Game Research on Multimodal Transport Freight Enterprise and government Based on principal-agent Theory

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Abstract. A carbon tax as an important factor, was used the principal-agent theory to make an analysis of intermodal freight business decisions abatement and research the goal coordination of government and enterprise. The results showed that the carbon taxes affect the level of effort and reduce emissions of freight revenue cargo business enterprises. Introduction of a carbon tax can effectively guide enterprises to consciously freight emissions. Therefore, developing a reasonable carbon tax is a key to achieving the overall efficiency of the intermodal transport.

Introduction

Exacerbate global warm, human survival are facing serious threats and challenges [1]. As a new form, vigorously developing low carbon multimodal transport is of great significance to environmental protection in our country. The Government is the manager to coordinate the various multimodal transport links to build a unified and coordinated management mechanism. The Government's goal is to maximize social benefit and multimodal participating companies' goal is to maximize economic benefits. Therefore, how to implement the goal of unity is the key to achieve safety, environmental and high efficiency advantages of low carbon multimodal transport.

L. Wang [2] (2011) establish a Principal-Agent module in emissions reduction issues where the enterprise is concerned about the economic benefits to work out the best responsibility sharing ratio and to achieve the Pareto optimality of the whole society. W.G. Liu [3] (2010) used multi-task principal-agent model studies the optimal incentive mechanism of the enterprise development a low carbon economy. Y.M. Hou[4](2015)build a multi-task principal-agent model between the government and enterprise to explore how to design effective incentive mechanism under symmetric information and asymmetric information to encourage and guide enterprises to actively carry out energy conservation. B.H. Guo[5] (2013) used the principal-agent theory to analyze the government and enterprises in energy-saving management interests, showing that the government and the enterprise energy can save on the interests of consistency. Those existing research [6-8] provides a guideline for game research on Multimodal transport freight enterprise and government based on principal-agent theory.

Problem Description and Model Establishment

Problem Description. Consider the simple suitability, we assumed that the central government and local government have consistent interests and don't distinguish them from multimodal transport emissions research. Under the background of low-carbon economy development, the government pursues economic, social and environmental benefits of coordination, companies pursuing the goal of maximizing the economical profit. Transportation enterprise is a core subject in transportation about energy conservation and emissions reduction in China. Otherwise, the government has so many private information that the government can't clear and understand the degree of emission

efforts and implementation of the enterprises, which leads to form a principal-agent relationship between government and enterprises. Therefore, to response to the global climate warming and policy tools to reduce carbon emissions, a carbon tax is considered as an important economic tool.

Basic Assumption. Hypothesis 1: The calculation of carbon emissions is mainly carbon factor on the mode of transportation, the CO2 emissions per unit of freight turnover. Reference to W.M.[9], highway, railway, waterway transport CO2 emission factors are $f_1 = 119.7, f_2 = 22.7, f_3 = 12.1$, the unit of g/t.k. The government on the basis of the actual transport enterprise CO2, setting a carbon tax rate is t Yuan/tons of CO2 in the form of fixed rate a carbon tax.

Hypothesis 2: Carbon tax imposed by the government function is $T_g(E)$, E is the CO2 emissions of intermodal transport phase, $E = \sum_i E_i, E_i = f_i \times Q_i$, E_i is shipping enterprise's CO2 emissions, Q_i is the freight turnover. The government requests the observation E to the tax of shipping enterprises, $T_g(E)$ namely the design of an incentive contract for the government. C_g means that the government can supervise and measure the freight enterprise cost of CO2 emissions.

Hypothesis 3: The freight enterprise participate the multimodal transport which reduces the emissions and asks the corresponding effort cost, assuming for $C_i(b_i) = \frac{1}{2} l_i h_i^2 (i = 1,2,3)$, among them, l_i as the cost coefficient, related to the marginal cost and CO2 emissions reductions in carbon emissions, assumptions $l_i = MC_i \times E_i$, l_i is an effort to degree and $h_i \in [0,1]$.

Hypothesis 4: the intermodal freight transportation phase CO2 and the transportation road freight turnover are proportional and we assume that freight enterprise is $E_i' = E_i(1 - h_i)$.

Hypothesis 5: Multimodal transport freight enterprise carbon tax function for pay are $T_i(E)$, profit of no emission reduction is π_{i0}, the profits of carbon tax on emissions are $\pi_i = \pi_{i0} - C_i(b_i) - T_i(E_i)$, freight companies seek to maximize economic benefits, namely $u_i = \pi_i$.

Hypothesis 6: the government and enterprises are risk neutral.

Modeling and Solving.

Model Established. As the carbon tax rate is t, the firm's efforts for the enterprise h_i, so the enterprise and the government utility function are as follows:

The economic benefits of the utility function of enterprise:

$$\pi_i(b_i) = \pi_{i0} - C_i(b_i) - T_i(E_i) = \pi_{i0} - \frac{1}{2} l_i h_i^2 - t \cdot [E_i(1 - b_i)] = \pi_{i0} - \frac{1}{2} l_i h_i^2 - t \cdot (f_i Q_i)(1 - b_i)$$

The government utility function is as follows which reflects the sum of the economic and environmental benefits of transport:

$$\pi_g(t)=\sum_i \pi_{i0}+T_g(E)-C_g=\sum_i \pi_{i0}+\sum_i T_i(E_i)-C_g=\sum_i \pi_{i0}+\sum_i t\cdot(f_iQ_i)(1-b_i)-C_g$$

Therefore, building enterprise and the government's target of between coordination mechanism models is as follows:

$$\max \pi_g(t)=\sum_i \pi_{i0}+\sum_i t\cdot(f_iQ_i)(1-b_i)-C \tag{1}$$

$$s.t.\quad (IR)\ \pi_{i0}-\frac{1}{2}a_ib_i^2-t\cdot(f_iQ_i)(1-b_i)\geq \bar{u} \tag{2}$$

$$(IC)\ \pi_{i0}-\frac{1}{2}a_ib_i^2-t\cdot(f_iQ_i)(1-b_i)\geq \pi_{i0}-\frac{1}{2}a_i(b_i')^2-t\cdot(f_iQ_i)(1-b_i') \tag{3}$$

Formula (1) is the government objective function and Formula (2) is the agent of the individual rationality constraint, where $\bar{u}$ reserved for agent's income level and the enterprises can accept the lowest income levels. Formula (3) is the agent of the incentive compatibility constraint, showing that the government cannot be observed given freight enterprise the efforts of action h_i, but the government hopes enterprise to take action h_i to maximize the comprehensive benefits of transportation. h_i' shows that the enterprise can choose any action..

Model Solved. Freight enterprise determines the optimal degree of efforts. According to the incentive compatibility constraint, shipping enterprises select the optimal effort level h_i to maximize the economic benefits. To solve the extreme value of the first-order conditions $\frac{\partial \pi_i(h_i)}{\partial h_i}=0$ results

$$h_i^*=\frac{tf_iQ_i}{l_i} \tag{4}$$

Freight enterprise determines the optimal level of carbon emissions. After freight enterprise i chooses the level h_i^* to reduce emissions achieving the optimal level of carbon dioxide emissions:

$$E_i^*=f_iQ_i(1-\frac{tf_iQ_i}{l_i}) \tag{5}$$

At the optimal intermodal transportation phase, carbon dioxide emissions are

$$E=\sum_I E_i^*=\sum_i f_iQ_i(1-\frac{tf_iQ_i}{l_i}) \tag{6}$$

Generation h_i^* into the government objective function, according to the extreme value of the first-order condition $\frac{\partial \pi_g(t)}{\partial t}=0$, the solution:

$$t_i^* = \frac{1}{2}\frac{\sum_i f_i Q_i}{\sum_i \frac{(f_i Q_i)^2}{l_i}} \tag{7}$$

t_i^* is the optimal carbon taxes which determined by government and makes the government obtain the best economic benefits and environmental benefits and the enterprise achieved benefits.

Model Analysis

1) $b_i^* = \frac{tf_i Q_i}{l_i}$ indicates that freight enterprise efforts degree was positivity but reversed the related cost coefficient. Shipping companies will be more efforts to reduce CO2 emissions in order to reduce taxes and raise economic benefits. If the tax rate is too low, freight enterprises reduce the emissions of carbon tax less than economic benefits, and thus a carbon tax is difficult to encourage enterprises to actively emissions. If tax rates are too high, spending too much resources reduction, a sharp rise in the cost, freight enterprises economic benefits below reservation utility, freight companies to participate in the enthusiasm of multimodal transport.

2) $E_i^* = f_i Q_i (1 - \frac{tf_i Q_i}{l_i}) < E_i$, which indicates that a carbon tax would encourage freight enterprise to reduce carbon emissions. For t first order guide to get $\frac{\partial E_i^*}{\partial t} = -\frac{(f_i Q_i)^2}{l_i} < 0$, which shows that as a carbon tax rates rise, freight companies reduced CO2 emissions. We can conclude that carbon tax to encourage enterprises to reduce emissions in order to government obtaining environment benefit from $E = \sum_i E_i^*$.

3) $t^* = \frac{1}{2}\frac{\sum_i f_i Q_i}{\sum_i \frac{(f_i Q_i)^2}{l_i}}$, which indicates that the multimodal transport quantity, carbon emissions factor on the mode of transportation, the freight transportation enterprise influence government efforts cost the carbon taxes coefficient. This suggests that the government to formulate the optimal carbon taxes realizing the multimodal transport best economic and environmental benefit.

Example Analyses

Manufacturing enterprises A entrust the forwarder company B batch of 100 tons of cargo from Nanning to Vietnam Haiphong, choose the railway transport enterprise R and W form transport ship company supply chain. The benefits of the supply chain related parameters are as follows:

Table 1 Transport parameter values

Transport roads	company	Distance(km)	CO_2 (kg)	price(Yuan/ton-km)
Nanning-Fangcheng gulf	R	173	392.71	1.2
Fangcheng gulf-Vietnam Haiphong	W	280	338.8	1

Reduction of the marginal cost of the economy is the cost of the final unit CO2 emissions needed. According to research by Y. Yu [10] and considering the applicability of the science and study of data, this article selects Guangxi District CO2 emissions marginal costs $MC = 11.637$ Yuan/ton, $l_1 = 4.57, l_2 = 3.94$, Thus $t^* = 6$, $h_R^* = h_W^* = 0.52$, $E_R^* = 188.5$, $E_W^* = 162.6$.

Conclusions

The analysis of the empirical results shows that carbon tax is an important economic means to reduce CO_2 emissions. Government to levy a tax on carbon emissions would lead shipping companies to adopt measures to reduce CO_2 emissions, when a carbon tax rate set by the government 6 Yuan/tons, freight companies will reduce carbon emissions under the effort level of 0.52. At this point, the use of carbon tax reduction minus the cost. Hence, using carbon tax control carbon dioxide emissions and multimodal transport freight enterprise transport realizes the unity of the multimodal transport environmental benefits and economic benefits are of great significance.

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