Proceedings of the 7th International Conference on Economic Management and Green Development
DOI: 10.54254/2754-1169/27/20231227

Water Pollution and Decoupling Status in the Yangtze River Economic Belt

Jerry Cao[1,a,*]

[1]*University of British Columbia, Vancouver, Canada, V6T 1Z4*
a. c.jerry.v@gmail.com
**corresponding author*

Abstract: Monitoring and reducing Water pollution is critical for the sustainable and green development of socio-economy. This paper combined the concept of Grey Water Footprint and Decoupling theory to evaluate the water pollution status in Yangtze River and the related Economic Belt from 2003 to 2018. By understanding the pollution status, a clearer insight into whether Yangtze River achieved decoupling and where to further improve water quality could be found. According to the result, although some regions, such as Yunnan and Jiangxi, did not display a descending pattern during the period, Yangtze River Economic Belt as a whole showcased a steady decline in total GWF since 2010. In regarding to the economic development, every region within Yangtze River Economic Belt significantly increased their GDP throughout the period. Therefore, according to Tapio's decoupling model, it was always decoupling status for Yangtze River Economy from 2003 to 2018, and it has been strong decoupling status for 7 years. This paper provides some information and references for the formulation of water resources management policies, and finally promotes the green development of the areas in the Yangtze River Economic Belt.

Keywords: water pollution, Yangtze River Economic Belt, grey water footprint, Tapio's decoupling model

1. Introduction

Water resources, as the most basic and important resources of human development, are a critical factor in regional socio-economic development [1]. According to Water Organization, water environment quality is positively related to economic development, high quality water environment even has the potential to increase economic returns [2]. Hu and Cheng [1] also state that water environment underpins rapid economic development. In other words, water quality is indispensable for a healthy and growing economic development. Yangtze River Economic Belt(YREB) is a typical example of water resources and economic growth. However, due to the pursuit of rapid economic development in past several years, the shortage of water resources and water pollution in the Yangtze River were severe.

What happened to Yangtze River perfectly match the preceding part of environmental Kuzenets curve (EKC): the growth of economy will deteriorate the environment [3]. The later part of the EKC, which states improvements to environmental quality will take place when economy matures, is yet to achieve. OECD has invented a word for the later part of the EKC- decoupling [4]. As defined by

DOI: 10.54254/2754-1169/27/20231227

OECD to break the relationship between increase in economics and increase in pollution, decoupling now serves as an ultimate goal for most environmental improvement and protection policies [4].

In order to quantify and measure the water pollution in Yangtze River, grey water footprint (GWF) was applied in this article. By combining and utilizing both GWF and decoupling theory, this paper analyzes the status of Yangtze River water quality and determine if Yangtze River has achieved the goal of decoupling. This paper has the potential to provide information and reference for the formulation of water resources management policies, and finally promotes the sustainable and green development of the areas in the YREB.

2. Methodology

2.1. Study Area

YREB is one of the largest economic belt in China as it spans to the west, the east, and the middle part of China. Chinese government has also assigned it as one of three critical strategies. The area is about 2 million km^2. Provinces and municipalities within the area includes Shanghai, Jiangsu, Zhejiang, etc. As China's current industry and manufacturing base, and the corner stone for future development, the water quality issue in Yangtze River is urgent and pivotal. YREB supports approximately 40% of all population and produces over 40% of GDP of China. Yangtze River is one of the key factors that enable China economy to grow rapidly [5].

Unfortunately, the economy growth in YREB causes comes with cost. Firstly, although the total amount of water resources in the Yangtze River is abundant, the per capita occupancy is low [6]. On the other hand, a relatively low rate of utilization of water resources and serious waste of water resources are urgent and problematic. Moreover, due to inadequate supervision, a considerable amount of unprocessed industrial wastewater and urban sewage are directly discharged into the Yangtze River, which has far exceeded the self-purification capacity of Yangtze River [7]. With the continuous rapid economic growth and the accelerated pace of industrialization and urbanization, the water demand in YREB is estimated to increase. Therefore, it is important to manage the water environment for Yangtze River.

2.2. Data Source

In this study, GDP is chosen as an index for economic growth. Grey water footprint, or GWF, is chosen for the quantification of water pollution. GDP data for all regions is gained from CEIC databank, which is initially published by Chinese government. Given that there is no official data about GWF in China, the GWF data for all cities and provinces are sourced from He et al.'s report [8].

2.3. Model

2.3.1. Grey Water Footprint

Grey water footprint is firstly introduced in 2010. According to by Hoekstra and Arjen, the definition of the Grey water footprint is the amount of clean and fresh water that is needed to assimilate the load of pollutants based on natural background concentration and existing ambient water quality standard [9]. According to Hoekstra and Chapagain [9], grey water footprint includes agriculture GWF, industry GWF, and life GWF. The GWF used for research in this paper is the sum of these three types of GWF, GWFtotal, and it is calculated as:

$$\mathrm{GWF}total = \mathrm{GWF}agr + \mathrm{GWF}ind + \mathrm{GWF}dom \tag{1}$$

DOI: 10.54254/2754-1169/27/20231227

2.3.2. Tapio Decoupling Model

Decoupling theory is applied to evaluate the interdependence relationship between the growth in economy and pollution in water resources. The main concept of decoupling is to break the relationship and to establish an growing economy without polluting the environment. According to Tapio's model [10], decoupling could be divided into 2 types, strong and weak decoupling. Strong decoupling means that economy is growing while the pollution and resource consumption is reducing. Weak decoupling, on the other hand, refers that pollution and resource consumption increase with economy but at a lower rate. In this paper, Tapio's model [10] is being applied to calculate the decoupling index, or decoupling elasticity, and decoupling status for the Yangtze Economy Belt as well as the cities and provinces inside of it. GWF and GDP is used to calculate Tapios' decoupling elasticity. The decoupling theory is basically the ratio of percentage changes in pollution and percentage changes in GDP. In this paper, the formula is:

$$e = \frac{\%\Delta \text{ GWF}}{\%\Delta \text{ GDP}} = \frac{(\text{GWFn-GWFn-1})/\text{GWFn}}{(\text{GDPn-GDPn-1})/\text{GDPn}} \tag{2}$$

Decoupling elasticity showcases if decoupling is achieved and to what extent. According to Tapio's model, there are 8 types of decoupling Status [10], as shown in Table 1.

Table 1: Eight types of decoupling status [10].

Decoupling Status		**ΔGDP**	**ΔGWF**	**Elasticity**
Decoupling	Strong	>0	<0	≤0
	Weak	>0	>0	0<e<0.8
	Recessive	<0	<0	≥1.2
Negative decoupling	Strong negative	<0	>0	≤0
	Weak negative	<0	<0	0<e<0.8
	Negative decoupling of growth	>0	>0	≥1.2
Connectivity	Growth connectivity	>0	>0	0.8<e<1.2
	Declining connection	<0	<0	0.8<e<1.2

3. Data Analysis

3.1. Analysis of the GWF and GDP of 11 Cities and Provinces

As Table 2 shows, GWF is significantly different in each cities and provinces. Besides Yunnan and Jiangxi, all other provinces and cities have a lower of GWF in 2018 compared to the value they had in 2003.

DOI: 10.54254/2754-1169/27/20231227

Table 2: The GWF of cities and provinces in the YREB from 2003 to 2018 [8].

The GWF of 11 Cities and provinces in the Yangtze River Economic Belt from 2003 to 2018												**Units in billion m³**
Year	**Shanghai**	**Jiangsu**	**Zhejiang**	**Anhui**	**Jiangxi**	**Hubei**	**Hunan**	**Chongqing**	**Sichuan**	**Guizhou**	**Yunnan**	**Total GWF**
2003	6.5	24.9	13.8	20.2	14.6	23.8	29.1	9.7	38.2	14.8	18.5	214.2
2004	5.4	26.3	13.8	19.7	15.4	23.9	30.5	10.0	38.0	15.1	19.3	217.5
2005	5.8	28.2	14.5	19.7	15.8	24.3	31.7	10.1	37.8	15.8	19.7	223.2
2006	5.7	27.6	14.4	18.6	15.9	23.8	31.9	10.0	38.3	16.1	19.8	222.0
2007	5.6	25.9	13.5	16.4	14.3	22.7	28.5	8.9	35.0	12.7	18.9	202.3
2008	5.1	25.3	13.2	16.2	14.2	23.1	28.5	9.0	35.0	12.9	19.0	201.5
2009	4.6	24.9	12.8	16.3	14.4	23.5	28.6	9.3	35.5	13.0	19.4	202.3
2010	4.2	24.4	12.4	16.2	14.6	23.6	27.9	9.3	35.3	12.9	19.7	200.4
2011	4.1	25.0	14.2	18.5	15.9	24.3	26.2	10.2	35.1	13.5	23.3	210.2
2012	3.9	24.3	13.7	18.4	16.0	24.5	26.1	10.1	34.7	13.3	23.5	208.7
2013	3.8	23.5	13.3	18.4	16.0	24.3	26.2	10.0	34.4	13.3	23.6	206.8
2014	3.6	22.9	12.6	18.2	16.1	24.0	26.3	10.1	34.8	13.7	23.9	206.1
2015	3.4	22.2	11.8	18.0	16.2	23.3	25.9	10.1	34.6	14.1	23.7	203.1
2016	3.1	21.8	10.9	17.4	16.0	21.7	24.2	9.8	33.8	13.7	23.8	196.1
2017	3.0	22.0	10.6	16.3	15.3	20.1	23.3	9.0	31.8	13.6	24.5	189.3
2018	1.7	20.6	10.1	15.2	15.2	19.5	22.6	8.9	31.2	13.0	24.3	182.3

Among all the regions, Shanghai always has the least amount of GWF, and it has the largest percentage reduction in GWF, which is about 74%. Sichuan's GWF is always the highest, but a steady reduction in GWF was experienced by Sichuan from 2003 to 2018 as the number dropped from 38.2 to 31.2 with limited number of rebounds.

Table 3: The GDP of 11 cities and provinces in the Yangtze River Economic Belt from 2003 to 2018.

The GDP of 11 cities and provinces in the Yangtze River Economic Belt from 2003 to 2018											Units in billions RMB	
Year	**Shanghai**	**Jiangsu**	**Zhejiang**	**Anhui**	**Jiangxi**	**Hubei**	**Hunan**	**Chongqing**	**Sichuan**	**Guizhou**	**Yunnan**	**Total GDP**
2003	680.40	1244.29	975.34	430.78	281.27	475.75	466.00	261.56	534.62	142.90	263.34	5756.25
2004	810.16	1482.31	1148.21	512.91	339.81	554.68	554.26	305.95	630.40	164.94	313.64	6817.27
2005	914.40	1827.21	1336.50	537.58	405.62	648.45	647.36	306.91	738.51	194.20	347.23	7903.97
2006	1029.70	2154.84	1564.89	614.19	461.88	749.72	749.32	348.62	863.78	226.74	400.19	9163.86
2007	1200.12	2556.01	1863.84	734.57	546.93	915.00	914.50	411.18	1050.53	271.03	472.18	10935.87
2007	1200.12	2556.01	1863.84	734.57	546.93	915.00	914.50	411.18	1050.53	271.03	472.18	10935.87
2008	1369.82	3031.26	2148.69	887.42	648.03	1133.04	1115.66	509.67	1250.63	333.34	570.01	12997.56
2009	1490.09	3406.12	2283.24	1005.29	758.92	1283.15	1293.07	652.87	1415.13	389.35	616.82	14594.06
2010	1687.24	4090.33	2722.68	1226.34	943.50	1580.61	1590.21	789.42	1689.86	459.40	722.01	17501.60
2011	1919.57	4860.43	3200.01	1511.03	1158.38	1959.42	1963.52	1001.11	2102.67	570.18	875.10	21121.41
2012	2010.13	5405.82	3460.63	1721.21	1294.85	2225.02	2215.42	1145.90	2384.98	680.22	1030.98	23575.16
2013	2160.21	5916.18	3756.85	1903.89	1433.85	2466.85	2450.17	1265.67	2626.08	800.68	1172.09	25952.52

Table 3: (continued).

2014	2356.09	6508.83	4015.35	2084.88	1570.86	2736.70	2704.85	1426.54	2853.67	925.10	1281.46	28464.33
2015	2496.50	7011.64	4288.65	2200.56	1672.38	2955.02	2904.72	1571.97	3010.31	1050.26	1371.79	30533.79
2016	2746.62	7608.62	4648.50	2411.79	1836.44	3229.79	3124.47	1755.88	3268.05	1173.44	1487.00	33290.58
2017	3013.39	8590.09	5176.83	2751.87	2081.85	3652.30	3459.06	1950.03	3698.02	1354.08	1653.13	37380.64
2018	3601.18	9320.76	5800.28	3401.09	2271.65	4202.20	3632.97	2158.88	4290.21	1535.32	2088.06	42302.60

In sharp contrast with other regions, the GWF of Jiangxi and Yunnan did not drop in the last decade. Jiangxi showcased a slight increase in GWF from 2003 to 2015, as the number increase from 14.6 to 16. In 2016, this ascending trend was ended, and the number dropped from 16 to 15.2 in the next 2 years. In Yunnan, the pattern of changes in GWF is opposite to other regions. The GWF increased from 18.5 to 24.3 in the last 15 years, which is about a 31% increase from 2003 to 2018.

Unlike the GWF, the GDP for all regions showcased a similar pattern (Table 3). All cities and provinces experienced increases in GDP every single year. No regions had a GDP recession at any point from 2003 to 2018.

Among all the regions, Guizhou has the most percentage changes in GDP. From 2003 to 2018, Guizhous' GDP increased from 142 billion RMB to 1535.32 billion RMB, which is a tenfold increase.

3.2. Analysis of the Decoupling status of YREB

As discussed in the previous section, the Economy of YREB displays a rising pattern while the GWF showcases a descending pattern. Although the economy grows with an increase in GWF in Year 2004, 2005, 2009, and 2011 (see Figure 1). Overall, the GDP and GWF moves in opposite directions. GDP has increased eightfold from 2003 to 2018 and GWF reduced by 16%. The change in GDP is tremendous in comparison to the change in GWF.

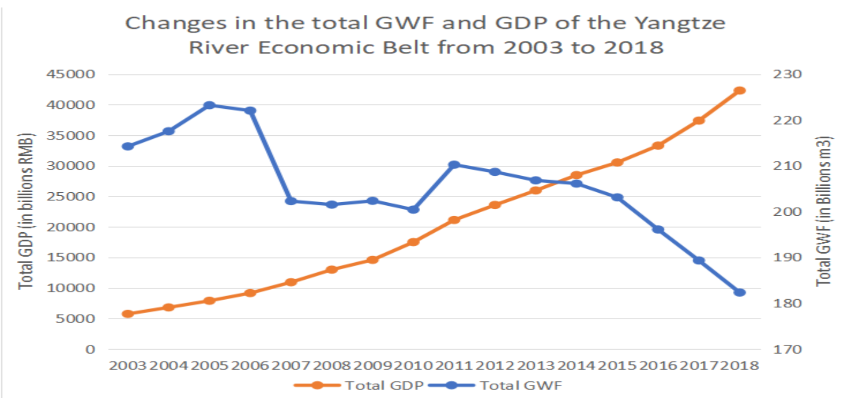

Figure 1: Changes in the total GWF and GDP of the Yangtze River Economic Belt from 2003 to 2018.

By aggregating all the GWF and GDP for all regions, changes in GDP, changes in GWF, and decoupling elasticity could be calculated. Also, by comparing the direction of changes in GDP and GWF as well as the elasticity to the model constructed by Tapio (2021), the decoupling status could be determined.

As shown in the Table 4, given that changes in GDP is always positive and changes in GWF is nearly all negative, the calculated elasticity each year is either relatively small value or negative. In other words, decoupling has been achieved for Yangtze River from 2003 to 2018. Between 2003 to 2011, strong decoupling and weak decoupling took place alternately. Also, after 2011, the changes in GWF and Elasticity is always negative, which means that the pollutions in Yangtze River keeps reducing since 2011. Therefore, it is always strong decoupling after 2011 as the economy keeps increasing and GWF shows a declining pattern.

Table 4: The decoupling elasticity and status of Yangtze River Economic Belt from 2003 to 2018.

Years	%Δ in GDP	%Δ in GWF	Elasticity	Decoupling status
2003~2004	0.155637	0.015171	0.097477	weak
2004~2005	0.137488	0.025448	0.185092	weak
2005~2006	0.137484	-0.00531	-0.03866	Strong
2006~2007	0.162037	-0.09759	-0.60225	Strong
2007~2008	0.158621	-0.00382	-0.02409	Strong
2008~2009	0.109394	0.004102	0.037498	weak
2009~2010	0.16613	-0.00958	-0.05766	Strong
2010~2011	0.171381	0.046618	0.272013	weak
2011~2012	0.104082	-0.00752	-0.07229	Strong
2012~2013	0.091604	-0.0089	-0.09712	Strong
2013~2014	0.088244	-0.00344	-0.03904	Strong
2014~2015	0.067776	-0.01477	-0.21794	Strong
2015~2016	0.08281	-0.03575	-0.4317	Strong
2016~2017	0.109417	-0.0357	-0.32632	Strong
2017~2018	0.116351	-0.03833	-0.32948	Strong

4. Conclusion

In order to conduct a comprehensive investigation on the relationship between water pollution and economic growth in YREB, a combination of GWF concept and decoupling theory is introduced in this paper. Firstly, the GDP and GWF value and pattern for all cities were gathered. Secondly, by aggregating GDP and GWF for all regions, the GDP and GWF as well as the decoupling elasticity was calculated for the entire YREB. Lastly, the decoupling status was found based on the Tapio's decoupling model [10] and the directions of the changes in GDP and GWF. Main conclusions are:

DOI: 10.54254/2754-1169/27/20231227

(1) Besides Jiangxi and Yunnan, all other cities and provinces showcased a descending pattern on the GWF. The GWF of Jiangxi in 2018 is similar to the number in 2003 (15.2 in 2018 and 14.6 in 2003), and Yunnan's GWF increased from 18.5 to 24.3 from 2003 to 2018.

(2) All regions within YREB experience an increase in GDP every year.

(3) Although some regions GWF did not reduce, overall YREB achieved decoupling.

(4) Before 2011, Strong decoupling and weak decoupling were experienced by Yangtze River Economy Belt alternately.

(5) After 2011, the total GWF in Yangtze River Economy Belt kept decreasing each year, and strong decoupling was always the case.

In addition, although the total pollution in Yangtze River has been dropping for 7 years, contribution to this reduction varied significant by the regions. Regions such as Shanghai, Hunan, and Sichuan showcased great decreases in GWF while some regions, such as Jiangxi and Yunnan, did not display such descending trend. In order to further improve the water quality in Yangtze River, it is critical for regions with limited or no reduction in GWF to decrease their GWF. New policies, stricter requirement, and better surveillance on grey water emission and processing are all potentially helpful.

References

[1] Hu Y. & Cheng H., Water pollution during China's industrial transition [J] Environmental Development, vol 8, 2013, pp. 57-73.

[2] Water Organization, An economic Crisis, 2022. https://water.org/our-impact/water-crisis/economic-crisis/.

[3] Diao X., Zeng S., Tam C. & Tam V., Ekc Analysis For Studying Economic Growth And Environmental Quality: A Case Study In China [J] Journal of Cleaner Production, volume 17, no 5, 2009, pp. 8.

[4] OECD, Indicators to Measure Decoupling of Environmental Pressure From Economic Growth. May 16, 2002. http://www.oecd.org/officialdocuments/displaydocumentpdf?cote=sg/sd(2002)1/final&doclanguage=en

[5] Sun S., Xu L. & Chen J., A study on the decoupling relationship between agricultural grey water footprint and agricultural economic growth: based on the empirical analysis of 11 provinces and cities in the Yangtze River Economic Belt [J] Water Saving Irrigation, Vol 6, 2022, pp.17-23.

[6] Zhang L., Lu M., Zhang X. & Wang Z., Water pollution control in the Yangtze River Economic Belt under the interaction of economic development and environmental regulation [J] Water Resources and Hydropower Engineering, vol 53, no 5, 2022, pp. 128-136.

[7] Zhang L. & Che L. & Wang Z. & Hao L., Study on evolution and driving factors of relationship between water pollution and economic decoupling in Yangtze River Economic Zone [J] Water Resources and Hydropower Engineering, Vol 52, No 12, 2021, pp. 47-59.

[8] He W. & Kong Y. & Shen J., Two-dimensional decoupling analysis of grey water footprint and economic growth in the Yangtze River Economic Belt [J]. Journal of Hohai University (Philosophy and Social Sciences Edition) , vol 24, no 1, 2022, pp. 68-74.

[9] Hoekstra & Ashok. Globalization of Water: Sharing the Planet's Freshwater [J] Geographical Journal, 2009

[10] Shang M., Luo J. The Tapio Decoupling Principle and Key Strategies for Changing Factors of Chinese Urban Carbon Footprint Based on Cloud Computing. [J] Int J Environ Res Public Health, vol 18, no 1, 2021, pp. 1-17.