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Green financial policies and capital flows

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HIGHLIGHTS

- Market rate is related to policy choice between green credit and output subsidy.
- Green-credit contributes to the capital flow to renewable energy industry.
- Lower green credit rates lead to more capital for renewable energy industry.
- Carbon tax and negative externality positive correlate to renewable energy's capital.

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ABSTRACT

As traditional energy is depleting, it is urgent to search for substitutes of traditional energy. Therefore, policies promoting the development of renewable energy are introduced. Under the condition of non-capital constraints, the green-credit policy and the production subsidy about renewable energy enterprises are compared. The results show that changes of market interest rate provide different implications for regulators to choose between the two policies. Under the condition of capital constraints, it is found that the green-credit policy has positive effect on renewable energy enterprises, and the effect enlarges when the difference between green rates and market interest rate becomes wider. With the increase of carbon tax and the negative externality of traditional energies, the capital flows into renewable energy enterprises. This article provides support for the development of renewable energy and its policies based on the comparison of the two policies. According to the results of this study, it is believed that the implementation of both types of policies will have a more positive effect.

1. Introduction

Energy is an important pillar for human's existing and modern economy development [1]. Meanwhile, energy is also an important strategic material for a country's economy development. Since modern times, the human society and the world economy cannot be separated from energy development and utilization [2,3].

However, when we enjoy the benefits from all kinds of energy, a series of problems emerges [4]. For example, the energy shortage and environmental pollution from the consumption of the traditional energy gradually [5], which threats human's development seriously [6]. Therefore, many countries take new energy development actively as the major task. And as a new

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rising industry, new energy has high production costs and long payback period, so it is at a more disadvantaged position when competing with the traditional energy industry [7]. Therefore, the government must help renewable energy enterprises to develop [8–11]. Currently, regulators introduce many kinds of policies to promote the development of renewable energy industries [12]. Among that, the policies can be divided into direct-subsidy policy and indirect-enhancement policy. The direct-subsidy policy means financial contributions provided by governments and any other public authorities or the support for the price and income. Besides, there are many indirect-enhancement policies, including green-credit policy, carbon tax and so on.

The green-credit policy is a kind of financial policy like low interest or soft loan, which lightens the burden on enterprises in paying off the currency interest and reduces production cost. But the government needs to raise some funds to support soft loan policy or cut interest rate. The more is the amount of loan, the more is the amount of soft loan, which means to raise more money for that. Therefore, the condition of capital supply is the vital factor to affect the persistence of a policy. At present, Germany gives low-interest loans to wind power projects and photovoltaic projects, where the rate is from 2.5% to 5.1% [13]. From 2011, Italy installs small photovoltaic systems (5∼50 kW) on roofs or other parts of buildings. Meanwhile, the country provides interest-free loan, equal to 85% of the project input in money, to this project [14]. Besides, credit agencies in Spain make interest deduction plans for individual investment and enterprise investment in renewable energy sources. After 2002, the interest after reduction is 2%∼4%. The maximum loan is as much as 63 million Euros. The total credit at this year is 0.15 billion Euros. The amount of compensating interest is 12 million Euros [15,16]. France has also drawn up a plan to support to install photovoltaic system over 1 kW. Its Ministry of Economic Affairs provides low-interest loan to these projects, where the repayment period is 10 years and the loan need not be paid at the first two years. If the photovoltaic system can operate well after that, other loans can also be cleared out. The financing limit of single system can be up to 100% of the total of investment. The maximum limit is 0.5 million Euros [17].

Currently, as to the development of renewable energy sources, many scholars put forward excellent researches. However, few researchers take contrastive analysis on different renewable energy policies. Based on that, on the condition of the same government's cost, the article compares and analyzes direct payments and green-credit policies on renewable energy sources. And when capital constraint, carbon tax and green-credit policy coexist, how the capital flows between renewable energy enterprises and traditional energy enterprises is analyzed in this article.

In this article, the main contributions are as follows: this article compares the differences in production between direct measures and green-credit policies, which promote the development of renewable energy sources as an indirect measure. We find that different market interest rate provides different guides for regulators to choose between the two measures. Besides, on the condition of capital constraints, the research finds that the increase of negative externality and carbon tax policy can cause the capital to flow to renewable energy enterprises. And when the two policies are implemented simultaneously, positive effects can be realized.

The second section of the article is the literature review. In the third part of this article, the basic model is put forward, including renewable energy enterprises and traditional energy enterprises. In the fourth part, green-credit policy and the most common subsidy according to the output are contrasted and analyzed. In the fifth part, on the condition of capital constraint, under the governmental guidance of GDP and Green GDP, the article analyzes that how the capital flows between renewable energy enterprises and traditional energy enterprises. The last part is about the conclusion and policy suggestions.

2. Literature review

The incentive mechanism of renewable energy can be divided into direct and indirect incentives. The direct incentives refer to the government's direct support for renewable energy, including renewable energy subsidies, carbon tax and so on. The indirect incentive refers to the market incentive mechanism under government supervision, including feed-in tariff and green credit policy.

Many researchers analyze the indirect incentive such as green-credit policy. It is proved that both supply side policy and environmental development policies are associated with higher levels if venture capital relative to more sort-term fiscal policies based on data from 2005 to 2010 across 29 countries [18]. Meanwhile, market impact of different support schemes on electricity market in Germany is analyzed. The results showed that when fixed feed-in tariffs lead to higher market impact, more market-oriented support schemes decrease the extent to which markets are affected [19]. Some researchers focus on the effect of biofuel policy, specifically impact of Low Carbon Fuel Standard program on renewable Fuel Standard credit markets, based on the case of the United States [20]. The green credit policy is not fully implemented in China [21], but proves resistant to China's massive economic upheaval following the global financial crisis [22].

Subsidies on renewable energy and carbon tax, as the direct incentive, means that, in order to reduce the consumption of fossil fuel and the emission of carbon dioxide, the taxes are laid on fossil fuels like coals and petroleum, and the subsidies are given to power plants of clean energy. These policies increase the production cost of the traditional energy industry and market competitiveness of renewable energy sources.

A research figures out that there is an optimal rental allocation between private and public consumption based on an integrated model [23] and under the condition of asymmetric information, the optimal subsidy increases with the growth of the number of firms with high cost according to a duopoly model [24]. Yang and Nie [25] divides government subsidies into three, and compare and analyze them. Based on a dynamic model, the impact of renewable energy investment on social welfare is discussed [26]. Meanwhile, the energy price equivalence of carbon tax and emission trading in an energy market is estimated based on a theoretical model [27].

However, situation varies in different countries. Based on the analysis of the carbon tax policy by Portuguese government, some researchers find that there is no reduction in emitted carbon dioxide emission when compared to the level of 1990 [28]. Researchers argue the policy by Portuguese government deviated from their intentions as well, illustrating that authorities need to quickly amend the existing legislations to avoid misguided attempts turning into a missed opportunity [29]. In Chile, the imposed carbon tax, indicated by the research, produces an expected annual reduction in carbon dioxide emission, though accompanied by 3.4% increase in the marginal cost of power production [30]. Some researchers concentrate on the application of carbon exergy tax to biomass integrated gasification combined cycle based on the analysis of sugarcane industry in Brazil [31]. It is demonstrated that in Malaysia, the implementation of grid-connect PV system is highly feasible with PV array cost by analyzing the effects of component cost feed-in tariffs and carbon tax [32]. Impact of carbon tax on China's economy is analyzed by both Computable General Equilibrium (CGE) model [33] and multi-regional input–output model [34]. Chen and Nie [35] compared the impact of carbon tax in production links, consumption links and redistribution links based on a social welfare model with the data of China. The result shows that only the carbon tax in production links makes contributions to the higher social welfare while the carbon tax in other links leads to the drop of social welfare. Additionally, an energy–economy–environment aggregated model is constructed for calculating the optimal carbon taxes in China [36].

The present study analyzes various incentive mechanisms of renewable energy from different perspectives. Because indirect incentive policies involve many factors and the data of energy enterprises are difficult to obtain, and the application of direct incentive policies is earlier than indirect incentive policies, the current research on support policies for renewable energy mainly focuses on direct incentive policies. For indirect incentives, especially green-credit policy, there are few studies. However, there are fewer studies comparing the direct incentive policy with the indirect incentive policy based on the background of developing countries. This article puts forward some suggestions by comparing renewable energy subsidies and green-credit policy.

3. Basic model and equilibrium solution

In this article, a Cournot Duopoly Model is set, including renewable energy enterprise R and traditional energy enterprise D. Both of the two enterprises borrow amount of capital for production. Enterprise production is expressed as Cobb–Douglas production function: $Y_i = \theta_i K_i^{\alpha}, i \in \{R, D\}$. In this model, we suppose that other production factors are fixed, and the effect on the production from the capital is solely considered, and the two elastic coefficients α to the capital are the same. Besides, we propose that the production functions of the two enterprises are diminishing with the scale of the capital $0 < \alpha < 1$. And as an exogenous variable, we propose product price to be 1. The variable of international energy price remains unchanged. As a result, the mathematical expression in this model is as follows.

π_i–the profit function of renewable energy enterprises and traditional energy enterprises

γ_i–the capital's cost coefficient of renewable energy enterprises and traditional energy enterprises

θ_i–the production efficiency of renewable energy enterprises and traditional energy enterprises

τ–the carbon tax on traditional energy enterprises imposed by the government

The profit function of traditional energy enterprises is calculated. Firstly, we calculate the product of the production of traditional energy enterprises times the price. And then we subtract the usage cost of the capital and the carbon dioxide on the traditional energy enterprises levied by the government from that product. As a result, the profit function of traditional energy enterprises is

$$\pi_D = \theta_D K_D^{\alpha} - \gamma_D K_D - \tau\theta_D K^{\alpha} = (1-\tau)\theta_D K_D^{\alpha} - \gamma_D K_D. \tag{1}$$

where $\theta_D K_D^{\alpha}$ delegates the gross profit of traditional energy enterprises, equaling to the production times the price. $\gamma_D K_D$ and $\tau\theta_D K^{\alpha}$ are usage cost of the capital of traditional energy enterprises and the carbon tax on the traditional energy enterprises levied by the government respectively.

Similarly, the profit function of renewable energy enterprises is

$$\pi_R = \theta_R K_R^{\alpha} - \gamma_R K_R. \tag{2}$$

where $\theta_R K_R^{\alpha}$ delegates the gross profit of renewable energy enterprises, equaling to production times the price. $\gamma_R K_R$ is the usage cost of the capital of the renewable energy enterprises.

Because renewable energy sources are in the development stage, its production efficiency is lower than the traditional energy's, so there is $(1-\tau)\theta_D > \theta_R$. But the government can promote the development of renewable energy enterprises by the regulation of the interests compared with traditional energy enterprises, renewable energy enterprises can get loan with lower rate. In this model, that relationship can be expressed that the cost coefficient of capital of traditional energy enterprises is higher than renewable energy enterprises, implying $\gamma_D > \gamma_R$.

Apparently, the profit functions of both traditional energy enterprises and renewable energy enterprises are about concave functions of loaned capital K. Therefore, by calculating the partial derivatives of the profit function about the loaned capital K, the first order condition of profit maximization is

$$\frac{\partial \pi_D}{\partial K_D} = \alpha(1-\tau)\theta_D K_D^{\alpha-1} - \gamma_D = 0, \tag{3}$$

$$\frac{\partial \pi_R}{\partial K_R} = \alpha\theta_R K_R^{\alpha-1} - \gamma_R = 0. \tag{4}$$

By solving (3) and (4), the optimal equilibrium quantity of traditional energy enterprises and renewable energy enterprises is

$$K_D^* = [\frac{\gamma_D}{\alpha(1-\tau)\theta_D}]^{\frac{1}{\alpha-1}}, \tag{5}$$

$$K_R^* = (\frac{\gamma_R}{\alpha\theta_R})^{\frac{1}{\alpha-1}}. \tag{6}$$

Under the condition of non-capital constraint, (7) and (8) delegates the equilibrium quantity of loans when enterprises take profit maximization as orientation.

The smaller the value of the carbon dioxide on traditional energy enterprises levied by governments τ_D is, the bigger the value of $\frac{(1-\tau_D)\theta_D}{\theta_R}$ is. That means, when the government levies less carbon dioxide on traditional energy enterprises, there is more possibility of optimal equilibrium quantity of renewable energy enterprises bigger than traditional energy enterprises', which is accord to the inhibiting effect from carbon tax on the optimal equilibrium quantity of traditional energy enterprises.

4. The comparison between green-credit policy and the subsidy according to the production

Currently, regulators propose many policies to promote the development of renewable energy sources. The policies can be divided into two sorts: one is the direct subsidy to renewable energy enterprises, like the subsidy according to the production; the other is all kinds of good policies provided to renewable energy enterprises, which are called indirect subsidies. For example, the loans superior in the rate provided to the renewable energy enterprises. In this part, we will compare and analyze the promotion effectiveness to the development of renewable energy enterprises from green-credit policy and the subsidy according to the production.

Under the green-credit policy, the profit function of renewable energy enterprises is similar to Formula (2). In this part, we propose either the direct subsidy policy or the green credit policy exists. So, when the government provides direct subsidy to the renewable energy enterprises, the profit function is

$$\pi_R = (1+S_O)\theta_R K_R^{\alpha} - \gamma_D K_R. \tag{7}$$

In Formula (9), S_O delegates the subsidy of the government to renewable energy enterprises per unit in production. Without green-credit policy, γ_D, the capital cost of renewable energy enterprises, is the same with that of traditional energy enterprises. By taking the partial derivatives of Formula (9) about K_R, we can get the following first order condition.

$$\frac{\partial \pi_R}{\partial K_R} = \alpha(1+S_O)\theta_R K_R^{\alpha-1} - \gamma_D = 0. \tag{8}$$

By solving Formula (10), when the government provides the subsidy according to the production to renewable energy enterprises, the optimal capital quantity of renewable energy enterprises is

$$K_R^{*S} = [\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}. \tag{9}$$

The production of enterprises is proportional to its capital input. Comparing the production of renewable energy enterprises under the two policies and the capital input under different policies, we can obtain

$$\frac{K_R^*}{K_R^{*S}} = [\frac{\gamma_R(1+S_O)}{\gamma_D}]^{\frac{1}{\alpha-1}}. \tag{10}$$

where, K_R^* is the optimal capital quantity of renewable energy enterprises on the condition of green-credit policy, just as Formula (8) shows, $K_R^* = (\frac{\gamma_R}{\alpha\theta_R})^{\frac{1}{\alpha-1}}$. K_R^{*S} delegates the optimal capital quantity of renewable energy enterprises on the condition of government's subsidy according to the production, as Formula (11) shows, $K_R^{*S} = [\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}$.

At that time, we do not take the capital into consideration. And we just compare the scale of production of renewable energy enterprises provided that the degrees of support of the two policies are the same. Therefore, the constraint condition is

$$(\gamma_D - \gamma_R)K_R^* = S_O\theta_R K_R^{*S}. \tag{11}$$

Proposition 1. *When the rate of green-credit policy is close to market interest rate, the relation $\gamma_D < \alpha(1+S_O)\theta_R e^{-\frac{\ln(\alpha)(1-\alpha)}{2\alpha-3}}$ only exists. Otherwise, when there is a huge difference between the rate of green-credit policy and market interest rate, $\gamma_D > \alpha(1+S_O)\theta_R e^{-\frac{\ln(\alpha)(1-\alpha)}{2\alpha-3}}$ exists. The promoting effect of green-credit policy on renewable energy sources is superior to the effect of direct subsidy according to the production.*

Proof. See in the Appendix.

Because the society and environmental awareness of the public is insufficient in developing countries, the supervision of related national department at home on green-credit policy is not as good as abroad. However, under the pressure of international environmental degradation, the related national departments in some developing countries have to pursue the green-credit policy, but in practice there are so many difficulties.

At present, because of low information transparency, strengthening the supervision of relevant departments must lead to the rapid rise of regulatory cost. Meanwhile, the development of green-credit policy faces three problems: imperfect policies and incentive mechanisms, incomplete environment and social risk management and inadequate techniques and talents. Therefore, it is vital for the government to build up suitable incentive mechanism of the green-credit policy, to promote the development of green-credit policy (taking banks as the core).

According to the conclusion, in order to promote the development of green-credit policy, the government should adopt corresponding policies based on different market interest rate. When the market interest rate is bigger than a certain value, the government should provide a green-rate value far different from the market interest rate. When the value of market interest rate is too small, the government should provide a green-rate value considerably close to the market interest rate, so that it is more effective to promote the development of renewable energy enterprises, compared with direct subsidy policies. As a result, the direct subsidy policies are developed.

From the incentive methods of all countries about green-credit policies, it is clear to the legal status of green-credit policies. There is a strict regulation about environmental assessment as to the credit and loan of financing institutions, which promotes both sides in financing to take environmental risk into consideration in the process of financing. Meanwhile, with subsidy in financing, banks will follow the green-credit policy based on the benefits. To some extent, it is feasible to promote China's development of green-credit policy by subsidy, which is of reference significance.

5. The capital flow under the capital constraint

In some countries with immature monetary market, the rate is controlled by the central bank. In this stage, the deposit service and the loan service of banks are the main channels to accumulate and provide social funds, which are the main business. On the premise of the central bank controlling the rate directly, because of wide spreads, most of the banks rely on the net lending-deposit interest rate spreads, a kind of high capital consumption, to make profits. In the process of fastening interest rates liberalization, this kind of banks, relying on their own capital accumulations, could not catch the step of the credit scale. As a result, under the government constraints, the article analyzes the green-credit policy of the government with different preferences.

5.1. The maximum producer surplus under capital constraints

As to many developing countries, GDP is an important indicator to show economic growth, economy of scale, economic development per capita, economic structure and general price level of a nation or region. Therefore, GDP is often seen an orientation as to measure the economic development.

In the model of this part, GDP can be measured by producer surplus, so we propose that the aim of governmental regulation is the maximum producer surplus. By the constraints of credit capital, this part will discuss how to allocate capitals reasonably to realize he maximum producer surplus.

Provided that the capital stock is K and all of that can be invested into renewable energy sources enterprises and traditional energy enterprises. When $K \geq K_D^* + K_R^*$, that means $K_D = K_D^*, K_R = K_R^*$, the maximum producer surplus can be gotten. So, when the value of capital stock is very large, the two kinds of enterprises can get the optimal capital to be engaged into production, which is not consistent with the production status of non-capital constraint, which we do not discuss in this article. In this article, we only research how to allocate the capital with insufficient capital stock.

Under the condition of insufficient capital stock, we just talk about the capital allocation assuming that there is the maximum producer surplus. Therefore, the objective function of the government is the sum of the maximum profits of the two enterprises.

$$\max\{\pi_D + \pi_R\} = \max\{(1-\tau)\theta_D K_D^\alpha - \gamma_D K_D + \theta_R K_R^\alpha - \gamma_R K_R\}. \tag{12}$$

where $(1-\tau)\theta_D K_D^\alpha - \gamma_D K_D$ is the profit of traditional energy enterprises, $\theta_R K_R^\alpha - \gamma_R K_R$ delegates the profit of renewable energy enterprises. On the condition of capital constraints, when capital amount K is allocated into the two enterprises, we can get the relation $K_D + K_R = K$, that is $K_R = K - K_D$. When we put that relation into Formula (9), the objective function of the government is

$$\max\{(1-\tau)\theta_D K_D^\alpha - \gamma_D K_D + \theta_R (K-K_D)^\alpha - \gamma_R (K-K_D)\}. \tag{13}$$

Apparently, Formula (10) is a concave function about K_D, we take partial derivative about K_D . When the partial derivative is zero, the first order condition with the maximum producer surplus is

$$\alpha(1-\tau)\theta_D K_D^{\alpha-1} - \gamma_D - \alpha\theta_R (K-K_D)^{\alpha-1} + \gamma_R = 0. \tag{14}$$

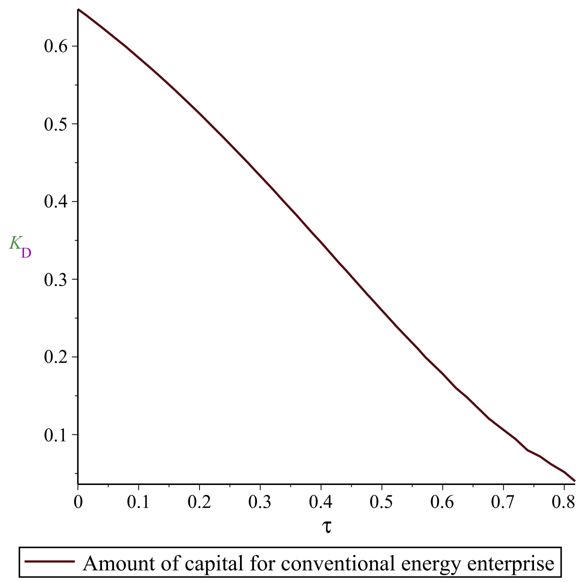

Fig. 1. The change of the traditional energy enterprises to borrow capital for $\alpha = 0.5$, $\gamma_D = 0.3$, $\gamma_R = 0.1$, $\theta_D = 1$, $\theta_R = 0.5$, $K = 1$.

According to Formula (10), we can the following conclusions

Proposition 2. *On the condition of the capital constraint, under the guidance of GDP, the government provides the green-credit policy to renewable energy enterprises, which increases the size of loan from renewable energy enterprises and expands the scale of production of renewable energy enterprises. When the gap between γ_D and γ_R becomes bigger, renewable energy enterprises can get more capital.*

Proof. See in the Appendix.

As a new industry in recent years, renewable energy sources play an important role in solving the problem of drying up traditional energy because it is clean and environmentally friendly. Compared to traditional energy enterprises, its greatest disadvantage is immature production technology, which could lead to high cost of production. On the primary stage of development, it is difficult for them to continue without the help of the government. After implementing the green-credit policy from the government, renewable energy enterprises can get the loan with a low rate, which decreases the production cost of renewable energy enterprises. Because of a longer payback period, the loan with low rate can decrease the production cost of renewable energy enterprises, so that renewable energy enterprises can get more profit. Therefore, some entrepreneurs with environmental awareness are willing to leap into renewable energy enterprises.

As a strategic emerging industry, the new energy industry, such as photovoltaic power generation enterprises and wind electricity enterprises, faces challenges in policy and market. Generally speaking, strategic emerging industries are not suitable to credit aid, because this kind of industries cannot get scale, even cannot make profits. It is sure that the preferential interest rates to renewable energy industries can make enterprises have more intentions to invest renewable energy industries. But as to banks, it maybe means more credit risks or the decrease of the profit. So, the existing banks issue Green financial bonds to raise money and support the Green industrial projects. When implementing green finance policy, we must rely on the combination of Market constraints and government guidance. Firstly, we should make sure that the issuers of bond indeed issue bonds to raise money, which is used into the eligible Green industry projects. Besides, strengthen the requirements about information disclosure to increase the transparence of raising money, so that investors will strongly support it. And the benign interaction between Green investment trend and Green investment and financing can be formed.

Proposition 3. *Under the condition of capital constraint, the capital quantity allocated to traditional energy enterprises becomes less with the increase of carbon tax.*

Proof. See in the Appendix.

From Figs. 1 and 2, we can see that there is a negative correlation between the capital quantity of traditional energy enterprises and their own carbon tax. That means leaving the carbon tax can control the scale of production of traditional

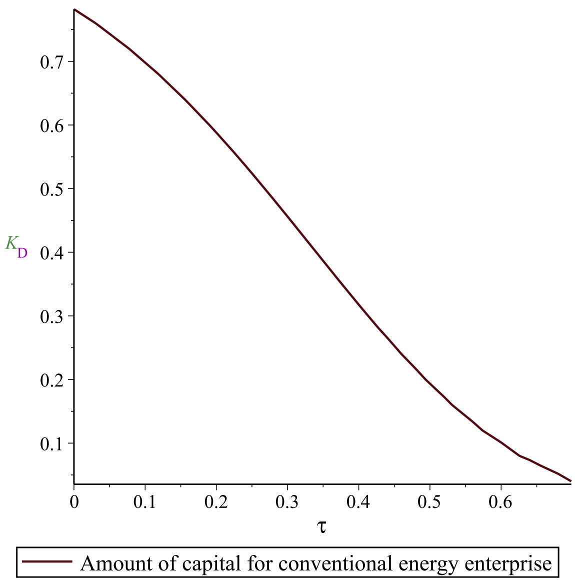

Fig. 2. The change of the traditional energy enterprises to borrow capital for $\alpha = 0.7$, $\gamma_D = 0.3$, $\gamma_R = 0.1$, $\theta_D = 1$, $\theta_R = 0.5$, $K = 1$.

energy enterprises effectively. When there is capital constraint, the scale of production of renewable energy enterprises can be expanded.

By comparing Figs. 1 and 2, we can see that with the increase of α, the slope and intercept will also increase. That is to say, the larger is the elastic coefficient of the capital, the better the control effect of carbon tax on traditional energy enterprises is. Meanwhile, the trends in Figs. 1 and 2 are the same, which means the model results are of stability.

As a measure of market regulation, carbon tax can stimulate the development of enterprises which are high efficiency and clean and with energy conservation and emission reduction. Carbon tax can change and lead the behaviors of economic agent by relative commodity price, in order to decrease the emission load, so that renewable energy enterprises will develop. From the practical experience of countries which implement Carbon tax policy firstly, like Sweden, Finland and the Netherlands, a reasonable carbon tax policy, without compromising the enterprise competitiveness, can promote the development of clean energy enterprises. The emission of carbon dioxide can be controlled, and the win–win relationship can be realized in ecological benefits and economic benefits.

In the view of implementing carbon tax, there are some advantages about carbon tax adjusting the production. Firstly, the implementation of carbon tax system can rely on the existing tax institutions without establishing newly incorporated institution. So, the difficulty of implementing carbon tax system is low, and there is not the hinder in administrative system. The carbon tax system has features of simple calculation and easy operation and convenient detection. So as to tax staffs, it is easy to operate and there is no need of complicated examination. Secondly, when levying the carbon tax, it is fair and transparent, which reflects the principle of whoever causes pollution is responsible for its treatment. And that shows that the tax burden of people has been less affected by levying the carbon tax. By reforming the current tax policy, the tax on investment can be decreased, so that the tax burden can be transformed into the aspects about pollution. Thirdly, carbon tax has transparent effects and small negative effects, which are good to increase productivity. In the short term, levying the carbon tax could make the energy become more expensive, so that the cost of production can be enhanced and enterprises reduce their outputs and GDP decreases. In order to escape this situation, we can make up by reducing other taxes and improving energy efficiency. But on the long term, carbon tax can increase the income of the government, accumulate the capital, increase productivity and counteract the negative effects from the cost of consuming the energy.

However, levying carbon tax could bring certain drawbacks such as the great loss of GDP. In a country where open economy policy is implemented, its energy enterprise is in a bad situation, compared with other enterprises which need not pay carbon taxes in their countries. Because in other countries, not levying carbon taxes can internalize the externality. In order to make up that disadvantage, we can give subsidy to enterprises rather than free of carbon tax. Though giving subsidy can increase the number of pollution enterprises, and conflicts with the principle polluter pays. But among all unilateral actions, subsidy may be the best one.

5.2. GDP maximization under capital constraint

Application amount of fossil energy booms since the Second Industrial Revolution. Exploiting and using fossil energy makes contributions to the convenience of people's life and the development of the world economy, though there is side

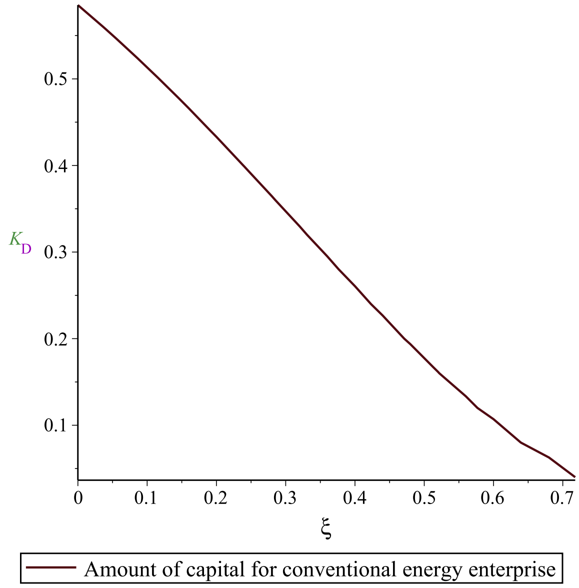

Fig. 3. The change of the traditional energy enterprises to borrow capital for $\alpha = 0.5$, $\tau = 0.1$, $\gamma_D = 0.3$, $\gamma_R = 0.1$, $\theta_D = 1$, $\theta_R = 0.5$, $K = 1$.

effect of pollution as well. It is well known that large amount of exhaust gas is discharged during combustion of fossil energy despite the development of energy saving and emission reduction technology. It illustrates that the negative externality of using traditional energy cannot be eliminated completely. Recently, more attention to environmental protection is paid by governments due to the higher living environment demands. Considering the environmental damages caused by negative externality of traditional energy, many governments advocate high green GDP instead of single high GDP. In that case, the object function of a government is

$$\max\{\pi_D + \pi_R\} = \max\{(1-\tau)\theta_D K_D^\alpha - \gamma_D K_D + \theta_R K_R^\alpha - \gamma_R K_R - \xi\theta_D K_D^\alpha\}. \quad (15)$$

In Formula (12), $\xi\theta_D K_D^\alpha$ is negative externality of emission caused by traditional energy, which positively correlates with negative externality coefficient of traditional energy, ξ, and output of traditional energy, $\theta_D K_D^\alpha$. $(1-\tau)\theta_D K_D^\alpha - \gamma_D K_D$ is the profit of traditional energy enterprises and $\theta_R K_R^\alpha - \gamma_R K_R$ is the profit of renewable energy enterprises.

Similarly, the total capital is K and $K < K_D^* + K_R^*$ considering capital constraints. Then the object function of government is rewritten as

$$\max\{\pi_D + \pi_R\} = \max\{(1-\tau-\xi)\theta_D K_D^\alpha - \gamma_D K_D + \theta_R (K-K_D)^\alpha - \gamma_R (K-K_D)\}. \quad (16)$$

The first order condition is

$$\alpha(1-\tau-\xi)\theta_D K_D^{\alpha-1} - \gamma_D - \alpha\theta_R (K-K_D)^{\alpha-1} + \gamma_R = 0. \quad (17)$$

Since there is large number of variables in the model, we explain the relationship between the capital quantity of traditional energy enterprises and negative externalities of traditional energy intuitively by numerical simulation.

Proposition 4. *Under capital constraint, allocated capital quantity of traditional energy enterprises decreases with the growth of negative externality of traditional energy. Meanwhile, production capacity of renewable energy is larger considering the negative externality of traditional energy compared with that without considering the negative externality.*

According to Figs. 3 and 4, the capital quantity of traditional energy enterprises negatively correlates with negative externality of traditional energy. That means renewable energy enterprises obtain more capital for production when traditional energy enterprises cause heavier pollution or governments pay more attention to environmental conservation. By comparing Figs. 1 and 3, it is obvious that the loan capital of traditional energy enterprises is less considering negative externality of traditional energy compared with the situation that the negative externality is neglected.

The features of renewable energy industry are high upfront capital expenses and average cost, long payback period, and demand for policies, regulations and even subsidies by government because the operation of the industry require supporting intellectual property and technology. The externality of energy industry is distinct. First, traditional energy is of huge negative externality while renewable energy is of positive externality. Secondly, external cost of traditional energy, such as environmental disruption, is not included in the final product cost accounting. However, high initial cost for renewable energy with positive externality is borne by particular enterprises. Thirdly, the two types of externalities result

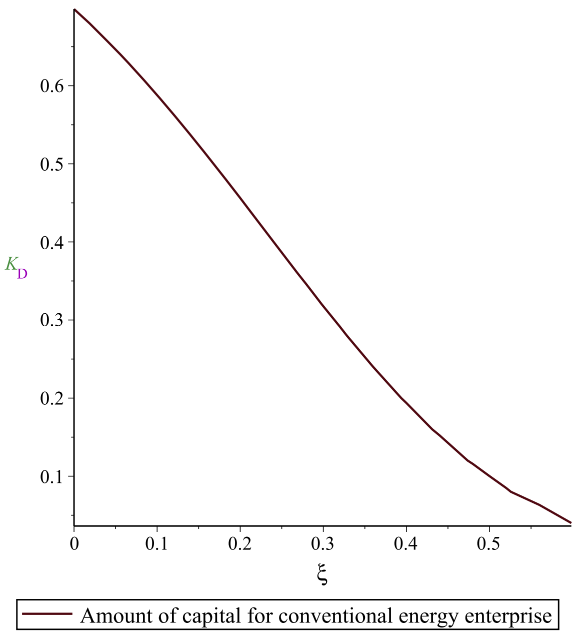

Fig. 4. The change of the traditional energy enterprises to borrow capital for $\alpha = 0.7$, $\tau = 0.1$, $\gamma_D = 0.3$, $\gamma_R = 0.1$, $\theta_D = 1$, $\theta_R = 0.5$, $K = 1$.

in the inferiority of renewable energy enterprises in the market competition, which further affects the allocative efficiency of resources.

Financing of renewable energy enterprises plays a pivotal role in optimization of energy structure and resources and environmental protection. Renewable energy enterprises may compete with traditional energy enterprises only if the capital of renewable energy enterprises is sufficient for production. Under that condition, other policies might work. Currently, financing mode of renewable energy enterprises includes indirect finance guided by government, the new financial format such as risk investment, and direct finance led by capital market. The indirect finance, as the main financing mode, is of great significance for renewable energy industry, which contains the World Bank credit, National debt projects and projects of policy banks.

World Bank credit, as one of governmental foreign debts, is benefit for its preferential terms despite its inflexibility compared to commercial bank loans. Specifically, donations for renewable energy for environmental reservation and sustainable development contribute to solution of shortage of funds for developing the renewable energy industry in some countries. However, it is infeasible that enterprises depend on the credit only. With the boom of economy, application for loans is much harder than before while the World Bank could only help part of the industries. Therefore, the renewable energy industry is badly in need of other financing modes.

National debt projects, belonging to government project, are mainly guiding projects for an industry regardless of operating effectiveness of the projects themselves. The projects cannot be widely used because capacity of issuing bonds by a government is limited in spite of the benefits those projects have. The national debt projects are mainly implemented for low-commercialization and policy-support required projects. The possibility that a renewable energy enterprise gets government subsidies would decrease due to the increasing numbers of project.

The new financial format makes up for the deficiencies of the traditional financial service, such as services from traditional banks and securities companies. The format contains private equity investment, risk investment, industries development fund and so on, where the risk investment is the most important type. At present, support of risk investment on renewable energy industry is not enough. Most venture capital involves in the enterprises in the late stage of expansion instead of in establishment for avoiding risks caused by information transparency and technique. This preference of risk investment results in the lack of capital and financial access in most medium and small-sized enterprises in establishment.

The capital market to finance renewable energy enterprises are mainly bond market and stock market. The enterprises in the maturation obtain capital by bonds and stocks in capital market. However, the financing scale of renewable energy enterprises from capital market is small and the possibility of financing and refinancing from stock market is small since the development of renewable energy industry is of high uncertainty.

Currently, researches related to financing of renewable energy industry mostly analyze differentiated finance channels in different periods based on life-cycle theory. According to life-cycle theory, the development of renewable energy industry experiences the introduction, the expansion, the maturation and recession. The renewable energy industry is in the transition stage between introduction and expansion, that desperately needs cash. However, financial institutions take a cautious approach to investment due to the high risks. In that case, own capital of enterprises and subsidies from government play a crucial role. After the renewable energy industry transferring to expansion period, the risk decreases. Under that circumstance, it would be much easier for renewable energy enterprises to obtain capital by borrowing capital from banking institution and raising capital in capital market.

6. Conclusion and policy implications

The global sustainable development would be restricted seriously because of the finiteness of fossil energies and environmental problem from exploitation and utilization. Two important strategies in worldwide sustainable development are to improve energy efficiency and develop renewable energy sources. As to the development of renewable energy industries, the shortage of the capital and effective financing mechanism is a main factor to its hinder industrialization development. So, in this article, on the condition of non-capital constraint, we compare and analyze the relation between production subsidies and green-credit policy to renewable energy sources. Besides, provided that capital constraint is existed, we build a Cournot model including traditional energy enterprises and renewable energy enterprises. Finally, after analyzing the aim of the government: the maximum producer surplus and the maximum Green GDP, we design the green loan policy suitable to renewable energy enterprises.

In this article, in order to promote the development of green-credit policy, the government should carry out different Green rates policy according to different market interest rates, so that the bad effect of other factors on Green rates policy can be reduced and the development of green-credit policy can be promoted. Whether the aim of the government is the maximum producer surplus or the maximum green GDP, providing preferential interest rate lower than market interest rate to renewable energy enterprises is good to enlarge their scale of production. When the government considers the negative externality of traditional energy enterprises, because traditional energy pollutes the environment, the government will provide more production fund to renewable energy enterprises compared with those taking producer surplus as orientation. The more the negative externality of traditional energy is, the less the share of traditional energy in the capital allocation market is. In this article, the effect of carbon tax is considered contemporarily, the analysis result shows that the amount of their capital possession can be enlarged when the government levies the carbon tax on the traditional energy enterprises. Besides, there is a positive correlation between the amount of the capital possession of renewable energy enterprises and the amount of tax to be paid to the carbon tax. As a consumption tax as according to the carbon content of fossil fuel to levy, carbon tax not only control the emission of greenhouse gases by adjusting energy price, but also is a kind of fiscal taxation policy.

In practice, because industrial area has great influence on national economy, levying carbon tax vigorously on this area will damage industrial competitiveness of this country. In order to improve the feasibility of carbon tax policy, the core work is to reduce the negative effects in industrial area. We can use this tax revenue to subsidize the industries where the taxpayer is, so that emission cost can be increased and the total cost of production keeps the same. Because developing renewable energy sources must rely on low-interest loans of the government, so this amount of funds can be taken from the income of carbon tax. Under the dual effect of carbon tax and green credit policy, the loss from the energy industry caused by carbon tax will decrease, meanwhile, the financial pressure of government subsidies can be reduced, so that the energy industry has strong intention to transit from traditional energy industry to new energy industry. The win–win outcome can be realized between the government and the enterprise in the environment and the development.

Since the subsidies and financing data of renewable energy enterprises are difficult to obtain, this article makes the qualitative analysis of renewable energy subsidies and green-credit policy based on the mathematical model. Empirical research based on renewable energy enterprise data will further quantify the impact of the two types of policies, which is also the future direction of this research.

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Appendix

Proof of Proposition 1. Substitute Formula (8) and Formula (11) into Formula (13), then

$$(\gamma_D-\gamma_R)(\frac{\gamma_R}{\alpha\theta_R})=S_O\theta_R[\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}. \tag{A.1}$$

Solve Formula (A.1) by taking γ_D and S_O as exogenous variable. Then,

$$\begin{cases}\gamma_{R1}=\frac{1}{2}\gamma_D+\frac{1}{2}\sqrt{\gamma_D^2-4\alpha S_O\theta_R^2[\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}}\\ \gamma_{R2}=\frac{1}{2}\gamma_D-\frac{1}{2}\sqrt{\gamma_D^2-4\alpha S_O\theta_R^2[\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}}\end{cases}. \tag{A.2}$$

Substitute γ_{R1} into Formula (12), then

$$\frac{K_R^*}{K_R^{*S}} = \{\frac{(1+S_o)\{\frac{1}{2}\gamma_D + \frac{1}{2}\sqrt{\gamma_D^2 - 4\alpha S_O \theta_R^2 [\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}}\}}{\gamma_D}\}^{\frac{1}{\alpha-1}}. \tag{A.3}$$

In Formula (A.3), $\frac{(1+S_o)\{\frac{1}{2}\gamma_D + \frac{1}{2}\sqrt{\gamma_D^2 - 4\alpha S_O \theta_R^2 [\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}}\}}{\gamma_D}$ is a monotone increasing function of γ_D. Let $\frac{(1+S_o)\{\frac{1}{2}\gamma_D + \frac{1}{2}\sqrt{\gamma_D^2 - 4\alpha S_O \theta_R^2 [\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}}\}}{\gamma_D} = 1$ and solve Formula (A.3), then

$$\gamma_D = \alpha(1+S_O)\theta_R e^{-\frac{\ln(\alpha)(1-\alpha)}{2\alpha-3}}. \tag{A.4}$$

$\frac{(1+S_o)\{\frac{1}{2}\gamma_D + \frac{1}{2}\sqrt{\gamma_D^2 - 4\alpha S_O \theta_R^2 [\frac{\gamma_D}{\alpha(1+S_O)\theta_R}]^{\frac{1}{\alpha-1}}}\}}{\gamma_D} < 1$ and $\frac{1}{\alpha-1} < -1$ when $\gamma_D > \alpha(1+S_O)\theta_R e^{-\frac{\ln(\alpha)(1-\alpha)}{2\alpha-3}}$. Therefore , $\frac{K_R^*}{K_R^{*S}} > 1$.

Similarly, only if $\gamma_D < \alpha(1+S_O)\theta_R e^{-\frac{\ln(\alpha)(1-\alpha)}{2\alpha-3}}$, $\frac{K_R^*}{K_R^{*S}} > 1$ when the difference between green interest rate and market rate is large.

Proof of Proposition 2.

According to Formula (11),

$$\alpha(1-\tau)\theta_D K_D^{\alpha-1} - \gamma_D = \alpha\theta_R(K-K_D)^{\alpha-1} - \gamma_R. \tag{A.5}$$

When there are no credit preferential policies for renewable energy enterprises by government, $\gamma_D = \gamma_R$, which illustrates that the capital cost of the two type enterprises are the same. As a result,

$$\alpha(1-\tau)\theta_D K_D^{\alpha-1} = \alpha\theta_R(K-K_D)^{\alpha-1}. \tag{A.6}$$

That is

$$\frac{K_D}{K-K_D} = [\frac{(1-\tau)\theta_D}{\theta_R}]^{\frac{1}{1-\alpha}}. \tag{A.7}$$

When there are credit preferential policies for renewable energy enterprises by government, capital cost of renewable energy enterprises is lower than that of traditional energy enterprises, which is $\gamma_D > \gamma_R$. According to Formula (A.1),

$$\alpha(1-\tau)\theta_D K_D^{\alpha-1} < \alpha\theta_R(K-K_D)^{\alpha-1}. \tag{A.8}$$

That is

$$\frac{K_D}{K-K_D} < [\frac{(1-\tau)\theta_D}{\theta_R}]^{\frac{1}{1-\alpha}}. \tag{A.9}$$

According to comparison of Formula (A.3) and Formula (A.5), credit preferential policies for renewable energy enterprises contribute to larger credit scale of renewable energy enterprises.

Proof of Proposition 3.

Take partial derivative of Formula (16) to τ based on implicit function theorem, then

$$[\alpha(\alpha-1)(1-\tau)\theta_D K_D^{\alpha-2} + \alpha(\alpha-1)\theta_R(K-K_D)^{\alpha-2}]K_D' = \alpha\theta_R K_D^{\alpha-1}. \tag{A.10}$$

Partial derivative of K_D to τ is calculated by solving Formula (A.10), then

$$K_D' = \frac{\alpha\theta_R K_D^{\alpha-1}}{\alpha(\alpha-1)(1-\tau)\theta_D K_D^{\alpha-2} + \alpha(\alpha-1)\theta_R(K-K_D)^{\alpha-2}} < 0. \tag{A.11}$$

As a result, K_D decrease with the growth of τ.

Proof of Proposition 4.

Take partial derivative of Formula (16) to ξ based on implicit function theorem, then

$$[\alpha(\alpha-1)(1-\tau-\xi)\theta_D K_D^{\alpha-2} + \alpha(\alpha-1)(K-K_D)^{\alpha-2}]K_D' = \alpha\theta_D K_D^{\alpha-1}. \tag{A.12}$$

Partial derivative of K_D to ξ is calculated by solving Formula (A.10), then

$$K_D' = \frac{\alpha\theta_D K_D^{\alpha-1}}{\alpha(\alpha-1)(1-\tau-\xi)\theta_D K_D^{\alpha-2} + \alpha(\alpha-1)(K-K_D)^{\alpha-2}} < 0. \tag{A.13}$$

As a result, K_D decrease with the growth of ξ.

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