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What are the impacts of demographic structure on CO_2 emissions? A regional analysis in China via heterogeneous panel estimates

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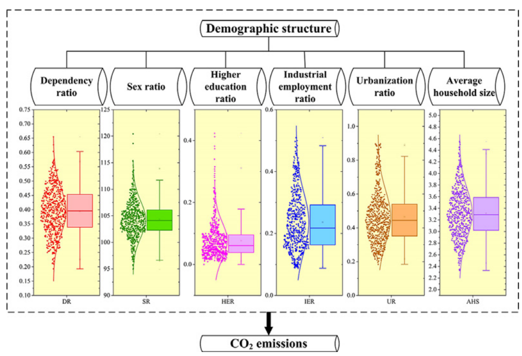
HIGHLIGHTS

- The impacts of the demographic structure on CO_2 emissions in China were estimated.
- Dependency ratio and average household size had negative effects on CO_2 emissions.
- Urbanization ratio exerted a positive impact on CO_2 emissions.
- The impacts of other independent variables on CO_2 emissions differed across regions.

GRAPHICAL ABSTRACT



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ABSTRACT

This study comprehensively investigated the impacts of demographic structure on CO_2 emissions in China at the national level and the regional level for the first time. Panel cointegration modeling was employed to test the long-run relationships between CO_2 emissions and six demographic structure variables, namely, dependency ratio, sex ratio, higher education ratio, industrial employment ratio, urbanization ratio, and average household size. The fully modified ordinary least squares method was then applied to estimate the long-run elasticity of CO_2 emissions for the six demographic structure variables. The results suggested that long-run relationships between CO_2 emissions and demographic structure existed at both the national level and the regional level. Dependency ratio was found to exert negative effects on CO_2 emissions in China and its three sub-regions. Positive associations between sex ratio and CO_2 emissions were revealed to exist in China and West China, and CO_2 emissions elasticity for sex ratio was relatively high in West China. Higher education ratio had a positive effect on CO_2 emissions in East China. Industrial employment ratio was found to positively correlate with CO_2 emissions in China, East China, and Central China. Urbanization ratio was demonstrated to increase CO_2 emissions at the national level and the regional level, and CO_2 emissions elasticity for urbanization ratio decreased from West China to Central China, and then to East China. Negative correlations between average household size and CO_2 emissions were detected at both the national level and the regional level. Based on the findings of this study, several practical recommendations were proposed, including optimizing age structure, promoting gender equality, advocating low-carbon lifestyles and low-carbon consumption patterns, promoting industrial upgrading and industrial structure optimization, building low-carbon cities and less carbon-intensive public infrastructure systems, and improving residential energy efficiency.

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1. Introduction

Global climate change now presents a serious threat to humanity (Clayton et al., 2015). Global warming, which is predominantly caused by anthropogenic greenhouse gases (GHG) emissions, is detrimental to both the natural environment and to social sustainability (Zhou and Wang, 2018). Whilst the mechanisms at work in population-climate interactions are complex, population has been identified as one of the major factors affecting GHG emissions, and in particular CO_2 emissions (Jiang and Hardee, 2010). According to demographic research, coming decades can be expected to witness significant demographic changes in the world's population (Cohen, 2003). First and foremost, it is believed that the growth of the global population will continue, and that most of this growth will occur through in urban areas (Wang et al., 2018a, 2018b, 2018c). Moreover, an increasing number of countries face aging populations as a result of low natality and low mortality. Last but not least, household size is expected to decrease due to shifts from multi-generational family structures to nuclear families. In view of the scope of these demographic changes, it is urgent to understand the effects that these shifts will have on CO_2 emission levels. With rapid urbanization and economic growth, China's energy consumption and consequent CO_2 emissions have increased rapidly (Ma and Cai, 2018; Wang and Liu, 2017; Wang et al., 2017a, 2017b). In particular, China's manufacturing started to expand sharply after the country joined the World Trade Organization (WTO) in 2001. Consequently, China's CO_2 emissions from the combustion of fossil fuels experienced swift growth, the majority of which was burned in the thermal power sector (Shan et al., 2016). China is now the world's largest developing country as well as the largest CO_2 emitter, and for this reason the country will play a major role in any global effort to address climate change (Shan et al., 2018). In addition, China has the world's largest population (nearly 1.4 billion), which accounts for almost one fifth of the world's population. Typical demographic changes such as rapid urbanization, aging, and household miniaturization are expected to be particularly marked in the Chinese context. The impact of demographic factors on China's CO_2 emissions therefore demands serious investigation.

A great deal of research has been conducted on the effects of population size on CO_2 emissions, with the majority of scholars arriving at the conclusion that population growth has been a significant driver of CO_2 emission growth in past decades. For example, based on cross-national panel data from 1960 to 2005, Jorgenson and Clark (2010) found a stable and significant positive correlation to exist between population size and CO_2 emissions (Jorgenson and Clark, 2010). In particular, the IPAT/STIRPAT model has been widely utilized in exploring the connections between population size and CO_2 emissions. The IPAT/STIRPAT framework allows for a more precise estimation of the elasticity of CO_2 emissions in relation to factors including population, allowing scholars to identify the most sensitive factors and propose effective policy recommendations accordingly (York et al., 2003). For instance, Dietz and Rosa (1997) used the IPAT model to examine the impacts of population, affluence, and technology on national CO_2 emissions (Dietz and Rosa, 1997). Employing the STIRPAT model, Wang et al. (2013) estimated the effects of population and seven other variables on CO_2 emissions in Guangdong Province, China, finding that population had the greatest effect on CO_2 emissions (Wang et al., 2013).

The impacts of structure on CO_2 emissions are a hot topic in energy and carbon emission studies, and various methods were used to estimate this kind of impacts (Wang et al., 2016a, 2016b, 2016c). For instance, the structural decomposition analysis (SDA) is a widely utilized analytical technique to assess the effects of structure on CO_2 emissions (Mi et al., 2017b). Applying SDA method, Mi et al. (2017a) estimated the determinants of China's carbon emission changes during 2005–2012, and found that the strongest factors offsetting CO_2 emissions have shifted from efficiency gains to structural upgrading. In addition to SDA, the index decomposition analysis (IDA) is another decomposition technique, in which the logarithmic mean Divisia index (LMDI) decomposition method dominated in recent years (Ang, 2015). Base on LMDI technique, Xu et al. decomposed China's energy-related carbon emissions into industry structure, energy structure, economic output, energy intensity, and population scale effects, finding that the economic output effect was the main driver of carbon emissions, while the energy intensity effect was a main inhibitory factor (Xu et al., 2014). In addition to population size, other demographic factors (mainly demographic structure factors) such as age composition, urban-rural composition, and household size also potentially bring about direct or indirect effects in relation to anthropogenic CO_2 emissions (O'Neill et al., 2010). Among all the demographic structure factors, age composition and urban-rural composition have been widely recognized as factors that significantly influence CO_2 emissions (O'Neill et al., 2012). Age structure is believed to have direct effects on CO_2 emissions, as emission-relevant consumption patterns are likely to change over a human lifespan (Menz and Welsch, 2012; Yamasaki and Tominaga, 1997) and the impact of population on CO_2 emissions thus varies across age groups (Liddle and Lung, 2010). More specifically, population aging tends to be negatively correlated with CO_2 emissions (Hamza and Gilroy, 2011; Kronenberg, 2009). Incorporating age structure into an energy–economic growth model, Dalton et al. (2008) found that population aging would reduce the US's CO_2 emission levels in the long term (Dalton et al., 2008). Likewise, CO_2 emissions were found to increase with the proportion of young population or working-age population by Lugauer et al. (2014), who examined the effects of age composition on CO_2 emissions using panel data for 46 countries (Lugauer et al., 2014). Moreover, an inverted U-shaped relationship between CO_2 emissions and population aging, which is known as the environmental Kuznets curve (KEC), has also been shown to exist (Okada, 2012). The relationship, however, is not simple: a study by Liddle (2011) that differentiated transport CO_2 emissions and residential electricity consumption concluded that young population contributed more to transport CO_2 emissions than the older population, while a U-shaped relationship existed between residential electricity consumption and age structure (Liddle, 2011). In addition to age structure, urban-rural structure is another significant demographic structure factor influencing CO_2 emissions, which has been demonstrated by many existing studies (York, 2007). Urbanization has been identified as one of the major driving factors in CO_2 emissions (Wang et al., 2012). Poumanyvong and Kaneko (2010) investigated the impacts of urbanization on CO_2 emissions in 99 countries, finding that the effects of urbanization on CO_2 emissions were significantly positive (Poumanyvong and Kaneko, 2010). Similar results were also obtained by Jorgenson et al. (2010), who estimated a panel model for a sample of less developed countries (Jorgenson et al., 2010). The EKC hypothesis between urbanization and CO_2 emissions has also been confirmed by a number of researchers. Martínez-Zarzoso and Maruotti (2011), for instance, found an inverted-U shaped relationship between urbanization and CO_2 emissions, concluding that CO_2 emissions in developing countries increased as their urbanization levels increased (Martínez-Zarzoso and Maruotti, 2011). Other studies have also indicated that urbanization can reduce CO_2 emissions, if a country's urbanization level is sufficiently high (Chikaraishi et al., 2015). With respect to China, an empirical investigation conducted by Zhang and Lin (2012) suggested that the rapid urbanization experienced by the country had led to increased CO_2 emissions and that the effects of urbanization on CO_2 emissions varied across regions (Zhang and Lin, 2012). The effects of other demographic structure factors on CO_2 emissions have rarely been addressed in existing studies, and only a limited number of recent studies have started to explore the impacts of household size (Yang et al., 2015), gender (Druckman et al., 2012), and educational attainment (Baiocchi et al., 2010; Lenzen et al., 2006) on CO_2 emissions.

Whilst the association between various demographic factors and CO_2 emissions has been investigated in previous studies, evident shortcomings still exist in this previous literature. Firstly, most studies have tended to focus on demographic quantitative factors (i.e., population