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The Assessment of Urban Sustainability in China

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Abstract

With the high speed of urbanization and economic growth, the Chinese urban areas are suffering from tremendous pressures. Using an assessment framework of DPSIR, this article evaluates the performances of 49 Chinese cities in 2008 and 2013 in terms of sustainable development and addresses three facts. Firstly, urbanization increases the environmental and social pressures in Chinese cities that highly dependent on resources and industry will challenge the long-term development of cities. Secondly, high rate of economic development could not guarantee a sustainable development, and blindly pursuing GDP growth may result in a decrease of sustainability. Thirdly, Chinese cities are experiencing a weak sustainable development that Chinese cities are performing better for being sustainable on driving forces (economic and social development) but are failing to reach a better ecological development.

Keywords: Urban Sustainability, DPSIR, Sustainability Assessment

1. Introduction

The 21st century is the era of the "city revolution". Cities play a significant role in the modern world because anthropic social and economic activities are congregating there (Mori & Christodoulou, 2012). Cities are the engine of social and economic growth; from 2010 to 2050, the top ranking 600 cities will contribute 65% of the world's GDP growth, and 440 emerging cities will account for 47% of the global GDP growth (Urban China Initiative, 2011). Such a high rate of urbanization is the result of unprecedented economic growth and industrialization in 21st century; the urban areas are rapid sprawling into the rural areas, with new construction of factories and enterprises, creating wealth and a prosperous social development, attracting investment, promoting high technological development and enhancing productivity and competitiveness (UN-Habitat, 2012; WCED, 1987). Currently more than half of the world's population is living in urban areas, from large megacities to small towns, indicating that urban areas have become the primary habitat for human beings (UN, 2007). Asia was predominantly rural, with only 17% of its 1.4 billion people living in cities or towns, while by mid–2020, 55% of Asia's 2.7 billion people will live in urban areas (Asian Development Bank, 2012).

On one hand, cities drive technological innovation, trade and business development, and promote residents' living standards. However, rapid urbanization has put tremendous pressures on the urban

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system with negative externalities, challenging the governments' power, resources and the reaction of government officials in the face of rapidly growing urban populations. Hence, the majority of the governments, especially in developing countries, need the ability, funds and experience to provide the new city residents with dwellings, services and facilities that meet the basic needs of life: housing, education and transport (WCED, 1987). As a result of overcrowding, cities need more land and resources to support the new residents, which results in sharp decreases of arable land, water and energy resources. The high population density also leads to heavy traffic congestion, air pollution and resource scarcity. Although rural migrants help to solve the problems of urban labor scarcity in manufacturing sector, highly skilled and educated talents are still in short supply (Urban China Initiative, 2011). If the current urbanization trend goes on without control, the city may face serious environmental pollution, resource scarcity and uneven social development. Therefore, the government needs to adopt effective policies to track measures and realize sustainable urban development. This paper will analyze the impacts of urbanization on the sustainable city development in China with a focus on quality of life by utilizing an indicator-based framework, Driving-Force-Pressure- State-Impact- Response (DPSIR).

1.1. Urbanization and Urban Growth

The underlying question for urban economics is why a city exists. Cities exist because technology has created production and exchange systems that provide humans with the material basis to challenge natural laws. O'Sullivan (2012) concludes that a city should satisfy three conditions to develop. First of all, the people outside cities must produce enough food to support themselves and urban residents. Secondly, urban residents must engage in production and produce some goods or services to exchange food with rural workers. Thirdly, a city must possess an efficient transportation system to make it convenient to exchange urban and rural products. In short, urbanization is because technology development increases the agricultural surplus, improves urban workers' productivity and boosts the efficiency of transportation and exchange.

In 1950, the urbanization rate was the highest in Oceania and North America, but the rate was less than 20% in Africa and Asia. It is predicted that, by 2050, the urbanization rate will increase largely all over the world and Asia and Africa will experience the largest increase (UN, 2014).

In addition, concentration in large cities keeps rising. In 1950, only New York and London had populations greater than 10 million, but by 2015 twenty-nine cities belonged to this category and this agglomeration accounted for 12% of the world urban dwellers. It is predicted that, by 2050, 41 megacities will exceed 10 million in urban population (UN, 2014).

What drives urban agglomerations to grow so rapidly? When geographical proximity can bring external benefits to firms and factories, these firms and factories cluster to exploit agglomeration economies, including localization economies at the industry level and urbanization economies at the city level (Button, 1976; O'Sullivan, 2012). Cities attract people and firms because they promote knowledge spillovers, learning, and social opportunities. Lager cities can offer better skill matches that result in higher productivity and wages. Agglomeration economies can generate self-reinforcing effects in a region; one firm moving to the city will encourage another firm to do the same (O'Sullivan, 2012).

Urbanization leads to two kinds of growth: economic growth and employment growth. Economic growth is defined as the increase of income per-capita. The increase of income is the result of capital deepening, increases in human capital and technological progress. Employment growth is defined as the increase of the total workforce of a city. However, rapid urban growth will bring about income and social inequality (Black & Henderson, 1999). Localized peer group effects, parental choices of neighborhoods and human capital investments lead to geographic stratification of the settlements and result in social and income inequality (Benabou, 1993; Durlauf, 1996).

1.2. Urbanization in China

In 2010, for the first time in history, the Chinese urban population exceeded the rural population. In 1950, nearly 90% of people in China lived in rural settlements, but by 2014 55% of Chinese population settled in urban areas, and by 2050 the urban population will account for 80% of Chinese people (UN, 2014). In 1975 there was only one large city and the majority of the cities were medium or small. From 1975 to 1990 the development of megacities and large cities was slow, and the majority of urbanization took place in medium and small cities. Currently, there are six megacities and China has experienced rapid urbanization in all sizes of cities during the past decades.

Wang (2010) divided Chinese urbanization into three phases. The first phase was 30 years before reform and opening up, in which the urbanization rate lagged behind industrialization. During that period, the Chinese government gave priority to industrial development and the share of GDP of industry increased from 17.6% to 44.4%, while the urbanization rate only increased by 5%. It is obvious that such unnatural development leads to low productivity, rural-urban isolation, income inequality and underemployment.

The second phase was the period from the beginning of reform and opening up (1978) to the end of the 1990s. During this period, the Chinese government changed from limiting urban development to strictly control large city scale, reasonably develop middle and small cities and actively develop small towns and the urbanization rate increased to 33.3%. Nonetheless, the urbanization of this period was unbalanced because the amount of small towns and cities developed rapidly while large cities developed slowly.

The third phase is from the end of the 1990s to the present. During this period, the central government has revised the urban planning policy and officially announced the new policy that large, middle and small size cities and small towns should develop coordinately in 2011. Therefore, encouraged by the policy, urbanization in this period has reached a balanced development.

In terms of city scale, there is no consensus in the literature about the proper size of cities that can generate better agglomeration benefits. Wang and Xia (1999) analyzed more than 600 Chinese cities and discovered that different scales of cities resulted in different extents of agglomeration economies and externalities. To be specific, large cities with one million to four million dwellers reflected the highest net scale benefits (agglomeration benefits minus externalities); however, when population exceeds four million, the net scale benefits gradually diminish. In addition, small cities with populations of less than 100 thousand had no net scale benefits. Au and Henderson (2005) also estimated net urban agglomeration economies of Chinese cities. They argued that the relationship between urban agglomeration benefits and urban sizes is an inverted-U shape. Through analysis, they concluded that the average Chinese city scale is undersized, and the optimum city population size is 2.9 million to 3.8 million (Au & Henderson, 2005).

1.3. Sustainable Development

Sustainable development is notoriously vague as a concept which has no consensus among scholars and organizations (M. Holden et al., 2008), but the most famous definition is that of the World Commission on Environment and Development (WCED): sustainable development should guarantee the needs of present generations without endangering the ability of future generation to satisfy their own needs (WCED, 1987). The inherent ambiguity of the concept of sustainability gives rise to numerous interpretations. The disagreements among supporters are based on their emphasis on what is to be sustained, what is to be developed, how to link environment and development, and for how long a time (Parris & Kates, 2003). Although there is no consensus among scholars of the concept of sustainable development, it is widely accepted that sustainable development pursues a proper balance among three pillars, economy, society and environment, in both spatial and temporal range. Accordingly, development must be equitable (between economic and social pillars), livable (quality of life), and viable (economic development should not degrade the capacity of ecosystems)(Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010).

Under this broad definition, two main approaches can be discerned: weak sustainability and strong sustainability. Although the goal of both is development without compromising the wellbeing of future generations, the demands for sustainable development are different. Weak sustainability requires the preservation of overall stocks of capital that allow substitution among environmental, human and economic capital. In the view of weak sustainability, natural capital is the same as other resources(Gutes, 1996). On the contrary, strong sustainability critically limits the consumption of natural capital and stimulates the importance of environmental function. Therefore, strong sustainability does not accept substitutions among human, environmental and economical capital(Mori & Christodoulou, 2012).

2. Methodology

2.1. Sustainability Assessment

Indicators are useful tools for decision makers to conduct more effective actions by simplifying and abstracting information from raw data. Policy has a life cycle from identifying an issue to be solved to the design of the policy and its implementation, assessment and adaptation, and finally to its elimination or integration into another policy instrument (Moldan et al., 2007). The indicators must meet the needs of each stage to support the policy life cycle with data, information and knowledge. Although a considerable number of sustainable city indicators have been explored, a key set of indicators that properly reflects the economic, social and environmental qualities have not yet been identified (Steg & Gifford, 2005). Therefore, to be effective, the indicators must be credible, legitimate in the eyes of stakeholders, and relevant to decision makers (Moldan & Dahl, 2007).

The challenge for the indicator-based approach is mainly to define a measurable framework and then select a proper set of indicators. The evolving assessment frameworks of the terms "sustainable development" and "sustainability" have already been explored by a variety of international organizations, countries and scholars, which have also acted as instruments to help decision makers to measure and calibrate sustainable development trajectory as well as make sound decisions and policies. Agenda 21 initiates the requirement for an integrated assessment framework and the international community raises economic, social, and environmental pillars of sustainable development (UNCED, 1993; United Nations, 2002). In some frameworks, a fourth institutional pillar is added, as the framework for indicators designed by the Commission on Sustainable Development (CSD). Others prefer to treat sustainable development as a two-part framework reflecting the interaction between human activities and environment impacts (EEA., 1995; OECD., 1998; Prescott-Allen, 2001). Although many approaches have been explored to assess sustainable development, the frameworks are lacking theoretical foundation and the selection of indicators is arbitrary.

The assessment of sustainable city development has not been well established because the definition of city sustainability and the required conditions of city sustainability assessment system remain vague (Mori & Christodoulou, 2012). Multiple city sustainability assessments have been used by numerous organizations, scholars and companies from developed and developing countries (ARCADIS, 2015; Global City Institute, 2007; Siemens, 2012; UN-Habitat, 2007; Urban China Initiative, 2011). Tanguay et al., (2010) surveyed 23 studies of sustainable city assessment indicator frameworks in developed countries and discovered that 72% of the indicators are utilized for only one or two studies, and few indicators are present in more than five studies (Tanguay et al., 2010) This shows that the design of indicators differs in the purpose and understanding of city sustainability. Mori et al. (2012) proposed two principles in designing sustainable city indicators: to include indicators covering economic, social and environmental pillars, and to consider the direct and indirect externalities in other areas (Mori & Christodoulou, 2012).

2.2. DPSIR Framework

Different approaches have been explored and utilized to evaluate the impacts of anthropogenic activities on the environment. The Press-State-Response (PSR) framework was developed by the OECD, which is based on the following casual relationship: human activities exert 'pressures' on the environment, result in changes in the quality of environment (state), and finally society responds to these changes through environmental, economic and social policies (OECD., 1998). The European Environment Agency (EEA) slightly extended PSR in the DPSIR framework, which is used to structure a comprehensive model to analyze the interplay between the environment and socioeconomic activities. This framework is usually used to design assessment, select indicators, and communicate results to decision makers to improve environmental quality (Stanner et al., 2007). In DPSIR analysis, socioeconomic activities drive changes that exert pressures on the environment, then change the quality and state of the environment. These changes will influence, for example, human health, ecosystem functioning, the economy, and finally the society and policy makers response to affect earlier parts (D, P, S, I) directly or indirectly.

From information to indicators, there is a clear need for indicators in each part of DPSIR, reflecting the casual relationship between human activities, environmental changes and social reflections. Driving forces represent the human activities in the pursuit of economic and social development, including demographic and socioeconomic indicators such as population growth, changes in production and consumption, and people's lifestyles promotion. Through these changes of production and consumption, the driving forces exert pressures on the environment. These pressures include the uses of land and resources and the release of substances (emissions). Examples of pressure indicators are CO_2 emissions, energy consumption, water consumption by sectors, and arable land use for roads and construction. State indicators describe the transformation of the quality and quantity of the physical phenomena, the biological environment and chemical concentration in a certain area. The state indicators are, for example, temperature, CO_2 concentration, and level of noise of the living quarters. Impact indicators are used to reflect the environmental and social impacts resulting from the change of the environmental state. These indicators include resource availability, the crime rate, and adequate conditions for health. Response indicators deal with the responses of different groups and decision makers to prevent environmental degradation and social stratification and promote the efficiency of production, environmental conditions, and quality of life in adapting to the change of environmental state. Examples of response indicators include expenditures on the environment, utilization of green power, and recycling of domestic waste (Stanner et al., 2007).

Since the DPSIR framework was first applied in the program of EEA, which was sponsored by the Dorbris Assessment of European Environment covering the issues of air water and soil (EEA., 1995), it has been widely used by a considerable number of organizations and scholars to assess other environmental issues. This framework brings together the economic, social, environmental and institutional in an integrated framework by establishing cause-effect relationships between human activities and environmental, social and economic impacts. The DPSIR framework has been extended by other organizations and researchers to better understand specific issues obeying the causal links of DPSIR model. Examples are DPSWR (Cooper, 2012), DPCER (Rekolaninen, Kamari, & Hiltunen, 2003), DPSER (Kelble et al., 2013), and DPSEEA (WHO., 2002), DPSIR＋C(Zhang & Fujiwara, 2007).

2.3. DPSIR and Urban Sustainability

2.3.1. DPSIR Model of Sustainable City Index (SCI)

The assessment framework was designed based on the casual relationship that people and firms cluster in urban area to exploit agglomeration economies, but such clusters cause social and environmental externalities (Au & Henderson, 2005; Black & Henderson, 1999; Button, 1976; O'Sullivan, 2012; X. L. Wang, 2010)

Driving forces: The unprecedented urbanization and urban growth is the driving force that exerts pressures and cause changes in the urban environment. Demographic change increases the demand for resources, infrastructure and settlements. Industrialization has also increased the land need to accommodate factories and their related service sectors (Jago-on et al., 2009).

Pressures: Urbanization and industrialization exert pressures on urban environmental and ecological systems. The pressures mainly include the consumption of resources and release of substances, such as energy consumption, water consumption, waste emissions and SO_2 emissions.

States: When the urban environment changes, the state of the environment also changes, such as the concentration of SO_2, NO_2 and particulate matter (PM10), noise and air quality. In this paper, environmental efficiency indicators are selected, such as energy efficiency and pollutants emission per unit GDP.

Impacts: As discussed before, urban growth causes not only environmental problems but also social issues. Cities attract large numbers of migrants from rural areas, influencing security and employment in urban areas. In addition, large needs for settlements increase the housing prices and rents significantly. Furthermore, overcrowding also challenges the urban transportation system and results in serious traffic congestion, and people have to spend more time commuting.

Responses: Responses are the means to improve the quality of urban systems, such as the government's expenditure in education, technology and medical treatment and public health.

2.3.2. Hypothesis of DPSIR Model

H1: The high speed of urbanization, including economic and demographic development, increases environmental problems because of high resource consumption and pollutant emissions;

H2: The pressures on the environment accompanied by the the deterioration of the environmental state;

H3: Urbanization improves the quality of life of the citizens;

H4: The social response reduces environmental pressures;

H5: The social response promotes the performance of the other four sectors.

2.4. Data Pre-processing

In indicator-based framework, it is important to select proper data standardization methods. Here, I utilize 0–1 scaling to standardize the data; therefore all of the data can be transformed into 0–1 scales. Through this way, the linear relation among the data does not change. In order to compare two years' data, we refer to the method of Sun et al. (2009) to analyze the two years' cross-sectional data.

Initially, this paper designed the amount of evaluating indicators is m and the amount of evaluating objects is n, and in t years, then forms an original value matrix $X=(x_{ij}^{t})_{mT*n}$:

$$X=\begin{bmatrix} x_{11}^{1} & x_{12}^{1} & \cdots & x_{1n}^{1} \\ x_{21}^{1} & x_{22}^{1} & \cdots & x_{2n}^{1} \\ \cdots & \cdots & & \cdots \\ x_{m1}^{1} & x_{m2}^{1} & \cdots & x_{mn}^{1} \\ \cdots & & \cdots & \\ x_{11}^{T} & x_{12}^{T} & \cdots & x_{1n}^{T} \\ \cdots & \cdots & & \cdots \\ x_{m1}^{T} & x_{m2}^{T} & \cdots & x_{mn}^{T} \end{bmatrix} \tag{1}$$

where $i=1,2,..., m, j=1,2,..., n; t=1,2,..., T$.

In order to eliminate the influence of magnitude and positive (the larger the better) and negative (the smaller the better) orientation, the data is standardized using equation (2) and (3) to get $R=(r_{ij}^{t})_{mT*n}$:

$$\text{Positive indicator: } r_{ij}^{t}=\frac{x_{ij}^{t}-min(x_j)}{\max(x_j)-min(x_j)} \tag{2}$$

$$\text{Negative indicator: } r_{ij}^{t}=\frac{\max(x_j)-x_{ij}^{t}}{\max(x_j)-min(x_j)} \tag{3}$$

Where x_{ij}^{t} represents the value of indicator j in city i in year t; $\max(x_i)$ and $\min(x_j)$ is the maximum and minimum value of j indicator in all cities, respectively. Thus all the data is standardized in the range of [0,1] (S. Wang, Ma, & Zhao, 2014).

2.5. Entropy Method

Despite data standardization, another important process is defining weights for each indicator. There are two kinds of weighting methods: subjective weighting method (Analytic Hierarchy Process, Delphi Method), objective weighting method (Principal Component Analysis, Entropy Method). Entropy method has been wildly utilized in ecology, economy and finance, etc. Information entropy measures the amount of useful information based on the data. When the difference of the value of each indicator is high and the entropy is small, the weight of the indicator is high as well correspondingly and vice versa(Zou et al., 2006). The way of calculating entropy is an objective way which can avoids objective influences by choosing the best indicators that can reflect the different sustainable development level among sample cities. In order make it comparable between two years, The entropy of j indicator is defined as (5):

$$H_j = -k\sum_{t=1}^{T}\sum_{j=1}^{n} f_{ij}^t \ln f_{ij}^t,\ j=1,2,\ldots,n \tag{4}$$

Where, $f_{ij}^t = \dfrac{r_{ij}^t}{\sum_{t=1}^{T}\sum_{j=1}^{n} r_{ij}^t}$, $k = \dfrac{1}{\ln mT}$

In order to diminish the influence of 0 in the equation (2), the matrix R is translated into a new matrix A$=a_{ij}^t$: where $a_{ij}^t = r_{ij}^t + 0.0001$.

The weight of entropy of j indicator is defined as:

$$w_j = -\frac{1-H_j}{n-\sum_{j=1}^{n} H_j} \tag{7}$$

2.6. Assessment Framework of Sustainable City Index

The indicators are selected based on the Sustainable Development Goals of the UN (2015), which includes a set of 17 Sustainable Development Goals (SDGs) to end poverty, fight inequality and injustice, and limit climate change by 2030. To be specific, the 17 SDGs are no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate actions, life below water, life on land, peace and justice, strong institutions, and partnership for the goals. Under the goal of sustainable cities and communities, the goals are:

- By 2030, provide access to adequate, safe and affordable housing and basic services for all;
- By 2030, guarantee the access to safe, efficient and convenient transportation systems for all citizens;
- By 2030, strengthen the sustainable urbanization and the participation of all countries;
- mprove the protection of cultural and natural heritage;
- By 2030, reduce the adverse environmental pressures per capita by enhancing national and regional planning;
- By 2030, make safe and green open spaces accessible to all, especially women and children;

• Uphold positive linkage between economic, social and environmental pillars;
• By 2020, significantly increase the amount of urban areas that adopt and implement the policies on resource efficiency, climate change, and resilience to disasters;
• Support least developed countries through means including financial and technical aids in constructing sustainable and resilient buildings in local areas.

The International Organization for Standardization establishes a set of 17 themes on sustainable community focusing on city services and quality of life. The 17 themes include economy, education, energy, environment, finance, fire and emergency response, governance, health, recreation, safety, shelter, solid waste, telecommunication, transportation, urban planning, wastewater and water and sanitation.

Therefore, this paper constructs the framework of indicators basing on the UN SDGs and ISO 37120. Limited by the concrete condition of Chinese cities and data availability, only 27 indicators are selected in the DPSIR framework of urban sustainability (Table 1). The data of this paper are taken from China Urban Statistics Year Book, China Statistical Yearbook 2014, China New Urbanization Report, the yearbook and government work reports of each province and municipal city, the local Statistical Bureau, Inspection Bureau and Environmental Protection Agency.

3. Study Areas

3.1. Urban Agglomerations in China

Figure 1 demonstrates 20 emerged or planned urban agglomerations in China. Among these urban agglomerations, five of them are national urban agglomerations, nine are regional urban agglomerations and six are local urban agglomerations. Currently, there are 10 emerged urban agglomerations: Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta, Central and Southern Liaoning, Shandong Peninsula, Western Coast of the Taiwan Strait, Central Plains, Central Shanxi Plain, Chengdu-Chongqing and Central of Yangtze River; the others are planned by the National Development and Reform Commission (NDRC).

3.2. Study Areas

This research assesses the urban sustainability of 49 main Chinese cities, and these cities cover 20 urban agglomerations in China: four municipalities (Beijing, Tianjin, Shanghai and Chongqing), 26 provincial capital cities (Shijiazhuang, Taiyuan, Huhehot, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chengdu, Guiyang, Kunming, Xi'an, Lanzhou, Xining, Yinchuan and Urumuqi), five cities specifically designated in the state plan (Dalian, Qingdao, Shenzhen, Xiamen and Ningbo), five coastal cities and port cities (Nantong, Yantai, Weihai, Zhuhai and Beihai), three resource-dependent cities

Table 1　DPSIR Framework of Urban Sustainability

Rule Hierarchy	Component	Factor Hierarchy	Source	Positive or Negative	Weight
Driving forces	Economic Development Level	Unemployment Rate (%)	Year Book of Each Province and Municipal City	−	0.082
		Disposable Income Per Capita (yuan)	Year Book of Each Province and Municipal City	+	0.082
		GDP per capita(yuan)	Year Book of Each Province and Municipal City	+	0.078
		The Ratio of Tertiary Occupation (%)	Y Year Book of Each Province and Municipal City	+	0.018
		GDP Growth Rate (%)	Year Book of Each Province and Municipal City	+	0.027
	Demographic Growth	Population Growth Rate (%)	Year Book of Each Province and Municipal City	−	0.060
	Private Car	Private Car Ownership Per Person	Year Book of Each Province and Municipal City	−	0.029
Pressures	Resource Consumption	Energy consumption per unit GDP (ton of standard coal equivalent/yuan)	Year Book of Each Province and Municipal City	−	0.019
		Water consumption per unit GDP (ton/yuan)	China Urban Statistics Year Book	−	0.011
	Pollutant Emission	SO_2 emissions per unit GDP (ton/yuan)	China Urban Statistics Year Book	−	0.015
		Waste water emission per unit GDP (ton/yuan)	China Urban Statistics Year Book	−	0.022
		Industrial dust per unit GDP (ton/yuan)	China Urban Statistics Year Book	−	0.005
State	Air Quality	SO2 concentration (mg/m^3)	The Report of Local Environmental Protection Agency	−	0.017
		NO2 concentration (mg/m^3)	The Report of Local Environmental Protection Agency	−	0.011
		PM10 concentration (mg/m^3)	The Report of Local Environmental Protection Agency	−	0.009
		Number of days of air quality equal or above grade Ⅱ (days)	The Report of Local Environmental Protection Agency	+	0.022
	Urban Green	The Ratio of Green Area	Year Book of Chinese Cities	+	0.029

Impacts	Density	Population Density of Construction Area (person/km^2)	Urban China Initiative	−	0.028
	Housing	Ratio of House Price to Disposable Income	China Real Estate Year Book	−	0.011
	Welfare	Urban Pension Coverage (%)	Urban China Initiative	+	0.057
	Education	Ratio of Primary Education Teachers to Primary Students	China Urban Statistics Year Book	+	0.053
	Doctor Resource	Number of Doctors Per Capita	China Urban Statistics Year Book	+	0.049
Responses	Pollution Treatment	Comprehensive utilization of solid waste (%)	China Urban Statistics Year Book	+	0.022
		Sewage treatment rate (%)	China Urban Statistics Year Book	+	0.016
		Decontamination rate of urban refuse (%)	China Urban Statistics Year Book	+	0.010
	Technology Investment	Science and technology input/GDP (%)	China Urban Statistics Year Book	+	0.099
	Public Transportation	Average times of using public transportation per person per year	China Urban Statistics Year Book	+	0.118

Source: Author

Figure 1 Urban Agglomerations in China

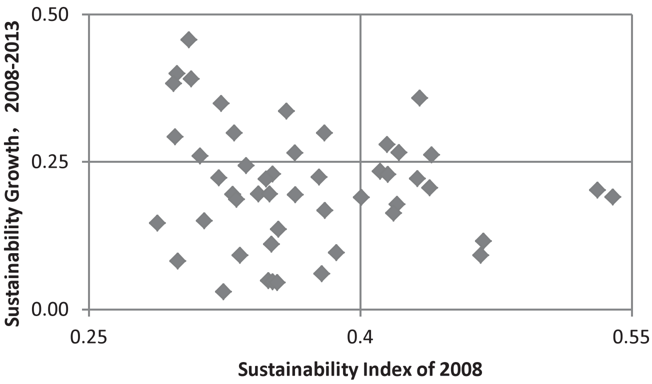
Source: Author

(Daqing, Baotou, Tangshan), and seven specially selected influential cities (Wuxi, Suzhou, Zhongshan, Dongguan, Luoyang and Guilin). Lhasa, limited by data availability, will not appear in the ranking. In addition, because the statistical standards of Hong Kong and Macao are inconsistent with the mainland, this research will not include these two cities.

4. Results

On the whole, all of the 49 cities experienced positive sustainable development from 2008 to 2013, and some of the cities reached high sustainability growth, with 30% to 50% improvement, while some of the cities developed slowly. Figure 2 illustrates the growth of sustainability from 2008 to 2013 of 49 cities that are separated into four groups; group one are the cities with lower sustainability (less than 0.4) and lower growth rate (less than 0.25); group two includes the cities with higher sustainability (more than 0.4) and lower growth rate; group three are those cities with lower sustainability and higher growth rate (more than 0.25), and group four's cities had both a higher level of sustainability and growth rate. In group one, the majority of the cities are inland cities (e.g. Yinchuan, Kunming and Guilin) whose economic development is limited by their resources and locations, while the others are northern and northeastern resource-based and industrial cities (e.g. Tianjin, Shenyang and Baotou) whose economic development level is higher but suffer serious resource and environmental problems. In addition, in group two all of the cities are coastal cities (Beijing, Shanghai and Shenzhen) which rank at the top of the sustainability index and enjoy the benefits of earlier economic opening. Group three (Changsha, Nanjing and Fuzhou) are cities which are developing rapidly in recent years with good policy support and rational industrial structures, and only four cities (Guangzhou, Zhuhai, Hangzhou, Ningbo) belong to group four and reflect a desirable tendency of sustainable development. With respect to each component, the driving forces of urbanization have increased in all cities; however,

Figure 2 Sustainability Growth from 2008 to 2013



Source: Author

the pressures exerted from urbanization on the environment rose, accompanied by the decline of environmental state. Divided by GDP (2008), the average sustainability score of small and middle (GDP smaller than 200 billion yuan), large (200–500 billion yuan), and super economies (larger than 500 billion yuan) are 0.38, 0.39, and 0.46 respectively.

On the whole, as shown in Table 2, in 2013 Shenzhen, Beijing, Zhuhai, Guangzhou, Ningbo, Weihai, Dalian, Haikou and Suzhou's performance ranked highest among the 49 cities; all of the cities are located in eastern China and eight of them are coastal cities. This is because the eastern coastal areas enjoyed the benefits of earlier economic opening, policy support from the central government, and exceptional advantages of geography. In addition, these cities are more attractive to highly-competent people, with high salaries and more opportunities for young people. Therefore, the coastal areas develop with vitality and have become the most successful region in China.

Table 2 Top 10 Cities in Sustainability of 2013

Rank	City	Sustainability	Location
1	Shenzhen	0.64	Eastern
2	Beijing	0.64	Eastern
3	Zhuhai	0.59	Eastern
4	Guangzhou	0.55	Eastern
5	Hangzhou	0.53	Eastern
6	Ningbo	0.53	Eastern
7	Weihai	0.53	Eastern
8	Dalian	0.53	Eastern
9	Haikou	0.52	Eastern
10	Suzhou	0.51	Eastern

Source: Author

Within the top ten cities, the urban density ranged from 4000 to 14000 per square kilometer and the majority had a density between 7000 and 10000 per square kilometer. Among the top performing cities, the GDP per capita ranged from 90–130 thousand yuan, with the exception of Haikou, with only 40 thousand yuan per capita. The highest GDP per capita is around 150 thousand Yuan, which is not the high compared with some cities, meaning that high economic development cannot necessarily guarantee sustainable development, and a balanced development among all pillars is needed.

As discussed above, the top ten performing cities benefit from the earlier start of economic opening, but the current performance does not necessarily reflect a better growth rate of sustainability. Table 3 demonstrates the top ten cities' improvement in sustainability, and the results contradict those of the best performing cities in that the majority of the cities are located in the west, except Zhuhai, Ningbo and Wuhan. The high-speed sustainable development of western cities is the result of the develop-the-west strategy, abundant natural and labor resources, and the experience of eastern cities' development.

In addition, the high speed of tertiary vocational education development reinforces the retention of talents in western areas. Although the sustainable development of the west is much higher than the majority of the eastern cities, the level of sustainability is still behind coastal cities.

Table 3 Rank of Sustainability Growth, 2008–2013

Rank	City	Sustainability	Location	City scale by population
1	Guiyang	0.46	Western	Medium
2	Nanning	0.40	Western	Medium
3	Xian	0.39	Western	Large
4	Lanzhou	0.38	Western	Medium
5	Zhuhai	0.36	Eastern	Medium
6	Wuhan	0.35	Central	Medium
7	Fuzhou	0.34	Eastern	Medium
8	Nanjing	0.30	Western	Medium
9	Nantong	0.30	Central	Medium
10	Xining	0.29	Western	Medium

Source: Author

Among the worst performing cities (Table 4), six of the cities are located in central and western cities, and the majority of them are resource-based cities. These resource-based cities, especially eastern cities, also show a slow sustainable development during the five years, meaning that development that mainly depends on resources could not maintain sustainable development. It is urgent for the high resource-based cities to transform their industrial structure or there is a danger of resource scarcity in these areas.

Table 4 Bottom 10 Cities in Sustainability, 2013

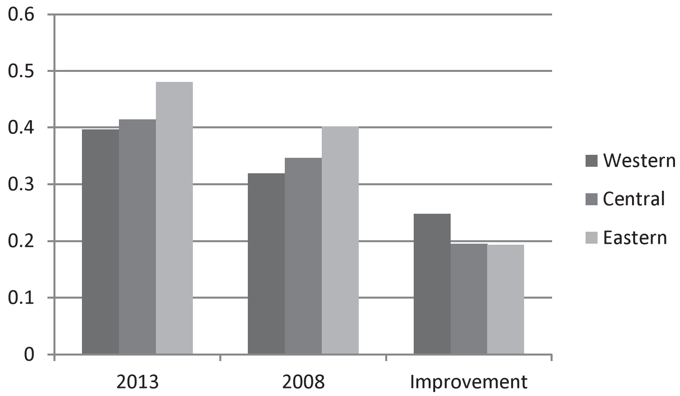
Rank	City	Sustainability	Improvement	Location
40	Taiyuan	0.39	0.11	Central
41	Xining	0.38	0.29	Western
42	Baotou	0.37	0.05	Western
43	Changchun	0.37	0.05	Eastern
44	Huhehot	0.37	0.05	Western
45	Haerbin	0.36	0.09	Eastern
46	Luoyang	0.36	0.15	Central
47	Shijiazhuang	0.33	0.03	Eastern
48	Chongqing	0.33	0.15	Western
49	Tangshan	0.32	0.08	Eastern

Source: Author

4.1. Regional Sustainable Development

In 2013, there was an apparent correlation between the level of sustainability and the location. As discussed above, with respect to the best performing cities, the eastern coastal cities show a high level of sustainability, while the western cities reflect a high rate of sustainable development. Figure 3 demonstrates the average score in the level of sustainability in 2008 and 2013, and sustainable growth for 2008–2013 respectively. The majority of the eastern cities performed well and retained the highest sustainability level among all regions. They were followed by central cities, and western cities still lag behind the other two regions. However, the average improvement rate in sustainability of western cities is higher than central and eastern China, and the level of western cities' sustainability is approaching central cities.

Figure 3 Sustainable Development by Region

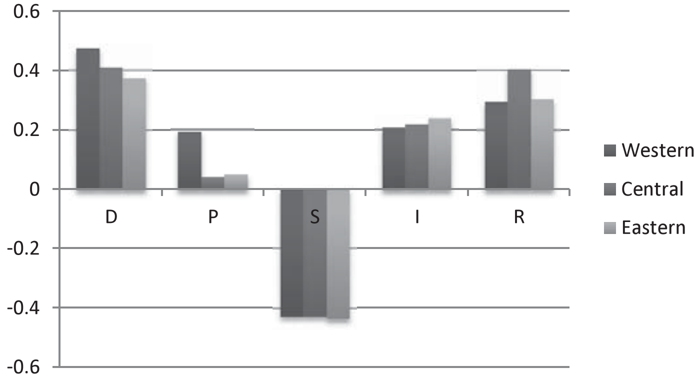


Source: Author

Figure 4 demonstrates the sustainability improvement with respect of each category of DPSIR in different regions from 2008 to 2013. Eastern cities developed fastest in social impacts, but the lowest in environmental state. Central cities improved a lot in the responses sector but lowest in decreasing resources efficiency. Western cities experienced the fastest economic development while slowest in social development. Table 5 illustrates the three best performances cities in each region. Among western cities, Guiyang has experienced a significantly sustainable development from 2008 to 2013 and ranking the top among western cities while two cities of Inner Mongolia Baotou and Huhhot have changed slightly since both of them are high resource-based city. In addition, Changsha remains the top ranking among middle cities and Zhuhai becomes one of the best performance cities in 2013 with the largest sustainable development.

As with the previous results, the eastern urban agglomerations perform better in sustainability than other areas; however, the sustainability of western urban agglomerations has developed faster. Among the top 10 urban agglomerations, large cities and megacities play an important role in driving

Figure 4 Sustainable Development of Each Category by Region, 2008–2013



Source: Author

Table 5 Top Three Cities of Each Region

Region	2013	2008	Improvement
Western	Guiyang, Xian, Yinchuan	Baotou, Chengdu, Huhhot	Guiyang, Nanning, Xian
Central	Changsha, Wuhan, Hefei	Changsha, Nanchang, Hefei	Wuhan, Hefei, Changsha
Eastern	Shenzhen, Beijing, Zhuhai	Beijing, Shenzhen, Haikou	Zhuhai, Fuzhou, Nanjing

Source: Author

Table 6 Rank of Urban Agglomerations in 2013

Rank	Urban Agglomerations	Sustainability Growth (2008–2013)
1	Pearl River Delta	Central of Guizhou
2	Yangtze River Delta	The Central Shanxi Plain
3	Western Coastal of Taiwan Strait	Western of Lanzhou
4	Central and Southern of Liaoning	Urumqi-Changji-Shihezi
5	Shandong Peninsula	Ningxia-Yellow River
6	North Bay	Yangze Huaihe
7	Central of Guizhou	North Bay
8	Central of Yangtze River	Central Plain
9	Yangtze-Huaihe	Yangtze River Delta
10	Beijing-Tianjin-Hebei	Shandong Peninsula

Source: The Author

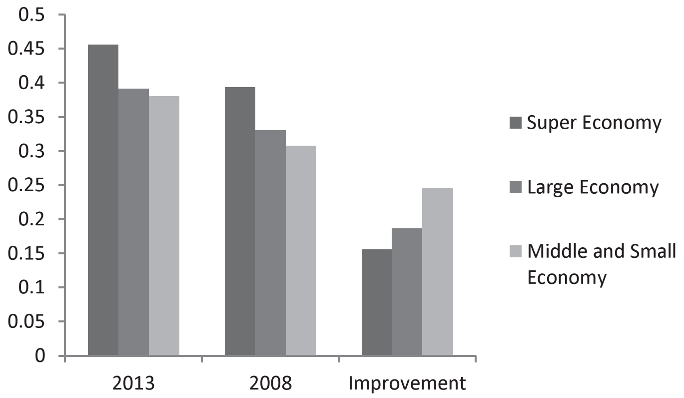
the sustainable development of the whole urban agglomerations, such as the Pearl River Delta urban agglomeration and Yangtze River Delta urban agglomeration. However, the Beijing-Tianjin-Hebei urban agglomeration is an exception in this area, Beijing is one of the top performing cities, while the cities of Hebei province all rank at the bottom; in other words, Beijing's sustainable development is scacifying the development of surrounding areas. Therefore, Beijing's development is not an example of strong sustainable development.

4.2. The Sustainable Development by City Scale

This paper divides cities using two kinds of classification, by population and by GDP. For population size, megacity, large city, medium city and small city are the cities with more than 10 million, 5–10 million, 1–5 million and under 1 million urban inhabitants respectively. For GDP, a super city's GDP is larger than 500 billion yuan, large cities are those with GDP from 200–500 billion yuan, small and medium cities are smaller than 200 billion yuan.

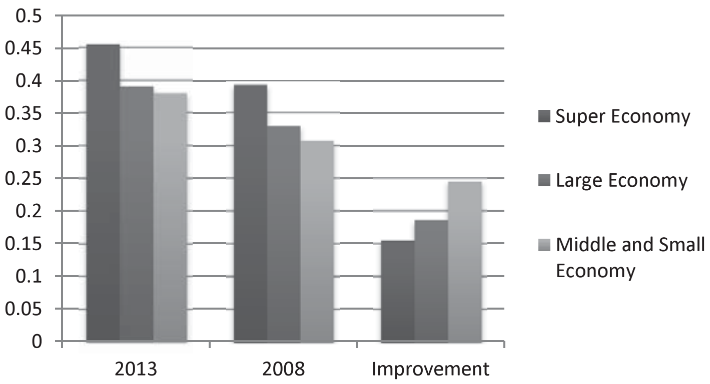
Divided by GDP (Figure 5), super economies demonstrate better performance in sustainability than other economies, while the average development speed of medium and small cities is faster. Similarly, based on figure 6, the average sustainability of megacities is higher than large, medium and small cities, while medium and small cities improve more than the other cities. The advantages of larger cities remain, while the potential of small economies also cannot be ignored.

Figure 5 Sustainable Development by City Scale (Population)



Source: Author

Figure 6 The Sustainable Development By City Scale (GDP)

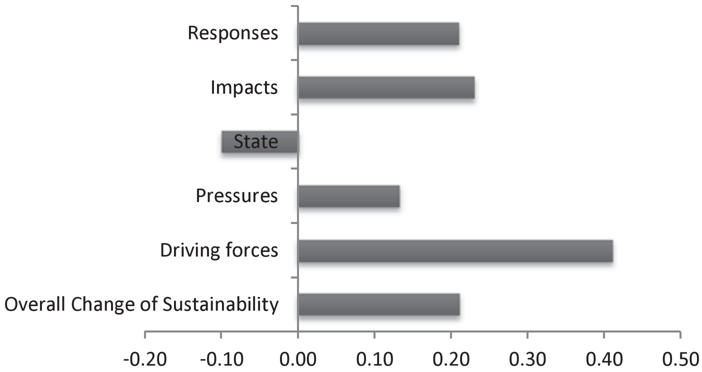


Source: Author

4.3. The Absolute Change of DPSIR Framework

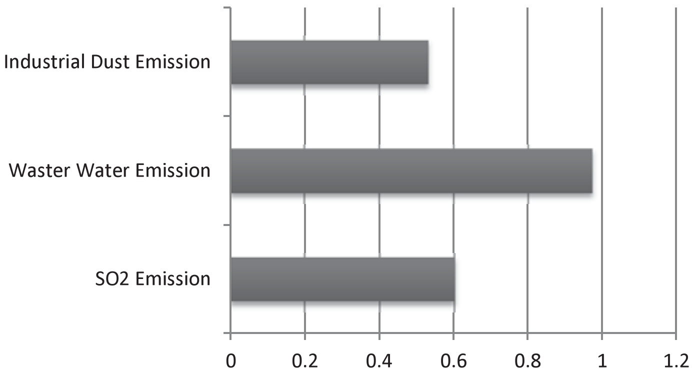
Figure 7 illustrates the change of each sector of the DPSIR model. From 2008 to 2013 the driving forces contributed a large proportion of sustainable development with a high speed of economic growth and demographic change, and the environmental efficiency has also been increased. Nonetheless, the state of the environment declines as the increase of resource consumption and pollutant emissions as a result of the significant increase of pollutants from 2008 to 2013 (Figure 7). Although, the environmental state deteriorates with urbanization, the quality of life of the citizens has been promoted as a result of economic development. Even though the response of society increased, the environmental degradation remains and the environmental quality keeps deteriorating. The result can verify the assumption of the DPSIR model that the promotion of economic development will result in the increase of environmental pressures. The environmental pressures are followed by serious environmental pollution, and influence the quality of life. However, the quality of life is also highly dependent on the development of the economy; therefore, although the environmental state is poor in

Figure 7　Change of D-P-S-I-R



Source: Author

Figure 8　The Absolute Change of Resources Consumption and Pollutant Emissions, 2008–2013



Source: Author

some coastal cities, the quality of life remains at a high level. The responses of the society can help improve the environmental efficiency and decrease pollutants; however, more responses are needed to improve sustainable development.

5. Conclusion

The study applies the DPSIR model to assess the sustainability of 49 Chinese cities in 2008 and 2013. The DPSIR model is a tool to analyze sustainable development based on a causal relationship between each sector. It was found that from 2008 to 2013 all selected cities show an increase in terms of the level of sustainability and eastern cities remain better performing than central and western cities.

5.1. Urbanization Increases Urban Environmental Pressures

Economic development is the driving forces of sustainable development; however, the high speed of economic development is based on the increasing pressures on the environment and the deteriorating environmental state. Therefore, high dependence on resources and industry will challenge the long-term development of cities. The majority of the eastern cities enjoyed earlier economic opening and kept a high speed of economic development for the past 30 years, while some of the eastern cities are facing the challenges of scarcity of resources, such as the cities of Hebei and North East China. These cities are praised as the "eldest sons of the republic", with a huge contribution to the development of the new China. However, currently these cities are suffering from the problems of unsuccessful industrial transformation, resource scarcity and serious environmental problems.

5.2. Sustainability Should Reach a Balanced Development among the Three Pillars

A high rate of economic development cannot guarantee sustainable development, and blindly pursuing GDP growth may result in a decrease of sustainability. Based on an in-depth study of DPSIR, western cities The cities with balanced development in three pillars, economy, society and environment, will promise the cities a better future. Admittedly, urbanization helps a large number of people get out of poverty and improve their living standards; however, the disorderly development of urban areas and urban populations will lead to serious environmental problems which threaten the health of city residents.

5.3. The Majority of Chinese Cities' Sustainable Development Is Weak

The urban development of Chinese cities is still weak sustainable development, which is highly reliant on resources and heavy industry. Even though many of the coastal cities show a high level of sustainability, the sustainability is at the expense of the unsustainable development of other cities.

Therefore the western cities should not follow the traditional development mode of eastern cities, and realizing a strong sustainable development is still one of the difficult tasks in China. DPSIR model provide is necessary for the policy makers to trace the whole influence of human activities on the environment and ecosystem. More responses are required, including technology innovation, environmentally friendly resource exploration, and investment in technology and environmental protection. Moreover, DPSIR can be utilized on analyzing special environmental issues based on the actual situation of each city. For western cities, the policy makers should focus on improving the resources efficiency and decreasing energy intensity as well as pollutant emissions intensity in pursuing high rate of economic and social development. While for eastern cities, the local governments should continue to control population growth rate, optimize urban design, improve the proportion of green energy and circular economy and increase investment in technology innovation. Finally, it is also important to enhancing the cooperation between among local governments, NGOs, research institution to share advanced technology, successful experiences and research achievements to reduce the unbalanced development among regions.

5.4. Limitations of the Paper

In this paper only 49 cities were selected, and the majority of the cities are key cities with policy support from the central government. These cities do not represent the development of 661 Chinese cities, and more research needs to be done regarding the remote cities and little-known cities. In addition, a comparative assessment between Chinese cities and international developed cites is needed in order to explore this gap and learn experiences from successful cities, especially the successful experience of other Asian cities such as Tokyo, Singapore and Seoul. Therefore more works are needed to enrich the research of sustainable city development in the future.

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