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How ESCOs Moderate Impact of Industrialization and Urbanization on Carbon Emissions in China?

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Abstract

Energy service companies (ESCOs) have emerged to carry out energy efficiency retrofit projects, playing an important role in mitigating carbon dioxide (CO_2) emissions in China. However, it remains unclear how exactly ESCOs contribute to CO_2 mitigation in relation to urbanization and industrialization. We conducted regression analyses on data collected in 29 provinces in China as the first case study to investigate the moderating effect of ESCOs in relationships between urbanization, industrialization, and CO_2 emissions. The results indicate that urbanization had a significantly negative influence on CO_2 emissions. In contrast, industrialization displayed a statistically significant positive influence on CO_2 emissions. ESCOs have a significant moderating effect on the relationship between industrialization, urbanization, and CO_2 emissions. The analysis also revealed that ESCOs have a better performance in areas with lower industrialization and greater urbanization. ESCOs may invest more in regions with limited ESCO activities and huge CO_2 emission reduction demand, while energy saving technology innovation should be advocated in regions with sufficient ESCO activities.

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1. **Introduction**

Climate change is an increasing threat to society and human beings. Amongst several environmental pollutants causing climate change, carbon dioxide (CO_2) emission is the primary driver. CO_2 emissions from fossil fuel combustion and industrial processes contributed to about 78% of the total increase in GHG emissions from 1970 to 2010 (Pachauri et al., 2015). Countries around the world formulate policies and alliances such as the Kyoto Protocol, the Copenhagen Accord, and the Paris Agreement to reduce the impact of carbon dioxide emissions on the environment. China, as the world's largest CO_2 emitter, accounted for approximately a quarter of the world's total emissions in 2014. Emissions from China represented up to 68% of the total increase in global CO_2 emissions between 2000 and 2010 (Nandi, 2013). Considering the momentum of China's economic development and increasing energy demand, the International Energy Agency (2013) forecasted that China's share of global CO_2 emissions would further increase by approximately 33% by 2035. China's CO_2 emissions significantly influence global climate change (Hao et al., 2016).

China has been active in crafting and implementing various strategies to curb climate change and its negative impacts, including economic instruments, regulatory approaches, and technology innovations. In the emerging “industrial ecology” view, the use of technology helps offset these impacts generated by population growth. Theoretically, technology innovations can affect energy structures and improve energy efficiency, which will compensate for the impact of increasing populations (Chertow, 2000). Technology innovation is recognized as an important option to meet climate objectives (Zheng et al., 2018b). Some energy consumers have realized the importance of saving energy. However, they lack the technical expertise necessary to design and set up energy saving systems. To solve this dilemma and promote energy conservation measures, energy performance contracting (EPC) was introduced in China beginning in 1996. EPC is a new market-oriented, energy-saving service mechanism which allows the client to use future energy-saving profit to carry out energy efficiency retrofit projects, thus saving operating costs and energy use (Deng et al., 2017; Liu et al., 2018). The contractors are called energy service companies (ESCOs), which are usually experts in energy-saving technologies. The ESCO industry developed at a dramatic speed as consumers have become more aware of the need to protect the environment, reducing carbon emissions in China by 45% in 2015 (Zheng et al., 2018b).

Many factors are thought to contribute to CO_2 emissions, such as affluence growth, energy consumption, urbanization, and industrialization (Martínez-Zarzoso and Maruotti, 2011; Yin et al., 2015). Among these factors, industrialization and urbanization are the most commonly cited (Li and Lin, 2015; Nejat et al., 2015; Liddle and Lung, 2010; Madlener and Sunak, 2011; Satterthwaite, 2009). Previous studies have evaluated the relationship between industrialization and urbanization on CO_2 emission (Mi et al., 2015; Poumanyvong and Kaneko, 2010), demonstrating that urbanization and industrialization have a significant impact on carbon emission. In general, urbanization and industrialization lead to industrial transformations and changes in energy consumption structures, as well as boost economic activities that also increase CO_2 emissions (Al-Mulali and Ozturk, 2015; Xu and Lin, 2015). Nevertheless, urbanization and industrialization have also led to more effective use of urban infrastructure and industrial agglomeration, consequently mitigating CO_2 emissions (Newman and Kenworthy, 1989). Research findings are contradictory, with both positive and negative effects reported regarding the relationship between industrialization, urbanization, and CO_2 emissions, which is referred to as the IU-C relationship. However, the majority of studies only examined direct relationships between these elements, ignoring the fact that their relationships may be affected by several other factors.

Prior evidence has demonstrated that technological progress may have an effect on the IU-C relationship. Some researchers have in particular asserted that ESCOs advance technological progress in China (Yin et al., 2015; Zheng et al., 2018a). In the present study we conducted regression analyses on several variables from data collected on 29 provinces in China to investigate the moderating effect of ESCOs on the relationships between industrialization, urbanization, and CO_2 emissions. To conduct this investigation, we (i) analyzed the current IU-C relationship in China; (ii) selected the explained variable, explanatory variables, and control variables; and (iii) developed four regression models to explore the moderating effect of ESCOs.

2. Theory and hypotheses development

2.1. The relationship between industrialization and CO_2 emission

Industrialization refers to the period of social and economic change that transforms a human group from an agrarian society into an industrial society, involving the extensive re-organization of an economy for the purpose of manufacturing (Hewitt and Wield, 1992). Industrialization positively influences CO_2 emissions by: (i) contributing to general gross domestic product (GDP) growth, (ii) having a dramatic overall impact on energy demand, and (iii) using carbon-intensive production methods.

GDP has a positive impact on CO_2 emissions, given that economic growth has been identified as the main driver for sharp CO_2 emissions increases (Liu et al., 2016; Zhang et al., 2008). As capital accumulates, more resources are drawn out of agriculture and into manufacturing, increasing the domestic production of industrial goods. During the initial stage of industrialization, there is a shift from agriculture, mining, and light manufacturing to resource-related heavy manufacturing, with changes mainly in the scale and composition of production rather than in the pace of technological progress. Manufacturing always requires massive use of energy and alteration of natural systems from their pristine states. For example, industries like petroleum refining, primary metals, chemicals, and paper and allied products tend to be more energy intensive than agriculture or textile industries (Jones, 1991).

Since the industrial revolution, humans have tremendously increased the rate of alteration of the climate and the environment through changing agricultural and industrial practices and the pumping greenhouse gases into the atmosphere. Massive CO_2 emission has resulted from increasing land use for agricultural use and urban development to meet the growth in population. Scholars have also reported a positive relationship between industrialization and CO_2 emissions (Ahmad et al., 2019; Al-Mulali and Ozturk, 2015; Xu and Lin, 2015; Zhang and Lin, 2012). Cherniwchan (2012) analyzed sulfur emissions data for 157 countries over the period 1970 to 2000 and found that an 11.8% increase in the level of emissions per capita resulted from a 1% increase in the industry's share of total output. Asane-Otoo (2015) adopted a multi-region, input-output model and demonstrated that industrialization exerted significant positive effects on CO_2 emissions in middle-income countries in Africa such as Sudan and Zambia. Zhou et al. (2013) and Tian et al. (2014) found that industrialization significantly increased emissions at the national level in China. This body of evidence indicates that industrialization increases energy demand and related CO_2 emissions. Therefore, the following hypothesis was proposed:

H1a: Industrialization increases CO_2 emissions.

In contrast to the notion that industrialization increases CO_2 emissions, some researchers have found an opposite outcome, in which industrialization could mitigate climate change and facilitate adaptation through providing the means to accelerate the transfer of employment from agriculture to industry (Xu and Lin, 2015; Zhou et al., 2013). Industrialization itself could potentially reduce pressure on deforestation and clearing of land for agriculture, which are two important sources of CO_2 emissions (Szirmai et al., 2013). Existing energy research suggests that industrialization can reduce CO_2 emissions by enhancing technological progress, retiring inefficient technologies, and changing the structure of energy systems and patterns of energy services (Nakicenovic et al., 2006). As industrialization proceeds, development slows down. More effort is devoted to technological progress, improving energy efficiency in the industry. Some resource-related heavy manufacturing is shut down and the share of the service industry increases. With these considerations in mind, which run contrary to hypothesis H1a, we formulate the following hypothesis:

H1b: Industrialization decreases CO_2 emissions.

2.2. The relationship between urbanization and CO_2 emission

Urbanization is the process of economic and social modernization, transferring rural labor to urban areas with the industrial sector predominating (Poumanyvong and Kaneko, 2010; Turok and McGranahan, 2013; Williams et al., 2019). Urbanization affects CO_2 emissions through three primary channels: directly influencing the preferences of households for energy or other goods consumed; influencing income, which indirectly affects the level or composition of consumption; and influencing energy supply infrastructure, in particular, electricity access, which also indirectly affects consumption. These consumption effects, in turn, influence CO_2 emissions. The world's energy demand is mainly characterized by urban demand (Madlener and Sunak, 2011)

During the process of urbanization, more citizens move from rural areas to urban areas to obtain higher incomes and better social resources . As income increases, the affordability of various energy services increases, which leads to high penetration of end-use technologies to meet the elevated energy service demands in urban areas. Urbanization permits economies of scale in production but requires more transportation. Resources have to be transported to urbanized populations and agricultural populations are modernized, entailing considerable increases in agricultural energy-use. A number of production activities executed in rural areas using human or animal energy are instead fueled by modern energy sources when performed in cities. The largest single source of change in energy consumption is personal transportation. Passenger transport in cities is heavily weighted towards fuel-using modes, particularly as incomes increase. These changes increase the energy demand that increases the amount of CO_2 emissions (Jones, 1991; Parikh and Shukla, 1995; Romero Lankao, 2007).

Scholars have investigated the dynamic relationship between urbanization and CO_2 emissions and have found a positive relationship. Parikh and Shukla (1995) provided an analysis of the effect of urbanization on CO_2 emissions in 83 developing countries. Their results showed that an increase in a country's urban population leads to a rise in its per capita CO_2 emissions. A similar pattern was observed by Sharif Hossain (2011) from panel data of 9 newly industrialized countries over the period from 1971 to 2007, and also found to be the case for China (Lin et al., 2009; Zhu and Peng, 2012). In particular, Zhang and Lin (2012) found that the impact of urbanization on CO_2 emissions in the central region of China was greater than that in the eastern region. Therefore, the following hypothesis is proposed:

Hypothesis 2a. Urbanization causes an increase in CO_2 emission.

Urbanization boosts technological innovation, an urban agglomeration, and a shift toward knowledge and service-based industries, each of which can reduce environmental impacts. The compact city theory states that urbanization can alleviate the damage to the environment in part by reducing the demand for traveling and hence transport emissions. Higher urban density facilitates economies of scale for public infrastructure (e.g. public transportation, water supply, electricity production, schools, hospitals) and these economies of scale cause less damage to the environment compares to low urban intensity society. (Sadorsky, 2014; Capello and Camagni, 2000; Newman and Kenworthy, 1989). For instance, high-density cities, such as Hong Kong, show far lower transport energy consumption than low-density cities, such as Houston (Madlener and Sunak, 2011). Urbanization entails the construction of buildings and various kinds of infrastructure. Construction activities are one of the major contributors to CO_2 emissions nationally. The energy costs of on-site housing are too high, higher density apartments would lead to great energy saving compared with houses and low-density apartments when meeting the same house demand.. Household energy expenditure surveys also reveal that conventional household energy expenses are greater than that in high- or low-rise flats (Jenks et al., 1996). During urbanization, people's awareness about the need to protect the environment increases. Advanced technologies and environmental management systems are used to reduce CO_2 emissions. Similarly, a negative and statistically significant relationship between urbanization and carbon emissions has been found by Fan et al. (2006). Given this background, the following hypothesis is proposed:

H2b: Urbanization leads to a decrease in CO_2 emissions.

2.3. Impact of ESCOs on CO_2 emissions

An ESCO offers energy-efficient technologies, including development and design emission reduction solutions that focus on improving energy efficiency through installing and maintaining energy efficient equipment, with project energy savings monitored and verified to guarantee savings for clients in public, industrial, commercial, or residential sectors (Deng et al., 2017; Marino et al., 2011; Vine et al., 1999). ESCOs advocate energy saving measures such as re-circulating cooling water systems, interval technologies, photovoltaics, and light emitting diode lights (Zheng et al., 2018b). Fang and Miller (2013) demonstrated that ESCOs have contributed more to the reduction of CO_2 emissions than the Kyoto protocol. ESCO remuneration relies directly on the amount of energy saved through EPC, and this motivates ESCOs to continuously improve energy efficiency to gain more profit in all areas. Based on these considerations, the following hypothesis is proposed:

H3: ESCO industry development has a negative relationship to CO_2 emissions.

2.4. The moderating role of ESCOs on the IU-C relationship

There exist differences in the impact of industrialization and urbanization on CO_2 emissions (Li and Lin, 2015). Scholars have argued that technological progress has probably improved environmental quality and acts as an underlying term impacting the IU-C relationship (Yin et al., 2015). The technological progress has been found to have a significant moderating effect on the CO_2 Kuznets curve, which shows an inverted U-shaped relationship between development and CO_2 emissions (Yin et al., 2015). ESCOs can promote technological progress, improve energy efficiency, and reduce CO_2 emissions (Fang and Miller, 2013; Fang et al., 2012). Thus, ESCO could have a moderating effect on CO_2 Kuznets curve.

Since advanced technologies can exhibit different levels of performance in different areas in China (Zheng et al., 2018b), the impacts of ESCOs can also vary. In regions that have advanced technologies, there is a lower potential to improve energy efficiency and reduce CO_2 emissions. The impact of urbanization appears to be positive in low-income regions while it seems to be negative in high-income regions (Martínez-Zarzoso and Maruotti, 2011). Poumanyvong and Kaneko (2012) found a positive relationship between urbanization and CO_2 emissions, and assert that the relationship was more pronounced in the middle-income regions. Their results also reveal that countries with larger urban populations had significant bi-directional long-term relationships between urbanization and CO_2 emissions compared to countries with smaller urban populations. Dynamic relationships have also been observed in China. Zhang and Lin (2012) found that the impact of urbanization on CO_2 emissions in the central region was greater than that in the eastern region in China. Liao and Cao (2013) found that regions with a higher level of industrialization/urbanization and denser population tend to emit more CO_2. Fan et al. (2006) also found that different human behavioral patterns could greatly influence CO_2 emissions. In other words, the impact of urbanization and industrialization on CO_2 emissions varies across regions. Zheng et al. (2018a) demonstrated that ESCOs perform better in undeveloped regions than in developed regions of China. Specifically, ESCO performance was found to be the highest in the eastern part of China, followed by the western then central parts. With these considerations in mind, the following hypotheses are proposed:

H4: The relationship between industrialization and CO_2 emission is stronger when the ESCO industry further develops.

H5: The relationship between urbanization and CO_2 emission is weaker when the ESCO industry further develops.

An overview of all the hypotheses is presented in Figure 1.

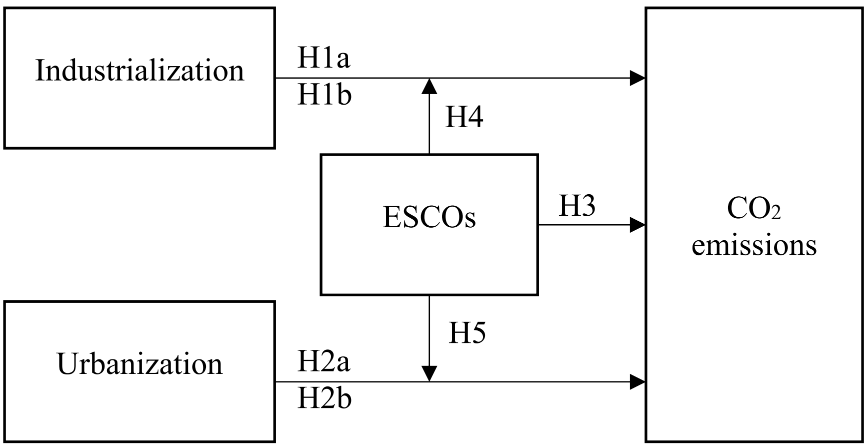


Figure 1: Conceptual model of all hypotheses

3. Methodology and data source

3.1. Variables Determination

Explained variable: CO_2 emissions. In previous research, sectoral and reference approaches have often been adopted to estimate the amount of CO_2 emissions (İpek Tunç et al., 2007; Shan et al., 2018, 2017). In the present study, the mean values of the sectoral and reference approaches were adopted in the estimation of CO_2 emission at the provincial level as collected from the China Emission Accounts and Datasets and from Shan et al. (2018).

Explanatory Variables: Industrialization (IND). The industrialization has a great influence on CO_2 emissions (Wen and Shao, 2019). Compared to agricultural and tertiary industries, energy consumption and CO_2 emissions in the industrial sector are much higher, especially in heavy industry. Industrialization is represented as the ratio of industrial added value to provincial GDP.

Explanatory Variables: Urbanization (URB). When rural residents move into towns, their production and lifestyles are gradually affected by urban life, which then increases energy consumption and CO_2 emissions. However, their awareness of the need to protect the environment can also be heightened by interactions with other urban residents. As a result, the urbanization rate is an important influencing factor for CO_2 emissions (Parikh and Shukla, 1995; Xu and Lin, 2015). The urbanization rate is represented as the urban population divided by the total population of the province.

Moderating variable: ESCOs. Previous theories and studies have found that the IU-C relationship could be affected by technological progress and other factors (Yin et al., 2015). In this study, we focus on the moderating effect of ESCOs on the IU-C relationship. Regions, where ESCOs can reduce more carbon emissions, are usually considered as regions with developed ESCO industry. In this research, the variable is represented as the carbon emission reduction contributed by ESCOs via energy efficiency retrofit projects as described in Zheng et al. (2018a) which will be demonstrated in section 3.2.

To choose the proper control variables, we refer to the IPAT model (I = PAT) which was proposed for investigating the role of various factors in driving CO_2 emissions (Wen and Li, 2019; York et al., 2003). In the IPAT model, I represents impact measured as the emission level, P denotes population size, A represents a society's affluence and T is a technology index. In this research, society's affluence is measured by per capita GDP while the technology level is indicated by the amount of investment in the research and development.

Per capita GDP (PCG) represents the level of economic development. Economic development increases the energy demand and consumption. Anthropogenic causes of climate change are intimately related to economic behavior, and economic growth has been identified as the main driver for sharp CO_2 emission increases (Yang et al., 2020; Zheng et al., 2020). The PCG was calculated as the value of gross domestic production in a region divided by the permanent population at the year-end.

Population size is considered to have a large impact on CO_2 emission. Firstly, human beings can produce CO_2 emissions as direct emitters. Secondly, an increase in population leads to increases in energy demand and consumption (Zhu and Peng, 2012). These energy consumption changes thus cause changes in CO_2 emissions. In the present study, population is measured as the permanent population at the year-end.

Gross domestic spending on R&D is defined as the total expenditure (current and capital) on RD carried out by all resident companies, research institutes, universities, and government laboratories, etc. It includes R&D funded from abroad but excludes domestic funds for R&D performed outside the domestic economy. This index can reflect the technology level of a province. Table 1 provides a detailed description of the variables used in this study.

Table 1: Definition of all relevant variables used in the study.

Variables	Definition	Unit of measurement
Explained variable		
CO_2	Per capita CO_2 emissions	Ton
Explanatory variable		
IND	Industrialization level	Percent
URB	Urbanization level	Percent
Control variable		
PCG	Per capita GDP	Yuan
P	Population	
R&D	Research and development investment	Yuan
Moderating variable		
ESCO	ESCO capability in reducing CO_2 emissions	Ton

3.2. Samples and Data Source

The samples consist of cross-province observations for 29 provinces in Mainland China (excluding Tibet, and Hainan). Data used in this paper were obtained from the China Statistical Yearbook (2011-2015), the China Energy Statistical Yearbooks (2011-2015), Provincial Statistical Yearbooks (2011-2015) and reports from the China Energy Management Companies Association (known as EMCA). An example from projects in EMCA reports is shown in Table 2.

Table 2: Example information of ESCO projects

Year	Name of ESCO	Region	Name of the project	Energy saving (tons of standard coal)
2011	Liaoning Nengfaweiye Energy Technology Co., Ltd.	Liaoning	Renovation of the circulating water system	7100
2011	Cornell (Shanghai) Energy Technology Co., Ltd.	Shanghai	People’s Hospital/Central Air Conditioning System Energy Saving Reform	1000
2012	Cornell (Shanghai) Energy Technology Co., Ltd.	Shanghai	LED lamp energy-saving renovation projects in Shanghai Jiadeli Supermarket	0.75

The measurement of variable ESCO which represents for carbon reduction contributed by ESCOs in province j in the year i can be calculated as the Equation 3-1:

$$ESCO_{i,j} = 2.46\left(\text{kg}\frac{CO_2}{kg}\,standard\ coal\right) \times Energy\ saving_{i,j} \qquad \text{(Equation 3-1)}$$

Where 2.46 represents the CO_2 emissions coefficient of standard coal (Yu et al., 2014).

The energy saving contributed by ESCOs in province j in the year i can be calculated as the Equation 3-2:

$$Energy\ saving_{i,j} = \sum_{k=1} Energy\ saving_{i,j,k} \qquad \text{(Equation 3-2)}$$

Where k represents the kth ESCO project in province j in the year i. Following research done by Zheng et al. (2018a), the ratio that represents the carbon reduction share of all the ESCO projects per year per province from the total carbon reduction in China can be calculated. Thus, we can get the amount of carbon reduction in each province.

4. Results and discussion

4.1. Descriptive statistics and correlation of variables

The descriptive statistics and correlations of all variables are tabulated in Table 3 and Table 4. Most correlation coefficients were considered low to moderate, whereas the correlation coefficients between URB and PCG exceeded 0.9. To test for collinearity, a variance inflation factor (VIF) test was utilized. The results shown in Table 5 indicate no collinearity, with the VIF value below 10 (Fan et al., 2006; O'brien, 2007). Thus, we can conduct a regression for further analysis.

Table 3: Descriptive statistics for the variables.

	N	Minimum	Maximum	Mean	Std. Deviation
IND	145	0.20	0.59	0.48	0.07

PCG	145	1.64	10.69	4.77	2.14
P	145	568.00	10849.00	4632.02	2654.97
URB	145	0.35	0.90	0.56	0.13
R&D	145	0.00	1801.20	328.63	425.87
ESCO	145	675.96	2288427.58	279966.47	327977.61
CO_2	145	43.40	1014.75	353.83	226.25
Valid N (listwise)	145				

Table 4: Correlation matrix.

	IS	**PCG**	**P**	**UR**	**R&D**	**ESCO**	**CO_2**
IND	1						
PCG	-.340**	1					
	.000						
P	.187*	-.105	1				
	.024	.210					
URB	-.397**	.934**	-.170*	1			
	.000	.000	.041				
R&D	-.287**	.579**	.448**	.493**	1		
	.000	.000	.000	.000			
ESCO	-.056	-.024	.214**	-.034	.117	1	
	.502*	.777	.010*	.689	.159**		
	.046	.087	.027	.061	.005	.000	
CO_2	.290**	.037	.565**	-.073	.267**	.488**	1
	.000	.658	.000	.382	.001	.000	

** p<0.01
* p<0.05

Table 5: Collinearity statistics for variables

	Tolerance	VIF
IND	.739	1.353
PCG	.104	9.602
P	.527	1.897
URB	.116	8.649
R&D	.366	2.735
ESCO	.943	1.060

4.2. Model estimation

We verified the hypotheses by estimating several multiple regression models. CO_2 emissions were found to be related to population, per capita GDP, and research and development investment. Model 1 was estimated with only the control variables:

$$\mathrm{C} = \alpha + \beta_1 \mathrm{PCG} + \beta_2 P + \beta_3 RD \qquad \text{(model 1)}$$

Model 2 combines the explanatory variables.

$$\mathrm{C} = \alpha + \beta_1 \mathrm{PCG} + \beta_2 P + \beta_3 RD + \gamma_1 URB + \gamma_2 IND \qquad \text{(model 2)}$$

Model 3 was used to incorporate the moderating variable.

$$\mathrm{C} = \alpha + \beta_1 \mathrm{PCG} + \beta_2 P + \beta_3 RD + \gamma_1 URB + \gamma_2 IND + \delta ESCO \qquad \text{(model 3)}$$

This study explores whether ESCOs might have a moderating role in the IU-C relationship. Model 4 examines the moderating effect of ESCOs. We made predictors mean-centered before the calculation of interaction terms and the regression analysis to avoid the collinearity between the interaction term and the explanatory variables (Dawson, 2014).

$$\mathrm{C} = \alpha + \beta_1 \mathrm{PCG} + \beta_2 P + \beta_3 RD + \gamma_1 URB + \gamma_2 IND + \delta ESCO$$

$$+\mu_1 IND \times ESCO + \mu_2 URB \times ESCO \qquad \text{(model 4)}$$

4.3. Moderating effects of ESCOs

The results obtained in these four regression models are presented in Table 7. Our results record R^2 values that range from 0.577 to 0.768, producing a significant increase, which reflects a better explanatory power of the variables incorporated

Model 1 shows that some of the control variables explain significant portions of CO_2 emissions. Greater population size and higher per capita GDP both have a positive effect on CO_2 emissions, which is in line with the findings of Fan (2006) and Sharif Hossain (2011).

This indicates that more people and economic development results in greater energy consumption, and thus more CO_2 emissions. Population growth also impacts natural resources and the ecosystem, which in turn affects productivity and resource endowment (Zhu and Peng, 2012).

In the second model, it is revealed that industrialization and urbanization had a significant effect on CO_2 emissions across provinces. Echoing previous research (Zhou et al., 2013), our analysis reveals a positive relationship between industrialization and CO_2 emissions while urbanization shows a negative relationship with CO_2 emissions, thus confirming hypotheses H1a and H2b. As part of China’s rapid development, the country’s industry structure is now shifting. The industry share of GDP is decreasing while the service industry share is increasing, especially in such developed regions as Beijing, Jiangsu, Shanghai, and Guangdong. The industry sector is the leading producer of CO_2 emissions (Tian et al., 2014; Zhou et al., 2013). This shift in industrial structure corresponds to a slowing industrialization rate, with a concomitant reduction in CO_2 emissions. While urbanization plays a leading role in CO_2 emissions in China (Zhang and Lin, 2012) it also improves the efficient use of public infrastructure, which can scale back CO_2 emissions. China has stepped into the medium-and-later stage of urbanization, paying increasingly more attention to the environment (Yuan et al., 2014). To promote more sustainable development in China, stricter standards and regulations have been launched, such as the Environmental Protection Tax Law and the Cleaner Production Scheme. which has to lead to a negative relationship between urbanization and CO_2 emissions.

It was revealed by the third model that ESCOs have a significantly positive relationship to CO_2 emissions, which supports hypothesis H3. Although ESCOs play an important role in reducing CO_2 emissions, as demonstrated by Zheng (2018b, 2018a), they still cannot compensate for the increase of CO_2 emissions nationwide. While China is pursuing strategies to reduce the impact of CO_2 emissions, including adopting renewable energy and cleaner production plans, CO_2 emissions are still rising as a result of rapid economic growth and improved living standards.

When we consider the fourth model, the incorporation of the interaction between ESCOs with industrialization and urbanization significantly affects CO_2 emissions. Industrialization and urbanization both have significantly positive coefficients of 0.213 for ESCO*IND and 0.02 for ESCO*URB, indicating that the negative effect of urbanization on CO_2 emission and the positive effect of industrialization on CO_2 emissions are reinforced by higher ESCO levels. Thus, hypotheses H4 and H5 are supported.

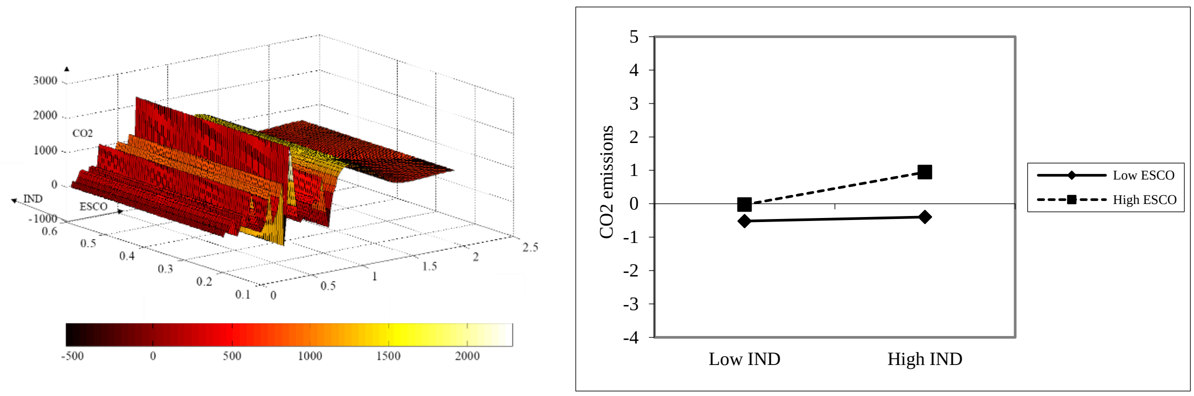
Table 6: Moderating effect of ESCOs on IU-C relationship

Variable	1	2	3	4
Control				
PCG	0.170*	0.584***	0.590***	0.588***
P	0.634***	0.532***	0.439***	0.400***
R&D	-0.115	-0.040	-0.043	-0.042
Explanatory variable				
IND		0.208***	0.255***	0.274***
URB		-0.426**	-0.413**	-0.369**
Moderating variable				
ESCO			0.413***	0.458***
Moderation				
ESCO×IND				0.213***
ESCO×URB				0.202**
F	23.517***	18.755***	29.763***	24.42***
R^2	0.577	0.635	0.751	0.768

*** p<0.01
** p<0.05
* p<0.1

Figure 1 depicts how ESCOs interact with industrialization and urbanization when explaining CO_2 emissions and how ESCO moderates the IU-C relationship. Figure 1(a) suggests that industrialization has a more positive effect on CO_2 emissions when ESCO development level is high. The rate of industrialization in various regions of China is slowing down and turns to decrease these years since the manufacturing sector is changing to the service sector. From the right graph in Figure 1(a), it is revealed that in regions where ESCOs contribute more to CO_2 reduction, industrialization will decrease more CO_2 emissions}Surprisingly, in regions with the same industrialization, we found that regions with higher ESCO development produce more CO_2 emissions. This may be due to the fact that ESCO projects are also regarded as economic activities that themselves consume energy and produce CO_2 emissions. Also, ESCOs generally only start operating in a region where there’s demand for energy retrofit when the energy problem becomes sever. The regions with more ESCO projects tend to be regions with more CO_2 emissions to be reduced. Although ESCOs can reduce CO_2 emissions at the project level, when the economy is considered as a whole, ESCOs do not necessarily lead to a reduction of CO_2 in the region (Zhou et al., 2013). Even though the overall CO2 in the area may still be very high, it would have been even higher in the absence of ESCOs’ efforts

(a)



(b)

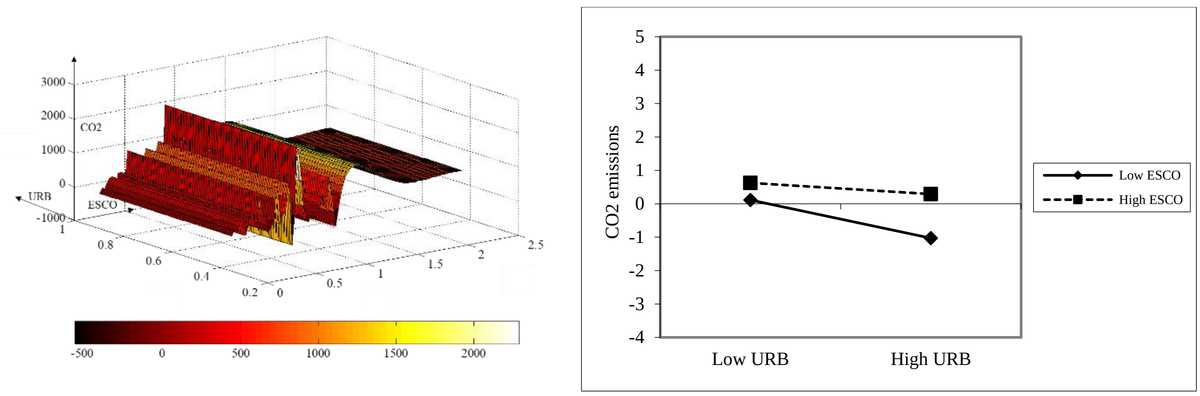


Figure 2: Interaction graph for the relationship of ESCOs to (a) industrialization, (b) urbanization.

Figure 1(b) shows when the ESCO development level was low, the urbanization rate had a more negative effect on CO_2 emissions. In other words, ESCOs reinforced the negative relationship between urbanization and CO_2 emissions. Urbanization is often thought to increase energy demand and CO_2 emissions, a perception that diverges from the findings shown in Figure 1(b). This difference may be because regions with lower urbanization rates are usually undeveloped regions with less environmental protection awareness (Zheng et al., 2018a). When the ESCOs developed more, the negative slope between urbanization rate and CO_2 emissions became flat and the margin of ESCOs' ability to reduce CO_2 emissions diminished over time compared to the initial stage (Zheng et al., 2018b). This trend may be due to ESCO projects investing in energy efficiency retrofit projects during a certain year and the ESCOs gaining profit during the subsequent contract period. The profit mainly depends on the energy savings that they can deliver after completing the projects. For an ESCO project, in the contract period, the total investment of ESCOs was included when calculating the provincial total CO_2 emissions since the ESCO activities are a part of economic activities. However, the measurement of variable 'ESCO' which is the amount of CO_2 emission reduction to which the ESCOs contributed only represents the first year of the overall CO_2 emissions reduction experienced in a given region. Thus, ESCOs show a positive relationship with the CO_2 emissions and dampen the negative relationship between urbanization and CO_2 emissions.

5. Conclusion and policy implications

By applying regression analyses on data collected from the EMCA, this paper empirically investigated the impact of ESCOs on the IU-C relationship. Our study reveals a dual role that ESCOs play in the IU-C relationship. ESCOs behave as a direct determinant of CO_2 emissions yet also act as a moderating variable. The results showed that ESCOs enhance the positive relationship between industrialization and CO_2 emissions while reinforcing the negative effect between urbanization and CO_2 emissions.

These results not only contribute to advancing the existing literature but also deserve attention from ESCOs and policy-makers in China. As further confirmed in this study, industrialization generally increases CO_2 emissions. Thus it would be beneficial to shift from low-value, highly-polluting secondary industry and instead develop the service sector. Notably we found that urbanization shows a negative effect on CO_2 emissions, as people move from rural areas to urban areas where infrastructure can be used more efficiently. It is imperative to develop urban areas with energy efficient infrastructure. In addition, awareness of low-carbon development should be advocated among urban residents during the process of urbanization.

Understanding how different levels of economic development and their corresponding urbanization and industrialization impact on CO_2 emissions can help policy-makers formulate the most appropriate emission-reducing policies based on a given region's characteristics. Regions with a high rate of urbanization and low rate of industrialization generally have more advanced infrastructure systems and awareness of the need to reduce CO_2 emissions. However, a higher rate of urbanization could increase the energy demand and increase the CO_2 emissions.

It is therefore critical to develop energy-saving and low-carbon infrastructure systems and develop technologies for sustainable development. In regions where the urbanization rate is relatively low, it is crucial to speed up urbanization and improve social awareness about the importance of protecting the environment.

As for ESCOs, they need to make decisions according to the conditions of the provinces in which they operate. ESCOs will have better performance in those areas with low industrialization and high urbanization levels. ESCOs should put more investment into qualifying areas such as Shanxi, Hebei, and Inner Mongolia. In contrast, the potential for CO_2 reduction is relatively lower in more developed areas, where ESCOs should invent in developing more advanced technologies rather than just expand the scale of their projects. According to the results, since ESCOs have a moderation effect on the IU-C relationship, ESCOs should be encouraged to reduce more CO_2 emissions during the industrialization and urbanization process. On the other hand, ESCOs are not as capable of reducing CO_2 emissions in relation to urbanization. Many scholars are already studying China's growing investments and policy support in low-carbon technologies as a way to reduce both energy costs and pollution. As for the ESCO industry, the government should make policies to relief the uneven development. For those regions with few ESCO activities and huge CO_2 emission reduction demand, it is advisable to introduce more ESCO projects. While for those regions with enough ESCO activities, expanding the ESCO industry scale is not suggested. Instead, policies should be made on boosting the energy saving technology innovation to reduce more CO_2 emissions.

There are some limitations to the present study. Lifecycle assessment was not employed in this study, though it could be applied to better distinguish the ESCO investment period and CO_2 reduction period. Other variables representing ESCO development could also be considered, such as a number of ESCO employees, ESCO investment, and ESCO profit.

Resolving such issues, however, requires more comprehensive ESCO project data which is a major obstacle in conducting ESCO research due to the inadequate data resource.

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