Research on high-carbon and low-carbon energy prices interaction mechanism and policy based on EPE analysis model

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Abstract: In the backdrop of the global response to climate change and high-carbon (fossil) energy price going up with fluctuation, the prospect of low-carbon (non-fossil) energy is in sight highlighted. By the research about the interaction and relevance between low-carbon energy and high-carbon energy prices, the low-carbon and high-carbon energy price equilibrium analysis model (EPE analysis model) is proposed in this paper. By analyzing the principle of how two types of energy price trend line intersect at points (equilibrium), the methods and approaches of policy selections to enhance the price competitiveness of low-carbon energy are proposed: first, closing up the gap; second, changing the slope; third, adjusting to increase and decrease simultaneously etc, to provide new ideas for national energy policy

Keywords: Low-carbon (non-fossil) energy; EPE analysis model; policy

In response to climate change, reducing carbon dioxide emissions and accelerating the development of low-carbon (non-fossil) energy has become the focal point of energy policy across the global. In September 2009, President Jintao Hu proposed the objective of "take the initiative to reduce" carbon dioxide emission in China when he attended the UN Climate Change Summit, which specified that the "non-fossil energy share of total primary energy consumption will reach at 15%." Either from the perspective of environment improvement or energy security, low-carbon energy has become the focus of national energy development strategy. Under the background of placing together low-carbon energy development and high-carbon (fossil) energy price changes, the research on the interaction and relevance between the prices of two kinds of energy is not only theoretical value, but also practical significance for the selection of scientific and rational research tools for national energy policy.

1. Fully understand the interaction between high-carbon and low-carbon energy prices

1.1. The definition of high-carbon energy and low-carbon energy

Energy is the foundation for human being to survive and thrive. Economic development and social progress is closely related to the use and exploitation of energy. Agricultural society is a low-carbon society. The solar energy provides huge impetus not only for the cycle of natural ecosystems but also for human being. The industrialized society is basically a high-carbon society. Because fossil fuel such as oil, natural gas and coal is convenient and its density is large, the scale and level of exploiting and using fossil energy become a symbol of the development of modern society.

Table 1. comparing the number of CO2 produced by all types of energy

Energy type	coal	oil	gas	non-fossil energy
CO2 produced in burning per ton of material (tons)	0.7	0.54	0.39	0
CO2 produced in burning per unit of heat (gas-1)	1.61	1.19	1	0

Source: CNIK knowledge metabase.

In Table 1, comparing the number of CO2 produced by all types of energy, we can see that traditional fossil energy produces more CO2 than non-fossil energy used. Therefore, we call coal, oil, natural gas and other fossil energy as high-carbon energy, and the water, nuclear, wind, solar, geothermal, ocean, biomass energy and other renewable non-fossil energy as low-carbon energy. Under the dual pressures in response to energy shortage and climate change, the countries around the world develop low-carbon energy as an important part of energy strategy [1].

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1.2. The gap of costs and prices between the two kinds of energy is obvious

Because of low density of low-carbon energy, poor stability and the constraint of technology and industrial-scale, currently it is less competitive than high-carbon energy. The costs of high-carbon and low-carbon energy are compared in a report of National Development and Reform Commission, Energy Research Institute (Table 2), the gap of prices between two kinds of energy is obvious. The research on the progress of low carbon energy technologies and policy has become a political and academic hot issue.

Table 2. Comparing the cost in generating electricity with high-carbon and low-carbon energy (Unit: cents/kWh)

type	high-carbon energy			low-carbon energy				
category	coal	oil	gas	hydro	wind	solar	biomass	ocean
cost	**3-7**	**5-13**	**4-10**	**4-10**	**7-10**	**14-30**	**6-15**	**15-25**

Source: National Development and Reform Commission, Energy Research Institute.

1.3. The shift law of interaction between two types of energy prices

The structure adjustment of energy price system is the basis for optimal allocation of resources in the market. It is shown that: high-carbon energy and low-carbon energy price changes have interactive relevance of changing in the shift in the market. Although international oil price going up with fluctuation results in negative impact on economic growth, it will positively push the low-carbon energy development. In the 70-80s in 20th century, the "second oil crisis" injected a powerful driving force into developed countries to seek alternative energy, especially low-carbon energy. In the late 90s, international oil prices continued to go up, leading high-carbon energy prices to rise. Correspondingly, the scientific and technological progress and innovation drove industrialization and marketization of low-carbon energy in a large scale. The exploiting costs and market prices of low-carbon energy are in the decline within 10-20 years and its advantage is highlighted. Especially when oil prices break through 60-70 dollars/barrel, low-carbon energy will become profitable. The world will go in the "Golden Age "of the development of low-carbon energy [2].

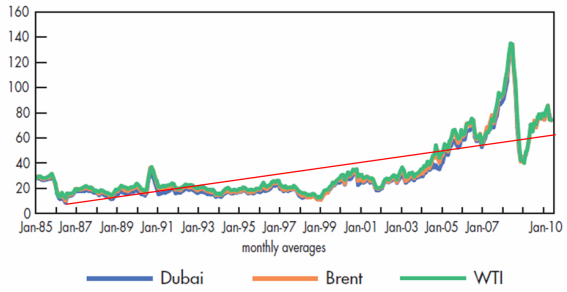
1.4. Scientific and rational energy policy can affect the market trend of energy prices

Currently, there is a gap between the costs two types of energy. Without government intervention and full marketization, low-carbon energy price is less competitive than high-carbon energy. To improve low-carbon energy price competitiveness, the countries in the world use policy force, such as, legislative, tax, financial, technological, economic and management measures to affect the market trend of energy prices and upgrade energy market competitiveness. For example, the U.S. government promulgated *the new energy bill* to promote low-carbon energy development and gradually get rid of dependence on oil in 2007. In order to encourage the development of bio-fuel ethanol, the government gave producers subsidies so that they earned more profit to actively study and produce it. The cost of bio-fuel ethanol cut down.

2. The history curves of high-carbon and low carbon energy price changes

2.1. The history curves of high-carbon energy price changes

According to Figure 1, from 25- year international key crude oil spot prices, we can analyze the trend of high-carbon energy prices.



Source: International Energy Agency, IEA

Figure 1. Key crude oil spot prices（in USD/barrel）

Due to various complex factors in the market, high-carbon energy prices show price fluctuation (Figure 1). International oil prices had reached 147 dollars/barrel in 2008 and later went down due to the international financial crisis, staying at 70-80 dollars/barrel now. However, the trend of the price of high-carbon energy going up with fluctuation will not change. The impact of the trend of international oil price on high-carbon energy and derivative energy is positive and indicative. It is determined by the scarcity of non-renewable high-carbon energy and environmental cost.

2.2. The history curves of low-carbon energy price changes

2.2.1. Wind

Wind-power is the fastest growing low-carbon energy. By the end of 2009, the world's total of wind-power had reached 159.213 million kilowatts. Germany is one of the countries with the largest wind-power industry and the most technologically advanced technology in the world. It installed 25777MW of wind-power, accounting for 28% of the world. Wind-electricity accounts for

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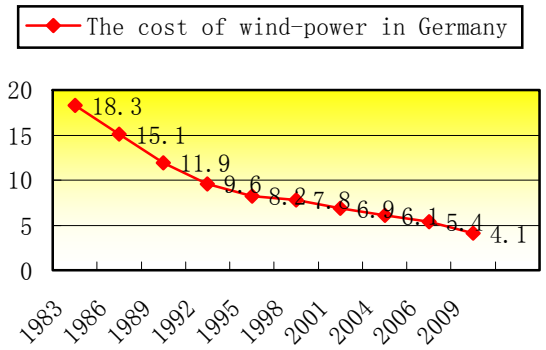
about 9% of electricity demand. With technological progress and industrial scale, the cost of wind-power in Germany continued to decline (Figure 2), and now it has closed to the cost of thermal power.



Source:European Wind Energy Association(EWEA), 2009, The Case of Wind Energy in Germany.

Figure 2, The trend of the cost of wind power in Germany (euro cents/ Kwk)

2.2.2. Biomass

Brazil is the world's largest ethanol exporter with its leading technology and production of bio-ethanol fuel made from sugarcane in the world. The fuel ethanol production in Brazil reached 25.5 billion liters in 2009.The industrialization of ethanol fuel made the cost falling from 1.68 dollars/L in 1982 to 0.58 dollars/L in 2004, to 0.22 dollars/L in 2006. Today, the price of ethanol is generally cheaper 30% than that of gasoline at only 0.19 dollars/L in Brazil.

2.2.3. Solar Energy

In the 90s of last century Japan carried out the "new sun" program, focusing on developing solar battery and solar power technology. Solar power was produced in large scale with advanced technology. Thus, its cost was moving downside from 35.9 cents/Kwh in 1980 to 18.5 cents/Kwh in 2005. In 2009, Japan developed a new solar thermal power technology, which decreased the cost as low as 11.6 cents/Kwh.

China is the country with the largest production and consumer of solar water heater. For a decade the average growth rate of the installation has reached 24.7%. It is expected that the total area will reach 100 million square meters, accounting for 63.1% of the global total in 2010. it will be strongly competitive in the market with advanced technology , large market size and reduced cost.

By analyzing these three low-carbon energy prices, we can show the low-carbon energy price curve with in the following Figure 3(see right).

Obviously, it is a declining line step by step. Since 70 s in the 20th century, after the First Oil Crisis the developed countries have attached great importance to low-carbon energy technology research and policy support. The technical progress and market scale has been upgraded. The low-carbon energy prices are going down in an irreversible manner (Figure3.) to be competitive in the market.

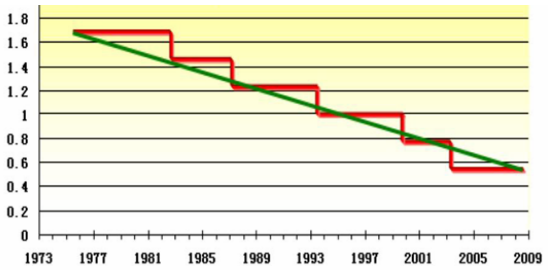


Figure 3. The trend of Low-carbon energy prices (in USD / Kwh)

2.3. The price trend lines two kinds of energy is interactive and relevant

The price trend lines of high-carbon energy and low carbon energy seem to be independent. However, they are essentially interactive and relevant. The reserve of high-carbon energy and the technology level of low-carbon energy have a critical influence on their prices. The coexistence of two types of energy in the market can lead to a dynamic equilibrium price problem [3][4]. If you leave the movement of high-carbon energy price aside, it is obviously incomplete and unscientific to discuss the competitiveness of low-carbon energy in the market. If high-carbon energy prices sustained rising rapidly, the competitiveness of low-carbon energy would be naturally highlighted. If high-carbon energy price continued to drop with fluctuation, the competitiveness of low-carbon energy would be weakened. Climate change is a new driving force to reduce the use of high-carbon energy and promote the development of low-carbon energy. It particularly need government support and the guidance of policy about the environment [5][6].

No matter how the high-energy prices fluctuate, the direction of promoting low-carbon energy by reducing cost via policies remains unchanged. Following by creating high-carbon and low-carbon energy price equilibrium analysis model (EPE analysis model), we can further explore the internal law about the interaction mechanisms of two kinds of energy prices.

3. Establishment equilibrium analysis model of high-carbon energy and low-carbon energy prices and dissection of the model

3.1. Creating equilibrium analysis model of high-carbon energy and low-carbon energy prices

The high-carbon energy history prices trend P_0 indicates the fluctuation of international oil price with reduction

processing. The low-carbon energy prices history trend Y_0 points to the fluctuation of three kinds of low-carbon energy price with reduction processing. Thus, the high-carbon energy and low carbon energy price equilibrium (EPE) analysis model is formed through potential extensions of high-carbon energy and low carbon energy historical price trend lines. (See below Figure 4).

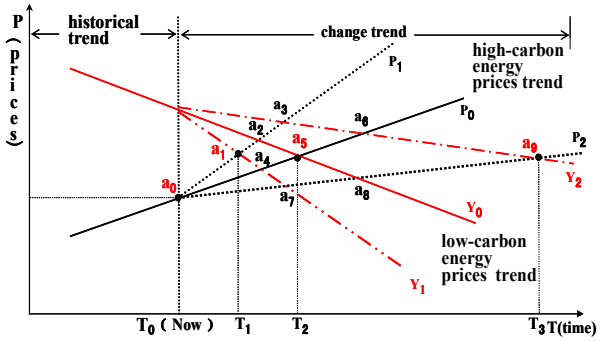


Figure 4. The high-carbon energy and low carbon energy price equilibrium (EPE) analysis model

3.2. High-carbon energy and low -carbon energy price trend lines and distribution of the intersections

Based on the figure, there are three ways for the trend lines of changes in low-carbon energy price (1) the original trend line Y_0; (2) accelerated downturn of the trend line Y_1; (3) slow downturn of the trend line Y_2. There are three types of high-carbon energy price trend lines: (1) The original trend line P_0; (2) accelerated upturn of the trend line P_1; (3) slow upturn trend line P_2.

So there are 9 intersections with the combinations of 6 price trend lines (Figure4. a_1-a_9), in which a_5, the intersection of the high-carbon and low-carbon energy prices in original trend lines Y_0 and P_0, is the benchmark point. There are two most typical intersections: First, the price of low-carbon energy accelerates to decrease while the price of high-carbon energy accelerates to increase, a_1, the intersection of the trend lines Y_1 and P_1, is located at the forefront; second, the price of low-carbon energy decreases slowly while the price of high-carbon energy increases slowly,a_9, the intersection of the trend lines Y_2 and P_2, is located in the last place.

The other intersections a_2, a_3, a_4, a_6, a_7, a_8 are located between a_1-a_9 and around the benchmark point a_5 because up or down movement of high-carbon and low-carbon energy price trend lines are inconsistent.

3.3. The mechanism of the formation of high-carbon energy and low-carbon energy price equilibrium points and policy intervention action

In the absence of influence from external factors and without any policy intervention, high-carbon energy and low- carbon energy maintain the existing situation (T_0) unchanged, that is, high-carbon energy prices do not increase while low-carbon energy prices do not decrease. In that extreme situation, the two type of energy cannot form equilibrium prices. In today's open era of economic globalization, high-carbon and low-carbon energy could not exist in isolation, price changes cannot at a standstill. By the dual constraints of scarcity and limits on greenhouse gas emissions, the increase in high-carbon energy price is apparently predictable, followed by the preference of low-carbon energy. Policy intervention is an objective requirement and undoubted choice, and lower low-carbon energy price is a foreseeable trend. Therefore, the formation of the price equilibrium of the two energies is inevitable.

According to EPE model, high-carbon energy and low-carbon energy price trend lines have different directions, forming four categories, nine price equilibrium points (a_1-a_9) in total, corresponding to the 9 intersection points in Figure 4. Each formation mechanism of equilibrium has a different meaning of interpretation and value of policy analysis:

(1) Benchmark equilibrium: the high-carbon and low-carbon energy prices follow the original trend lines Y_0 and P_0 to intersect at the equilibrium point a_5. Without external political pressure, the development of the two types of energy maintains in the original natural state, completely regulated by the laws of the market, with the price to maintain the original trend. The equilibrium is called the market equilibrium, which is a benchmark to compare the timing of the formation of equilibrium points when the price trends of the two types of energy change.

Apparently, the benchmark equilibrium is a motivator of the price interaction mechanism of the two types of energy. For example, early in this century when oil prices exceeded 70 dollars / barrel, the production of the U.S. fuel ethanol companies was stimulated because the price is the break-even point of the production of fuel ethanol, which is the market benchmark.

(2) The first equilibrium point: high-carbon and low-carbon energy prices are changing along accelerated trends of the curves Y_1 and P_1 to intersect at equilibrium a_1, which is the typical earliest form of equilibrium. On the one hand, the government issues supportive policy and increases efforts to develop low-carbon energy, resulting in accelerated decline in the price of low-carbon energy and at same time use the measures by taxation etc, to accelerate the increase in high-carbon energy price. The dual efforts promote the formation of

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the first price equilibrium point at which the competitiveness of low-carbon energy in price begins to play out at the earliest time. Obviously, the high ground advantage is acquired by positive effectiveness of energy strategy policy.

(3) The latest equilibrium point: high and low-carbon energy prices are changing along the slow trend lines Y_2 and P_2 to intersect at the equilibrium point a_9, which is typical latest form of equilibrium. Due to lack of funding and policy support, low-carbon energy encounters negative factors obstacles such as technical bottlenecks so that low-carbon energy prices are dragged down slowly. At the same time, high-carbon energy sources may be in capacity expansion to defer the increase in high-carbon energy prices, together dragging price equilibrium at the latest arrival. This situation reveals the phenomenon of government's short-sighted vision and incapability, and also runs counter to the international community's anxiety about the global climate change and expectations about relevant policy.

(4) Intermediate equilibrium point: If the changes of high-carbon and low-carbon energy price trend lines are not in step or in reverse development , that is, one energy price develops in accordance with the original trend line while the other energy price develops in accelerated increase (or decrease) trend line or in slow increase (or decrease) trend line; Or, one energy price develops in accelerated increase (or decrease) trend line while the other energy price develops in slow decrease (or increase) trend line, the corresponding equilibrium points are a_2, a_3, a_4, a_6, a_7, a_8, which are earlier than the latest equilibrium a_9 but later than the first equilibrium point a_1. This situation may be caused due to imbalance or delay of the government's policy, which further illustrates the importance of policy adoption.

Thus, the formation of high-carbon and low-carbon energy price equilibrium is the result of interaction of price changes in the two types of energy. The national choice of policy in promoting the usages of high-carbon and low-carbon energy is the critical factor for the timing of formation of price equilibrium.

4. Selection of Policy tools to promote the price competitiveness of low carbon energy

The key to promote the competitiveness of low carbon energy price is to establish the price equilibrium between high-carbon and low-carbon energy. It is scientific and reasonable to set up a systematic research platform of price related and interaction of high-carbon and low-carbon energy and to explore the equilibrium mechanism of the two kinds of energy price in the context of changeable high-carbon energy price which is affected by the development of low-carbon energy. There are several policies for price equilibrium, but their mechanisms and influences are different. The Law on Renewable Energy which is launched in Germany in 2000 is a price mechanism with elastically favorable price to protect low-carbon energy. Based on the change of the high-carbon energy price and the development of low-carbon energy technology, this mechanism of price equilibrium is dynamic [7]. We build the high-carbon energy and low carbon energy price equilibrium (EPE) analysis model. It would be provided as a systemic policy analyzing tool for exploring the inherent laws of interactive prices and studying the functions and impacts in policy making in both qualitative and qualitative approaches.

Currently, the policy research of academia on how to improve the competitiveness of low-carbon energy prices in the policy research focuses on two aspects. First, according to the modes of action and mechanism of the policy, there are direct policy tools and indirect policy tools. Direct policy tools include direct financial subsidy, long-term protective tariff (Feed-in-Traiff), share price and other economic incentives[8][9][10]; indirect policy tools guide the behavior of energy companies mainly through regulation and other non-economic incentives[11][12]. Second, according to the stage of the value chain of low-carbon energy development, there are research and development policy, investment policy, production policy and consumer policy [13]. We believe that these research programs at home and abroad have been some reasonable, but early research was confined to specific times. Especially in the 21st century when energy development patterns and trends in the world have a new change, we need to examine the traditional relationship between high-carbon energy and low carbon energy and make new energy policy for two types of energy equilibrium and the sustainable development from the perspective of resources and the environment to create a favorable policy environment and market mechanisms for accelerating the development of low-carbon.

The ways of policy choosing about improving the competitiveness of low-carbon energy price based on EPE analysis model:

4.1. Close up the gap

Fill up the gap between high-carbon energy and low-carbon prices directly.

(1) Use the financial transfer system and invite public bidding. The government can give priority in the low carbon energy in government purchasing policy.

(2) Implement Compulsory quota system for low-carbon energy, that is, to promote the low carbon energy credit license and build the green business system. High-carbon energy enterprises have to take the responsibility of acquisition quota in low carbon energy.

(3) Keep the stable price of low-carbon energy in long term for the profitability of low-carbon energy firms to

improve the firms' enthusiasm and encourage them to develop the low-carbon energy.

(4) Build the 'carbon budget' system with legally binding. Resource companies, sales companies and the society share the exploitation cost of low-carbon energy to enlarge the environment and social benefit of low carbon energy.

4.2. Change the slope

Lower the cost and price of low-carbon energy indirectly from the end of technology and industry.

(1) Build the special fund for developing low-carbon energy. The state fiscal fund helps to promote the technology and industrialization of low-carbon energy to support its development.

(2) Lead the banks and invest agencies to build the risk investment fund of low carbon energy and encourage private capital take part in technological innovation and exploitation of low-carbon energy.

(3) Include the low-carbon energy technology into the national strategy of science development and increase the commitment in tech innovation of low-carbon energy, increase the R&D funds, and expand R&D team.

(4) Establish the model which demonstrates the low carbon energy's industrialization; put priority in exploiting low -carbon energy to develop the low-carbon energy industry in large scale.

4.3. Adjust to increase and decrease simultaneously

Raise the cost of high-carbon energy and the benefit of low-carbon energy.

(1) Formulate tax policy to levy resource tax from mining high-carbon energy enterprises and resource consumption tax and consumption value-added tax from high-carbon power enterprises, which will be transferred to pay for low-carbon energy industry.

(2) Make the favorable policy for the production and consumption of low-carbon energy; implement duty-free or lower tax rates; provide interest subsidies or low interest loans to reduce the costs of the low-carbon energy companies.

(3) Constrain high-carbon energy consumption and levy CO2 emission tax form high energy-consuming enterprises to promote the enterprise development to low-carbon.

(4) Encourage enterprises to participate in the development of low-carbon energy projects for a gain through the Clean Development Mechanism (CDM) in the international carbon market fostered by the "Kyoto Protocol" to add fresh vitality in order to enhance the competitiveness of low-carbon energy.

In the context of the global endorsement of low-carbon energy, we put the promotion of the competitiveness of low-carbon energy into the system of the change of the prices of high-carbon energy so as to discuss their interactivity and relativity. At the same time, original EPE analytical model is used to work out the mechanism how the trend lines of two types of energy price change and cross (equilibrium). The combination of qualitative and quantitative research method reveals the mode of action and interaction of policy options in achieving equilibrium of energy prices, which can provide the establishment of low-carbon's development policy with scientific basis and theoretical support.

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