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Changes in energy-related carbon dioxide emissions of the agricultural sector in China from 2005 to 2013

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ABSTRACT

This study analyses the changes in energy-related carbon dioxide (CO_2) emissions of the agricultural sector in China from 2005 to 2013. Using the logarithmic mean Divisia index (LMDI) decomposition method, this study attributes the changes in agricultural CO_2 emissions to agricultural CO_2 emissions intensity, agricultural productive income intensity, rural residents' income structure, the distribution pattern of residential income, the distribution pattern of national income, economic development, provincial population distribution, and population scale, and treats these factors as technology, distribution, and population effects. Based on this, the nested decomposition problem, which has not been mentioned in related studies, is solved. To emphasize the importance of the logarithmic mean weight functions, two different chain LMDI decomposition methods are developed that are based on differences in the logarithmic mean weight functions. The results show that the distribution pattern of national income and rural residents' income structure are two key factors that separately stimulate and suppress the changes in China's agricultural energy-related CO_2 emissions. After nested decomposition of the distribution pattern of residential income, the suppressing influence from the rural population proportion is stronger than the stimulating influence from rural-urban income inequity. Although the results of the two chain LMDI decomposition methods are similar, only the distribution pattern of national income and rural residents' income structure maintain positive impacts on the changes in China's agricultural CO_2 emissions by year, while the rural residents' income structure, distribution pattern of residential income, and rural population proportion continue to have negative impacts on changes in China's agricultural CO_2 emissions by year. Furthermore, the technology, distribution, and population effects could not suppress China's agricultural CO_2 emissions simultaneously in most years.

1. Introduction

Although the appeal of low carbon development and a green economy has become widely accepted worldwide, it is not easy to move from traditional fossil fuel to renewable and sustainable energy, and reduce CO_2 emissions; this is especially true for China, which is the world's largest energy consumer and largest producer of CO_2 emissions. Many studies have analyzed the reduction of CO_2 emissions in China [1] (see Table 1[1]). However, there are few studies on the changes in CO_2 emissions in China's agricultural sector. While the Chinese population accounts for 1/5 of the world's population, cultivated land in China only accounts for 1/10 of the world's cultivated area. Achieving a win-win situation that combines supporting 1.3 billion people with saving energy and reducing the emissions of the agricultural sector has long been a problem faced by the Chinese government. Thus, it is meaningful to discuss the agricultural CO_2 emissions of China.

As the foundation sector of the national economy, agricultural development and energy saving and emissions reduction are directly related to people's daily lives and the sustainable development of the economy [18–20]. Compared to other sectors, energy consumption and CO_2 emissions in the agricultural sector have three features. First, although the processes of crop/livestock farming and aquatic products fishing produce CO_2 emissions [21–23], the energy consumed and CO_2 emissions produced by these production processes are far less than that of sectors traditionally considered as high emitting and high energy-consumption [24]. Second, the channel of energy consumption and CO_2 emissions in the agricultural sector is varied, so saving energy and reducing emissions is generally related to other sectors [20,25,26]. Third,

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[1] In this study, we use the LMDI decomposition method to evaluate the factors that cause the changes in energy-related CO_2 emissions in the agricultural sector in China. Thus, we only list some representative literature that uses the LMDI decomposition method.

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Table 1
Representative literature on changes in CO_2 emissions in China.

Sectors	Time interval	Driving factors	Authors
Industry	1998–2005	Activity, energy intensity, fuel intensity, fuel mix, emissions coefficient, and structural shift effects	Liu et al. [2]
Manufacturing industry	1995–2010	Emission factor, energy mix, energy intensity, industry structure, and economic output effects	Ren et al. [3]
Iron and steel industry	1981–1996	Activity, structure, energy efficiency, final fuel mix, and emissions coefficient effects	Kim and Worrell [4]
Transport sector	2010–2050	Population, activity level, share of drive train, energy consumption per unit distance travelled, and emissions per unit energy consumed effects	Gambhir et al. [5]
Petrochemical industry	2000–2010	Economic output, industrial structural, and technical effects	Fan et al. [6]
Food industry	1986–2010	Carbon intensity, energy structure, energy intensity, industry activity, and industry scale effects	Lin and Lei [7]
Building and construction industry	1994–2012	Carbon emission factor, energy structure, energy intensity, unit cost, automation level by areas, machinery efficiency, and building materials consumption effects	Lu et al. [8]
Logistics industry	1980–2010	Logistics activity, transport intensity, transport mode shift, energy intensity, fuel mix, and CO_2 emission factors effects	Dai et al. [9]
Power industry	1985–2013	Emission factor, energy structure, energy intensity, capital productivity, and industrial-scale effects	Zhao et al. [10]
Mining sector	2000–2014	Industrial scale, energy intensity, and energy structure effects	Wang and Feng [11]
Cement sector	1991–2010	Carbon intensity, energy structure, energy intensity, labor productivity, and industry scale effects	Lin and Zhang [12]
Petroleum refining and coking industry	1995–2000	Emission coefficient, energy structure, energy intensity, industrial activity, and industrial scale effects	Xie et al. [13]
Chemical industry	1981–2011	Carbon intensity, energy structure, energy intensity, output per worker, industry scale effects	Lin and Long [14]
Textile industry	2000–2011	Emission factor, energy structure, energy intensity, and production scale effects	Huang et al. [15]
Commercial and residential buildings sector	1995–2012	Scale, intensity, structure, and income effects	Lin and Liu [16]
Residential sector	1991–2004	CO_2 emission coefficients, energy structure, energy intensity, income, and population effects	Zha et al. [17]

although agricultural CO_2 emissions may result from other than energy consumption, the impact of energy consumption on CO_2 emissions is expanding.

Reducing CO_2 emissions in the agricultural sector is not only a technical problem but also a socioeconomic problem. Agricultural CO_2 emissions are ultimately produced by agricultural activities. Different emission levels may be caused by different agricultural lands and mechanization levels, and directly impact agricultural energy consumption and CO_2 emissions [27,28]. Current studies show that changes in CO_2 emissions from the global agricultural sector are closely related to agricultural production categories and the transformation of agricultural land use in recent years [26,29], and technological progress can be effective for reducing agricultural CO_2 emissions [30,31]. Except for the constraint of technical conditions, farmers are often more concerned about input costs and income when making agricultural production decisions [23,32]. Without considering other sources of income, the higher farmers' net income from production, the more inclined they are to engage in high-income agricultural activities [33]. If farmers engage in non-agricultural activities, they can undoubtedly earn a significantly higher income than from agricultural activities [34,35].

Farmers care not only about their own absolute income from agricultural activities, but also their relative income compared with other members of society, especially the income gap with urban residents [36,37]. Rising income inequality between urban and rural residents has not only induced a massive wave of farmers into urban areas [38], but has also had a profound impact on agricultural production activities [28]. On the one hand, the decrease in the number of agricultural producers will inevitably be supplemented by agricultural machinery, which will increase energy consumption and CO_2 emissions [28]. For instance, Van den Berg et al. [28] found that rapid urbanization not only creates opportunities for farmers' non-agricultural employment, but also leads to the integration of agricultural land. Those farmers who migrate to urban areas tend to lease their land to other farmers, thereby creating conditions conducive to the use of large agricultural machinery. On the other hand, farmers that have moved into urban areas also often remit money to their hometowns [38]. The income levels of rural families that receive remittances thus rise, making them better able to use energy such as electricity in agricultural production [39]. Manning and Taylor [40] found that the standard of living of rural families improves when they receive remittances from migrated family members. At the same time, they gradually reduce their wood burning in agricultural activities, instead using furnace gas and electricity. This change in fuel category directly influences the changes in CO_2 emissions from agriculture.

The government is also committed to improving farmers' income from agricultural activities, and economic development is the precondition for achieving this goal. Regardless of how many rural residents benefit from the national income and the degree to which the welfare level of the nation improves in the process of economic development, the continued expansion of economic "cake" must first be guaranteed. For most countries, saving energy and reducing CO_2 emissions in the agricultural sector, and improving farmers' incomes are the footholds of relevant policies [41]. Through the adjustment and optimization of policies, farmers will gradually shift their agricultural production categories (e.g., from farming to animal husbandry [42] or from traditional crop planting to genetically modified crop planting [43]). If we choose another point of view, the improved economic scale, increased income of residents, and expansion of the population are changing the demand for agricultural products (e.g., from original grain to meat, milk, and eggs) [25]. Compared to technical conditions, these subtle changes also affect agricultural energy consumption and CO_2 emissions.

Compared with existing research, the contribution of this study is threefold. First, there are few studies on the topic that reflect the agricultural sector in China, and this is a useful attempt. Although many scholars have attempted to identify the factors that change CO_2 emissions in China, most of them have concentrated on energy-intensive and high-emissions sectors, such as the industrial sector, rather than on the agricultural sector. Because of the relationship between agricultural CO_2 emissions and agricultural activities, and the relationship of the latter to people's daily lives and sustainable economic development, such as food security, it is useful to discuss energy savings and emissions reduction in the agricultural sector.

Second, this study introduces the rural–urban income Gini coefficient into the LMDI decomposition method, and nested decomposition into the extended LMDI decomposition method. The impact of rural-urban income inequality on agricultural CO_2 emissions is not found in existing literature. Because this study uses the LMDI decomposition method to evaluate the factors that cause changes in the energy-related CO_2 emissions of the agricultural sector in China, it is necessary to combine the rural–urban income Gini coefficient and the LMDI decomposition method. Ang [44] advocates that the LMDI decomposition method, which has good properties, should be developed in the future