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A Regional Analysis of China's Environmental Issues

ABSTRACT

Over the history of economic development, natural resources have always played an essential role. For instance, during the first Industrial Revolution steam engine greatly increased the efficiency of production: with the help of the combustion of black coal, and later oil, the worth of natural resources from the Earth was never devalued. For every economic entity, immense development at the beginning of the process seems inevitable, and China's economic development follows a similar trajectory, yet with the continuing development, environmental issues are becoming non-negligible anymore in China, which could potentially drag and slow down overall economic progress. What problems is China facing nowadays and what will it face in the future, and what sort of measures can have their own practical meaning to the world? We are going to look at the details in this paper.

Keywords: China, dynamic analysis, environmental pollution, middle income trap, tendency analysis

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INTRODUCTION

As a developing country, China emitted the most CO_2 in the world,[2] but in terms of CO_2 emission per capita, China is not on the top countries list anymore, following Germany, Poland, and Estonia (World Bank, 2019). Environmental protection is crucial for sustainable and rapid development, hence we believe China made some efforts to do it.

Natural resources, or energy as we usually say, are limited within a given area, and spatial distribution is uneven on the Earth. Fossil fuel is a good example: biomass plays an essential role, which requires certain climates (photosynthesis needs high solar energy, high humidity, high temperature, etc.): during the formation process with long-term tectonic movements and the various stratum strikes, different countries can obtain different types and amounts of fossil fuel, as well as wind energy, solar energy, hydropower, etc. Among the economic entities, there are no physical boundaries and the connection is strengthening because of the process of globalization and productive activities, while money flows among them (relatively) freely, but there are finite capacities of the local ecosystem to produce products and absorb the wastes (Lester et al., 1991).[3] A sustainable environment and development are crucial for an economic entity, and, apparently, the growth of the economy of China is constrained in terms of natural resources and environmental pollution. As the largest foreign direct investment (FDI) holder in the world (World Bank), China may also stress resistance to environmental protection from foreign investors due to the 'Pollution Haven Hypothesis' (PHH)[4] (Walter & Judith, 1979).

Moreover, it is worth noticing that the structure of the economic sector, as well as the proportion and the percentile of the tertiary sector increase fluctuated and the primary sector declined rapidly, while the secondary sector (which consumes most natural resources) is kept around 40% among the 3 economic sectors (Figure 1). The secondary sector always plays an important role in China's economy, compared to the two other sectors (World Bank 2019), although it is harder to predict the proportion in the future ($R^2 = 0.181$), yet here we believe that in the foreseeable future it will be steady and still (Made in China 2025).[5]

Until 2021, China's gross domestic product (GDP) was 17.73 trillion USD, which experienced a rapid increase from the 1990s (360.86 billion USD in 1990). During the past decades, the growth rate of GDP has been kept stable, between 7% and 13% (except in 2020, when the lowest growth rate

[2] 10,707,220 kt emitted in 2019, more than twice as much as the second country on the list, the United States, which emitted 4,817,720 kt, and the third country is India, which emitted 2,456,300 kt (World Bank 2019)

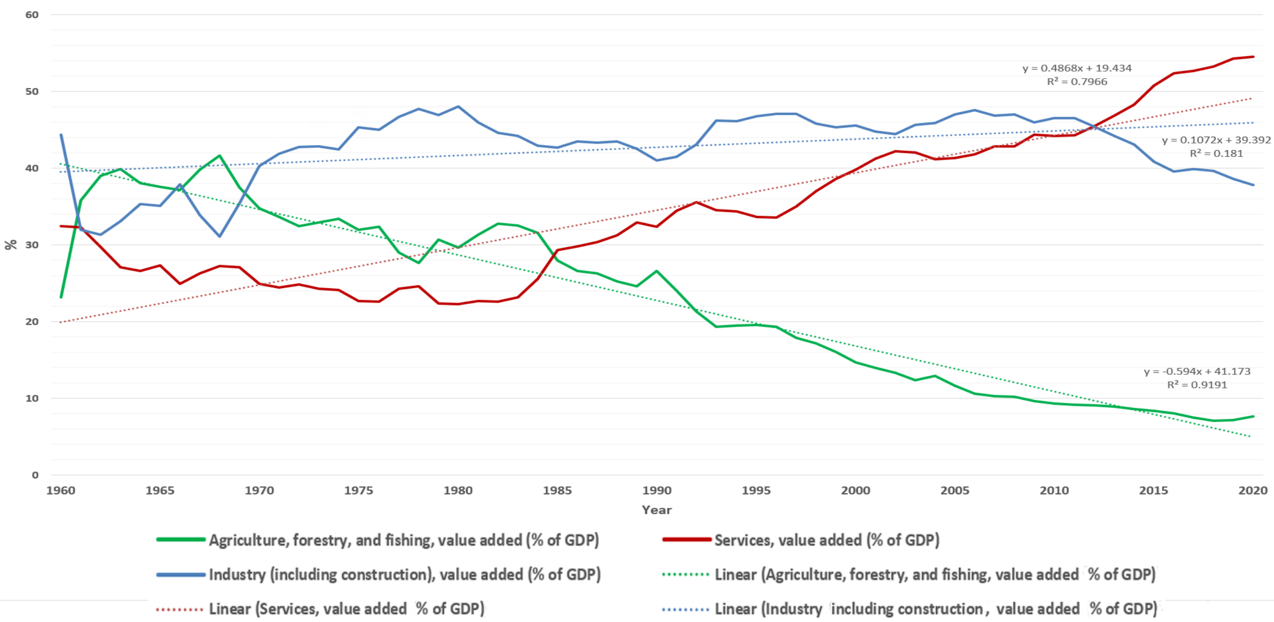
[3] Globally, we can also observe that with the development of countries, with the awareness of the value of resources, they are tending to protect the natural resources in terms of laws and regulations (Tatyana, 2004).

4 Among developed countries, to avoid high production costs due to stringent environmental policies, those high polluted industries tend to move to a developing country (usually with lenient environmental policies), which may be able to reduce production costs. That is the 'pollution haven hypothesis' (Walter & Judith, 1979).

[5] A long-term (30-year) strategy, which focuses on the secondary sector, aiming to achieve 1, improvement of manufacturing industry innovation; 2, deep integration of informatization and industrialization; 3, the strengthening of the basic industrial capability; 4, the build-up of high-quality brands; 5, full implementation of green manufacturing; 6, the breakthrough of key areas; 7, adjustment of manufacturing structure; 8, the build-up of service-oriented manufacturing and producer service; 9, improvement of internationalization of manufacturing (The State Council of the People's Republic of China, 2018).

(2.2%) was influenced by the COVID-19 global pandemic), and the average growth rate has been kept around 8% during the past decades (World Bank, 2022).

Figure 1. Economic sectors of China (Source: World Bank)
Horizontal axis is the Year, Vertical axis is the percentage (%) of GDP



Source: Based on the data of the World Bank edited by the author

China was not caught in the low-income status, or low-income trap (Christopher et al., 2016; Fitz & Gouri, 2021). In 2021, GDP per capita reached 12,556.3 USD (World Bank, 2022). The following issue China will face or is facing is the Middle Income Trap (MIT) and whether China can overcome the potential MIT. A country as an economic entity, during the progress of development, obviously, will experience such a process, from a low-income country to a middle-income country, finally reaching a high-income country. During this process, we can observe some countries (in East Asia, for example) after experiencing rapid growth of the economy, then being caught and failing to reach the high-income countries in a relatively long term (Gill & Kharas, 2007; Ohno, 2009; Jesus et al., 2012; Kei-Mu, 2021). Although the definition of MIT still varies, in general, there are mainly two: theoretical and empirical. For the theoretical definition, it is relatively hard to generalize a precise conclusion, which will be too ambiguous to analyze, so in Glawe & Wagner's research (2016) they tried to define MIT in terms of an empirical way and applied it to China (Glawe & Wagner, 2017). From the aspect of empirical definition (in an absolute way), defining whether a country is experiencing MIT, how long the period lasts, and the threshold of GDP per capita is crucial. According to those indicators, China has the possibility of being caught in the middle-income range but it is likely that China can avoid that and successfully become a high-income country (Jesus, 2012; Glawe & Wagner, 2016; Glawe

& Wagner, 2017).[6] The significant differences in income between urban and rural areas are mainly caused by labor migration in China, and since the implementation of the One-Child Policy, China will face the issue of aging society faster, and the uneven regional development will generate the risky potential for future economic development (Barnóczki et al., 2018; Vörös, 2014). One of the key factors to avoid the potential possibility of MIT is that China should develop in an efficient and environmentally friendly way (Juzhong, 2012).

Pollution overall includes many aspects, such as air pollution, water pollution, soil pollution, light pollution, etc. All the side effects of pollution can possibly cause health issues to human beings (also threatening the life of creatures or ecosystems, locally or globally). For instance, air pollution,[7] apart from the natural origin of air pollution, is mainly generated by the combustion of natural energy resources and during the process of industrial production (Masami, 2001). According to the Technical Regulation on Ambient Air Quality Index (on trial) of the People's Republic of China Environmental Protection Standard (HJ 633-2012), the calculation of the Air Quality Index (AQI) includes the following pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and ambient particles ($PM_{2.5}$ and PM_{10}).[8] Obviously, SO_2, NO_2, and CO are toxic gases, and according to previous studies, short-term exposure to O_3 can also cause respiratory and eye diseases, such as tracheitis, bronchitis, and glaucoma (Dongmin et al., 2022). The study in Lanzhou, China shows a strong relationship between respiratory cases and ambient O_3 from 2013 to 2016 (Yuxia et al., 2022), long-term exposure can also be harmful (Christopher et al., 2017) on a global scale, and also both $PM_{2.5}$ and PM_{10} play an essential role in terms of threats to human health. In the case of Guatemala, due to indoor heating and cooking, which caused the high concentration of PM_{10}, both the mortality and morbidity caused by acute lower respiratory infection (ALRI) among children under age five increased significantly (Kulsum et al., 2005), meanwhile, a high concentration of PM_{10} not only affects the health of children (under age 5) but is also harmful to pregnant women (Mahapatra, 2020). Moreover, the extra health costs from those effects can be numerous, $PM_{2.5,}$ for instance, caused health effects and economic losses of 382.30 billion RMB in China in 2014 (Bangzhu, 2019). Air pollution will not only threaten people's health, but can also generate extra-governmental and social health fiscal costs and be a burden of debt slowing the development of the overall economy (Tatyana, 2004; Ruiqiao, 2018; Kira, 2012).

In this paper, we are going to analyze the overall investments and efforts in environmental protection and the consequences during the past 5 years in China. We intend to describe and demonstrate the environmental issues by analysis. According to the data analysis along with time, we shall systematically understand the results of environmental protection in China, also we shall have a general view

[6] In terms of the classification of World Bank, China falls into the upper middle-income country group evaluated via GNI https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2022-2023.

[7] The United States Environmental Protection Agency (EPA) defined air pollution as 'The presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects' (2007).

[8] PM_{10}: inhalable particles, with diameters that are generally 10 micrometers and smaller; $PM_{2.5}$: fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller (EPA: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics).

of the consequences after those measures are adopted if they are efficient and proven. Data collection is mainly based on the national statistic yearbook issued by the Chinese National Bureau of Statistics. Additionally, reviewing Hungarian scientific literature and scientific dissemination articles, we have found quite a few publications on China's environmental issues, despite the global importance of the topic. These were published at least a decade ago, thus the assessment of the current processes in Hungary may not reflect reality. The Hungarian publications mostly apply a general approach (eg. Fleisher, 2010; Gálos & Wilhelm 2007; Joanovics, 2005; Pomázi, 2009; Vörös, 2010; Wilhelm, 2008), though we can find some focusing on environmental protection (Vörös, 2009; Wilhelm, 2001), while our research focuses on extending and renewing the related field of research.

METHODS

Our data collection is mainly based on the Year Book of China and the Environmental Year Book of China, also involving data from the World Bank and the United Nations, data included from years to decades, and panel data spanning 5 years. Our data include 30 provinces and cities (at the provincial level). Hongkong, Macao, Tibet, and Taiwan are excluded due to the lack of indicators or missing data.[9] Microsoft Office, QGIS, Grass GIS, and EViews are being introduced during the data processing and statistical analysis.

Many indicators can reveal the general environmental changes directly, such as CO_2 and SO_2 emissions, wastewater discharge, forest area changes, etc. For our research, we not only want to examine apparent environmental changes in China, but we are also curious in a backhanded way about what indicators can be the influential factors that China can improve the environment with, and then combine and compare the results for both. Behind all the superficial phenomena many factors are involved: for such a dynamic, complicated relationship among the variables, and also because of endogeneity, the Generalized Method of Moments (GMM) provides us with a decent tool to analyze. Inspired by the previous study (Xiaowen, 2021), we can have the statistical model *Eq. (1)* to process the data:

$$Y_{ij,t} = \beta_0 + \beta_1 X_{1ij,t} + \beta_2 X_{2ij,t} + \beta_3 X_{3ij,t} + \ldots + \beta_k X_{kij,t} + \beta_{k+1} \gamma_{ij,t-1} + \varepsilon_{ij,t} \tag{1}$$

Where $Y_{ij,t}$ is the explained variable and $X_{1ij,t}$ is the explanatory variable, from $X_{2ij,t}$ to $X_{kij,t}$ are the control variables, whereas $Y_{ij,t-1}$ is the one-period lagging data in our dynamic analysis. β_0 stands for the constant and $\varepsilon_{ij,t}$ stands for the error. According to the previous research (Pankaj et al., 2020) and the particularity of our research, wastewater discharge, air pollution, solid waste, and AQI can cover

[9] Some data of Tibet are not consistent in early years; no data record is found in the yearbooks for Hongkong, Macao and Taiwan.

all the main environmental factors that we need in this paper, and they will be used as the dependent variables.

Table 1. Attributes of the variables

Type of Variables	Variables	Definitions (Units)
Explained variables	AQI (AQI)	Days of air quality equal to or above grade II (Days)
	$GasSO_2$ (GS)	The volume of Sulphur Dioxide emission (Ton per 10000 people)
	Wastewater (WW)	Discharge of wastewater (Ton per 10000 people)
	Solid waste (SW)	Common industrial wastes (Ton per capita)
Explanatory variables	Secondary sector (SS)	Secondary sector of the economy (%)
Control variables	FDI (FDI)	Foreign direct investment (Million USD)
	GDP per capita (GC)	Gross domestic product per capita (CYN)
	Educational level (EL)	Number of degrees awarded (10000 people)

For a better understanding of the environmental variation trend, we are not only interested in the relationships among variables, but also curious about the changes of individual indicators, so a mapping analysis shall be involved. In terms of data tendency changes, we visualized the information on the maps; to show the period transformation, we use the same interval (based on the maximum and minimum value of each) to scale the legend, rather than using the same interval (quantile). Since we are dealing with the regional data of each of the provinces, and due to the uneven distribution of population, all data of $GasSO_2$, wastewater, and solid waste discharge are rescaled with population.

RESULTS

Regression model

By the explained variables, we made 4 regression models based on the GMM to analyze the dynamic panel data, which are AQI, SO_2 emission, wastewater discharge and solid wastes generated, explanatory variables, and control variables following respectively (Table 3). After the Arellano-Bond serial correlation test of each (Table 4), for both model 3 and model 4, the first order test (AR(1)) is statistically insignificant, so we reject the models; model 1 and model 2 are significant at a significance level of 5% and 1%, respectively, and both are statistically insignificant for the second order test (AR(2)), so we accept the validation for models 1 and 2 in terms of the Arellano-Bond serial correlation test. Moreover, for the over-identifying restriction test, we use the J – statistic and we got P values for models 1 and 2, which are 0.2931 and 0.4793, respectively. Since the P value of model 1 is greater than 0.1 and smaller than 0.3, in the end, we accept that the instrumental variables are suitable and valid, and the regression model is legit. The model 2 P value is greater than 0.4, so we consider this result skeptically.

Table 2. Statistical results of data

Variables	Min	Max	Standard deviation	Average
AQI	151.00	366.00	56.07	274.37
GS	1764.00	729757.00	136362.80	183696.40
WW	19677.00	1613096.00	364868.40	328168.20
SW	333.00	52037.00	10833.67	13097.93
SS	15.80	49.75	7.51	39.17
FDI	7527.00	2744956.00	438246.20	281782.10
GC	27643.00	163889.50	29596.75	65271.44
EL	0.77	30.05	7.07	12.85

Table 3. Dynamic panel data analysis results (regression model)

Model 1			**Model 2**			**Model 3**			**Model 4**		
Variable	Coefficient	t-Statistic	Variable	Coefficient	t-Statistic	Variable	Coefficient	t-Statistic	Variable	Coefficient	t-Statistic
AQI(-1)	0.3701***	5.3670	GS(-1)	0.5971***	20.7914	WW(-1)	-1.1199***	-11.8645	SW(-1)	-0.5099***	-9.0633
SS	-1.1212***	-8.4734	SS	0.0069	0.0471	SS	2.4656***	4.4135	SS	-1.0280***	-13.2325
FDI	-0.0300**	-3.3423	FDI	0.0270	0.7036	FDI	0.3050**	2.5826	FDI	0.0315	1.8570
GC	0.0364	0.5337	GC	-0.0182	-0.1489	GC	-1.4517***	-4.0475	GC	0.4235***	6.5202
EL	0.0290	0.2589	EL	-2.1503***	-7.1577	EL	13.0852***	24.9216	EL	-1.9117***	-23.5020
Mean dependent var	0.0557		Mean dependent var	-0.2222		Mean dependent var	0.4684		Mean dependent var	-0.0280	
S.E. of regression	0.1081		S.E. of regression	0.2416		S.E. of regression	0.6852		S.E. of regression	0.1620	
J-statistic	28.3260		J-statistic	24.6997		J-statistic	28.3212		J-statistic	24.0276	
S.D. dependent var	0.0816		S.D. dependent var	0.1931		S.D. dependent var	0.7968		S.D. dependent var	0.1694	
Sum squared resid	0.9925		Sum squared resid	4.9601		Sum squared resid	39.9029		Sum squared resid	2.2294	
Instrument rank	30		Instrument rank	30		Instrument rank	30		Instrument rank	30	
Prob(J-statistic)	0.2931		Prob(J-statistic)	0.4793		Prob(J-statistic)	0.2933		Prob(J-statistic)	0.5178	

Note: ***, **, * represent the significance level at 1%, 5%, and 10% respectively

Table 4. Arellano-Bond serial correlation test

Model 1					**Model 2**					**Model 3**					**Model 4**				
Test order	m-Statistic	rho	SE(rho)	Prob.	Test order	m-Statistic	rho	SE(rho)	Prob.	Test order	m-Statistic	rho	SE(rho)	Prob.	Test order	m-Statistic	rho	SE(rho)	Prob.
AR(1)	-3.2223	-0.3050	0.0947	0.0013	AR(1)	-4.5865	-0.6486	0.1414	0.0000	AR(1)	-0.1029	-0.2922	2.8413	0.9181	AR(1)	0.0439	0.0072	0.1651	0.9650
AR(2)	-0.0884	-0.0037	0.0422	0.9295	AR(2)	-0.7654	-0.2404	0.3142	0.4441	AR(2)	-1.9872	-3.5301	1.7764	0.0469	AR(2)	-0.8772	-0.0960	0.1094	0.3804

According to the result (Table 3), we can observe the negative effect of the secondary sector and FDI acting on the overall air quality, where the coefficient is -1.1212 (significant at 1%) and -0.0300 (significant at 5%), respectively. The higher the percentage of the secondary sector, the worse the air quality will become, meanwhile, the effect on environments of FDI also meets our expectations, which means that, in terms of air quality, PHH exists in China. Compared to the proportion of industrial production activities in the economy, overseas investment has a relatively slight influence. By assumption, economic development will improve the local environmental conditions, and so will the quality of the population (better awareness and capability of environmental protection). In our model, the economic development and educational level of the population both have positive influences on air quality in China (0.0364 and 0.0290), but the results are statistically insignificant.

The tendency to changes

Air quality

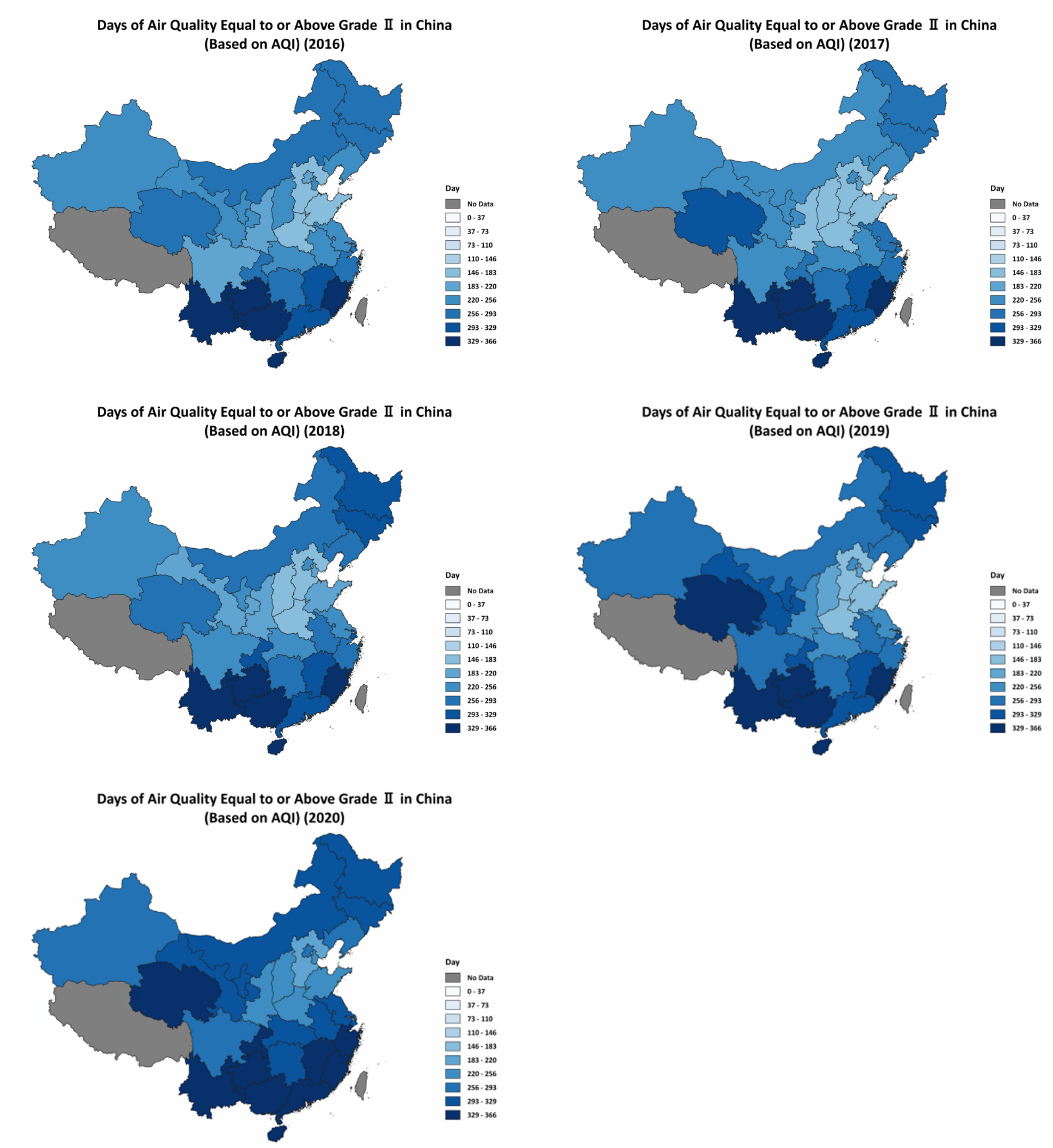
Air quality (Figure 2) poses a serious health threat to human beings. According to the 5-year variation, we can observe that in general, the southern part of China has a relatively good situation: Yunnan, Guizhou, Fujian, Guangxi, and Hainan have the best air quality all the time, with the number of days of air quality above grade II exceeding 329 each year. As we know, northern and north-western China are usually heavy industrial zones, also typically Shanxi, for instance, is the traditional black coal mining extraction province. Among those areas, in particular, the middle regions (Shanxi, Shaanxi, Hebei, Henan and Shandong) have heavy industrial factories, and pollution concentration productive activities mainly contribute to air deterioration. During the 5 years, we can observe that those areas had worse air condition than the neighboring regions (which only have good air condition around 73–146 days a year). As opposed to this, in south China, such as in Guangdong, those provinces are traditional light industrial areas, and emissions are much less frequent there. Apart from the anthropogenic factors, physical environmental conditions are quite different in the north than in the south. The Qinling-Huaihe Line is one of the most essential division lines that 'divide' the climate type into two. The northern part of this line has a long and dry winter season, under the control of Siberian high pressure, a north-eastern wind blows through northern China till the south-east, without vegetation protection, and PM_{10} is usually much higher in North China (generally Xinjiang, Ningxia, Gansu and Inner Mongolia have the highest PM_{10}), on account of the degradation of forests and grass, the circumstances can be even worse. Meanwhile, during the winter, heating system operation based on coal combustion will generate more pollution as well. South China does not need to use the heating system, has better vegetation coverage, a humid climate, and has less heavy industry, so within the last 5 years, the southern part has always had better air quality.

In general, the air quality of both North and South is getting better, due to vegetation recovery and environmental policies (for instance, the plantation of artificial forests and stringent environmental policies), especially for Qinghai, the number of days of the above mentioned air quality grade II is greater than 329 per year in 2019 and 2020.

Sulphur Dioxide emissions

During the 5 years, SO_2 emissions (Figure 3) prominently declined in the whole country. Maximum emissions changed from 282.8 tons per 10,000 people in Ningxia to 114 tons per 10,000 people in Inner Mongolia. Spatial distribution presents that the northern part emitted more SO_2 than the southern part. Mainly because the heavy industry distribution is concentrated in the North. But to the constraint of stringent environmental policies and environmental protection investments, the traditional heavy SO_2 pollution regions tend to emit less than before, and so does the South in China, which has less emission in the early years.

Figure 2. The changes of days of air quality equal to or above grade II in China in the last 5 years (based on the same data scale)

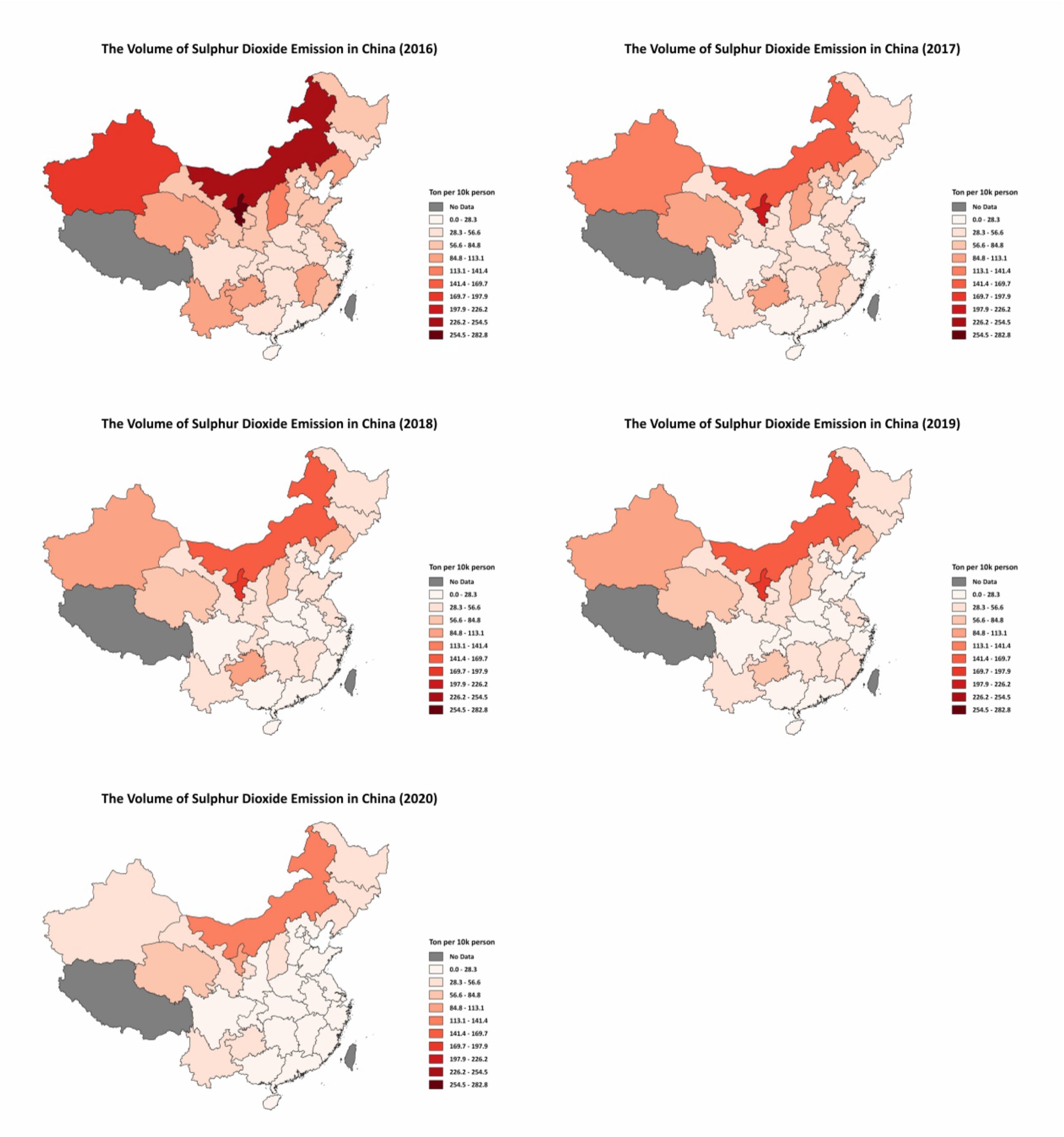


Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

Discharge of wastewater

From 2016 to 2019, the wastewater discharge (Figure 4) steadily reduced, as Xinjiang, Ningxia, and Hunan had an obvious fall-off tendency. We can observe in Figure 5 that the abatement is mainly contributed to by industry and agricultural production activities, meanwhile, the household discharge is kept stable. Unlike the decline tendency in industry for the whole 5year span (in 2020, in terms of industrial resources, also less compared to 2019), in 2020, household wastewater discharge doubled compared to 2019, and the most prominent is the case of agriculture: in 2019 it discharged 186,126 tons and in 2020, 15,932,272 tons instead, which makes the situation of total wastewater discharge much worse compared to the early years.

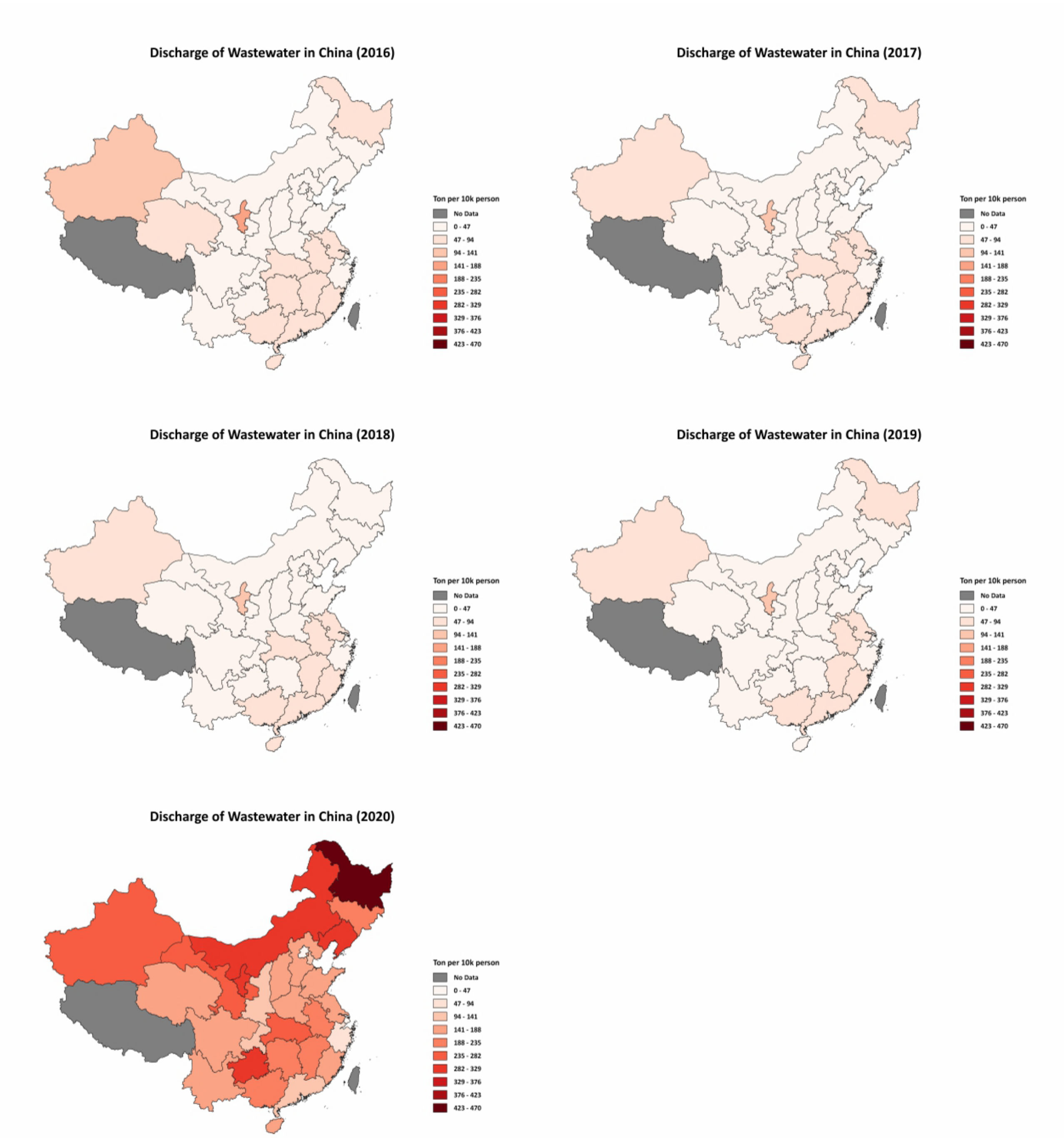
Figure 3. In the last 5 years, Sulphur Dioxide emissions changed in China (based on the same data scale)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

Because of the outbreak of the COVID-19 pandemic at the end of 2019,[10] the import and export trade was affected infinitely, and so were agricultural products. Due to the loss of imports, the pressure of domestic needs transferred to agricultural productivity, to supply a market of 1.4 billion people. For instance, Heilongjiang, one of the typical national crop production bases, generated 1,288,929 tons of wastewater in 2020 only by agriculture. A similar status can be observed in the whole country, typically in crop production regions, such as Liaoning, Jilin, Guizhou, etc.

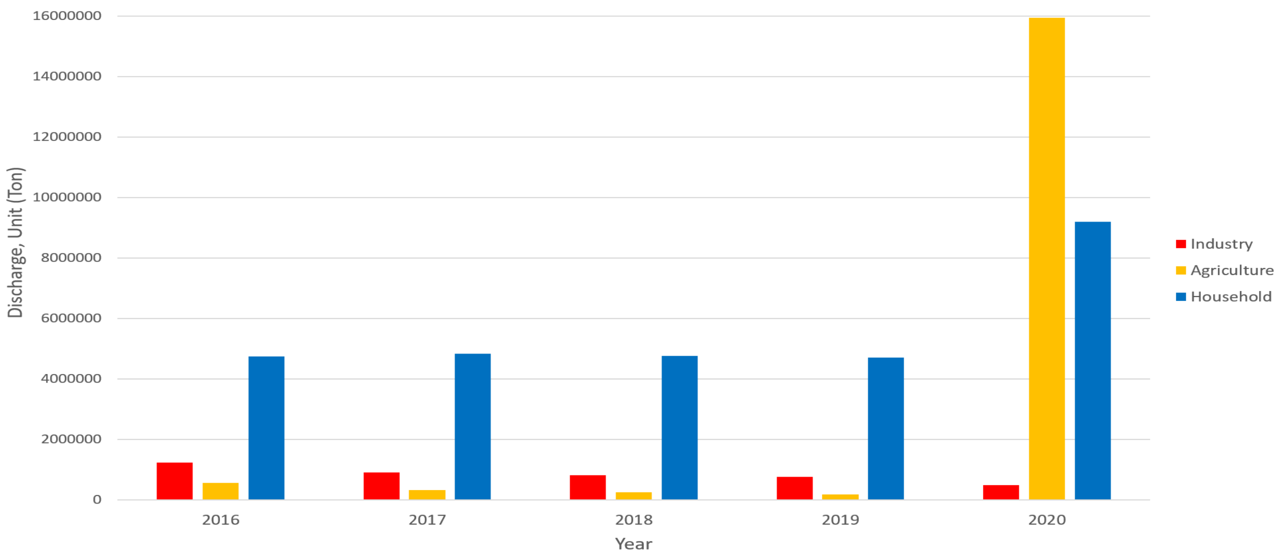
Figure 4. In the last 5 years, the discharge of wastewater changed in China (based on the same data scale)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

[10] The timeline of COVID-19, WHO: https://www.who.int/news/item/27-04-2020-who-timeline---covid-19.

Figure 5. The total discharge of wastewater in China in the last 5 years (by three resources)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

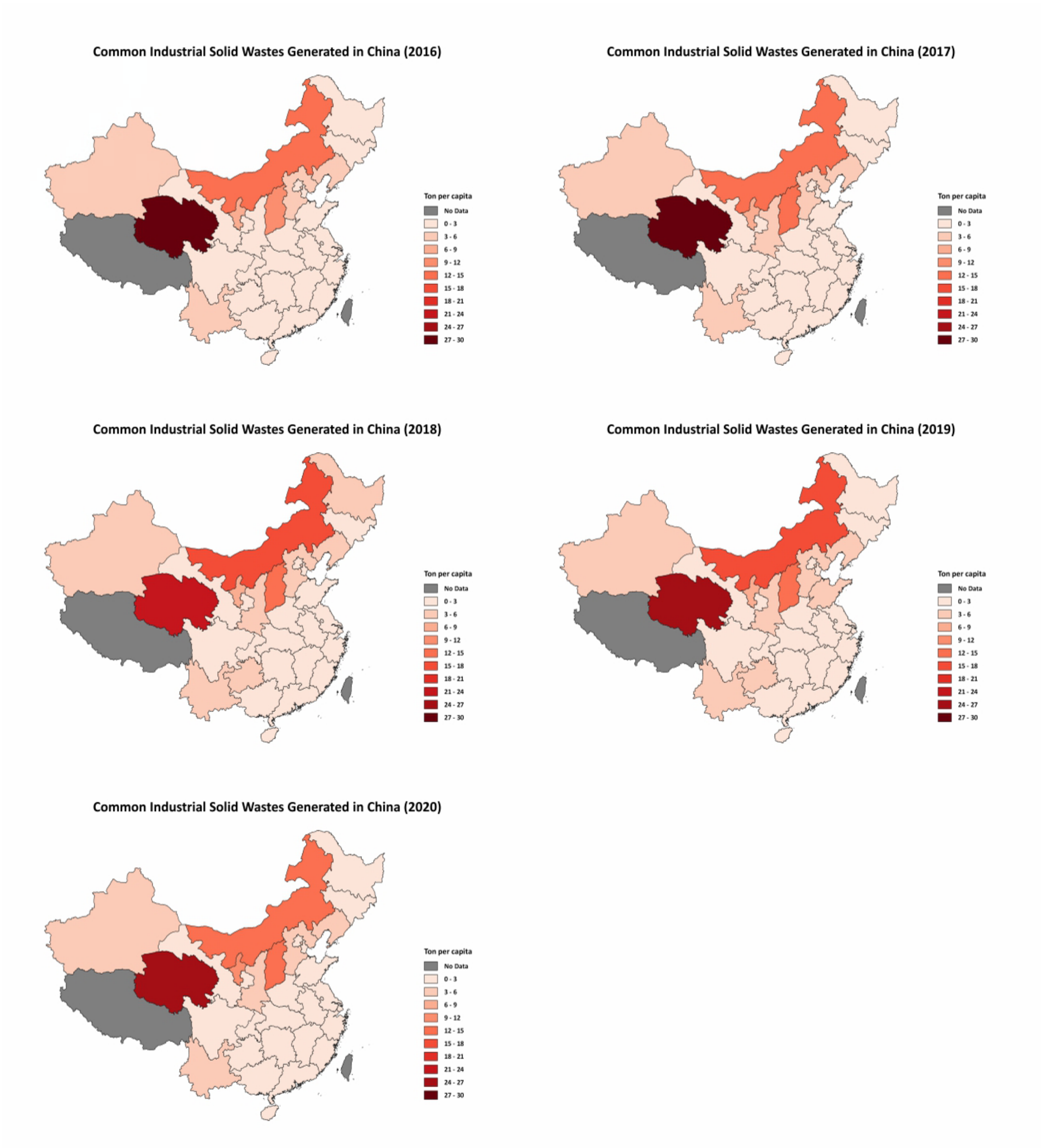
Solid wastes generated

The high pressure of the disposal of solid wastes is higher in northern China, which is not surprising, since the northern regions, such as Inner Mongolia, Shanxi, and Shaanxi, are the top three in terms of black coal mining and output. In Figure 6, those provinces have deeper color compared to the periphery regions. During the past 5 years, on both regional and national scales, the amount of solid waste generation has not changed generally. However, Qinghai faces a severe challenge to dispose of solid waste, which is because, compared to the other provinces, Qinghai has incomplete environmental policies and a relatively low development level, also since Qinghai has abundant asbestos resources, the production activities of asbestos can make the situation even worse.

The secondary sector proportion

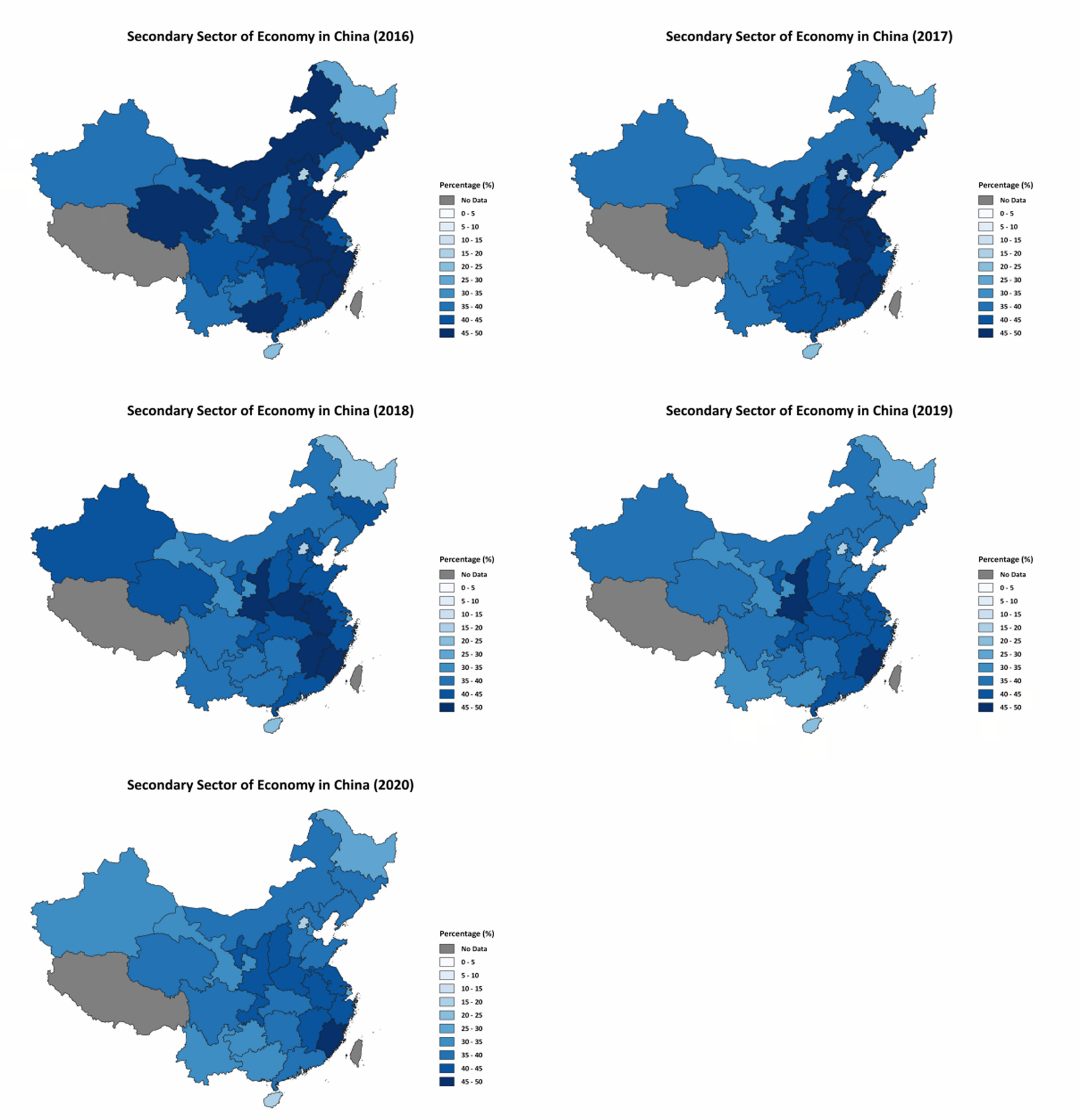
On the scale of 60 years, we can observe that the secondary sector in general slightly ascended (Figure 1), but the tendency in the future is hard to foresee: in recent years, during 2016–2020, we can observe a moderating trend in the secondary sector in the whole country; in the early years, on the whole, the secondary sector in China (Figure 7) had a relatively high proportion (in 2016, for instance), around 50% in most provinces in the middle and northern parts, while, with the tertiary development and industrial structure optimization, the secondary sector occupies smaller proportions, nearly 30% in most areas. With the economic development, we expect to see the decline of the secondary sector, similar to what we can observe in the trend of the changes in the last five years, yet, based on the policy Made in China 2025, China does not want to abandon the secondary sector development. On the contrary, China will strengthen industrial development with the innovation, integration, and informatization of industrialization. Improving the industrialization level through structural upgrade and transformation will be the general development trajectory, hence we believe that, even if the secondary sector proportion slightly decreases shortly (because of the GDP growth of the entire country and the increase of the tertiary sector), in general, the future will be hard to predict (we tend to believe that the proportion of the secondary sector will be relatively stable in the long term).

Figure 6. Common industrial solid waste generated changes in China in the last 5 years
(based on the same data scale)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

Figure 7. The secondary sector proportion of economic changes in China in the last 5 years
(based on the same data scale)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

Foreign direct investment

Since the reform and opening-up policies, China has attracted many foreign investments: not only because of the opening-up policies but also because of the economic growth, China has become one of the biggest consumer markets in many aspects. Although spatial distribution is uneven, as we can see in Figure 8, coastal provinces are the main attraction areas in terms of FDI: Guangdong, Shandong, Jiangsu, Beijing, and Shanghai are the most obvious ones on the maps. This is not surprising, since maritime regions have natural advantages: based on the coastline, FDI can have lower transportation costs to achieve the most benefits; the local governments provide friendly external policies to FDI (some regions, such as Shenzhen, have the laws and regulations of the special economic zones); and, also importantly, those provinces have higher GDP compared to other regions in China and the larger economic market.

Hainan is a special example in the most recent time: in 2018 the State Council of the People's Republic of China issued instructional documents about the further comprehensively expanding in-depth reform,[11] and in 2020 it issued the overall construction planning of Hainan free trade port.[12] Measures of the policy mainly focus on the further fair and open market, including infrastructure support, the reform of the fiscal and taxation systems, low and zero tariffs, etc. The main goal is to increase the opening degree and build a new example and standard of opening up.[13] The influences are notable, because in 2020, FDI in Hainan experienced an explosive expansion from 184,126 million USD in 2019 to 2,744,956 million USD in 2020.

GDP per capita

Similar to the circumstances of FDI, the economic development level of China has an inhomogeneous distribution (Figure 9). Unlike the inner landlocked regions, coastal regions contributed more GDP per person. The highest citizen income on average can be found in Beijing and Shanghai in the 5-year data. As we observed, on the regions map a long economic axis running from Beijing to Guangdong can be seen, which is similar to the Blue Banana in Europe,[14] China also has its Blue Banana: it passes all along from the political center, Beijing, to the Yangtze River Delta Economic Zone till the Pearl River Delta Economic zone, while the main cities included are Shanghai, Guangzhou, Macao, Zhuhai, Shenzhen, etc. Thus, it consists of most of the economic hub cities. In the foreseeable future, we can expect that Hainan will join the 'Banana' region since Hainan will become the next dynamic special economic zone, having numerous potentials (the phenomena can be observed in the trend of FDI changes in Hainan).

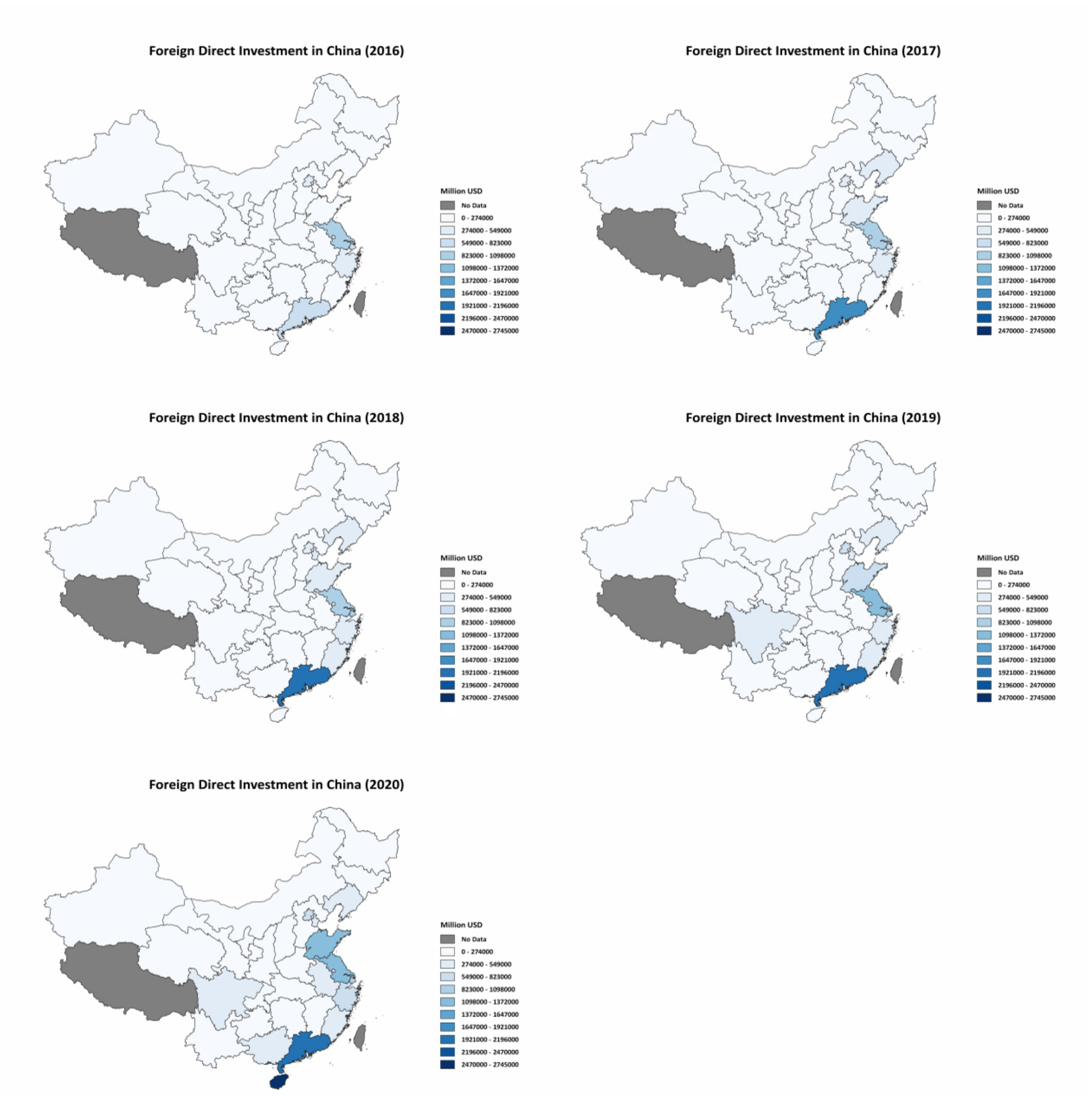
Educational level

China is an original and traditional Confucianist nation: although it remains a developing country, the consciousness of education is always prevalent in the whole society. Education of the child is a matter of utmost importance and also benefits from the numerous population resources. In terms of higher education, the average educational level and the absolute number of university diploma holders grow rapidly (Figure 10). But the conditions of an educational level have spatial differences. In Northwestern

[11] http://www.gov.cn/zhengce/2018-04/14/content_5282456.htm.
[12] http://www.gov.cn/zhengce/2020-06/01/content_5516608.htm.
[13] http://en.hnftp.gov.cn.
[14] A geo-economic and geo-political concept, the aisle which crosses through Europe from the United Kingdom to Italy, forming an economic corridor and political center (Brunet, 1989).

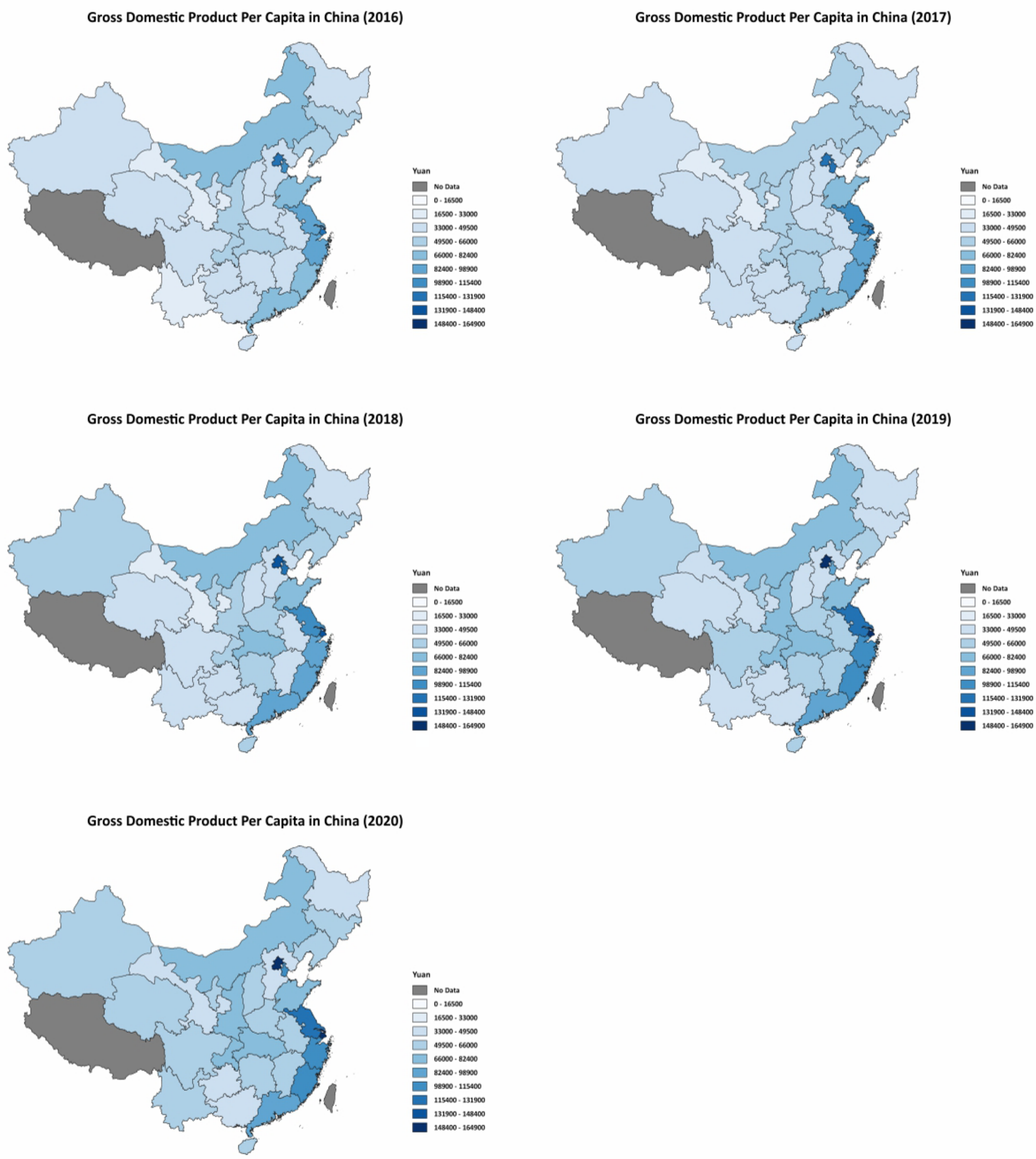
China, typically Qinghai, Xinjiang, Gansu, and Inner Mongolia are the traditionally underdeveloped provinces. Usually from compulsory education to higher education, public schools hold the optimum educational resources, but on account of the economic base (or economic foundation), people are seeking the chances to pursue higher education in the east and southeast provinces, such as Shanghai, Guangdong Jiangsu, etc; the second reason is the high-quality universities spread over those regions, so a higher educational level can be observed in Sichuan, Henan, Hubei, Hebei, Shaanxi, and Liaoning, for example, which do not belong to the Chinese Blue Banana axis (other reasons can also be involved, such as, for some provinces, like Shandong, the status of being traditional education provinces).

Figure 8. Foreign direct investment changes in China in the last 5 years (based on the same data scale)



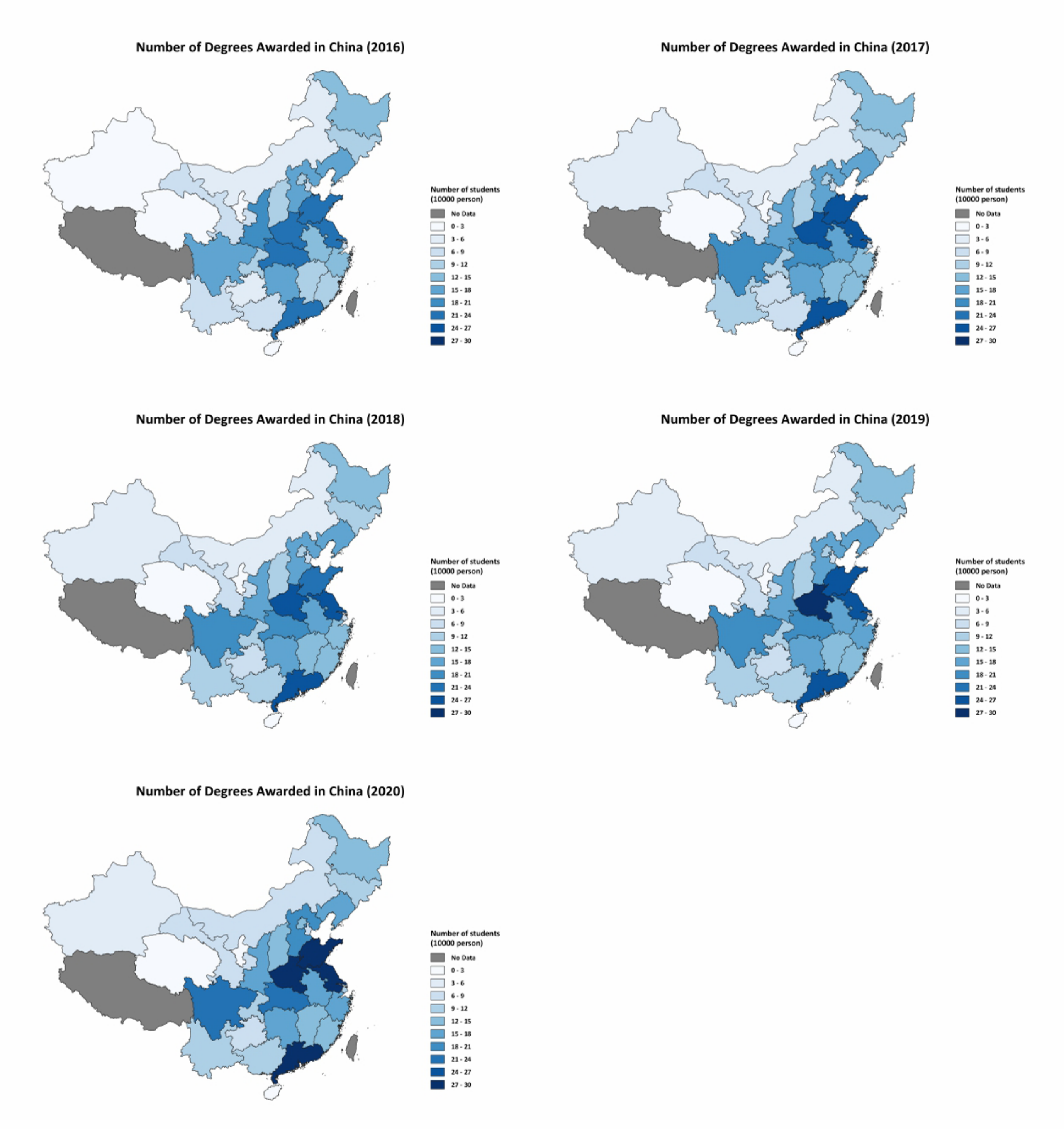
Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

Figure 9. In the last 5 years, GDP per capita changed in China (based on the same data scale)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

Figure 10. In the last 5 years, educational levels changed in China (based on the same data scale)



Source: Based on the data of the National Bureau of Statistics Yearbooks edited by the author

The Pollution Haven Hypothesis and the secondary sector uncertainty

In the early years, China had gained a competitive advantage in the global manufacturing market with low prices for labor force. After decades of development, China had built up complete industrial chains. We notice that in recent years, with the economic development of China, labor force prices are increasing, and China is seemingly losing the advantage in the global competition (manufacturing factories may choose to move to other developing countries, such as Vietnam, for instance), yet the abundant natural resources and the reductions of costs, brought by the agglomeration effect and complete industrial chains, still keep China in a dominant position in terms of manufacturing industry.

China is not only the main producer in the global market but also the consumer: as one of the biggest potential commercial markets, the giant potential of consumption places China in a very special position from the foreign capital point of view.

China is continuously practicing the implementation of opening policies. As one of the most important globalization participants, China is always active and willing to increase the degree of opening since the Reform and Opening-up policy of 1978. Generally speaking, the foreign capital has confidence and holds a positive attitude towards investing in China (mainly among the coastal regions). According to the up-to-date political orientation, the trend of deepening the process of opening up is apparent, and, as a consequence, we can observe that FDI keeps increasing and is mainly distributed in the coastal provinces. Especially, Hainan, for instance, as the next trial region of the new special economic zone, with the support of related regulatory policies, has become the most attractive region in terms of FDI.

Substantial economy is essential for a country, and among them, secondary industry is one of the most crucial economic growth engines. For China, secondary industry will be even more critical for future sustainable development and keep the vantage among global trade, and, in reality, we can also observe the policy support of China's government. All in all, hence we believe that: a) FDI will keep increasing, and the secondary sector proportion will be kept relatively stable and play an important role in the economy of China; b) Whereas we have already proven in China, the increase of FDI and the secondary sector will affect the air quality negatively, so how to manage the effects brought by the secondary sector and the increase of FDI on the air quality will be the issue for China.

Middle-income trap

As we demonstrated before, with the high speed of economic development, China has reached the threshold to face the MIT (as an upper-middle income country). Sustainable and stable development can be crucial during the next couple of decades of the century, with the importance of the environment greatly increased more than ever before, whereas, due to historical reasons, environmental degradation is severe in China.

During human development history, usually in the early period, since the limitation of producers' consciousness and capable technology, or the fewer investments in environmental protection during the production process, do not affect the added value of the final products in the end too much, so there will be less relative investments. In the case of China, at the stage of industrialization in the last century, aggressive exploitation caused various environmental issues including, but not limited to, the soil and water losses of the loess plateau, desertification of Inner Mongolia province, and heavy air pollution in industrial cities (cities in Shanxi province). The environment suffered tremendous damage from a number of industrial activities since then. In terms of air quality, GDP cannot solve it automatically, and economic development shall not make the situation better According to the distribution and statistical analysis, we believe that they are more likely to be the separated indicators.

2600 years ago, the famous philosopher and thinker Lao Zi proposed his philosophy, Taoism. One of the most important ideas is that we, humans, should not 'take' from nature unlimited or 'interrupt' nature too much, otherwise, it will break the harmony between human beings and the universe, which is the so-called Dao, and that is what we should seek. For long-term sustainable development, the way in which the Laozi seek balance and harmony in the universe has its practical meaning nowadays. To achieve that, it needs not only the awareness of ordinary people, but also governmental policies, regulations, and investments.

Similar philosophical ideas across thousands of years can still fit circumstances in China nowadays. Even if we can observe the positive relationship between air quality and the development of the economy, we believe it is more unlikely to happen. With the pressure from the challenge of MIT, China should take more proactive environmental policies.

The meaning of the educational level and economic development

According to our statistical analysis results, we cannot observe if the assumption that the educational level of the population and economic development can positively affect the air quality is legit, yet high-income and quality population can provide more possibilities. The health threats caused by worse air quality had been proven, since the high-income social groups are tending to focus more on the potential issues (both awareness and capabilities), the air quality control measures can be well accepted, and in daily life, those people are also more likely to consciously choose an environmentally friendly lifestyle. A prosperous economy, on the other hand, can provide the local municipality with a more fiscal budget, which allows more investment to improve air quality. Among the regions where the population is facing air quality decline challenges, Shandong, Jiangsu, and Guangzhou are the three provinces which are more resilient to deal with air quality deterioration.

CONCLUSIONS

China is a developing country, and air quality and water quality are getting better, meanwhile, less and less solid waste is generated. Although in 2020 wastewater discharge was affected by COVID-19, we still believe that in the foreseeable future China will discharge less wastewater, and this overall trend will not change. For air quality, the main threats are the FDI and secondary industrial activities, and we could not observe the convincing evidence to prove that economic development and population educational quality changes can make air quality better.

The eastern coastal regions, the south-eastern and middle part of China will face more pressure on air quality degradation, since we found that the secondary sector does have a negative effect on air quality. Despite the statistical uncertainty of the secondary sector in China, we can notice the determination of the central government to proceed with the industrial development, so the proportion of the secondary sector will not decline rapidly. Even if China is crossing the upper-middle income country stage to high-income country stage, which means to usually suppose that those countries should have relatively lower secondary sector proportion, PHH is also valid in China. The more overseas investment is involved, the worse the air quality will be. Coastal regions will face air quality deterioration due to this reason, yet it has several minor influences compared to the secondary sector, since China has more stringent environmental policies nowadays, so the negative environmental effects are considered manageable.

Generally speaking, China's economic development and changing direction is for the better overall, but during the development progress, environmental pollution has become one of the critical problems which can drag and slow the process. From the deeper reason (for instance, the social extra medical burden; the requirement of sustainable development; in case of air quality deterioration, which is caused by FDI, etc.), we believe China needs to implement some measures (such as more stringent environmental policies; increase the emission standard; West-to-East Electricity Transmission: a national project initiated in the last century, the use of the abundant water resources and the great elevation differences and the sunlight resources in Xinjiang to generate electricity in western China to be transmitted to eastern regions, can reduce the amount of fire power plants to control environmental conditions, etc.) to improve the environmental situation. Based on our analysis in this paper, we can observe the positive environmental changes in recent years of China. Among the different environmental pollution indicators, air quality is influenced a lot in terms of many perspectives of sustainable and high-speed development, and China can manage the effects of the secondary sector and FDI to improve air quality, and can also face the challenges in the future better.

By and large, as the second largest economic entity, China has a positive changing trend in terms of the environmental situation, yet it still faces many challenges and risks. For instance, local environmental conditions are different, and the overall environmental degradation situation is inhomogeneous. So, it requires different measures for different regions. And also, apparently, environmental protection policies should match the local factual condition. The high GDP per capita regions are the coastal provinces, whereas the west, northwest, and northeast are relatively less developed. Economic foundations determine the superstructures, and without economic support, environmental protection regulations will be hard to process. So, China should give a more preferential policy to support local economic development.

Different regions have their special environmental problems, which require more flexible regional policies. For instance, Beijing has been suffering from sandstorms for years, due to the original reason: the afforestation shall be introduced; whereas in Shanxi, a traditional heavy industrial province, to control the environmental deterioration, more stringent local environmental regulations should be announced.

In terms of the improvement of air quality, we shall process from two different perspectives: directive and indirective. First, directive, from the municipal level, more stringent environmental policies shall be introduced, this approach is supposed to have immediate effects after the policies' implementation.

a) It can be vertical: top-down management, which involves air quality control into the indicators for the performance of local municipalities;
b) it can be horizontal as well: the local government should formulate the adapted environmental policies and consummate the relative standard, without issuing a production license if the producing entity cannot conform to the emission requirements; periodical inspection shall also be involved, pushing the companies to seek for more environmentally friendly development models.

In terms of the secondary sector, the government should be more active to push forward the structural upgrade of the local industrial companies. Give necessary technological support to let producers abandon the outdated, extensive production model voluntarily. Ordinary people are also the main factor, to propagandize the negative effects brought about by air pollution and what people can benefit from environmental protection, organizing thematic activities about air quality and popularizing the basic knowledge of air pollution. Since people are the main participants in social activities, improving environmental protection awareness can tremendously relieve the pressure of air pollution. Indirective, keeping on enhancing and improving the educational quality, as well as giving more support (both policies and finances) to low-developed regions can be crucial not only for environmental protection but also for high-quality, high-speed, and sustainable development, solidifying the foundation to become a high-income country in the future.

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