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Towards green growth and management: Relative efficiency and gaps of Chinese cities

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ABSTRACT

Efforts to deal with anthropogenic environmental impacts are focussed predominantly on cities. This paper applies metafrontier-data envelopment analysis (DEA) to evaluate the capacity of 286 Chinese cities of different sizes and in different regions towards green growth development and assesses gaps in their efficiencies. The determinants of efficiency, including regional and population size effects, were estimated using logistic regression model. Results show that the state of green growth efficiency was different for cities of different sizes and from different regions, and gaps existed compared to the best production frontier. The paper suggests that more endeavours are required for environmental and social dimensions, and a short-term target can include achievement of group frontier efficiency and significant reduction in technology gap ratios. Owing to significant population size effect, policy programs should have target plans for cities of different sizes as they differ in performance and capacity building.

1. Introduction

Environmental change has become an important consequence of global development [11,34]. With rapid urbanization, it challenges city development to focus on ecological environment and social needs of the people [47] rather that proactive economic growth only. Some approaches proposed include green economy [15,32,53], eco-cities [23,35,54], and low carbon cities [16,20,48], which significantly affect the thought and practice of city development. Particularly, the idea of green growth connects two main agendas, growth and environmental promotion, providing an alternative perspective of urban development and management [32,42].

However, the progress of realizing green growth is slow as cities need to avoid environmental deterioration and simultaneously meet economic and social demands [4,68]. The progress towards green growth relies on technical means such as cleaner production or eco-design [32] and requires management improvement [39,49]. Thus, a city should be able to optimize economic outputs and social development, while reducing undesirable environmental impacts.

To measure such multidimensional input-output attributes, the technique of data envelopment analysis (DEA) can be applied to evaluate desirable outputs (economic growth) against undesirable outputs (environmental impacts) [52]. DEA captures the multidimensionality by preserving the inherent idiosyncrasies of cities while considering each dimension of green growth. It measures the efficiency of cities towards green growth through production frontiers, through which a city's performance is compared with others. There is a growing body of research employing this technique that explores the efficiency of resource utilization promoting development while counteracting environmental degradation [12,56].

However, we also need to acknowledge that cities may share some grouping features, such as population size and geographic location among others, which significantly affect the cities' trajectory and management [61]. Therefore, there is a gap among the cities in different groups in their capacity to deal with green growth. For instance, cities in humid or dry regions face different environmental issues or it is harder for a city with 10 million people to deal with environmental issues compared to a city with 1 million. To a large extent, these heterogeneous characteristics are overlooked in the measurement but need to be considered for a more realistic assessment. Therefore, this research employs metafrontier-DEA to investigate efficiency towards green growth of cities within heterogeneous groups, using two criterions: geo-location (region) and size (population numbers) that are tested using Logistic Regression (LR) model for Chinese cities.

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Chinese cities have achieved considerable economic and population growth in the past decades. This growth has been overshadowed as many problems associated with high levels of energy consumption, environmental pollution [26,44,9], and shortage of social services have emerged. In particular, air pollution has been a significant cost of economic development threatening cities' future. There are many studies that have investigated environmental-economic relationships at a provincial level [57], on a small number of selected cities [52], or in specific sectors only [65]. However, a systematic examination of Chinese cities is limited, although urban development has been advocated as the main strategy for promoting economic growth and as a medium for exploring sustainable development in China [31]. This paper incorporates a number of economic, social, and environmental indicators to fulfil this goal.

The rest of the paper is organized as follows. Section 2 proposes and analyses efficiency as a measurement of the city's capacity towards green growth, presenting two hypotheses tested in this research. Section 3 describes the methodology of metafrontier-DEA to measure green growth efficiency and the LR method to test the hypotheses. Section 4 presents the results. The implications of these findings are discussed in Section 5. Section 6 concludes by summarising the findings, limitations, and directions for future research.

2. Efficiency as measurement of progress towards green growth

Green growth is a strategy that uses natural resources in a sustainable manner to develop economy. It can be theoretically justified by concepts like ecological economy [17,40], industrial ecology [50], cleaner production [27,8], and integrated product policy [14,29,55], which illustrate various alternatives of efficient use of resources and energy and mitigate climate change. Yet, environmental issues cannot be simply reduced to a question of growth as they are inherently interlinked with economic and social demands. As Alkemade and Hekkert [1] argue, uncoordinated initiatives are unlikely to be effective in realizing green innovation and societal transformation. Following a survey, Byrka et al. [4] pointed out that technological progress alone does not guarantee sustainable consumption patterns, and it is critical that the innovations in green product should be accepted by the consumers. This partially explains why the pace of progress towards clean energy has failed to match the urgency to address climate change [13]. Therefore, green growth calls for an inclusive solution, which considers a wide range of parameters that appeal to social needs, economic growth, and environmental protection. As seen from the United Nations Environment Program [63], searching for such win-win solutions and virtuous cycles of progress and prosperity makes green growth quite different from previous sustainable discourses. Particularly in developing countries, green growth should be an important strategy which helps implement sustainable developmental policies that expedite the growth process and improve welfare [70].

Improving sustainability is an essential responsibility for urban planners and managers, and green growth provides an important solution. Moving towards green growth, a city can manage, build, and distribute urban resources to address needs of the urban population, including access to cleaner air and water, convenient transportation, functional urban services, and friendly civic environment making residents feel physically, culturally, and spiritually connected to the city [64]. Several researchers report that urban planning and management can significantly affect the impact of human activities on the environment, such as urban sources of greenhouse gas emissions [2], energy use [22], transportation generated air pollution [69], and lifestyle-related urban waste [72]. There is also a trend of cleaner production processes using materials and energy more efficiently while minimizing waste and emissions [27,7]. The capacity of a city to be sustainable is not static, but is dynamic and improvable, and can be continuously enhanced by the interactions between economic production, technology utilization, human preferences, consumption patterns, and better planning and management [25,64].

While dealing with complex interactions between humans and nature, efficiency is an important indicator to assess the capacity of a city towards green growth by looking at its ability to generate services and goods with limited resources and energy and meet human demands while reducing social instability and environmental degradation. Some research has been devoted to investigating the relationship between socioeconomic and ecological systems with an efficiency approach. In very recent literature, DEA methods have been extensively used. For instance, Toshiyuki and Mika [60] employed a DEA-based Malmquist index using fuel mix, electricity, and CO2 levels as indicators to examine the degree of frontier shift in economic and environmental production in ten industrial nations. Zhang et al. [71] used DEA to model environmental production characteristics in Boyanghu Lake in China. Carboni and Russu [6] applied DEA to investigate the wellbeing and quality of life in Italy. A significant contribution of DEA in environment-related studies is that it effectively separates outputs as desirable and undesirable ones [60]. The DEA approach provides a comparative perspective of efficiency measure, acknowledging comparative rather than absolute state in the development, and therefore encourages learning process among cities.

Although various DEA applications skilfully handle multiple dimensions (inputs/outputs) without imposing tight structures on the relationships between the variables [6], heterogeneity of cities are largely overlooked. Evaluation may be biased because heterogeneity across groups might lead to different production technologies. Specifically, production environments of the decision-making units (DMUs) of one group might be different from the other group [9]. Cities may develop under different processes and states and therefore operate under different technologies to pursue sustainability, constrained by different topography, climate, and degrees of production structure. Acknowledging this heterogeneity can facilitate targeted policy making. Therefore, two hypotheses are examined in this paper:

H1. the odds of cities in different regions achieving efficient management towards sustainability are different.

H2. the odds of cities with different sizes achieving efficient management towards sustainability are different.

H1 addresses the regional effect, particularly effects of climate and natural conditions on efficient management. H2 assumes that complexity increases with an increase in population size and results in different management efficiencies.

3. Methods and data

3.1. Data

Selection of appropriate indicators in DEA applications is important as different datasets can lead to different results and implications for assessment. Currently in China, the most pressing issues concerning urban development are improvement of resource use efficiency, including energy and materials, and reducing air pollution [31], while improving economic and social wellbeing of citizens. According to normal production theory, evaluation will include labour forces, land, and fixed investments as main inputs for the city's operation and production and include water, electricity, and gas as energy and resources consumed [45,64]. The main outputs include:

- gross domestic product as an indicator of the economic wealth created in the city [36,51]
- disposable income that indicates personal wealth creation [21,28]
- unemployment as a key indicator of social justice [46]
- green coverage ratio of built-up areas as an indicator of friendly urban physical environment and green park area per capita [43,62],
- number of teachers per capita in primary schools to measure the capacity of educational development