Research on Option Pricing Strategies for Forestry Carbon Sinks Based on Black-Scholes Modeling-Take Sanming City as an Example

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Abstract. Sanming City, Fujian Province, is known as the green capital of China. This paper focuses on the local forestry carbon sink projects in Sanming City and analyzes their carbon trading prices based on the real option pricing theory and the Black-Scholes model and concludes that the value of the forestry carbon sink projects in Sanming City has been underestimated. This paper seizes the undervalued situation and puts forward certain suggestions for working on projects to develop forestry carbon sink in Sanming, such as increasing the well-being of residents by utilizing forestry carbon sink projects, increasing the number of trading entities in the carbon market, and perfecting the carbon trading market, etc. It also points out that the rationalization of forestry carbon sink products should be carried out reasonably. At the same time, it also points out the significance of reasonable pricing of forestry carbon sink products for the local carbon trading market, which leads to the significance of the rational development of forestry carbon sinks for China's green development.

1 Introduction

1.1 Research background

Global climate change has become one of the world's most important ecological and environmental issues today, and China has made great contributions to global environmental governance to cope with the worsening climate problems. At the 75th session of the United Nations General Assembly, China formally put forward the "dual carbon" goal of carbon peaking and neutrality. To realize the "dual-carbon" goal, China has been promoting the development of forestry carbon sinks in combination with the theory of a low-carbon economy. Forestry carbon sinks can give full play to the carbon sequestration function of forests, reduce the concentration of greenhouse gases in the atmosphere, slow down global warming, and directly improve the ecological environment. As of 2022, China has set up 18 key forestry carbon sink cities and 21 state-owned forest farms to pilot forestry carbon sinks nationwide and has carried out several forestry carbon sink projects. The rapid development of forestry carbon sinks has a direct effect on mitigating the harm of global climate change, and while improving the global environment, it can obtain green economic gains, facilitating the development of the forestry economy, and contribute to the progress of the forestry industry.

1.2 Literature review

Forestry carbon sinks are an innovative combination of forestry and finance, linking forest carbon sequestration to financial products with multiple benefits. Since the option value of forestry carbon sinks is prosperous, option pricing is assessed for forestry carbon sinks. The trading process of forestry carbon sinks belongs to a kind of carbon trading, and the pricing and optimization of such carbon trading can better promote environmental protection and the social welfare process [1]. Regarding the pricing of forestry projects, scholars earlier evaluated forestry projects based on the traditional Faustmann model and pricing by real option method [2]. Gao Yongqi Pan et al. improved the above method and assessed the value of forestry carbon sinks by binomial tree real options based on the Hartman model [3]. Zhang Kaixuan et al. selected the Black-Scholes option model to evaluate the value characteristics of real options [4]. Anqi Chen et al. analyzed the option characteristics of forest resources [5]. They thought it was necessary to use real options for the value evaluation of forest resources. The Black-Scholes option model also provides a good basis for pricing forestry options, which is a great inspiration for this paper.

1.3 Research framework

In summary, this paper first determines the research method, based on Black-Scholes Modeling, to evaluate the pricing of forestry carbon sink projects through the real options method. Secondly, the research object is selected. Analyze the specific research object with the

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selected method. Summarize the experience according to the results obtained from the analysis, and finally put forward relevant suggestions for developing forestry carbon sinks.

2. Case description

Carbon financial derivatives such as futures and options have played a dominant role in the European carbon market. They have significantly increased the liquidity and marketization of the market, and have contributed greatly to the discovery of the true price of carbon. Forestry carbon is a form of carbon emissions trading that integrates ecological, economic, and social benefits , it is an effective tool for ecological compensation and the realization of ecological product value [6]. By freeing up space at the national level, carbon emissions can be reduced.

China has proposed to develop forestry carbon sinks utilizing the Chinese Certified Emission Reduction (CCER) program. CCER is a voluntary certification which is registered with carbon exchanges. The proposal demonstrates China's commitment to reducing carbon emissions by incentivizing the development of carbon sinks.

By utilizing CCER, China aims to facilitate and promote implementation of low-carbon technologies and practices while promoting sustainable development. The forestry carbon sinks proposed under this initiative have the potential to play a vital role in reducing carbon emissions while providing numerous co-benefits such as biodiversity conservation, soil conservation, and improved ecosystem services. Chinese Certified Emission Reduction is not the only option for some pilots, and the Fujian carbon market can use the Fujian forestry carbon sink [7]. At the end of 2016, the Fujian carbon market included forestry carbon sink trading, pioneering the FFCER. The carbon sink afforestation project in Youxi County, Sanming City, Fujian Province, passed the FFCER project filing in 2018, and this paper selects the project as an example for empirical analysis. Youxi County Forestry Construction and Investment Company operates the Youxi County Carbon Sink Afforestation Project to increase forest carbon sinks, which utilizes the carbon sink function of forests and reforest trees to increase forest carbon sinks, reduce the overall CO2 content in the atmosphere, and achieve the purpose of slowing down the trend of climate warming. The project is in Youxi County, Sanming City, and was developed using a methodology documented by the National Development and Reform Commission (NDRC), with an operating area of 2,283 hm2. The afforestation activities of the proposed project commenced on March 31, 2005, and the first crediting period is from May 01, 2005, to April 30, 2025 (inclusive of the first and last days). During the first 20-year crediting period, the proposed project is expected to generate 561,529t CO2e of GHGs, which will be used as a carbon sink. During the first 20-year crediting period, the proposed project is expected to generate a total of 561,529 tCO2e of GHG emission reductions, with an average annual emission reduction of about 28,076t CO2e.

3. Analysis of the problems

3.1 Data description

The selected site of the Youxi County Carbon Sink Forestation Project is Youxi County, located on the southwest side of the Minjiang River in the middle of Fujian Province. The project's boundary is sketched on-site using a 1:10,000 topographic map and GPS for accuracy control. Then, the plot boundary is determined with the assistance of GIS software (ArcGIS), and the boundary coordinates of the project plot are read to determine the plot boundary.

3.2 Project income

In September 2020, the first phase of monitoring emission reductions of 131,600 tons of CO_2e through the provincial Department of Ecology and Environment for the record and issued in October to enter the Straits Equity Exchange listed on the market, and now complete the transaction of 88,600 tons of CO_2e, the turnover of 14,966,681 yuan.

3.3 Project costs

Forestry carbon sink projects incur costs such as land use fees, afforestation inputs, baseline measurements, monitoring, and carbon sink forest operating costs, along with other inputs.

The silvicultural model involves planting an average of 200 seedlings per mu per year in pure pinyon pine, pure fir, and mixed pinyon pine-fir forests. This is done every year from 2005 to 2012, resulting in annual silvicultural inputs.

3.4 Estimated value of carbon sinks

The project owner, Youxi County Forestry Construction Investment Company, organized the implementation of carbon sink afforestation from 2005 to 2012, with a total afforestation scale of 35,133 mu (2,343 ha), of which 241 mu were afforested in 2005, 447 mu in 2006,1,266 mu in 2007, 575 mu in 2008 and 575 mu in 2009.

Of these, 241 mu were afforested in 2005, 447 mu in 2006, 1,266 mu in 2007, 575 mu in 2008, 3,199 mu in 2009, 21,438 mu in 2010, 7,644 mu in 2011, and 323 mu in 2012. The afforestation tree species are mainly ponytail pine and fir, of which 16,001 mu are fir, 15,927 mu are ponytail pine, and 3,205 mu are mixed fir-horse forests, as shown in Table 1.

Table 1. Sink benefits (Unit: tCO2e·a- 1)

Timing	Project carbon sinks	Cumulative carbon sinks
May 01, 2005-December 31, 2005	13.87	1

January 01, 2006-December 31, 2006	9	10
January 01, 2007-December 31, 2007	50	59
January 01, 2008-December 31, 2008	172	232
January 01, 2009-December 31, 2009	447	679
January 01, 2010-December 31, 2010	1096	1775
January 01, 2011-December 31, 2011	2623	4398
January 01, 2012-December 31, 2012	5617	10014
January 01, 2013-December 31, 2013	10349	20363
January 01, 2014-December 31, 2014	16660	37032
January 01, 2015-December 31, 2015	24059	61082
January 01, 2016-December 31, 2016	31917	92999
January 01, 2017-December 31, 2017	39615	132614
January 01, 2018-December 31, 2018	46640	179254
January 01, 2019-December 31, 2019	52630	231884
January 01, 2020-December 31, 2020	57373	289257
January 01, 2021-December 31, 2021	60790	350047
January 01, 2022-December 31, 2022	62902	412949
January 01, 2023-December 31, 2023	63807	476755
January 01, 2024-December 31, 2024	63645	540400
January 01, 2024-December 31, 2025	21129	561529
Total	561529	

3.5 Estimating the price of carbon sinks

Based on historical data on carbon market transaction prices in Fujian Province from 2017-2022, the gray prediction model is used to determine the transaction prices. The results of the calculations are shown in Table 2.

Table 2. Gray prediction model prediction results (Unit: yuan per ton)

Time	Real value	Predicted value
2017	13.03	13.03
2018	8.90	5.20
2019	9.11	8.25
2020	10.82	13.10
2021	22.64	20.81
2022	37.80	33.04

3.6 Construction of the black-scholes model

The value of forestry carbon sinks consists of two aspects: one is to utilize their inherent capital value, and the other is based on the investor's optionality, i.e., the price of real options. The Black-Scholes model has been used in the study of real options on financial products, and the main feature of the model is reflected in the fact that when investors are faced with the decision of future uncertainty, they can relate the expiration price of the option to the pricing of stocks, thus achieving the accurate pricing of stocks.

The Black-Scholes option pricing model is based on the following assumptions. Firstly, it presumes that the stock price conforms to a normal distribution within a standardized interval. Secondly, it assumes that the financial asset in question will not receive any dividends or other income during the option's lifespan. Lastly, it presupposes that the option is of a European-style breed, i.e., it can only be exercised upon expiry.

Therefore, in this paper, the Black-Scholes model is used to value the real options of forestry carbon sink afforestation projects in Fujian Province and provide a reference for the pricing of forestry carbon sink financial products. According to the forecast data, the gray forecast model was used to derive the volatility of China's treasury bond market c = 0.59, option price sensitivity d1=0.94, the possibility of option implementation d2=0.12, and the interest rate of risk-free treasury bonds r=8%. The value of forestry project is calculated as follows: S_0=267.4 ten thousand yuan ; K=868.4 ten thousand yuan

$$c=S_0 N(d_1)-Ke^{-rT}N(d_2) \quad (1)$$

$$d_1=\frac{\ln(S_0/K)+(r+\sigma^2/2)T}{\sigma T} \quad (2)$$

$$d_2=d_1-\mathrm{c}\ T \quad (3)$$

4. Suggestions

4.1 Selection of tree species

The Carbon Sink Forestation Project in Youxi County is a remarkable initiative to combat climate change by promoting afforestation. The project comprises a vast expanse of land, spanning over 35,133 mu, primarily covered by ponytail pine and fir trees. The project has been meticulously planned, with 16,001 mu dedicated to fir trees, 15,927 mu to ponytail pine, and 3,205 mu to mixed fir-horse forests. The region of Sanming City is known for its abundance of fir and ponytail pine trees, but the project's organizers understand the importance of biodiversity in carbon sequestration. Thus, they have incorporated diverse tree species into the project to enhance its effectiveness.

This approach will reduce the number of carbon sinks that fall short of the expected yield due to targeted disasters and promote rational timber forest replanting. Ultimately, the Carbon Sink Forestation Project will maximize Sanming's forestry strengths, contributing significantly to the region's economic and environmental sustainability.

4.2 Increased well-being of local populations

Increase the income of residents through forestry carbon sink projects. Forestry carbon sink projects increase local forest resources and should focus on increasing the income of forest farmers. Carbon credits afforestation and forest conservation activities provide more employment opportunities for residents and solve the problem of employment of local surplus labor. It is recommended to carry out forestry production work such as afforestation, planting, fostering, care, and fertilization during the project period to improve the quality of life of the local people, thus mobilizing the enthusiasm of the people and promoting the

development of forestry carbon sink projects, which is conducive to the improvement of the value of carbon sink options.

The process of creating forestry carbon sink projects should reduce the pressure on the protection of existing forest resources, especially natural forest resources, promote the structural adjustment of agricultural industries, strengthen the local forestry economy, increase forestry income, and is also an important measure to solve the "three rural" problem [8].

4.3 Improve the carbon trading market and increase the number of trading entities

To accelerate the scale of the carbon trading market, the Sanming government should primarily focus on increasing the number of entities engaged in forestry carbon trading while encouraging the circulation and trading of carbon options. The government should provide additional policy and financial support for forestry carbon sink projects to attract more trading subjects, such as enterprises, to the market. It is important to continuously refine the carbon sink trading mechanism so that a variety of trading subjects can be introduced effectively, which will facilitate the market's growth.

As the carbon trading market advances, carbon sink trading can more efficiently reduce the cost of carbon emission reduction while also generating economic benefits for underdeveloped regions with abundant forest resources [9-11]. Consequently, the value of forestry carbon sinks will be further enhanced, leading to a more sustainable future for the region.

5. Conclusion

5.1 Key findings

This paper analyzes the difficulty of option pricing for forestry carbon sinks and evaluates the investment value of the forestry carbon sink project in Youxi County, Sanming City, Fujian Province, using the gray model and the Black-Scholes model. It is found that the real option value of the forestry carbon sink is too low, and if the real options method is used to price the forestry carbon sink project reasonably and combined with the proposed suggestions to increase the reasonableness of tree species of the forestry carbon sink project, mobilize the enthusiasm of residents to participate in the forestry carbon sink project, improve the carbon financial trading market, and increase the main participants of the carbon trading market, the forestry carbon sink project can be greatly promoted, and the "dual-carbon" project can be facilitated.

5.2 Research significance

It also points out that the rationalization of forestry carbon sink products should be carried out reasonably. At the same time, it also points out the significance of reasonable pricing of forestry carbon sink products for the local carbon trading market, which leads to the significance of the rational development of forestry carbon sinks for China's green development. This can greatly promote the development of forestry carbon sink projects and facilitate the realization of the "double carbon" goal, which is of great significance to the green development of China.

5.3 Limitations and future study

This paper has some limitations in terms of data. Only the data of a forestry carbon sink project in Youxi County of Sanming City is selected, which does not completely cover the pricing problem of forestry carbon sink projects in the whole of Sanming. It may have a large deviation from the actual carbon trading market situation in Sanming. At the same time, the model also has certain limitations. The research on pricing using the real options method needs to be more in-depth, and only by continuously improving the model can we get more accurate prediction results.

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