

Analysis of the Tripartite Evolutionary Game between MRV Institutions, Government, and Enterprises in the Context of the Carbon Trading Market

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Abstract. As the global carbon emission trading market develops, the role of Monitoring, Reporting, and Verification (MRV) institutions is becoming increasingly important. This paper analyzes the tripartite evolutionary game among MRV institutions, local government, and enterprises within the carbon trading market context and explores the impact of various factors on market behavior through sensitivity analysis. We find that changes in carbon prices, market maturity, the rent-seeking cost of enterprises, penalty policies of local government, and the supervisory intensity of MRV institutions significantly influence the strategic choices of the participating entities. Notably, high carbon prices may lead to collusive behaviors between enterprises and local government, while strengthened supervision and a reasonable penalty mechanism can promote fairness and justice in the market.

Keywords: MRV system; Carbon market; Evolutionary game theoryList the; keywords covered; in your paper.

1. Introduction

The successful execution of carbon markets critically relies on local governments and enterprises' participation, yet this interdependence may foster a 'mutual understanding' that jeopardizes the system's integrity. Local governments, driven by economic imperatives, may collude with enterprises to underreport carbon emissions, compromising market fairness and efficacy. This malpractice distorts carbon prices and undermines market trust, emphasizing the urgent need for robust, independent Monitoring, Reporting, and Verification (MRV) institutions. Effective MRV institutions are vital to ensure accurate emissions reporting and to uphold the carbon market's long-term stability and fairness (Rode, 2021; Ren et al., 2021; Wang et al., 2023).

Through the tripartite evolutionary game, this work aims to simulate the strategy choices and interactions of these participants under different scenarios by answering the following questions:

1.How might local government and enterprises adjust their strategies when MRV supervisory institutions strengthen oversight?

2.How should MRV institutions respond when there is a cooperative relationship between local government and enterprises?

3. What are the key factors influencing these strategic choices, as well as the potential impact of these choices.

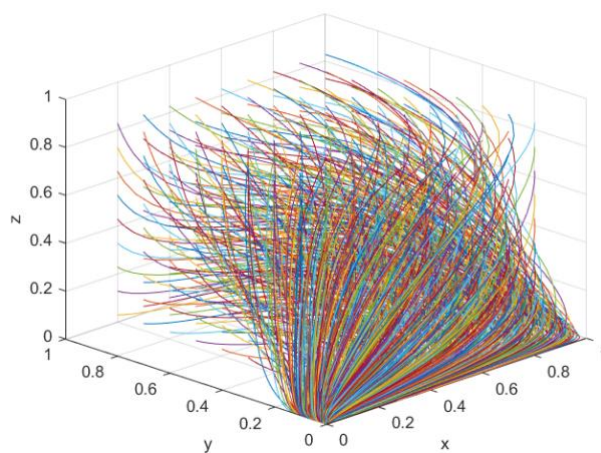
This paper innovatively uncovers the strategic choice in a carbon trading market involving MRV institutions, local government, and enterprises. It demonstrates how various factors, such as carbon price fluctuations, market maturity, and regulatory measures, intricately influence the strategies and interactions of these entities. The study highlights the importance of balancing supervision and incentives to foster honest emission reduction practices and prevent collusion. A significant recommendation is the empowerment of MRV institutions with legal authority and financial independence, ensuring unbiased market supervision. Additionally, the study proposes a flexible supervision mechanism that adapts to the compliance behavior of market participants, using a mix of incentives and penalties to encourage genuine emission reductions. This approach not only provides a theoretical foundation for effective carbon market policies but also offers practical

insights into maintaining market integrity and fairness, thus contributing to global emission reduction goals and sustainable development.

2. Numerical Simulation

Theoretical results suggest that in the absence of strict supervision by independent MRV (Monitoring, Reporting, and Verification) institutions, the strategy choices of local government and enterprises are unlikely to spontaneously evolve towards a stable state of non-collusion and honest emission reduction. The main reason for this phenomenon is that the implementation of environmental policies may affect the economic interests of local government, thereby fostering a potential motive for collusion between local government and enterprises. Therefore, the reinforcement of the supervision function of MRV institutions is particularly important.

The numerical simulation simulates the evolutionary path with the above value assignments as shown in Figure 1. The parameter assignments of the numerical simulation are consistent with the stability criteria of the equilibrium point $(1, 0, 1)$. As can be seen from Figure 4, the final evolutionary direction of the system is also $(1, 0, 1)$. This indicates that the results of the numerical simulation are consistent with the theoretical analysis. Moreover, as the initial intention of MRV institutions to choose a supervision strategy increases, the rate at which it converges to 1 accelerates. Similarly, as the initial willingness of enterprises to choose honest emission reduction increases, the rate at which it converges to 1 also accelerates. Conversely, the smaller the initial willingness of local government to refuse collusion, the greater the rate at which it converges to 0. The initial value changes do not affect the final convergence state of the MRV institutions, local government, and enterprises. This is because the changes in the initial values do not disrupt the stability conditions of that equilibrium point, namely they do not violate the conditions. The analysis of the evolutionary situation of other equilibrium points is similar to that of this equilibrium point.



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3. Literature References

This paper constructs a new tripartite game model based on the carbon market, analyzing the game relationship in reporting and verification behaviors among MRV institutions, emitting enterprises, and government. The aim is to reveal potential collusive behaviors between government and enterprises and to provide theoretical foundations and practical suggestions for central government in formulating MRV policies. This work offers a new perspective for understanding and optimizing the carbon emission verification process and provides valuable references for other regions or countries implementing MRV system.

The payoff matrix for the tripartite evolutionary game is as follows: for each set of strategies, the first row shows the profit of the MRV institutions, the second row shows the profit of the enterprise, and the third row shows the profit of the local government.

Local government	MRV institutions strong supervision		MRV institutions weak supervision 1-X	
	X		Enterprise	
	honesty Z	dishonesty 1-Z	honesty Z	Dishonesty 1-Z
Refuse collusion Y	$S - C_2 + \alpha F$	$S - C_2 - \alpha L + kM_2$	$S + \alpha F$	$S - \alpha L$
	$R_1 - C_1 + P_1$	$R_2 - P_2 - N - kM_2$	$R_1 - C_1 + P_1$	$R_2 - P_2 - N$
	$U_2 + \beta F$	$U_2 - \beta L + N$	$U_2 + \beta F$	$U_2 - \beta L + N$
Accept collusion 1-Y	$S - C_2 + kM_1 + \alpha F$	$S - C_2 + k(M_1 + M_2) - \alpha L$	$S + \alpha F$	$S - D - \alpha L$
	$R_1 - C_1 + P_1$	$R_2 + P_1 - Q - kM_2$	$R_1 - C_1 + P_1$	$R_2 + P_1 - Q$
	$U_1 - kM_1 + \beta F$	$U_1 - \beta L - kM_1 + Q$	$U_1 + \beta F$	$U_1 - \beta L + Q$

4. Summary

This study conducts an in-depth analysis of the tripartite evolutionary game among MRV institutions, local government, and enterprises in the context of the carbon trading market, revealing how several key factors influence the strategy choices and interaction patterns of each party. The results of the sensitivity analysis show:

1. An increase in carbon price leads to strengthened supervision by MRV institutions, a tendency for local government to collude with enterprises, and a gradual shift by enterprises towards honest emission reduction.

2. The rising maturity of the carbon market increases the profits from fraudulent emission reduction by enterprises, leading to a tendency towards dishonest reduction, while MRV institutions tend to intensify supervision.

3. As the rent-seeking costs for enterprises increase, local government may rapidly shift towards a collusion strategy, and high rent-seeking costs may compel enterprises to adopt honest emission reduction, possibly leading MRV institutions to weaken their supervision intensity.

4. Additional fines imposed by local government on enterprises encourage a shift towards honest emission reduction strategies by enterprises, accelerate the decision-making speed of local government to refuse collusion, and may slow down the supervisory momentum of MRV institutions.

5. Enhanced supervisory intensity by MRV institutions increases their income from fines, thereby sustaining a strong supervision strategy and influencing the collusion and emission reduction strategies of local government and enterprises.

These findings highlight the complex dynamic relationships that need to be considered in the design and implementation of carbon trading market policies. Particularly, the results indicate that adjustments in price mechanisms, market maturity, rent-seeking costs, penalty policies, and

supervisory intensity significantly impact the behavior of market participants. Therefore, policymakers should consider these factors comprehensively when optimizing the design and operation of the carbon market to ensure its effectiveness and fairness. The study also reveals areas that need further exploration, especially the importance of standardizing MRV in the global carbon market. Future research should further analyze the optimal supervisory intensity of MRV institutions under different market conditions and how to balance supervision costs with market credibility. This study provides a theoretical foundation and empirical support for formulating evidence-based carbon market policies, contributing to achieving global emission reduction goals and promoting sustainable development.

Central government should legislate to affirm the independence and authority of MRV institutions as supervisory entities. This includes providing MRV institutions with the necessary legal authorization to conduct market supervision, data auditing, compliance assessment, and enforcement of penalty measures. At the same time, ensuring the financial independence and decision-making freedom of MRV institutions is crucial to avoid interference from political and commercial interests, thereby guaranteeing the fairness and objectivity of the supervision results. Additionally, a flexible supervision mechanism can be designed, adjusting the frequency and intensity of MRV institution's supervision based on market behavior and risk assessment. In cases where enterprises and local government demonstrate good compliance records, a more relaxed supervisory strategy could be adopted, encouraging honest emission reduction behaviors through incentives such as tax reductions, financial subsidies, or public commendation.

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