February. GDP data is only available annually. If we use DJF mean, it would crosse years and comparison between GDP and climate would include the data of different year. We thus used the JFD mean climatic indices in correspondence with GDP. To show the global distribution of linkage between GDP growth rates and the teleconnection indexes, we will display global maps of the countries that have significantly high enough correlation between the economic indicators and the teleconnection index in Results section.

Since PDO has a linkage with SO to some degrees, there is possibility that the relationship of PDO index with GDP growth rate might be owing to SO. For example, the correlation coefficient between PDO and SOI in JJA is -0.40 and in JFD is -0.51. For this reason, we calculated a residual index by Eq. (4) to linearly exclude the SO influence,

$$R = \mathrm{PDO\ index} - \mathrm{SOI}\ \times \mathrm{r} \qquad (4)$$

where R describes the residual index, r denotes correlation coefficient between the PDO index and the SOI. The residual indexes are shown in Fig .4. The residual index is, by definition, independent of SOI.

To see the connectivity between GDP growth rates and the teleconnection indexes, we calculated correlation coefficient of GDP growth rates of all the countries with PDO index, SOI, and R. The number of the countries with statistically high enough correlation is not expected to be large because many factors have influences on GDP of individual countries. Climate is not expected to be a primary effect but a secondary one. To extract a hidden climatic effect on the GDP, following statistical procedure is performed. We first calculate the absolute value of the correlation coefficients of all the countries in the four economic levels. Then we extract the countries that have top 30 percentile in descending order of the absolute value in each economic level. The number ratio of positively correlated countries to negative ones is calculated by using the extracted countries in each economic level. The larger or the smaller the ratio, the stronger link between the climate and the GDP. The reason for choosing 30 percentile is that the 30 percentile corresponds to 10 or more samples since the number of the countries in each economic level is at least about thirties.

3. Results

3.1. GDP and climate

First, we show relationship between GDP and PDO. The second row of Table 1 summarizes the number ratio of positively correlated countries to negatively correlated countries in each GDP level in the top 30 percentile countries with the absolute value of the correlation coefficient. More than 80% of the countries in the level 1, 2 and 3 are negatively correlated with PDO in JJA. GDP response to the PDO index in the level 4 countries is in reverse to the level 1, 2 and 3 countries, e.g., 20.0% vs. 80.0% in the level 1 and 81.3% vs. 18.8% in the level 4. This indicates that the highest economic level countries tend to make profits whereas lower-level countries lose profits in the positive PDO years, and vice versa. Similar contrast is seen with less ratio when we use in the JFD-mean PDO index. The relation of GDP with SOI is also significant in level 1 countries both in JJA and JFD mean indices: 80 % countries of Level 1 raise the GDP in a La Niña year, i.e., a positive SOI year. The connectivity of GDP with PDO is, on average, larger than with SOI.

Since PDO has some relation with ENSO, the countries with negative correlation with PDO might be influenced by ENSO only. To see ENSO eliminated correlations, we use the residual PDO index, in which ENSO signature is linearly excluded as explained in the Method section. The results using the residual index of JJA is almost the same as those with PDO index with higher ratio in the level 1 at 90:10. Therefore, connectivity of the GDP growth rates with PDO is not an apparent connection.

Table. 2 shows the lists of the number of countries that have significant correlation coefficients with the climatic indices. The GDP growth rates of these countries significantly tie to the climatic teleconnection. The names of the countries with significant coefficients are listed in the appendix (Table. A.1). Figure 5a shows the map of significantly positively correlated countries with PDO or R indices regardless of the season in the level 4 group. The map signifies that many of level 4 countries are positively correlated with PDO. Figure 5b shows the same as Fig. 5a but for the level 1 group with the significantly negative correlation.

3.2. Industry group and climate

Next, we show dependency on industry groups, i.e., primary, secondary, and third sectors. Table 3 shows the same as in Table 1 but for the list classified by the industry groups. The most outstanding relation to the climatic teleconnections is the third sector of the level 4 countries, in which the positive/negative ratio for PDO index is 100:0. This indicates that many economically leading countries tends to make larger profits in the service sector in the positive PDO summer than in the negative PDO, and vice versa. In contrast, the ratio in the level 1 countries is 30:70 in the third sector. This see-saw like response between the level 1 and level 4 countries are the same as that of GDP growth rate shown in Table 1. This means that economically leading countries tends to make larger profits while least developing countries make smaller profit in the service sector in the year of positive PDO summer. The industry sector in the Level 1 countries also have similar response to PDO: e.g., the ratio is 10:90 in PDO in JJA.

The primary sector, i.e., the agriculture, does not have statistically significant correlation with both PDO and SOI overall. Dependency on the country level is also small. This result noteworthy because it was expected that agriculture is the most vulnerable to climate variation of all the industrial sectors. These results indicates that the contrasting response between level 1 countries and 4 countries is mainly owing to second and third industrial sectors. The contrast is not owing to agriculture. Similar relation is also seen in SOI index for the economically leading countries, i.e., the profits in the service sector of the leading countries are more in the El Nino summer than in the La Nina summer. The ratio, 0:100 is seen in the industrial sector of level 1 countries. Contrasting response between level 1 and level 4 countries is also see in SOI with relatively weaker connection than PDO. Again, agriculture section does not have significant ratio overall.

Table. 4 shows the same as in Table 2 but for the classification by the industrial sectors. Note that the countries of the secondary industry in level 4 are not always positively correlated with climatic indices. The names of the countries with significant coefficients are listed in the appendix (Table. A.2).

The relationship with residual index is resemble to PDO index. We thus consider that the PDO variation excluding the influence of ENSO are still related to the service section in Level 4 countries.

4. Discussion

Here we consider why the PDO index is systematically related to GDP in many remote countries. PDO, which is the phenomena within a North Pacific Ocean, influences weather and climate in other regions of the globe through climatic teleconnections. Similarly, the economy of one country can affect the economy of another. This can be described as "economic teleconnection". At the same time, weather and climate in a specific region affect the economy of the same region. Thus, climatic teleconnection and economic teleconnection acts as a chain response. Climatic teleconnection driven by PDO has an influence on remote country`s climate along with its economy, which further influences the economy of other countries through the economic teleconnection. The economy of the country that is located far from the North Pacific is thus connected to PDO. The presence of the chain of climatic-economic teleconnection may increase the significantly correlated counties with PDO.

There are many countries with low correlation coefficients although the values exceed the level of statistically significant. This implies that teleconnection is not primarily linked to the economy. We thus repeat that the climatic linkage with economy is not the primary but the secondary. Besides, large countries, such as Russia the United States, and China have different tendencies from those of their economic categories. Although their different responses are quite interesting, the consideration of these countries will be in the future.

Next, we compare the present results with a previous study. Iizumi et al., (2014) showed that the global-mean yields of all four crops during La Niña years tend to decrease. Present study shows that ratio of agriculture in level 1 countries is 70:30 for SOI, i.e., agriculture section of the GDP in level 1 countries tends to be positive in La Niña years. Overall connection of primary industry in level 2, 3 and 4 with SOI does not arrive the level of significant correlation. This discrepancy is partially owing to different the data and method; GDP versus the yields of four crops. Also, appropriate climatic conditions for a specific crop probably differ from others. The data we use includes fisheries and dairy.

5. Conclusions

The conclusions obtained in our study are as follows: First, the climatic teleconnections of PDO and ENSO have an influence upon economic variation in many remote countries over the world. Second, the economic response to the climatic teleconnections depends on the level of annual GDP per capita. GDP growth rates tend to decline in the poorest countries when PDO is positive. To the contrary, in the economically leading countries, the GDP growth rates tend to incline when PDO is positive. Therefore, the response of the poorest countries to the climatic teleconnection is opposite to that of the leading countries, i.e., global North-South divide is amplified by PDO. Third, PDO and ENSO have a strong linkage with the service sector of economically high-ranking countries. It should be noted that even the service sector of economical leading countries is influenced by climatic teleconnection. Our analyses did not show significant linkage between the agriculture sector and the climatic indices, contrary to expectations.

Our findings would provide the international economics with the consideration of global influence of climatic teleconnections. The present study implies the existence of a chain of climatic-economic teleconnection. Weather and climate in one region remotely affect weather and climate in another region through climatic teleconnections. Similarly, the economy of one country can affect the economy of another through economic teleconnection. Thus, these two kinds of teleconnection acts as a chain response. When we investigate the relationship between economy and weather or climate, it is thus necessary to consider from a global perspective, i.e., considering the chain of climatic-economic teleconnection.

However, problems remain. First, we have not fully shown the causal relationship between teleconnection and GDP growth. Second, larger countries, e. g., the United States of America, behave different from the other many countries of the same economic levels. These problems should be explored in the future. This study focuses only on two climatic teleconnections. Other teleconnections must be scoped in the next step. For example, North Atlantic Oscillation and Arctic Oscillation is known to have a strong impact on the weather and climate of extratropical regions of the Northern Hemisphere, such as Europe, East Asia, and North America. To anatomize the chain of climatic-economic teleconnections will deepen climatic effect on economy.

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The Grid Analysis and Display System (GrADS) was used to draw the figures.

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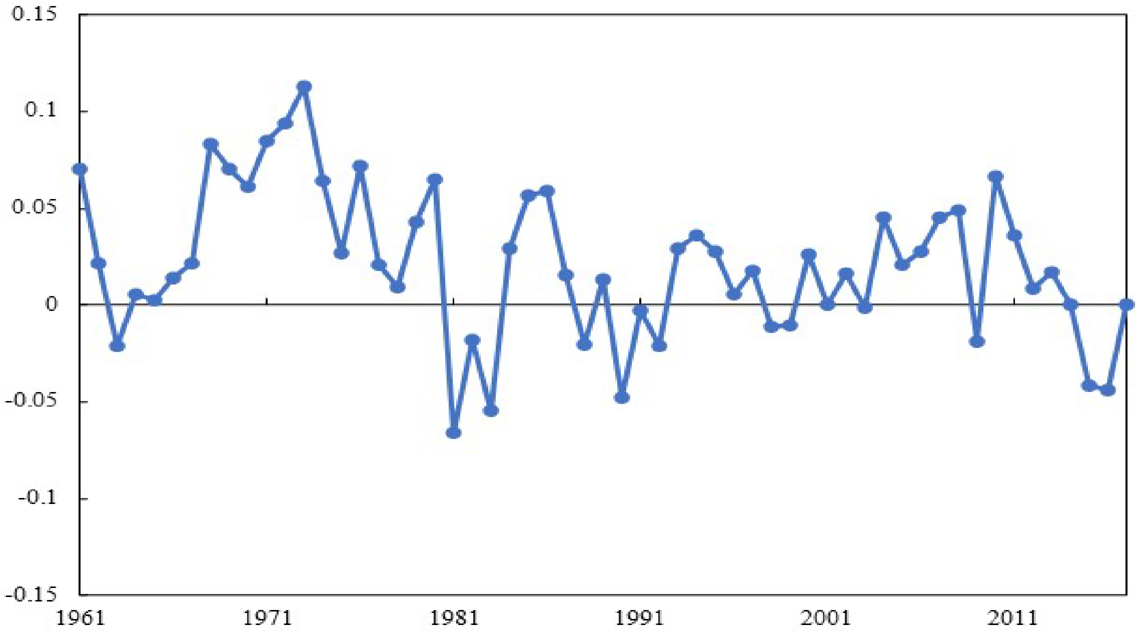
(a)



(b)

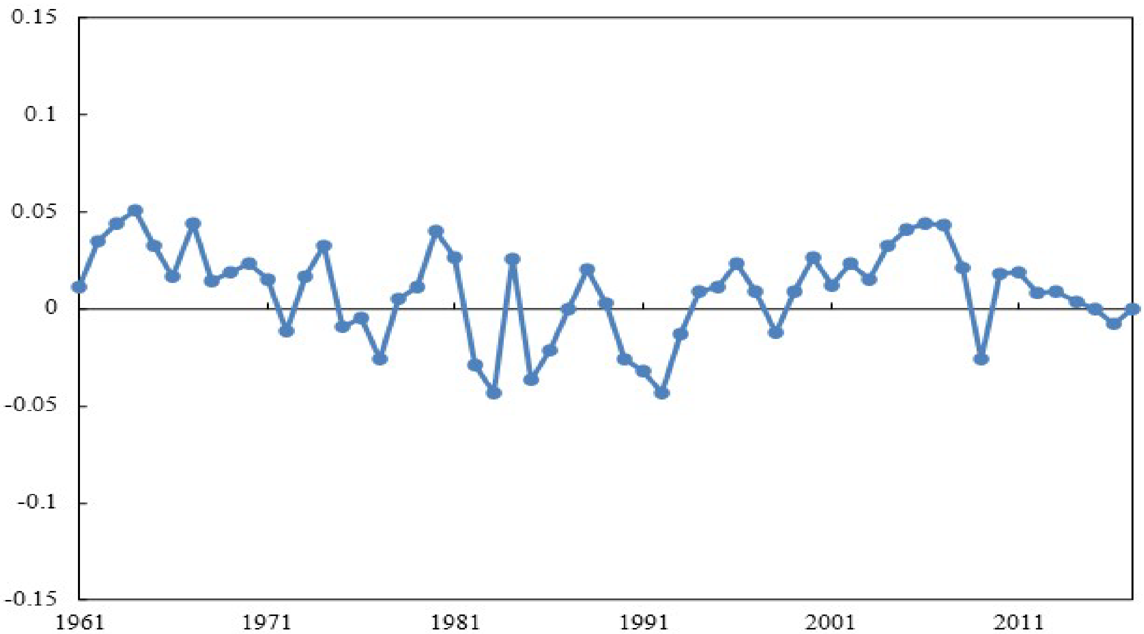


Fig. 1. GDP growth rate of (a) Brazil (%) and (b) South Africa (%). The vertical axis is GDP growth rate, and the horizontal axis is the year.

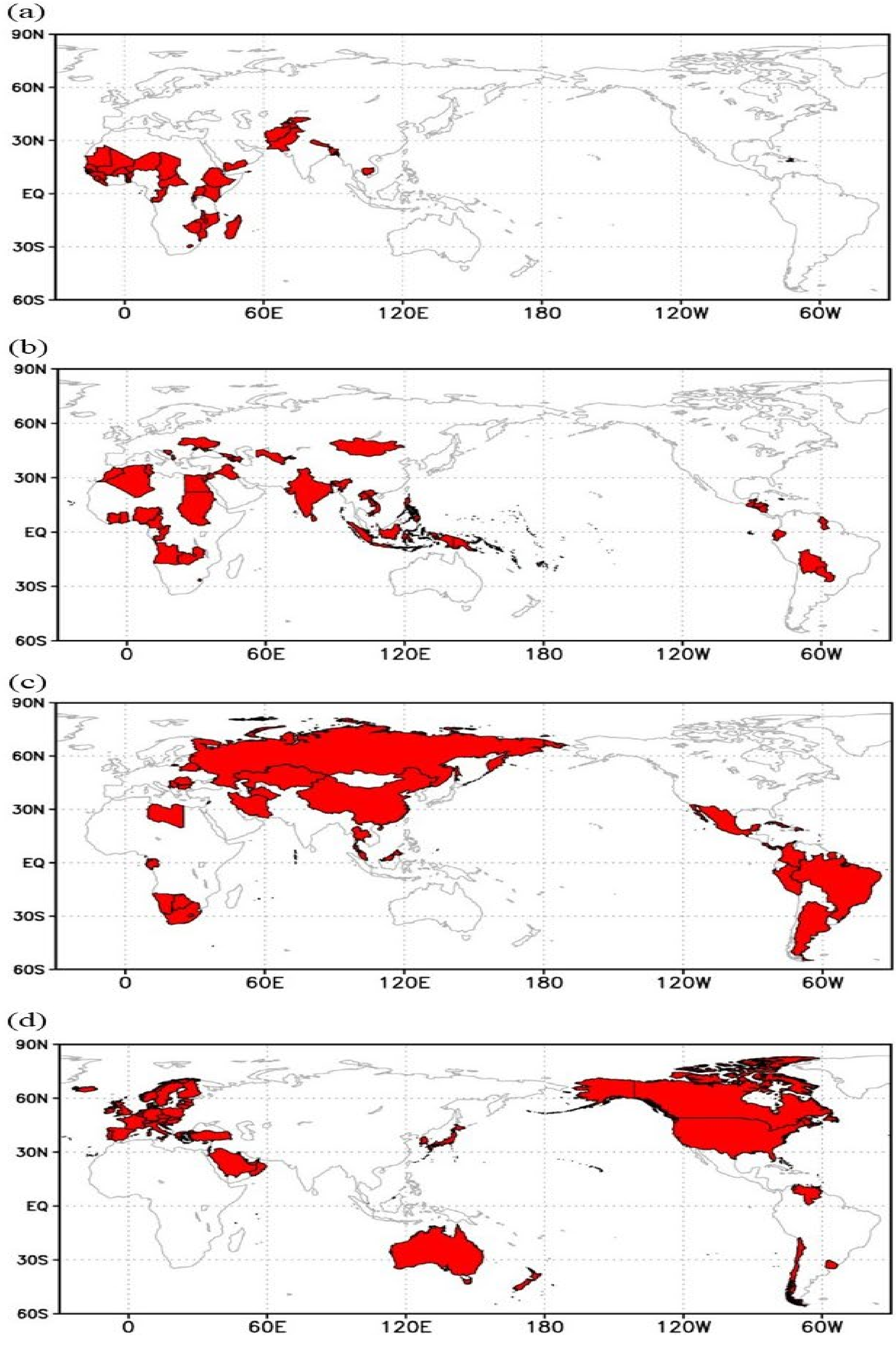


Fig. 2. Distribution map of countries in (a) Level 1, (b) Level2, (c) Level3, and (d) Level4

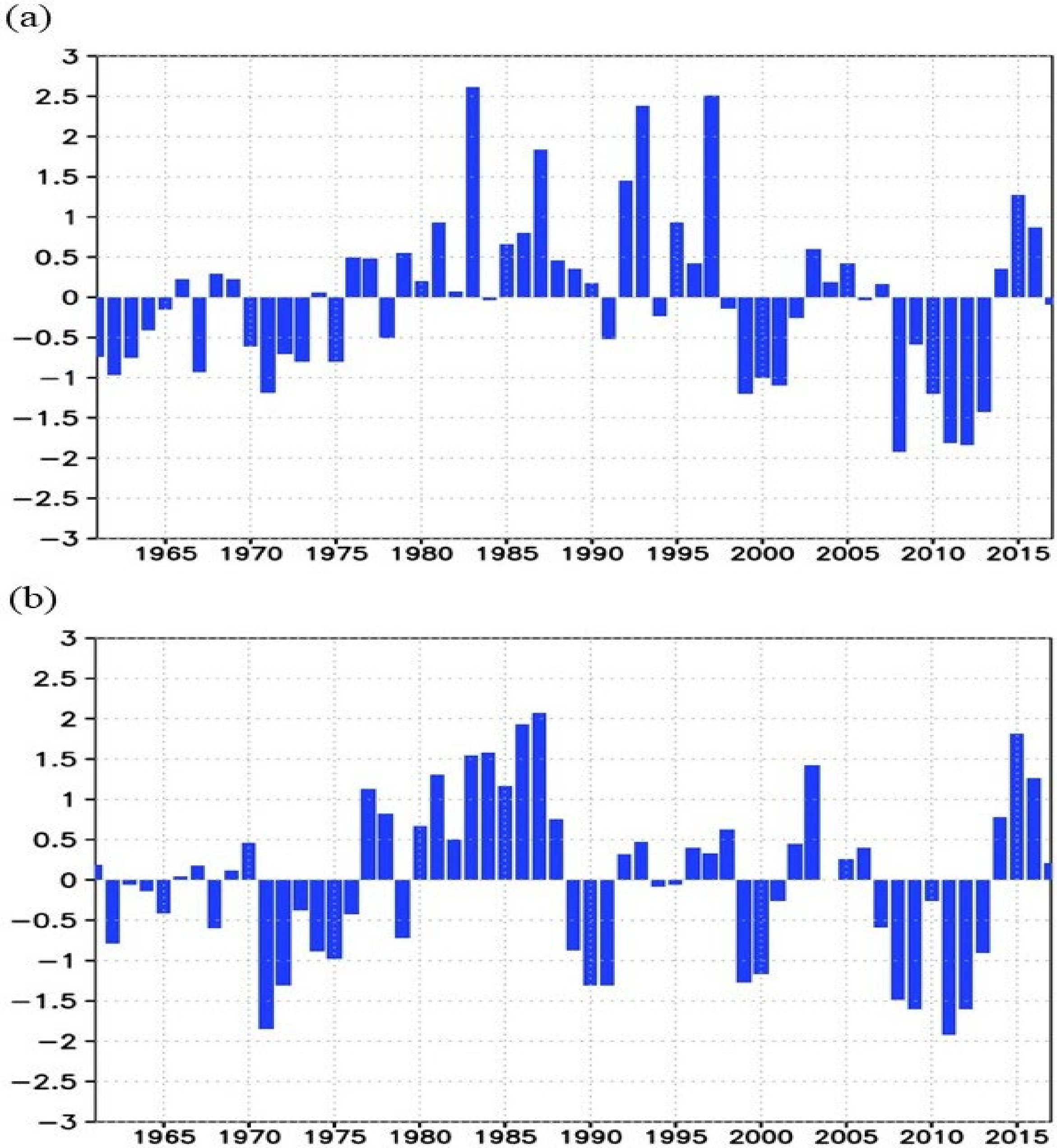


Fig. 3. PDO Index in (a) JJA, and (b) JFD. The vertical axis is PDO index (-), and the horizontal axis is the year.

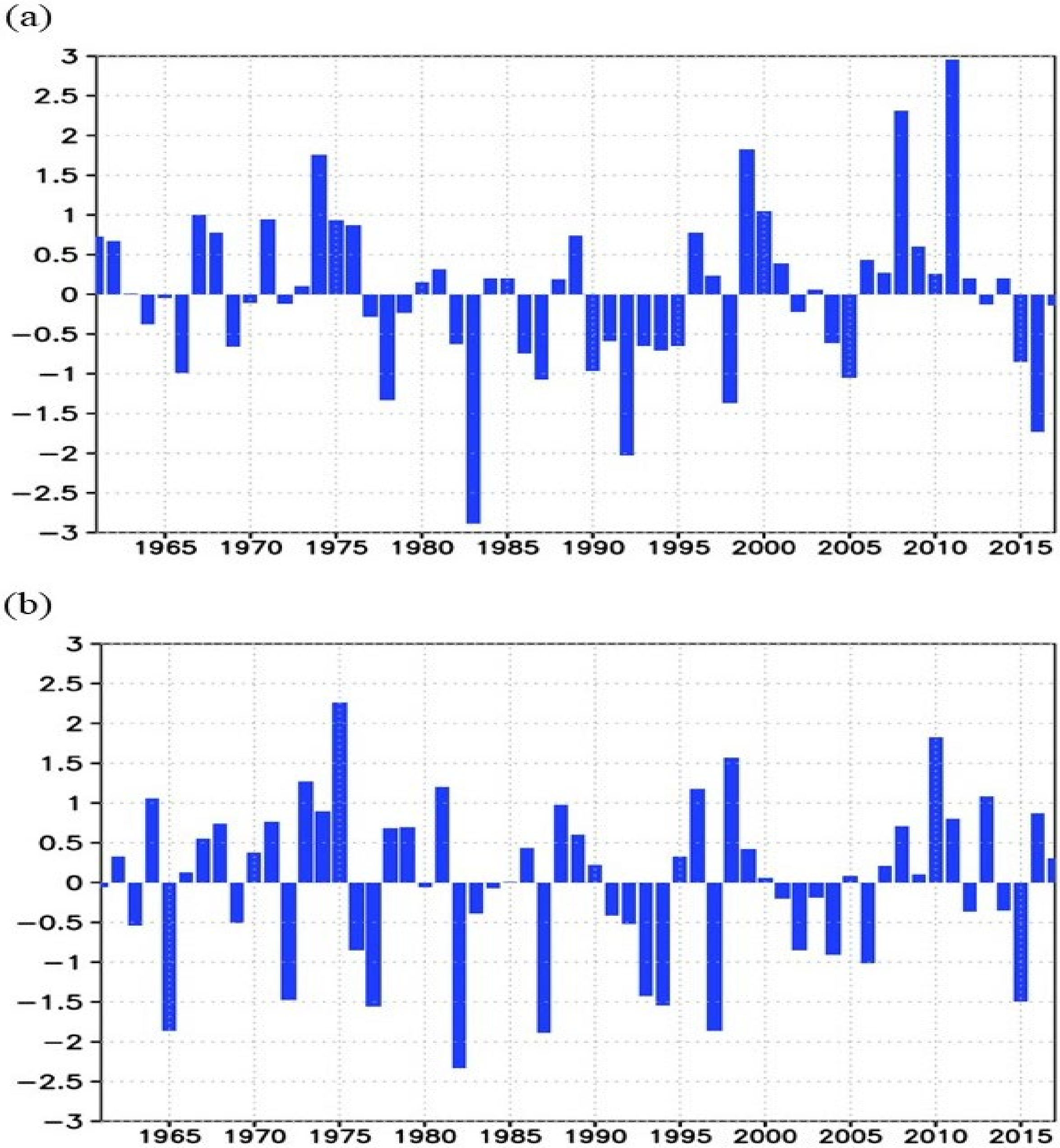


Fig. 4. SOI in (a) JJA, and (b) JFD. The vertical axis is SOI (-) and the horizontal axis is the year.

Table. 1. Positive / negative ratio of the top 30% of countries with the highest correlation coefficient between GDP growth rate and teleconnection indexes of each level.

teleconnection index	averaged month	correlation coefficient sign	Level			
			Level1	Level2	Level3	Level4
PDO index	JJA	plus	20.0%	20.0%	10.0%	81.3%
		minus	80.0%	80.0%	90.0%	18.8%
	JFD	plus	30.0%	40.0%	50.0%	81.3%
		minus	70.0%	60.0%	50.0%	18.8%
SOI	JJA	plus	80.0%	66.7%	70.0%	37.5%
		minus	20.0%	33.3%	30.0%	62.5%
	JFD	plus	80.0%	83.3%	60.0%	52.6%
		minus	20.0%	16.7%	40.0%	47.4%
R	JJA	plus	10.0%	20.0%	10.0%	81.3%
		minus	90.0%	80.0%	90.0%	18.8%
	JFD	plus	60.0%	53.3%	60.0%	75.0%
		minus	40.0%	46.7%	40.0%	25.0%

Table. 2. The list of the number of countries with significant correlation coefficient in Table 1

teleconnection index	averaged month	correlation coefficient sign	Level			
			Level1	Level2	Level3	Level4
PDO index	JJA	plus	2	1	1	5
		minus	4	9	7	3
	JFD	plus	2	1	3	9
		minus	2	7	8	6
SOI	JJA	plus	5	5	2	None
		minus	1	1	1	None
	JFD	plus	3	9	10	1
		minus	None	1	1	2
R	JJA	plus	None	2	None	4
		minus	3	6	8	3
	JFD	plus	2	3	4	10
		minus	3	3	5	7

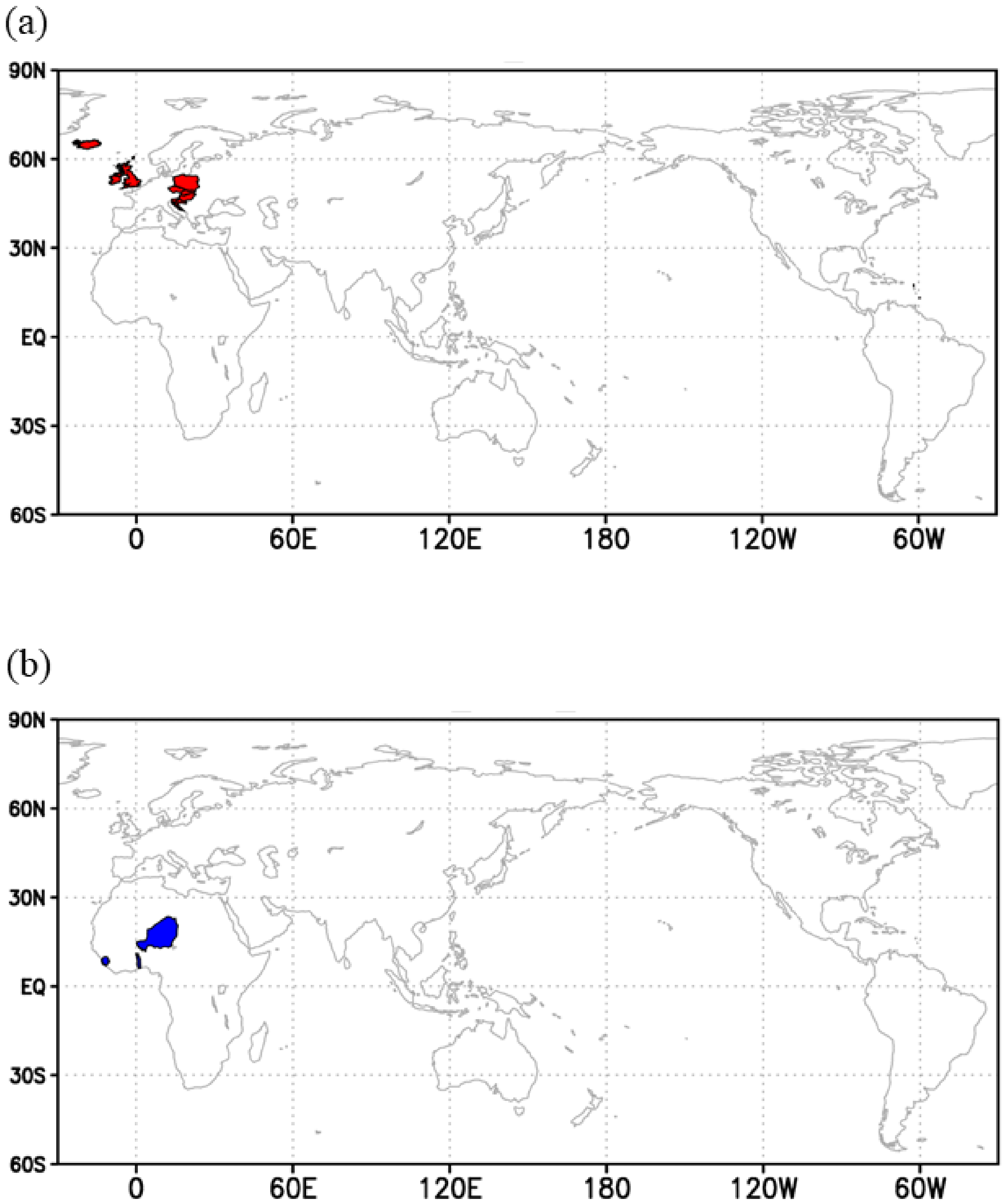


Fig. 5. The map of countries (a) for the level 4 group with the significantly positively correlation, and (b) for the level 1 group with the significantly negative correlation with PDO or R indices regardless of the season.

Table. 3. Positive / negative ratio of the top 30% of countries with the highest correlation coefficient between GDP growth rate and teleconnection indexes of each level classified by the industry groups.

sector	teleconnection index	averaged month	correlation coefficient sign	Level1	Level2	Level3	Level4
agriculture	PDO index	JJA	plus	50.0%	47.4%	45.5%	38.9%
			minus	50.0%	52.6%	54.5%	61.1%
		JFD	plus	33.3%	53.3%	60.0%	43.8%
			minus	66.7%	46.7%	40.0%	56.3%
	SOI	JJA	plus	70.0%	73.3%	40.0%	62.5%
			minus	30.0%	26.7%	60.0%	37.5%
		JFD	plus	63.6%	52.9%	69.2%	55.0%
			minus	36.4%	47.1%	30.8%	45.0%
	R	JJA	plus	60.0%	46.7%	30.0%	37.5%
			minus	40.0%	53.3%	70.0%	62.5%
		JFD	plus	50.0%	60.0%	90.0%	62.5%
			minus	50.0%	40.0%	10.0%	37.5%
industry	PDO index	JJA	plus	10.0%	40.0%	20.0%	62.5%
			minus	90.0%	60.0%	80.0%	37.5%
		JFD	plus	30.0%	26.7%	40.0%	68.8%
			minus	70.0%	73.3%	60.0%	31.3%
	SOI	JJA	plus	70.0%	60.0%	60.0%	56.3%
			minus	30.0%	40.0%	40.0%	43.8%
		JFD	plus	100.0%	86.7%	64.3%	61.1%
			minus	0.0%	13.3%	35.7%	38.9%
	R	JJA	plus	10.0%	33.3%	12.5%	71.4%
			minus	90.0%	66.7%	87.5%	28.6%
		JFD	plus	40.0%	33.3%	37.5%	71.4%
			minus	60.0%	66.7%	62.5%	28.6%
services	PDO index	JJA	plus	30.0%	57.1%	66.7%	100.0%
			minus	70.0%	42.9%	33.3%	0.0%
		JFD	plus	45.5%	50.0%	60.0%	93.8%
			minus	54.5%	50.0%	40.0%	6.3%
	SOI	JJA	plus	60.0%	35.7%	11.1%	12.5%
			minus	40.0%	64.3%	88.9%	87.5%

	JFD	plus	60.0%	57.1%	33.3%	5.9%
		minus	40.0%	42.9%	66.7%	94.1%
R	JJA	plus	20.0%	61.5%	66.7%	75.0%
		minus	80.0%	38.5%	33.3%	25.0%
	JFD	plus	50.0%	60.0%	33.3%	75.0%
		minus	50.0%	40.0%	66.7%	25.0%

Table. 4. The list of the number of countries with significant correlation coefficient in Table 3

sector	teleconnection index	averaged month	correlation coefficient sign	Level			
				Level1	Level2	Level3	Level4
agriculture	PDO index	JJA	plus	1	3	3	4
			minus	3	6	1	4
		JFD	plus	2	2	2	3
			minus	1	3	None	1
	SOI	JJA	plus	4	6	2	1
			minus	None	2	2	None
		JFD	plus	5	6	6	3
			minus	2	5	4	3
	R	JJA	plus	1	2	1	2
			minus	1	5	1	4
		JFD	plus	1	2	2	2
			minus	2	1	None	1
industry	PDO index	JJA	plus	1	2	None	8
			minus	6	5	5	6
		JFD	plus	2	2	2	12
			minus	4	8	6	7
	SOI	JJA	plus	6	4	1	1
			minus	1	1	2	5
		JFD	plus	4	5	5	7
			minus	None	1	3	3
	R	JJA	plus	None	3	None	9
			minus	4	7	6	6
		JFD	plus	2	3	3	13
			minus	5	7	5	7
services	PDO index	JJA	plus	None	2	5	14
			minus	3	3	1	1
		JFD	plus	1	2	2	9
			minus	4	2	4	1
	SOI	JJA	plus	2	1	2	None
			minus	1	3	3	6
		JFD	plus	1	3	None	1
			minus	1	None	3	6
	R	JJA	plus	None	3	3	13

	minus	3	4	1	1
JFD	plus	5	4	2	8
	minus	3	5	5	2

Appendix

Table. A.1 The list of countries with significant correlation coefficient in Table 1

teleco-nnection index	averaged month	correlation coefficient sign	Level			
			Level1	Level2	Level3	Level4
PDO index	JJA	plus	Ethiopia, Liberia	Bhutan	China	Antigua and Barbuda, Croatia, Iceland, Ireland, Slovenia
		minus	Lesotho, Niger, Sierra Leone, Togo	Bolivia, Ecuador, Fiji, Georgia, Lao, Mongolia, Morocco, Ukraine, Uzbekistan	Brazil, Nauru, Panama, Russia, South Africa, Suriname, Turkmenistan	France, Saudi Arabia, Trinidad and Tobago
	JFD	plus	Ethiopia, Nepal	India	Bulgaria, China, Dominica	Antigua and Barbuda, Barbados, Croatia, Czech Republic, Hungary, Ireland, Slovak Republic, Slovenia, United Kingdom
		minus	Niger, Sierra Leone	Belize, Bolivia, Ecuador, Guatemala, Lao, Nigeria, Tunisia	Botswana, Brazil, Gabon, Grenada, Iran, Malaysia, Panama, Suriname	Austria, Belgium, Brunei, France, Israel, Saudi Arabia
SOI	JJA	plus	Congo Dem. Rep., Gambia, Guinea, Niger, Rwanda	Cote d'Ivoire, Ecuador, Fiji, Paraguay, Swaziland	Gabon, Turkmenistan	None

		minus	Liberia	Jamaica	Palau	None
	JFD	plus	Congo Dem. Rep., Kyrgyz Republic, Uganda	Ecuador, Georgia, Ghana, Lao, Mongolia, Morocco, Ukraine, Uzbekistan, Zambia	Belarus, Brazil, Cuba, Gabon, Kazakhstan, Peru, Russia, South Africa, Suriname, Turkmenistan	Trinidad and Tobago
		minus	None	Marshall Islands	China	Iceland, United Kingdom
R	JJA	plus	None	Bhutan, Bosnia and Herzegovina	None	Antigua and Barbuda, Croatia, Iceland, Slovenia
		minus	Niger, Sierra Leone, Togo	Bolivia, Ecuador, Lao, Mongolia, Morocco, Nicaragua	Brazil, Namibia, Panama, Peru, Russia, South Africa, Suriname, Turkmenistan	France, Saudi Arabia, Trinidad and Tobago
	JFD	plus	Ethiopia, Nepal	Armenia, India, Samoa	Bulgaria, Dominica, Grenada, Romania	Antigua and Barbuda, Austria, Barbados, Croatia, Czech Republic, Hungary, Ireland, Poland, Slovak Republic, Slovenia
		minus	Malawi, Niger, Sierra Leone	Guatemala, Nigeria, Tunisia	Botswana, Brazil, Gabon, Iran, Malaysia	Belgium, Brunei, France, Israel, Japan, Saudi Arabia, Seychelles

Table. A.2 The list of countries with significant correlation coefficient in Table 3

sector	teleconnection index	averaged month	correlation coefficient sign	Level1	Level2	Level3	Level4
agriculture	PDO index	JJA	plus	Benin	Lao, Samoa, Timor-Leste	Costa Rica, Equatorial, Gabon	Bahrain, Malta, Oman, Seychelles
			minus	Burundi, Sierra Leone, Tajikistan	Albania, Armenia, Azerbaijan, Morocco, Philippines, Ukraine	Cuba	Bahamas, Czech Republic, Germany, Iceland
		JFD	plus	Benin, Congo Rep.	Bhutan, India	Costa Rica, Gabon	Brunei, Norway, Oman
			minus	Sierra Leone	Armenia, Marshall Islands, Philippines	None	Saudi Arabia
	SOI	JJA	plus	Burundi, Cambodia, Sierra Leone, Tajikistan	Albania, Cote d'Ivoire, Georgia, India, Paraguay, Vanuatu	Belarus, Mexico	Germany
			minus	None	Lao, Papua New Guinea	Equatorial, Gabon	None
		JFD	plus	Kyrgyz Republic, Nepal, Senegal, Sierra Leone, Tajikistan	Armenia, Guyana, Marshall Islands, Philippines, Ukraine, Vietnam	Cuba, Kazakhstan, Montenegro, Romania, Russia, South Africa	Czech Republic, Germany, Saudi Arabia
			minus	Benin, Congo Rep.	Bhutan, Iraq, Jordan, Samoa, Timor-Leste	Colombia, Equatorial, Gabon, Iran	Brunei, Norway, Oman

	R	JJA	plus	Benin	Egypt, Samoa	Costa Rica	Oman, Seychelles Spain
			minus	Sierra Leone	Albania, Armenia, Azerbaijan, Morocco, Philippines	Kazakhstan	Bahamas, Czech Republic, Iceland, United Kingdom
		JFD	plus	Benin	Bhutan, India	Costa Rica, Gabon	Oman, Sweden
			minus	Sierra Leone, Yemen	Philippines	None	New Zealand
industry	PDO index	JJA	plus	Ethiopia	Bosnia and Herzegovina, Sudan	None	Andorra, Belgium, Croatia, Hungary, Ireland, Luxembourg, Portugal, Slovenia
			minus	Lesotho, Liberia, Niger, Senegal, Sierra Leone, Togo	Bolivia, Ecuador, Egypt, Nicaragua, Ukraine	Colombia, Equatorial, Kazakhstan, Namibia, Panama	Bahamas, France, Kuwait, Qatar, Singapore, South Korea
		JFD	plus	Ethiopia, Nepal	India, Jamaica	Bulgaria, Libya	Andorra, Antigua and Barbuda, Croatia, Finland, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, Portugal, Slovenia
			minus	Liberia, Niger, Senegal, Sierra Leone	Bolivia, Ecuador, Egypt, Indonesia, Iraq, Micronesia Fed. Sts.,	Costa Rica, Equatorial, Guinea, Gabon, Iran, Malaysia	Brunei, France, Kuwait, Norway, Qatar, Singapore, United

				Nigeria, Tunisia		Arab Emirates
SOI	JJA	plus	Congo Dem. Rep., Guinea, Haiti, Malawi, Niger, Rwanda	Ecuador, Fiji, Morocco, Nigeria	Dominican Republic	Uruguay
		minus	Nepal	Vietnam	Peru, Suriname	Andorra, Croatia, Hungary, Ireland, Latvia
	JFD	plus	Burkina Faso, Kyrgyz Republic, Togo, Uganda	Ecuador, Georgia, Guyana, Morocco, Nigeria	Brazil, Colombia, Equatorial, Gabon, Russia	Australia, Kuwait, Netherlands, Norway, Oman, Trinidad and Tobago, United Arab Emirates
		minus	None	Papua New Guinea	China, Grenada, Palau	Andorra, Japan, Luxembourg
R	JJA	plus	None	Bosnia and Herzegovina, India, Sudan	None	Andorra, Belgium, Croatia, Finland, Hungary, Japan, Luxembourg, Portugal, Slovenia
		minus	Liberia, Niger, Senegal, Togo	Albania, Bolivia, Ecuador, Egypt, Guatemala, Nicaragua, Ukraine	Colombia, Equatorial, Kazakhstan, Namibia, Panama, Russia	Bahamas, France, Kuwait, Singapore, South Korea, Sweden

		JFD	plus	Ethiopia, Nepal	Georgia, India, Jamaica	Bulgaria, Libya, Maldives	Andorra, Antigua and Barbuda, Croatia, Czech Republic, Finland, Greece, Hungary, Ireland, Italy, Japan, Portugal, Slovenia, Switzerland
			minus	Liberia, Malawi, Niger, Senegal, Sierra Leone	Bolivia, Ecuador, Egypt, Indonesia, Iraq, Micronesia Fed. Sts., Tunisia	Costa Rica, Equatorial, Gabon, Iran, Malaysia	Brunei, France, Kuwait, Qatar, Singapore, Sri Lanka, United Arab Emirates
services	PDO index	JJA	plus	None	Bosnia and Herzegovina, Cape Verde	China, Kazakhstan, Malaysia, Palau, Serbia	Andorra, Antigua and Barbuda, Bahamas, Bahrain, Canada, Croatia, Czech Republic, Estonia, Greece, Iceland, Ireland, Kuwait, Malta, Slovak Republic
			minus	Afghanistan, Sierra Leone, Togo	Fiji, Mongolia, Morocco	Mexico	France

	JFD	plus	Pakistan	India, Iraq	China, Palau	Andorra, Antigua and Barbuda, Brunei, Croatia, Czech Republic, Hungary, Ireland, Kuwait, United Kingdom
		minus	Afghanistan, Guinea-Bissau, Uganda, Yemen	Fiji, Guatemala	Botswana, Brazil, Mexico, Panama	France
SOI	JJA	plus	Gambia, Zimbabwe	Fiji	Brazil, Gabon	None
		minus	Burundi	Angola, Lao, Sudan	China, Palau, Serbia	Andorra, Bahrain, Canada, Kuwait, Trinidad and Tobago, United Arab Emirates
	JFD	plus	Uganda	Georgia, Mongolia, Uzbekistan	None	Barbados
		minus	Pakistan	None	China, Colombia, Turkmenistan	Andorra, Bahrain, Brunei, Canada, Norway, United States
R	JJA	plus	None	Bosnia and Herzegovina, Cape Verde, Samoa	China, Kazakhstan, Serbia	Andorra, Antigua and Barbuda, Bahamas, Bahrain, Canada, Croatia, Czech Republic,

					Greece, Iceland, Ireland, Malta, Portugal, Slovak Republic
	minus	Afghanistan, Sierra Leone, Togo	Fiji, Mongolia, Morocco, Zambia	Panama	France
JFD	plus	Bangladesh, Kyrgyz Republic, Nepal, Tajikistan,	Georgia, India, Iraq, Samoa	China, Palau	Andorra, Antigua and Barbuda, Croatia, Czech Republic, Hungary, Ireland, Kuwait, United Kingdom
	minus	Afghanistan, Guinea-Bissau, Yemen	Belize, Ecuador, Fiji, Kiribati, Papua New Guinea	Botswana, Brazil, Colombia, Mexico, Panama	France, Venezuela