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Economic and Social Analysis of Haze Reduction Dilemma in China

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ABSTRACT

Since 1978, China's economy has developed fast and become the second largest economy in the world in 2011. However, the cost of China's economy soars along with the significant economic development. The environmental deterioration becomes heavier and heavier. Eventually, the haze pollution appears a severe problem and the problem does seriously affect almost everybody's life in the country. Therefore, it is urgent to take all kinds of measures to reduce haze. But there are many hinders in curbing haze. The paper aims to get a profound understanding of China's arduousness in the haze reduction and support the establishment of relevant institution, laws and policies by analyzing the difficulties in China's haze reduction from the perspective of the economy and society. Firstly, the paper investigates the critical reasons causing the frequent large-scale haze outbreaks recently through analyzing the long-term economic and social dynamics of the haze pollution. Then, the paper aims to discuss the difficulties in China's haze reduction by summarizing international experiences and comparing China's social and economic characteristics with its foreign counterparts. Finally, the paper proposes some policy suggestions on China's haze reduction.

Keywords: Haze reduction, Social analysis, Economic analysis, China, Sustainable development.

1. INTRODUCTION

In recent years, several regions of China have been plagued with haze pollution. The Shanghai Environmental Monitoring Center data for 7 p.m. on December 28, 2012 reported maximum and minimum PM2.5 density values of 327.3 and 258 micrograms per cubic meter, respectively, signifying moderate pollution levels. At 9 a.m. on January 12, 2013, maximum PM2.5 density levels in Beijing reached 456 micrograms per cubic meter, and on February 15, 2014, Beijing PM2.5 density levels for urban and suburban areas were higher than 400. In 2012, haze was detected in Northeast China, North China, South China, Northwest China, the Yellow River Basin, the Huai River Basin and in the south central reaches of the Yangtze River. A number of cities, including Beijing, Shanghai, Tianjin, Shijiazhuang, Nanjing and Jinan, were also affected by severe haze pollution. Although a series of reduction measures has recently mitigated haze pollution levels in cities of North China, such as Beijing and Tianjin, it is difficult to determine whether air quality levels will improve. Haze continues to represent a serious national issue.

Haze is traditionally an atmospheric phenomenon where dust, smoke and other dry particles obscure the clarity of the sky. The primary components of haze include sulfur dioxide, nitrogen oxides and particulate matter. Inhalable particles, which can cause atmospheric turbidity and visibility deterioration, are the primary components that aggravate haze pollution. Haze pollutants are traceable to various sources (i.e., industrial combustion, vehicle emission, construction dust, waste incineration, volcanic eruptions, etc.). On hazy days, haze pollution concentrations are higher and haze pollution contains large quantities of harmful, toxic substances. Haze has serious negative effects on urban resident health, social life, economic development, etc.

First of all, higher concentrations of bioavailable elements may significantly harm human health [1, 2, 3, 4]. Especially senior citizens, children and pregnant women are the most sensitive population groups. PM10 components in haze can increase incidences of cardiovascular and respiratory disease [5, 6]. Studies have shown that haze exposure increases yearly hospital patient admissions by 2.4 per 10,000 residents (31 percent more frequently than during normal periods), and health problems due to haze exposure result in economic losses of 91,000 USD on average [7]. The American Cancer Society (ACS) records show that every additional 10 mμg/m2 of PM2.5 can increase total mortality, cardiovascular mortality, and lung cancer mortality levels by 4%, 6% and 8%, respectively. The residents in North China live 5.5 fewer years on average than those in South China due to haze exposure [8].

Moreover, haze has extensive effects on resident social lives. Numerous experts have shown that harmful particles in haze limit visibility [9, 10, 11]. As a result, average seasonal visibility levels fall below minimum visibility criterion in Shanghai [12]. In 2013, the China Meteorological Administration (CMA) reported record numbers of hazy days in several cities. In light of this serious situation, several local governments have taken emergency measures by closing down highways, airports, construction sites and schools. Ever-increasing haze levels thus severely inconvenience daily life.

Haze also negatively affects Chinese economic development. In mitigating haze levels, the Beijing municipal government required that 30 percent of all official vehicles and 103 polluting enterprises remained out of operation and that all roads be closed to trucks that carry residue during the Spring Festival of 2013. The Wuhan Commission has called for the shutdown of a sintering machine, various power plants and 201 other dust-related projects either completely or partially. In cities coping with high haze levels, urban tourism sectors have been seriously affected [13]. In Beijing, the tourist visits and expenditures in city parks and modern recreational areas fell sharply during the 2013 National Holiday. Economic losses from environmental damage attributable to PM10, nitrogen oxides and sulfur dioxide amount to 7,714 USD per ton, 1,006 USD per ton and 1,006 USD per ton, respectively [14].

Previous studies have primarily examined haze pollution and government measures from the meteorological and physical perspective [15, 16, 17, 18]. However, whereas climate changes occur over longer periods, haze concentrations have increased to dangerous levels over a short period of time. Although haze aggregation is attributable to geographic or atmospheric changes directly, human activity in haze areas is the root of the problem [19]. Thus, haze pollution is primarily a social and economic problem. This article thus examines the social and economic mechanisms of haze pollution. In most cases, technical problems can be solved through scientific innovation and investment in technology. However, social and economic problems traceable to human activities are often difficult to change. Economic and social analyses of haze reduction strategies are thus no less critical than physical science studies.

The remainder of this paper is organized as follows. Section 2 presents a brief description of the analytical method. Section 3 describes the long-term economic and social dynamics of haze pollution in China. Section 4 investigates the social and economic causes of recent frequent haze outbreaks. Section 5 examines the barriers to haze reduction in China by comparing the country's haze reduction experiences with those of developed countries. Based on this analysis, Section 6 presents policy strategies for Chinese haze reduction. Section 7 concludes.

2. MATERIALS AND METHODS

This paper uses economic and societal perspectives to examine the barriers to Chinese haze reduction. To develop a thorough understanding of the barriers to haze reduction and to support the establishment of relevant institutions, laws and policies, qualitative methodologies (see Figure 1) based on relevant data and previous studies are employed. The combined effects of China's current status, the long-term dynamics of the problem, and the current short-term perspectives limit the applicability of foreign approaches to haze reduction in China and contribute to the current haze reduction dilemma.

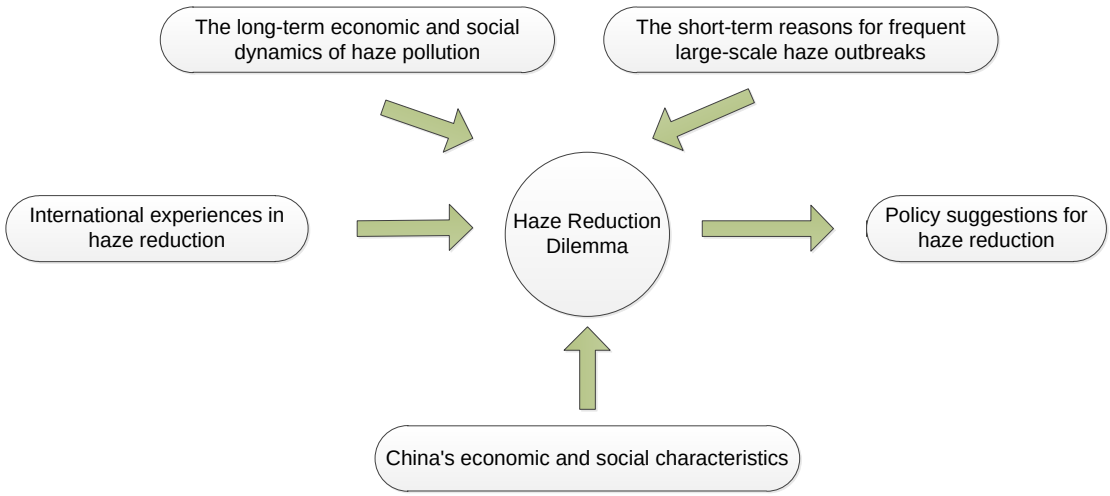

Figure 1. Illustration of the study methodology.

3. LONG-TERM ECONOMIC AND SOCIAL DYNMICS OF HAZE POLLUTION IN CHINA

3.1 Economic causes of haze pollution

3.1.1 High levels and unreasonable structures of energy consumption

The Chinese economy has rapidly developed since the country's economic and social reforms. GDP growth has rapidly increased in recent years and has maintained an annual growth rate of higher than 7%. With rapid economic growth, China's total energy consumption continues to rise and appears to be accelerating. Since 2002, Chinese energy consumption are growing with the rate above 2%. In 2008, total energy consumption in China exceeded that of the United States, making China the largest energy consumer in the world (see Figure 2).

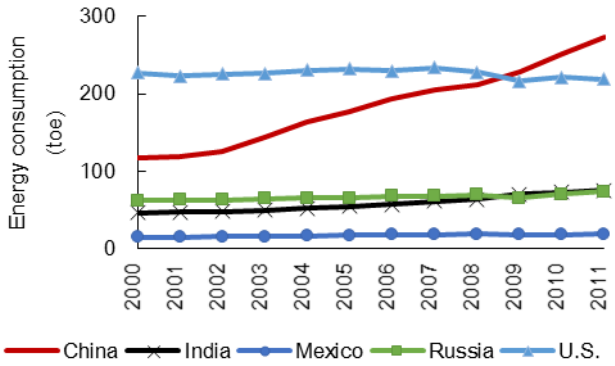

Figure 2. Total energy consumption of major countries. Data is available on the website of the Word Bank.

Furthermore, Chinese energy consumption is not sustainable. Over the last decade, coal has accounted for approximately 70% of the country's total energy consumption, whereas natural gas and other forms of clean energy/renewable energy have accounted for less than 15%. Chinese fossil energy consumption continues to rise, accounting for nearly 90% of the total energy consumption. Large-scale carbon dioxide, sulfur dioxide, oxynitride and particulate emissions are generated via fossil fuel combustion. With respect to global trends, oil and gas will continue to serve as major energy resources over the next ten years, and clean energy demand and utilization will rapidly increase. If China maintains its current consumption structure, national haze pollution levels will continue to exceed those of other countries [20].

3.1.2 International emissions management via foreign trade

Chinese exports have rapidly increased since the country joined the WTO in 2001 (see Figure 3). This increase has promoted economic growth. Chinese exports primarily include manufactured commodities, and most of them come from heavy energy-consuming and high-pollution industries (see Figure 4). China can currently be viewed as the largest factory in the world. Oil is imported from abroad and is used as raw material to produce exported goods and services, thereby increasing emissions in China [21]. Because coal dominates the country's energy consumption, China shoulders a substantial portion of the world's emissions.

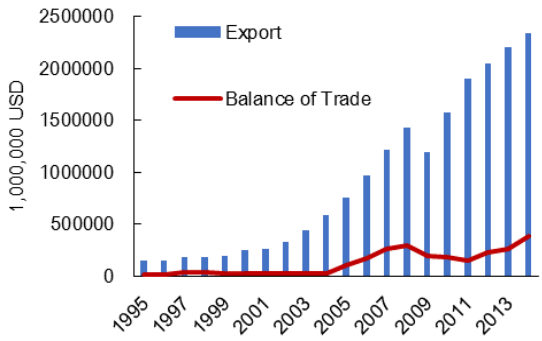

Figure 3. China's export from 1995 to 2014. The data source is China National Bureau of Statistics.

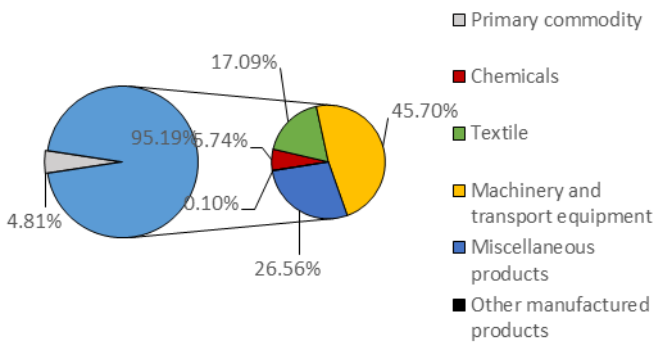

Figure 4. The proportion of exported commodities in 2014. The data source is China National Bureau of Statistics.

3.1.3 Low energy efficiency

China's energy efficiency and environmental loading intensity levels from energy consumption have declined and have fallen far behind the country's economic growth rates [22]. The average Chinese carbon dioxide emission efficiency levels increased from 2006-2010, whereas the average national production efficiency levels slightly decreased during the same period [23].

Energy-saving technologies have undergone rapid improvements in developed countries. Energy consumption levels in developed countries have recently fallen by more than 30%, and the fuel efficiency of motor vehicles has nearly doubled. Compared with developed country trends, clean energy technologies in China have been promoted less rigorously and fail to keep up with the pace of energy consumption.

Additionally, several state-owned monopolies manage Chinese domestic oil and gas pipelines and power grids, and transaction prices are controlled by the government. This limits the flexibility of the pipeline network and inhibits resource utilization efficiency to a certain extent.

3.2 Social causes of haze pollution

3.2.1 Increasing vehicle numbers and heavy traffic pollution

Studies have shown that vehicular exhaust may represent a primary source of harmful ambient air particles [24]. The number of private cars increases daily due to increased living standards and the development of more affordable motor vehicles. According to the data from the World Bank, the growth rate of vehicles per 1,000 residents in China has been substantially higher than that in developed countries (see Figure 5). Moreover, significant improvements in Chinese living standards also have increased the national appetite for forms of entertainment such as tourism. The number of tourists visiting China has increased and has aggravated domestic transportation loads (see Figure 6). Additionally, motor vehicle emissions standards and gasoline quality requirements in China are far less rigorous than those employed abroad, which compounds the effects of exhaust emissions.

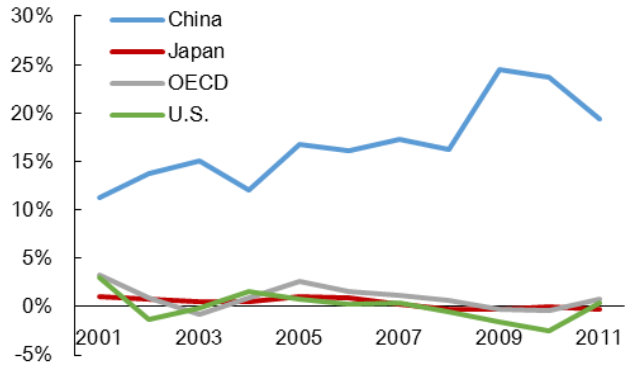

Figure 5. Vehicles' growth rate per 10,000 people from 2001 to 2011. The data source is the World Bank.

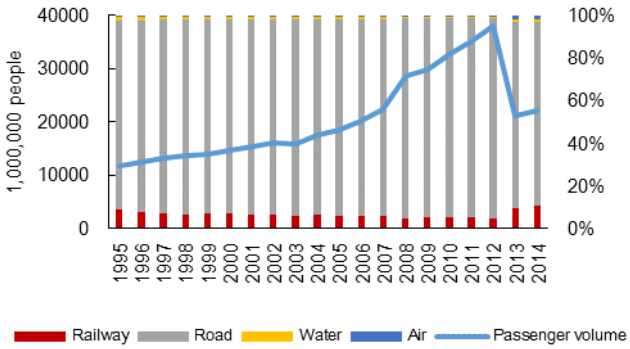

Figure 6. China's passenger volume from 1995 to 2014. The data source is China National Bureau of Statistics.

3.2.2 High-speed urbanization, vegetation destruction and greenbelt reduction

China has pursued high-speed urban development since the 1990s. As shown in Figure 7, more and more people migrate to big cities in order to get good education, public welfare and good security, which causes that Chinese house prices have boomed. Thus, major domestic and foreign real estate developers are increasing their investments in China. With the construction of high and high-density buildings, the calm wind and heat island become more and more serious.

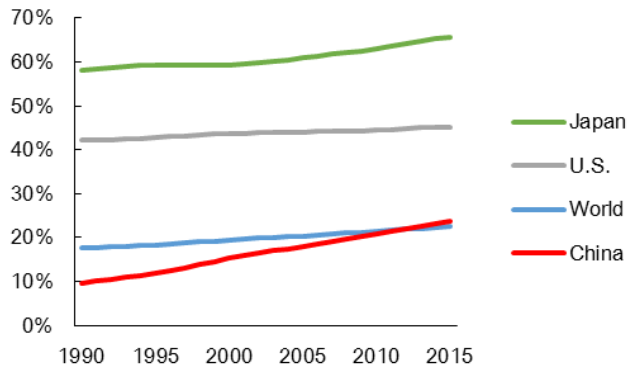

Figure 7. The population proportion in the cities with more than 1,000,000 residents. The data source is the World Bank.

Moreover, the real estate industry is closely related to the industries that emit haze, such as the steel and cement production sectors. For example, in 2009, carbon dioxide, sulfur dioxide, oxynitride and particle emissions traced to the cement industry accounted for 14.8%, 2.4%, 12.3%, and 26.2% of the total national emissions, respectively [25].

Furthermore, with the increasing fundamental demand of accommodation, the construction of green space is limited. In some cities, the local government even replace green space with dense residential. The area of green space in these big cities is insufficient to accommodate this large-scale expansion. Thus, it is difficult for the limited green space to absorb the pollution particles in the air. With the calm wind, the pollution particles can hardly be dispersed to the urban periphery.

3.2.3 Unsound regulatory systems and low-energy product standards

It is currently unclear which institutions are responsible for environmental protection in China. Ambiguous responsibility distinctions between regulation departments result in responsibility evasion. Environmental conservation efforts are thus inefficiently managed. Second, environmental conservation departments are only responsible for local regions. Cases of local protectionism and environmental supervision intervention are frequently reported in the media. Furthermore, current environmental laws and regulations are guided by vague penalty rules that render it difficult to hold responsible parties accountable, and penalties should be more severe. This has resulted in weak practical applications and ineffective environmental management.

Chinese oil product standards also fall far behind those of developed countries. In most regions, oil product sulfur content levels are 15- and 5-fold higher than those of products produced in Europe and the United States, respectively.

4. PRIMARY CAUSES OF RECENT FREQUENT LARGE-SCALE HAZE OUTBREAKS

The social and economic processes discussed above have been in practice for an extended period. However, frequent and large-scale heavy haze trends have only begun in recent years. In fact, the heavy haze pollution results from the reduced capacity of haze diffusion and vegetation adsorption.

Haze results from combined effects of large volumes of particles suspended in the air, meteorological conditions, and factors such as wind speed, relative humidity, air pressure, rainfall, geographic location and thermal inversion layers, among others [26]. Under normal conditions, air particles gradually diffuse in accordance with the above factors. However, in recent years, Chinese economic and social activities have significantly altered these factors. Calm winds, inversion layers, increased haze production and high aerosol concentration have resulted in a sharp decline in urban haze diffusion. Moreover, air pollution haze can harm herbaceous plant leaves [27]. Research from Pima County, Arizona shows that vegetation adsorption capacities sharply decline during extended high haze concentration periods. Such processes have contributed to the recent increases in haze levels. Figure 8 presents an illustration of haze dispersion and vegetation adsorption capacities under various condition

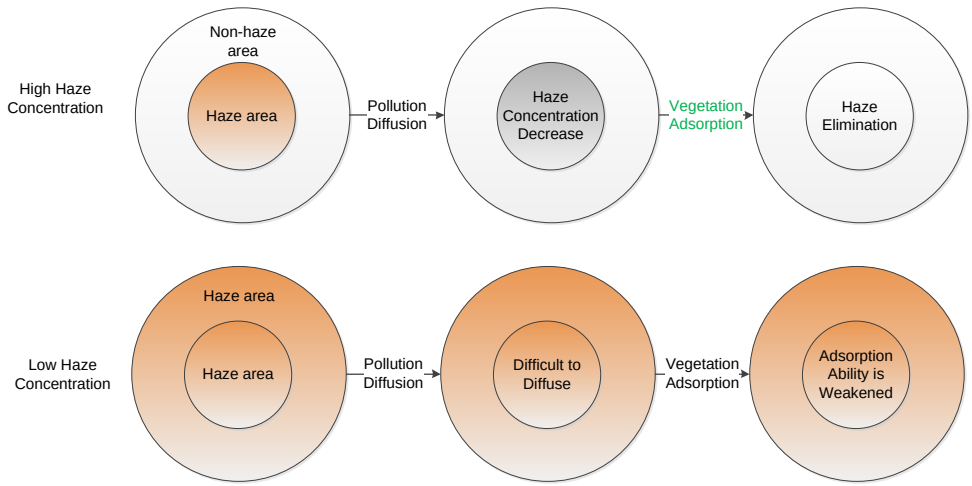

Figure 8. Haze diffusion and vegetation adsorption capacities under different conditions.

Haze pollution is thus a product of societal factors and unsustainable long-term economic development. Under current economic and social development patterns, China's natural environment cannot effectively disperse and absorb haze pollution. The negative effects of haze pollution on Chinese public health and societal and economic development have brought the issue to the forefront of the nation's attention. However, there are numerous barriers to developing new haze governance.

5. INTERNATIONAL EXPERIENCES AND DILEMMA OF CHINESE HAZE REDUCTION

Beginning in the 1940s, a series of air pollution-related incidents occurred in a number of developed countries (e.g., the Meuse River Valley haze incident in 1930, the Donora haze episode in 1948, the London haze episode in 1952, the Los Angeles photochemical haze episode in the 1940s and the Yokkachi Asthma incident in Japan from 1961 to 1972). These incidents seriously affected the health and lives of local residents and significantly increased the number of the patients suffering and dying from bronchitis and coronary heart disease (CHD). Developed countries have employed a variety of governance measures to achieve remarkable results. We analyzed the feasibility of these practices in China.

5.1 International experiences of haze reduction

Past severe air pollution events in developed countries have primarily been attributable to industrial pollution and air pollution resulting from automobile exhaust emitted during periods of industrial production and rapid societal and economic development. For example, the Los Angeles photochemical haze event was traced to hydrocarbon compounds and nitrogen dioxide in automobile exhaust, and London haze is primarily due to industrial, power plant and traditional stove emissions. In response, governments adopted a series of control measures to treat haze pollution. These measures reduced emissions and substantially limited the negative effects of haze pollution.

5.1.1 Environmental protection act introduction for mandatory emissions reduction

In 1952, the London municipal government issued the Clean Air Act, the world's first air pollution control act. A series of subsequent acts were instituted, including standards and benchmarks regulating fuel usage and factory exhaust. The government also required large-scale upgrades to urban resident stoves and limits to coal consumption. These laws restricted emissions and employed rigorous punishment measures. These efforts substantially reduced dust and particulate levels [28].

In the 1960s and 1970s, the Japanese government formulated the Public Nuisance Health Compensation Act and other laws to penalize acts that negatively impacted the environment. The Japanese government also formulated the Prevention and Control of Atmospheric Pollution Act and other laws and regulations, which required the Capital Highway Company and seven major car manufacturers to shoulder pollution prevention and governance costs.

Regulations on vehicle emissions were first introduced by the California Motor Vehicle Pollution Control Board in 1959 to address haze caused by vehicles. Vehicles have since been equipped with devices that reduce hydrocarbon emissions [29]. From 1980 to 1995, haze concentrations in the United States declined by more than 10% [30].

5.1.2 Transportation system and energy efficiency improvements

Since the 1980s, the London municipal government has prioritized public transport network development, controlled private car production, reduced vehicle emissions and traffic congestion levels, established a national air quality strategy, introduced the "congestion charge" and employed various measures to improve transport systems. The traffic congestion charge policy reduced car traffic by 20% in plaza tolls during chargeable periods, and the municipal government dedicated 122 million pounds in annual tax revenue to improving traffic conditions. The policy resulted in carbon dioxide emission reductions of 100 thousand tons each year.

Following the Los Angeles photochemical pollution incident, the United States introduced strict standards on traffic pollution sources. The Japanese national government provides buyers of efficient vehicle with financial subsidies and also requires that companies employing more than 200 vehicles use more than five percent high-efficiency vehicles by March 2016.

5.1.3 Promoting science and technology research to address pollution

During the Los Angeles Photochemical haze episode, the Haagen-Smit California Institute of Technology examined the

composition of air and identified sources of pollution to generate a scientific basis for pollution governance [31]. The United States government also increased investment in scientific research and management and developed general ecological impact assessment (EIA) software and technologies for pollution governance. On the premise of maintaining high quality of life levels, the London municipal government emphasized technological developments that address climate change and developing distributed energy supply, garbage power generation and renewable energy generation systems. Thereafter, London became an environmental technologies research hub.

5.1.4 Civil demands for clear air

Citizen participation and public opinion pressures also contributed to the success of the pollution governance efforts implemented in the above countries. Following the Los Angeles photochemical haze pollution incident, 20 million individuals across the country marched for environmental protection, forcing the government to take immediate action. After pollution governance laws and regulations were imposed in London, pollution levels were treated effectively, and urban visibility levels improved significantly after 1973 [32]. The UK's GDP and net national income were negatively affected (see Figure 9); however, British nationals were willing to accept the costs of pollution governance and economic slowdown in the interest of addressing pollution.

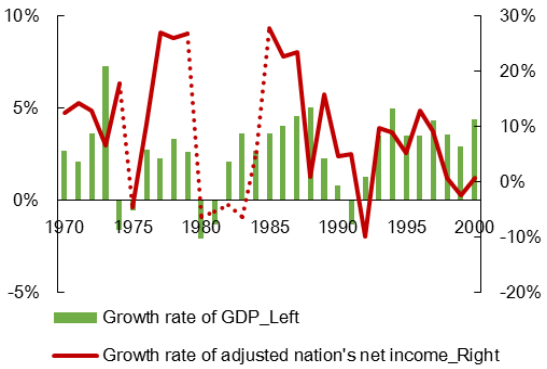

Figure 9. GDP growth and net national income in UK from 1970 to 2000. Data source is the World Bank.

It is thus evident that air pollution reduction measures can work effectively in developed countries. However, unlike pollution generated in developed countries, pollution generated in many developing countries is often attributable to poverty issues that involve tensions between populations, economies, resources and environments. In China, haze pollution issues are a product of long-term pollution problems. The country currently faces the challenge of balancing economic and societal concerns.

5.2 Economic barriers to haze reduction in China

5.2.1 Barriers related to economic slowdown and transformation

Policies of economic liberalization have altered traditional Chinese welfare aspirations. In the presence of a favorable development environment, China's economy has developed rapidly and has become the second largest economy. However, with respect to GDP per capita, China continues to lag behind developed countries. In 2014, China barely reached Britain's levels from the 1970s (see Figure 10). Moreover, China has the largest unemployed population in the world. Unemployment issues must be solved by creating more jobs through economic development. If economic growth trends reverse, existing problems may be compounded, affecting Chinese social stability. Thus, it would be difficult to implement environmental governance measures employed in London (those that involve sacrificing economic growth).

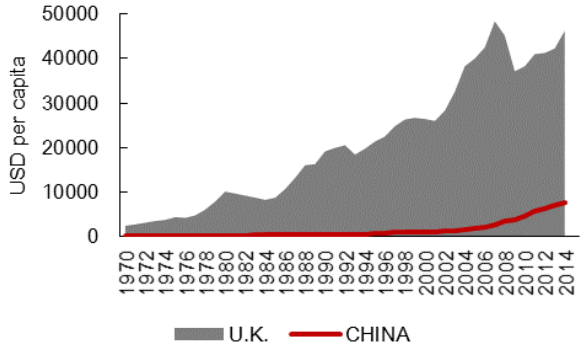

Figure 10. Net income per capita of China and UK. The data is available on the website of the World Bank.

It is also difficult to change patterns of economic development and realize economic transformation. Chinese economic development has depended on unsustainable practices of resource consumption and environmental pollution. Energy consumption and pollution levels continue to rise. Although the Chinese government regulates the activities of some energy-intensive polluting industries, the development of energy-intensive industries has accelerated in recent years. The added value in the manufacturing industry accounts for more than one third of the country's total value by 2014. In Northwest China, which has coal, calcium carbide, ferrosilicon, iron alloy and aluminum resources, energy-intensive industries offer financial support to local governments. These heavy pollution industries generate 30 percent of all industrial profits, dissuading local governments from restricting energy consumption in such sectors.

Additionally, China's high-tech service industries are developing slowly and cannot support national economic development. Given their economic contributions, heavy polluting industries are difficult to limit without sacrificing economic development.

5.2.2 Inefficiency in technological innovation

As a developing country, Chinese technological innovation levels lag behind those of developed countries. Most new technologies must be introduced from abroad. The United States, Japan and other OECD countries enjoy significant economic gains by exporting knowledge and technology.

China especially lacks "green" technologies that can preserve natural resources and the environment. Though "green" strategies of carbon capture and storage (CCS) and selective catalytic reduction (SCR) increase production levels while protecting the environment [33], these approaches are currently costly to apply and maintain. For instance, CCS costs will increase by 29% to 297% due to improper handling, and energy-saving technologies of the cement industry will also increase the costs of power consumption [34].

Hence, improvements in energy efficiency and environmental benefits require the support of a developed

economy [35]. However, loose intellectual property rights and limited cross-cultural coordination render it difficult to employ foreign green technologies in China in a cost-effective manner [36].

5.3 Social barriers to haze reduction in China

5.3.1 Limited incentives

Prior to economic reform, Chinese residents did not enjoy a high standard of living; the development of the commodity economy substantially improved living standards. Residents are thus reluctant to exchange a newly acquired higher living standard in the interest of haze reduction. For example, in rural areas, Chinese residents are more concerned about agricultural production than the environment [37]. In China, less developed provinces present lower levels of environmental efficiency than more developed provinces [35].

Moreover, social demands for cars and houses (or apartments) are substantially increasing. License plate lottery and odd-and-even license plate policies have not reversed the sharp increase in private car usage.

Additionally, although residents substantially benefit from engaging in polluting activities, they are not held responsible for the associated environmental costs. Instead, they benefit at the expense of society as a whole.

5.3.2 Rapid urbanization trends

For historical reasons, there is a substantial income gap between urban and rural residents in China. The introduction of new technologies has rendered rural labor redundant, and economic growth has required more workers in industry and service fields. In turn, rural populations migrated to urban areas in large numbers since the economic reforms. Rapid urbanization will continue in China for several decades, necessitating heavy concrete, steel, raw material and energy consumption and thus additional haze pollution. Chinese residents follow a tradition of purchasing homes and later purchasing larger homes, as most nationals could only afford small- or medium-sized apartments when the country entered the commercial housing market less than 20 years ago. The number of urban residential buildings in cities has in turn increased rapidly. Due to limitations on urban space, higher buildings have been built to satisfy demand. However, this has occurred at the cost of urban efficiency and environmental protection, rendering it difficult to diffuse and absorb increasing haze levels.

5.3.3 Policy bottlenecks and political impediments

China may face challenges in introducing an “Atmospheric Pollution Control Law” similar to that of Japan. China’s major polluters also constitute the country’s most prominent industries (i.e., petroleum, coal, electricity, etc.). Limiting energy consumption and emissions will significantly influence these enterprises. Such industries enjoy political bargaining power. Assessments by Chinese government officials should be more thoroughly informed. GDP growth results heavily determine official promotion decisions, causing many local officials to seek quick success and instant benefits. In turn, officials prefer to develop local economies rather than improve overall social welfare, leading them to neglect issues of environmental protection. Additionally, Chinese environmental policies and laws lack systematic focus, focusing primarily on specific problems while neglecting overall trends.

6. POLICY RECOMMENDATIONS FOR CURBING HAZE IN CHINA

Due to the differences between China and developed countries, it would be difficult for China to replicate their haze pollution reduction measures. We present a number of economic and social haze reduction policy measures.

6.1 Economic approaches

In the short term, China must slow down economic growth to a reasonable level and introduce foreign energy conservation and emission reduction technologies. According to IPCC results, global coal emission increases are attributable to rapid economic growth and excessive coal usage. From 2000 to 2010, global greenhouse gas emissions (i.e., carbon dioxide) were 7 billion tons higher than those of the prior decade [33]. Improving national living standards must therefore constitute the first priority of Chinese economic development, especially because numerous countryside residents cannot secure food, housing or other basic living necessities. Limits on economic growth should thus be controlled within a reasonable range to avoid the emergence of other social problems. According to Professor Shi of the Center of Virtual Economy and Statistical Science of the Chinese Science Academy, under resource and environmental constraints, sustainable Chinese GDP growth would fall in the range of approximately 6%. The country must also introduce advanced foreign technologies and develop technological, value-added industries to support economic transformation.

It is also necessary to simultaneously and quickly eliminate areas of excess production as well as optimize industrial structures. The government should restrict investments in companies with excess production and require such companies to solve excess production issues to increase usage capacity ratios. The government should also require polluting enterprises to shut down or transform manufacturing techniques, update machinery and adopt new technologies, thereby improving capacity levels while restricting unit consumption.

Additionally, we can hold companies accountable and maximize energy-saving and emission reduction efforts by allowing polluting industries to pay for environmental costs and by collecting resource taxes, from enterprises and individuals who engage in polluting, energy-intensive activities. Moreover, it is necessary to penalize polluting enterprises and create economic incentives to limit emissions. Recycling and waste treatment fees must also be imposed on enterprises based on emission quantities. Laws and regulations must also guarantee resource tax allocation in areas such as environmental protection, environmental education and environmental technology.

The haze problem in China is further complicated by the presence of an unsustainable energy structure. Therefore, adjusting the energy structure is central to curbing haze. Efforts must be made to transform the energy system by increasing reliance on gas and oil, reducing coal usage, and developing clean energy approaches to electricity generation. The market system should be opened to the oil and gas industries, and restrictions on nongovernmental capital for the exploration and development of conventional and unconventional petroleum sources must be lifted. Petroleum importation should be promoted, and oil and gas cooperation between China and overseas markets should be encouraged to

guarantee Chinese oil and gas supplies. Regarding coal, increasing efficiency, supporting research to use coal to produce oil and gas, and improving thermal power capacity should be exploited to save energy and reduce emissions. Regarding renewable energy sources, grid company locations should be adjusted, and wind, solar, water and safe nuclear power sources should be explored.

In the long term, Chinese economic development must be restructured. Recently, the growth of China's new market economy has stabilized, and the era of high-speed growth is nearly over. On the one hand, the country should invest in "Green Economy" strategies. The central government should in turn assess local government performance based on "Green GDP" measures. On the other hand, the country should adopt a "Technological Economy" based on high value-added industries as opposed to resource consumption industries. Such an approach would involve significant investments in technological talent and would thus intensify educational, research and technological innovation.

6.2 Social approaches

In the short term, efforts must be made to expand public environmental awareness and develop clean traffic protocols through incentives that motivate individuals and social institutions to save energy and reduce emissions. International strategies involving the collection of road congestion fees from private cars and oil product standard upgrades can be introduced in transportation management schemes.

Industrialization and urbanization processes must be effectively controlled. Urban and industrial development must be based on reasonable natural resource usage and environmental protection to sustain both priorities. Regarding building emission controls, real estate developers in Tokyo provide environmental benefit information (e.g., adiabatic degree, energy efficiency, green area, solar energy utilization and service life) when selling apartments; this could be adopted. Finally, civil transportation structures must be optimized to increase efficiency levels and limit haze pollution.

In the long term, rigorous environmental laws must be legislated that not only restrict company emissions but also exploit technologies transferred from overseas enterprises to domestic companies [38]. When legislating and promulgating environmental policy and laws, systematic research efforts must assess the suitability of such policies to avoid the shortage and redundancy of legal system. Additionally, institutional reforms must be implemented via democratic processes, and residents should be educated of their own rights to promote social support for environmental protection.

7. CONCLUSIONS

Large-scale haze problems in China are rooted in social and economic processes. This paper presented a thorough analysis of the causes of frequent large-scale haze outbreaks and of long-term economic and social sources of haze pollution. By comparing Chinese social and economic characteristics with foreign counterparts, the analysis shows that China could not effectively apply haze reduction policies employed in developed countries. China faces numerous barriers to haze pollution regulation. To curb haze levels, the country should employ comprehensive measures that are supported by the contributions of all Chinese citizens.

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