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Research Paper

Can spatial planning really mitigate carbon dioxide emissions in urban areas? A case study in Taipei, Taiwan

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ABSTRACT

Spatial planning plays an increasingly significant role in climate change mitigation by providing energy efficient settlements and promoting the utilization of renewable energy resources. However, the effect of urban spatial planning on spatial pattern of carbon dioxide emissions in cities is rarely discussed. The relationships between the changes in urban zoning plans and carbon dioxide emissions of major economic sectors has yet to be investigated on a scale smaller than an entire city. Using the Taipei metropolitan area as a case study, this study hypothesizes that: (1) carbon dioxide emissions have a spatial dimension within the city due mainly to the heterogeneous nature of land use activities and urbanization, and (2) changes in spatial planning can influence the urban form, and consequentially affect carbon dioxide emissions through changes in traffic demand and energy consumption. A downscaling analysis approach was used to estimate carbon dioxide emissions of different sectors for each administrative district in the Taipei metropolitan area. The analytical results reveal that the total carbon dioxide emissions of the four sectors in the Taipei metropolitan area increased with the increases in the growth of urban planned zones during the period 1981–2011.The carbon dioxide emission increases were correlated with the distribution of land uses in each administrative district. A negative correlation was found between the population density and the *per-capita* carbon dioxide emissions in the transportation sector. The compact development and planning of urban transit systems are believed to be the source of decreasing per-*capita* carbon dioxide emissions. While many studies have emphasized that spatial planning is important addressing climate change, this work demonstrates understanding the historic links between spatial planning and carbon dioxide is equally valuable.

1. Introduction

Although climate change is a global issue requiring top-down solutions based on international treaties, urban areas also play an increasing role in climate change mitigation (Rosenzweig, Solecki, Hammer, & Mehrotra, 2010). As the result of urbanization, the spatial organization of land use activities and transport systems are closely interrelated and in turn affect greenhouse gas (GHG) emissions in urban areas (Bulkeley, 2006; Marcotullio, Sarzynski, Albrecht, Schulz, & Garcia, 2016). The spatial organization of human settlements — including urban form — needs to be understood in order to formulate efficient and effective strategies for mitigating GHG emissions. The planning and design of the spatial pattern of urban development must encourage sustainable transportation such as public transportation options, cycling and walking, and reduced use of vehicles. In addition, compact and higher urban densities (lower surface-to-volume ratios) are considered much more energy efficient than low density buildings (Wende, Huelsmann, Marty, Penn-Bressel, & Bobylev, 2010).

Many researchers have investigated the empirical relationships between urbanization and CO_2 emissions and found positive correlations (Cole & Neumayer, 2004; Poumanyvong & Kaneko, 2010; York, Rosa, & Dietz, 2003). An analysis of 88 developing countries during the period 1875–2003 identified an inverted U-shaped relationship between urbanization and CO_2 emissions, with a positive correlation between urbanization and CO_2 emissions existing for less urbanized countries (Martinez-Zarzoso & Maruotti, 2011). Sardorsky (2014) found that urbanization has a positive and statistically significant impact on CO_2 emissions in emerging economies. Ponce de Leon Barido & Marshall (2014) examined the influence of strong national environmental policies in higher income nations. Cities in high income nations with strong environmental policies not unexpectedly showed reduced CO_2 emissions.

Spatial planning can help achieve a low-carbon future by promoting new technologies to create new urban forms (Crawford & French,

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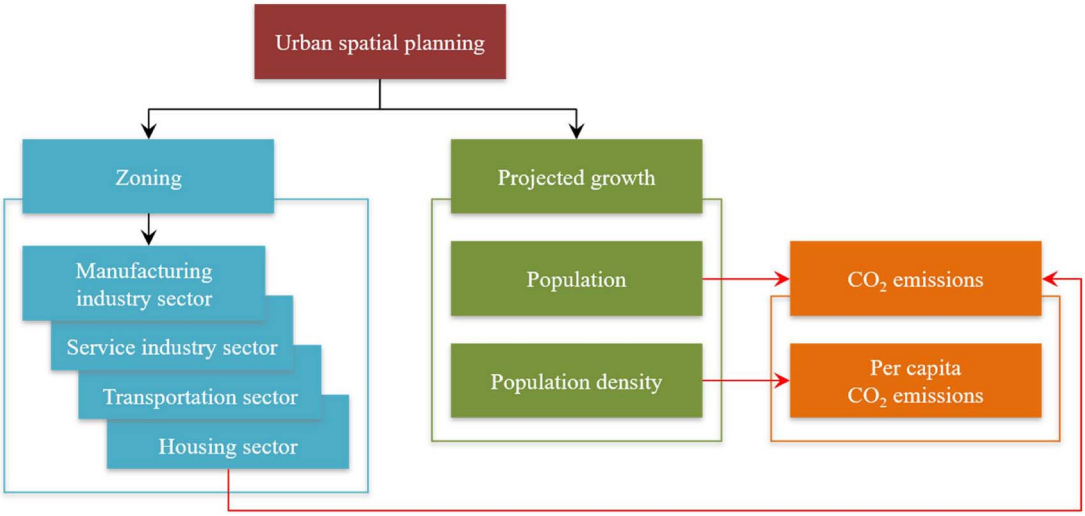

Fig. 1. The conceptual framework of urban spatial planning and CO_2 emissions.

2008). Spatial planning plays an increasingly important role in achieving climate change targets by helping mitigate CO_2 emissions through the rational allocation of land uses to improve energy efficiency and through protection of green infrastructure (Bulkeley, 2006; Campbell, 2006; Wende et al., 2010). In addition, spatial planning contributes to the development of integrated strategies, and also functions as a mechanism to implement local and regional strategies (Biesbroek, Swart, & van der Knaap, 2009). From neighborhood plans to metropolitan spatial development frameworks, spatial planning has helped determine the character of cities, significantly affecting urban system metabolism and resource use. The Intergovernmental Panel on Climate Change (IPCC) included a chapter on "Human Settlement, Infrastructure, and Spatial Planning" in Working Group III of IPCC AR5 in 2014 (Seto et al., 2014). This chapter reviewed and discussed spatial planning strategies to mitigate CO_2 emissions from different geographic scales to reduce urban sprawl and energy consumption in transportation.

Given the contribution by cities to CO_2 emissions, consensus is building around the role of cities in reducing emissions and reducing the impact of climate change. From a spatial planning perspective, urban form can have potentially significant impacts on energy use, resource consumption and the ability of a region to mitigate climate change (Blanco, McCarney, Oarnell, Schmidt, & Seto, 2011). Governments, authorities and individuals worldwide have deliberately planned cities to determine their character, and responded to the stimuli of demographic changes with associated demand for housing, economic opportunities and institutional changes. Spatial planning frameworks can modify urban form to mitigate climate change. Important measures to reduce CO_2 emissions include reducing traffic demand and energy consumption. Although spatial planning is claiming an increasingly important role in climate change mitigation by providing energy-efficient settlements and promoting the utilization of renewable energy resources, the impact of historic urban spatial planning activities on the current spatial patterns of CO_2 emissions in the cities has rarely been discussed. The relationships between the changes in urban zoning plans and the CO_2 emissions of major sectors has also not been widely investigated, especially on a scale smaller than a city.

Using the Taipei metropolitan area as a case study, this study hypothesizes that: (1) CO_2 emissions have a spatial dimension within the city due mainly to the heterogeneous nature of land use activities and urbanization, and (2) spatial planning can influence the urban form, and consequentially affect CO_2 emissions through traffic demand and energy consumption (Section 2). Following the brief description of the study area (Section 3), Section 4 describes the calculation of CO_2 emissions in each administrative district within the Taipei metropolitan area through the downscaling of the city-level CO_2 emissions of each sector (manufacturing industry, transportation, service industry and housing). Section 5 analyzes the relations between CO_2 emissions and land use variables; the impact of spatial planning on the spatial dimensions of CO_2 emissions are also discussed, and section 6 draws conclusions.

2. Framework

Urbanization creates enormous environmental change resulting from socioeconomic transformation in urban areas. Generally, urbanization is viewed as a phenomenon of the concentrated population in a specific area, as an intensive and high density land use of human settlement and land cover, and a series of interconnected processes and transitions of interactions between humans and their environment (Li, Sato, & Zhu, 2003; McIntyre, Knowles-Yánez, & Hope, 2000). Exploring the interrelationships between urbanization and the socio-ecological and technological components of urban areas can further understand how urbanization affected the spatial and temporal pattern of carbon emissions within and across cities (Romero-Lankao et al., 2014). Therefore, urbanization is related to demography, economy and infrastructure in a city (Li et al., 2003; Romero-Lankao et al., 2014).

Urbanization has also been identified as one of the main causes of increased CO_2 emissions (Martinez-Zarzoso & Maruotti, 2011; Sadorsky, 2014; Cetin & Ecevit, 2015). Urban spatial planning can influence the urban form, traffic demand and energy consumption, and thus affects CO_2 emissions. Moreover, CO_2 emissions have a spatial dimension within cities because of the heterogeneous nature of land use activities and urbanization. In order to investigate the relationships between the changes in urban zoning plans and the CO_2 emissions of major sectors on a scale smaller than a city, Fig. 1 illustrates the hypothesized framework of the effect of urban spatial planning on CO_2 emissions.

In Taiwan, urban spatial planning determines amounts and distributions of population and, at the same time, population density as shown in Fig. 1. Increases in population have been considered the most obvious direct phenomenon affecting CO_2 emissions in cities (Dietz & Rosa, 1997). Population growth is also a major factor causing the increase of CO_2 emissions in OECD countries (Hamilton & Turton, 2002). Sadorsky (2014) and Zhao & Wang (2015) formulated models to analyze the impacts of population on CO_2 emissions and discovered a clear positive linear relationship between population growth and CO_2 emissions. CO_2 emissions in many Asian countries, such as the Philippines, Malaysia, China and Japan, are concentrated in areas with