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ORIGINAL RESEARCH ARTICLE

Energy consumption structure model considering urban green and low-carbon transportation

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ABSTRACT

The importance of energy conservation and emission reduction has become the consensus of the international community, and Iraq is also actively improving the urban public transportation system to control carbon emissions. This paper collects panel data of Tikrit city in Iraq in the past 3 years, constructs a random effect variable coefficient model, and studies the impact of the development of urban low-carbon transportation system on the energy consumption structure. The study finds that the government can use public transportation pricing strategies to influence consumers. In order to realize the optimization of energy consumption structure, the impact of electric vehicles on energy consumption structure will decrease with the increase of urban development. The transportation sector can increase the purchase and travel costs of traditional cars by restricting travel, purchases, and charging parking fees, which affects the number of private cars and reduces the obstacles to optimizing the energy consumption structure. The government should increase financial subsidies, improve rail transit and reasonable bus (electric) vehicle operation systems, increase investment in new energy vehicle research and development, and encourage high energy density and low power consumption technologies. development, increase residents' demand for new energy passenger vehicles, and optimize the energy consumption structure.

Keywords: low-carbon transportation system; energy consumption structure; public transportation; new energy vehicles

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1. Introduction

Energy and environmental issues play a pivotal role in the modernization process of all countries in the world. Optimizing the energy structure is the only way for the country to achieve sustainable development. However, urban transportation energy demand is still dominated by fossil energy, supplemented by clean energy, and residents' travel mode has been continuously developed in the direction of green transportation. Therefore, it is necessary to improve public transportation infrastructure, promote the development of new energy vehicle industry, and improve a variety of shared travel. It has increased the demand for clean energy from multiple perspectives, and it is particularly important to optimize the energy demand structure. The optimization research on the energy demand of various vehicles in green and low-carbon transportation and the impact assessment on the energy structure are imminent[1].

Many researchers believe that the current urban carbon emission pressure is relatively high, and the existing urban transportation system is inefficient and needs to be further optimized[2]. There is still room for improvement. Fisch-Romito and Guivarch[3] believed that population and income growth, urbanization, private car travel preference, and per capita travel distance increase all lead to the pressure of urban carbon emissions. Zhang and Xu[4] believed that although public transportation is the most efficient way of traveling for residents with the lowest carbon emissions, the development process of public transportation in Iraq does not match the social and economic development. Gorji et al.[5] believed that residents' travel mode, road congestion, urban structure, and road density will affect the development of low-carbon transportation. Brough et al.[6] believed that the increase in car ownership, urban expansion and low public transportation coverage, and low low-carbon technology support are the main factors that affect residents' travel demand on carbon emissions. In the establishment of urban green and low-carbon transportation system, residents' travel choices are particularly critical. The preference for switching from driving a private car to a shared mode of travel is the conclusion of an ideal steady state. Baig et al.[7] studied the influencing factors of private car travel carbon emissions, and believed that although the establishment of a public transportation system could replace some private car travel demands, it could not reduce private car carbon emissions. Buehler[8] believed that the higher the utility of choosing to drive a private car, the lower the probability of residents choosing car-sharing travel, and the greater the government's control over private cars, the higher the utility of car-sharing travel. Tabti-Talamali and Baouni[9] believed that the development of renewable energy power generation will promote the growth of demand for new energy vehicles in the private and commercial fields, and is expected to reduce urban carbon emissions. Psaltoglou and Calle[10] believed that the government's establishment of transfer parking lots at large urban transportation hubs can influence the travel preferences of private car owners through infrastructure guarantees, and can promote their choice of green travel methods. Bartłomiejczyk and Kołacz[11] believed that residents' environmental awareness will affect travel preferences, and the higher the residents' environmental awareness, the lower the probability of choosing a private car to travel. Motienko[12] believed that the compact urban space planning with close work and housing is conducive to residents' low-carbon travel choices. Errampalli et al.[13] constructed an energy demand forecast model to predict Iraq's energy demand, energy structure, and carbon emissions, and believed that optimizing the energy structure could effectively control carbon emissions.

The paper focus on green and low-carbon transportation system and energy structure is relatively very limited, but they mainly focus on the impact of a single type of travel mode such as new energy vehicles on carbon emissions and energy structure. This paper considers the overall transportation system on the energy structure. In addition, the impact of optimization attempts to discuss the impact of different transportations on the energy structure, and to provide relevant suggestions for the optimization of the energy structure.

2. Proposed model

There is a certain substitution between taking public transportation and driving a private car. Reducing the travel cost of residents' public transportation will increase residents' demand for low-carbon travel modes, which will replace the demand for private car travel, thereby changing the energy consumption structure. At the same time, the public transportation pricing system is mainly determined by the government, and this pricing system has an important impact on residents' travel. The government can guide residents' travel behavior by adjusting the pricing system.

Residents with travel needs can be divided into two types: those with private cars and those without private cars. Residents without private cars cannot choose to travel by private cars, but can only choose the low-carbon travel mode of public transportation, so this section will not discuss them. From the perspective of energy demand, residents' demand for public transportation will lead to the demand for low-carbon emission energy, that is, the demand for new energy and high-utilization fossil energy, and the demand for driving private cars will lead to high-carbon emission energy demand, new energy vehicles still account for a small proportion of private passenger vehicles.

It is assumed that residents with private cars mainly consider economic cost when choosing travel mode, and travel time cost and comfort have little influence on residents' choice. Assume that the utility function of residents is as follows:

$$U(S, D) = AS^{\alpha}D^{\beta} \tag{1}$$

where, *U* is the travel demand of residents, *S* is the low-carbon energy demand brought by public transportation, *D* is the fossil energy demand caused by driving a private car, and $0 < \alpha, \beta < 1$. The budget line:

$$I = xS + yD \tag{2}$$

where, *I* is the travel budget of residents, *x* is the unit price of traveling by public transport, and *y* is the unit price of driving a private car.

According to consumer equilibrium, the choice of residents when utility is maximized:

$$\frac{D}{S_0} = \frac{\beta x}{\alpha y} \tag{3}$$

At this time, the government subsidizes or lowers the price of bus travel, and reduces the price per unit of bus travel by x_0, which triggers substitution effects and income effects.

At this time, the unit price of taking the bus and the budget line becomes:

$$I_1 = (x - x_0)S + yD \tag{4}$$

After the budget line changes, the residents' optimal choice is:

$$\frac{D}{S_1} = \frac{\beta(x - x_0)}{\alpha y} \tag{5}$$

Changes in demand structure:

$$\frac{D}{S_0} - \frac{D}{S_1} = \frac{\beta x_0}{\alpha y} \qquad \frac{\beta x_0}{\alpha y} > 0 \tag{6}$$

The demand structure of residents for low-carbon energy and fossil energy has changed before and after the government subsidizes bus travel. Due to government subsidies, the ratio of fossil energy demand to low-carbon energy demand has decreased, indicating that the demand for low-carbon energy has increased relatively, and the energy structure be optimized. With the improvement of urban infrastructure, the coverage rate of public transportation network has gradually increased traveling by public transportation brings residents higher comfort and saves time and cost. The marginal rate of substitution increases, making the government's price adjustment more efficient.

The proportion of low-carbon energy consumed in urban life in total energy consumption has increased. At present, the impact of the development of low-carbon transportation systems in most cities on energy consumption is mainly reflected in the replacement of gasoline and diesel consumption by electricity consumption. The proportion of electricity in total energy consumption is used as an explained variable to measure the energy consumption structure calculation method is as follows:

$$Y_{it} = \frac{E_{it} * Q}{GDP_{it} * EC_{it}} \tag{7}$$

where, *E* represents the urban electricity consumption (100 million kilowatt-hours), *Q* represents the electricity conversion factor of standard coal (tons of standard coal/kWh), *GDP* represents at the current price (100 million USD), and *EC* represents the total production per 100 USD. Value energy consumption (ton standard coal).

The panel data model type is selected by the *F* test as:

$$F_1 = \frac{(S_2 - S_1)/[(N-1)k]}{S_1/[NT - N(k+1)]} \tag{8}$$

$$F_2 = \frac{(S_3 - S_1)/[(N-1)(k+1)]}{S_1/[NT - N(k+1)]} \tag{9}$$

3. Result and discussion

The influence model of energy consumption structure from the panel data from Tikrit city in Iraq. According to the Hausman test, a random effect model should be selected for estimation. The specific form of the model is as follows:

$$Y = a_1\text{BUS} + a_2\text{CAR} + a_2\text{ECAR} + a_3\text{T} + a_4\text{S} + C \quad (10)$$

where, BUS is public bus; CAR is fuel car; ECAR is electrical car; T is taxi; S is for sharing car.

Table 1 shows that the data series of each variable are stable. On this basis, this paper uses the Kao test to test the cointegration of the six variables in the model. The test results are as follows.

Table 1. Model unit root test results.

Parameter	Test type	*t*-Value	*p*-Value
Y	(1, N, *)	−2.9120	0.0018
BUS	(1, N, *)	−2.5162	0.0059
CAR	(1, N, *)	−3.1763	0.0000
ECAR	(1, N, *)	−7.1793	0.0000
T	(1, N, *)	−15.5888	0.0000
S	(1, N, *)	−2.4869	0.0064

The cointegration test results that the null hypothesis is rejected at the 1% significance level, proving that there is a cointegration relationship among the seven variables. The model form is determined by the F test, and the residual sum of squares of the variable coefficient model is $S_1 = 0.1830$, the residual sum of squares of the variable intercept model is $S_2 = 0.8031$, and the residual sum of squares of the constant coefficient model is $S_3 = 2.6292$. Substitute into Equations (8) and (9) with the number of sections $N = 6$, the time span T = 11, and the number of explanatory variables $k = 6$, to obtain $F_1 = 2.7108$ and $F_2 = 9.1660$. At the 5% significance level, the critical values of F statistics are $F_1 \sim F_{0.05}(30, 24) = 1.94$, $F_2 \sim F_{0.05}(35, 24) = 1.91$, obviously F_1, $F_{0.05}(35, 24) = 1.91$. F_2 is greater than the critical value, so model B should use a variable coefficient model.

Table 2 shows the test results that model rejects the null hypothesis at the 1% significance level, indicating that there is a co-integration relationship between urban low-carbon transportation development and energy consumption structure.

Table 2. Model cointegration test results.

	Hypothesis	Statistics	Accompanying probabilities
ADF	No cointegration relationship	−2.5727	0.0050
ADF	No cointegration relationship	−4.390344	0.0000

4. Conclusion

The status of automobiles in the urban low-carbon transportation system is gradually growing, with the decline of new energy subsidies, high energy consumption, low power consumption battery technology, road wireless charging technology, the number of charging piles and battery quality and other operators and infrastructure optimization, consumer preferences will be more focus on new energy vehicles. In this paper urban low-carbon transportation development, analyzing the impact mechanism of low-carbon transportation development on Iraq’s energy consumption structure and empirical evidence, the following conclusions are obtained:

(1) The development of public and electric vehicles in Iraq started early and has a wide coverage. Although the development of rail transit started late, but the speed is relatively fast, and it is gradually sharing the passenger traffic with public vehicles.

(2) The pricing system in Iraq's public transport system has a certain influence on passengers' choice of public transport travel. The government's decision to reduce public transport prices can optimize the energy consumption structure by attracting passengers.

(3) Although the development potential of new energy vehicles in Iraq still low, and the use of traditional fuel vehicles is still the mainstream. So, to encouraging the development of new energy vehicles, the transportation department can also increase the cost of owning and driving traditional energy vehicles by restricting travel, purchases, and charging parking fees, so as to encourage residents to choose new energy vehicles or public transportation to travel by traditional energy vehicles. alternative.

Conflict of interest

The author declares no conflict of interest

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