Evolutionary Game Analysis of Copyright Protection for Digital Content Products (Postprint)

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Abstract

[Purpose/Significance] Evolutionary game analysis based on copyright protection facilitates the investigation of whether original entities of digital content products exhibit tolerance toward counterfeiting behavior, as well as the strategic choices for implementing copyright protection under varying counterfeiting levels, thereby offering guiding significance for regulating the behavior of market entities in digital content products.

[Method/Process] First, employing an evolutionary game model, we analyze the interest evolution process between original and counterfeiting entities, and explore the tolerance behavior of original entities toward counterfeiting levels under copyright protection; subsequently, by refining the profit function models for both parties in the game, we investigate the determinants of the tolerance level of original entities.

[Results/Conclusion] Original entities demonstrate certain tolerance for low levels of counterfeiting, while maintaining zero tolerance for high levels of counterfeiting. The maximum tolerance level for counterfeiting is jointly determined by four factors: the counterfeiting cross-benefit coefficient, the revenue model constant coefficient, the product R&D cost coefficient, and the multiplier of the original entity's product R&D effort level.

Full Text

Evolutionary Game Analysis of Copyright Protection for Digital Content Products

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Abstract

[Purpose/Significance] An evolutionary game analysis of copyright protection helps explore whether original creators of digital content products exhibit tolerance toward counterfeiting behavior and informs strategic choices for implementing copyright protection under varying counterfeiting levels, offering guidance for regulating market participant behavior in digital content markets.

[Method/Process] This study first employs an evolutionary game model to analyze the interest evolution process between original creators and counterfeiters, examining original creators' tolerance behavior toward counterfeiting levels under copyright protection. It then refines the profit function models for both parties to investigate the determinants of original creators' tolerance levels.

[Results/Conclusions] Original creators demonstrate tolerance for low-level counterfeiting but zero tolerance for high-level counterfeiting. The maximum tolerable counterfeiting level is jointly determined by four factors: the counterfeiting cross-benefit coefficient, the revenue model constant coefficient, the product R&D cost coefficient, and the original creator's product R&D effort multiplier.

Keywords: Digital Content Products; Copyright Protection; Counterfeit Level Tolerance; Evolutionary Game

1. Introduction

Digital content products represent a new product form centered on creativity and delivered through digital carriers [1]. These refer to clearly copyrighted content resources owned by rights holders, including audio-visual programs (materials), images, manuscripts, and commercial data stored in digital formats, which possess significant social and commercial value [2]. With the global information technology revolution, China's digital publishing industry has developed rapidly. In 2016, China's digital publishing industry generated total revenue of 572 billion yuan, representing a 29.9% year-over-year increase from 2015. Digital reading content alone grew by 88.2%, indicating the formation of a massive digital content consumption market.

However, digital content products are easily replicated and disseminated. With computer technology, high-quality pirated digital content can be readily produced, leading to rampant digital content piracy that causes tens of billions of dollars in annual losses to the global economy [3]. Consequently, regulating market participant behavior and ensuring digital content product quality have become critical research topics in the platform-based service economy era.

Copyright protection systems serve as powerful tools for constraining piracy and safeguarding rights holders' legitimate interests. Implementing copyright protection for digital content products is essential for achieving innovation-driven development. Existing research has examined digital content product copyright protection from two perspectives:

Technical Approaches: These focus primarily on patent technology descriptions and applications. J.M. Acken [4], Yu Guangzhou [5], and L.H. Zhang et al. [6] proposed copyright management schemes based on watermarking technology, which embeds data (such as watermarks) into digital content products to provide more effective copyright protection. T. Bause & S. Ng [7] introduced multi-channel embedded data technology, while Y.T. Chia [8] proposed a digital rights management system operating in distributed networks where content distributors can form encrypted digital content to protect copyrights. M.S. Wang [9] and C.Y. Chou et al. [10] suggested using uncopiable data storage disks in secure data storage systems within digital content and rights object management systems. M.S. Chang et al. [11] proposed that user devices could enhance digital content protection through partitioned secure/normal modes and device authentication.

Legal Approaches: These primarily involve discussions of copyright protection mechanisms. Xiong Li et al. [12] examined copyright management from the user perspective, finding that technological means alone cannot eliminate user infringement and that legal measures are necessary. K.J. Park [13] analyzed revenue functions, discovering that monetary incentives constitute the primary cause of illegal copying, with both monetary and psychological utility positively influencing attitudes and behaviors toward illegal duplication, thus suggesting that copyright protection mechanisms should reduce counterfeiters' monetary gains. L. Guo & X. Meng [14] studied how copyright protection affects consumer search costs, finding that stricter mechanisms can induce lower ex post surplus expectations, thereby reducing consumers' motivation to search for pirated products. Zhang Xumei et al. [15] used two-stage game analysis to demonstrate that when counterfeiting levels are high, governments can constrain piracy through strict copyright protection systems.

While existing literature addresses copyright protection from technical and legal perspectives, technical approaches emphasize patent applications without considering global cost-benefit issues, whereas legal approaches focus on theoretical discussions without effective data validation. This paper simultaneously considers both aspects by internalizing patent technology application costs and focusing on copyright protection system implementation. Through constructing an evolutionary game model between original creators and counterfeiters of digital content products, it analyzes how original creators implement copyright protection adaptively based on counterfeiting levels, explores original creators' tolerance behavior toward counterfeiting under copyright protection, and further analyzes determinants of this tolerance level using refined profit function models. Numerical simulations validate the theoretical models and conclusions throughout.

2. Evolutionary Game Model Between Original and Counterfeiting Subjects

Evolutionary game theory, rooted in biological evolution concepts, assumes bounded rationality rather than complete rationality. Game populations select strategies based on previous outcomes—choosing higher-benefit strategies after low or negative returns—and through individual learning and intergroup influence, eventually converge on uniform strategies to achieve system equilibrium [16].

2.1 Model Establishment and Basic Assumptions

The game involves two parties: digital content product original creators and counterfeiting subjects. Both possess bounded rationality as "economic agents," and information asymmetry during gameplay creates significant uncertainty in decision-making.

Original Creators: These comprise all organizations and individuals in the digital content product industry. Original creators implement copyright protection to safeguard digital content asset value. However, during initial product launch phases, they may relax copyright protection to rapidly increase product awareness. Considering supervision and enforcement costs, they cannot pursue every counterfeiting instance. Therefore, this model assumes original creators implement copyright protection with a certain probability.

Counterfeiting Subjects: These are economic speculators who produce and distribute copyrighted digital content products through imitation, plagiarism, or piracy for illegal profit. Faced with substantial profit temptations, they may engage in illegal operations for windfall gains or abandon counterfeiting due to fear of legal sanctions. Based on bounded rationality assumptions, counterfeiting subjects adapt strategies according to original creators' copyright protection implementation. Thus, this group also adopts counterfeiting behavior with a certain probability.

Strategy Choices: - Original creators have two strategies: "Enforce Rights" (维权) and "Not Enforce Rights" (不维权) - Counterfeiting subjects have two strategies: "Counterfeit" (仿冒) and "Not Counterfeit" (不仿冒)

The strategy combinations are shown in .

Model Parameters: - C_O: Original creator's R&D cost (content production and intellectual capital investment) - R_O: Original creator's product revenue (from digital content dissemination) - C_S: Original creator's supervision and rights enforcement costs (human, material, and financial resources) - R_S: Compensation obtained through successful rights enforcement - C_F: Counterfeiter's manufacturing cost for illegal copies - R_F: Counterfeiter's product revenue (assuming consumers cannot distinguish or prefer counterfeits) - R_S: Compensation for damages when counterfeiting is discovered and prosecuted

The payoff matrix is shown in .

2.2 Equilibrium Analysis of the Evolutionary Game

2.2.1 Payoff Analysis Assume strategy choices are random, independent, and can be repeated simultaneously. Initially, let α represent the proportion of original creators choosing "Enforce Rights" and $(1-\alpha)$ those choosing "Not Enforce Rights." Let β represent the proportion of counterfeiters choosing "Counterfeit" and $(1-\beta)$ those choosing "Not Counterfeit."

Original Creators: - Fitness when enforcing rights: $U_{1O} = \beta[R_O - C_O + R_S - C_S] + (1-\beta)[R_O - C_O - C_S] = \beta R_S + R_O - C_O - C_S$ (Formula 1) - Fitness when not enforcing: $U_{2O} = \beta(R_O - C_O) + (1-\beta)(R_O - C_O) = R_O - C_O$ (Formula 2) - Average fitness: $U_O = \alpha U_{1O} + (1-\alpha)U_{2O} = \alpha\beta R_S - \alpha C_S + R_O - C_O$ (Formula 3)

Counterfeiters: - Fitness when counterfeiting: $U_{1F} = \alpha[R_F - C_F - R_S] + (1-\alpha)(R_F - C_F) = R_F - C_F - \alpha R_S$ (Formula 4) - Fitness when not counterfeiting: $U_{2F} = 0$ (Formula 5) - Average fitness: $U_F = \beta U_{1F} + (1-\beta)U_{1F} = -\alpha\beta R_S + \beta(R_F - C_F)$ (Formula 6)

2.2.2 Replicator Dynamic Equation for Original Creators From Formulas 1-3, the replicator dynamic equation for the proportion of original creators enforcing rights is:

$F(\alpha) = \frac{d\alpha}{dt} = \alpha(U_{1O} - U_O) = \alpha(1-\alpha)[\beta R_S - C_S]$ (Formula 7)

If $\beta = \frac{C_S}{R_S}$, then $F(\alpha) = 0$, meaning all levels are stable states. If $\beta \neq \frac{C_S}{R_S}$, solving $F(\alpha) = 0$ yields two stable states: $\alpha = 0$ and $\alpha = 1$.

Taking the derivative: $F'(\alpha) = (1-2\alpha)[\beta R_S - C_S]$ (Formula 8)

Evolutionary stable strategy requires $F'(\alpha) < 0$ [17], requiring analysis of $\beta R_S - C_S$:

1. If $\beta R_S - C_S < 0$ (i.e., $\beta < \frac{C_S}{R_S}$), then $\alpha = 0$ is evolutionarily stable
2. If $\beta R_S - C_S > 0$ (i.e., $\beta > \frac{C_S}{R_S}$), then $\alpha = 1$ is evolutionarily stable

2.2.3 Replicator Dynamic Equation for Counterfeiters From Formulas 4-6, the replicator dynamic equation for the proportion of counterfeiters is:

$F(\beta) = \frac{d\beta}{dt} = \beta(U_{1F} - U_F) = \beta(1-\beta)[R_F - C_F - \alpha R_S]$ (Formula 9)

If $\alpha = \frac{R_F - C_F}{R_S}$, then $F(\beta) = 0$, meaning all levels are stable states. If $\alpha \neq \frac{R_F - C_F}{R_S}$, solving $F(\beta) = 0$ yields stable states $\beta = 0$ and $\beta = 1$.

Taking the derivative: $F'(\beta) = (1-2\beta)[R_F - C_F - \alpha R_S]$ (Formula 10)

Evolutionary stability requires $F'(\beta) < 0$, requiring analysis of $R_F - C_F - \alpha R_S$:

1. If $R_F - C_F - \alpha R_S < 0$ (i.e., $\alpha > \frac{R_F - C_F}{R_S}$), then $\beta = 0$ is evolutionarily stable
2. If $R_F - C_F - \alpha R_S > 0$ (i.e., $\alpha < \frac{R_F - C_F}{R_S}$), then $\beta = 1$ is evolutionarily stable

The equilibrium points are $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$, and (α_0, β_0), where $\alpha_0 = \frac{R_F - C_F}{R_S}$ and $\beta_0 = \frac{C_S}{R_S}$. When $\alpha_0 \in (0,1)$ and $\beta_0 \in (0,1)$, the evolutionary game phase diagram is shown in [Figure 1: see original paper].

2.3 Stable Strategy Analysis

For Original Creators: If enforcement cost C_S exceeds compensation R_S, then $\alpha = 0$ is evolutionarily stable. Regardless of initial counterfeiting levels, original creators evolve toward "Not Enforce Rights" when enforcement costs exceed benefits. As rational economic agents, profit losses eliminate their enforcement motivation, leading to tolerance of illegal counterfeiting.

If $C_S < R_S$ (i.e., $0 < \beta_0 < 1$), original creators' strategy evolution divides into two cases: - When counterfeiting proportion $\beta < \beta_0$, original creators ultimately choose "Not Enforce Rights" - When $\beta > \beta_0$, original creators ultimately choose "Enforce Rights"

Here, β_0 represents the tolerable proportion of counterfeiters—the counterfeiting level tolerance. When many counterfeiters exist ($\beta > \beta_0$), original creators increase supervision and enforcement to protect copyright interests and market share, evolving toward "Enforce Rights." When few counterfeiters exist ($\beta < \beta_0$), compensation is insufficient to motivate enforcement, and original creators may tolerate counterfeiting for brand promotion benefits, evolving toward "Not Enforce Rights."

For Counterfeiters: If operating revenue ($R_F - C_F$) exceeds penalties R_S, then $\beta = 1$ is evolutionarily stable. Regardless of original creators' enforcement levels, counterfeiters evolve toward "Counterfeit" when profitable. If $R_F < C_F$, then $\beta = 0$ is evolutionarily stable—counterfeiters exit when unprofitable.

If operating revenue is less than penalties, counterfeiters exhibit risk-taking behavior with two evolutionary paths: - When original creators' enforcement is low ($\alpha < \alpha_0$), counterfeiters gamble on avoiding detection and choose "Counterfeit" - When enforcement is high ($\alpha > \alpha_0$), detection probability increases, counterfeiters' 侥幸心理 (lucky mentality) collapses, and they evolve toward "Not Counterfeit"

2.4 Evolutionary Path Simulation Analysis

Based on the replicator dynamic equations, solving the differential equations yields time-dependent formulas for strategy proportions:

Original creators' enforcement proportion: $\alpha = \frac{e^{(\beta R_S - C_S)t}}{1+e^{(\beta R_S - C_S)t}}$ (Formula 11)

Counterfeiters' counterfeiting proportion: $\beta = \frac{e^{(R_F - C_F - \alpha R_S)t}}{1+e^{(R_F - C_F - \alpha R_S)t}}$ (Formula 12)

Simulation analysis shows that specific α and β values don't affect the evolutionary stable strategy, only the time to reach equilibrium. Parameter assignments for different scenarios produce the following stable states:

1. **When $C_S > R_S$ and $R_F > C_F$:** Evolutionarily stable strategy is $(0, 0)$. As shown in [Figure 2: see original paper], counterfeiters face technical barriers where manufacturing costs exceed revenue, while original creators lack resources to establish supervision systems, making enforcement costs exceed compensation. Both parties choose (Not Enforce, Not Counterfeit).
2. **When $C_S > R_S$ and $R_F - C_F > R_S$:** Evolutionarily stable strategy is $(0, 1)$. As shown in [Figure 3: see original paper], as counterfeiters overcome technical barriers and reduce manufacturing costs, counterfeiting becomes profitable—even exceeding penalty losses—driving evolution toward "Counterfeit." Original creators, focused on R&D and promotion, cannot address counterfeiting, resulting in (Not Enforce, Counterfeit).
3. **When $0 < C_S < R_S$ and $0 < R_F - C_F < R_S$:** Evolutionarily stable strategies vary by initial proportions, as shown in .

** Evolutionary Stable Strategies Under Different Strategy Proportions**

Condition	Stable Strategy
$\alpha < \alpha_0$, $\beta < \beta_0$	$(0, 1)$
$\alpha < \alpha_0$, $\beta > \beta_0$	$(1, 1)$
$\alpha > \alpha_0$, $\beta > \beta_0$	$(1, 0)$
$\alpha > \alpha_0$, $\beta < \beta_0$	$(0, 0)$

Simulation results under different parameters are shown in [FIGURE:4(a)]-[FIGURE:4(d)], with common parameters: $C_S = 4$, $R_S = 8$, $R_F = 8$, $C_F = 4$.

When gameplay falls in Region C (low counterfeiting proportion), original creators tolerate 零星 (sporadic) counterfeiters with immature technology, leading to evolution toward $(0, 1)$. As tolerance persists, counterfeiters improve technology, reduce costs, and increase market circulation, moving gameplay to Region B and threatening original creators' interests. Original creators then intensify supervision, evolving toward $(1, 1)$. Excessive counterfeiting disrupts market order, prompting original creators to increase enforcement and impose high penalties, moving gameplay to Region A and evolving toward $(1, 0)$. As enforcement intensifies, counterfeiters face excessive penalties, exit the market, and gameplay moves to Region D where few counterfeiters remain. Without penalty compensation, original creators relax supervision, and the market normalizes toward $(0, 0)$.

2.5 Conclusion Analysis

The evolutionary game analysis yields three key conclusions:

1. **Profit drives strategy selection.** When strategy costs exceed benefits, parties abandon that strategy, consistent with bounded rationality assumptions.

2. **Original creators tolerate low counterfeiting levels.** As shown in [Figure 3: see original paper] and [FIGURE:4(a)], when counterfeiting proportions are small, original creators relax supervision. Objectively, immature counterfeiting technology poses minimal threat, and low-level counterfeiting may provide brand promotion benefits. Subjectively, initial supervision costs are high while compensation is insufficient, reducing enforcement motivation.

3. **High counterfeiting levels create adversarial dynamics.** As shown in [FIGURE:4(b)]-[FIGURE:4(d)], rising counterfeiting levels prompt original creators to gradually increase supervision until counterfeiters are expelled. Different initial proportion selections lead to different evolutionary stable strategies—a process reflecting market mechanism self-regulation.

3. Analysis of Original Creators' Counterfeiting Level Tolerance

The evolutionary game conclusions confirm that original creators exhibit tolerance toward counterfeiting. To explore how original creators should determine this tolerance level, this section constructs refined profit function models for both parties.

3.1 Profit Function Model Parameters

Counterfeiters' R&D Cost (C_F): In the R&D domain, costs follow: $C_F = \frac{\gamma\sigma^2}{2}$, where $\gamma > 0$ determines the R&D cost coefficient (higher γ means lower profitability) [18], and $\sigma > 0$ represents the counterfeiter's investment cost—the tolerated counterfeiting effort level (higher σ means higher counterfeiting level).

Counterfeiters' Revenue (R_F): Following Chen Zhenling et al. [19], the revenue model is: $R_F = \tau \ln \sigma$, where τ is a constant coefficient. This logarithmic function reflects that counterfeiting revenue positively correlates with effort but does not increase indefinitely, capturing digital products' unique characteristics distinct from conventional quantity-price functions.

Original Creators' R&D Cost (C_O): $k\sigma$ represents original creators' investment cost, where $k > 1$ indicates original creators' effort level is a multiple of counterfeiters' and necessarily higher: $C_O = \frac{\gamma(k\sigma)^2}{2}$.

Original Creators' Revenue (R_O): Similarly, $R_O = \tau \ln(k\sigma)$.

Cross-Benefit Coefficient (δ): δR_F represents original creators' cross-benefit—the net value of brand promotion benefits minus market share losses from counterfeiting. $\delta > 0$ indicates positive net cross-benefit, the condition under which original creators tolerate counterfeiting.

Within tolerable counterfeiting levels, original creators don't enforce rights, so compensation is excluded. The profit functions are:

Original creator profit: $\pi_O = \tau \ln(k\sigma) - \frac{\gamma(k\sigma)^2}{2} + \delta\tau \ln \sigma$ (Formula 13)

Counterfeiter profit: $\pi_F = \tau \ln \sigma - \frac{\gamma\sigma^2}{2}$ (Formula 14)

3.2 Profit Function Model Solution

In this scenario, counterfeiters and original creators have a cooperative relationship—greater counterfeiter effort yields larger cross-benefits for original creators. Therefore, original creators' profit maximization depends on counterfeiters' cooperation.

First, solve counterfeiters' profit maximization by setting first-order condition $\frac{d\pi_F}{d\sigma} = 0$: $\frac{\tau}{\sigma} - \gamma\sigma = 0$. With $\sigma > 0$, the solution is $\sigma^* = \sqrt{\frac{\tau}{\gamma}}$. Thus, counterfeiters' effort range is $\sigma_1 \in \left(0, \sqrt{\frac{\tau}{\gamma}}\right]$.

Then solve original creators' profit maximization: $\frac{d\pi_O}{d\sigma} = 0$ yields $\frac{(1+\delta)\tau}{\sigma} - k^2\gamma\sigma = 0$. With $\sigma > 0$, the solution is $\sigma^* = \sqrt{\frac{(1+\delta)\tau}{k^2\gamma}}$. The effort range is $\sigma_2 \in \left(0, \sqrt{\frac{(1+\delta)\tau}{k^2\gamma}}\right]$.

Before counterfeiters reach maximum profit, they increase effort to pursue greater profits. Once maximized, they stop additional effort and abandon cooperation. Therefore, original creators' profit maximization condition depends on counterfeiters and requires $\sigma_2 < \sigma_1$.

Original creators' maximum profit is:

When $0 < \frac{(1+\delta)\tau}{k^2} \leq 1$: $\max \sigma = \sigma^* = \sqrt{\frac{(1+\delta)\tau}{k^2\gamma}}$

When $\frac{(1+\delta)\tau}{k^2} > 1$: $\max \sigma = \sigma^* = \sqrt{\frac{\tau}{\gamma}}$

3.3 Tolerance Level Analysis

From Section 3.2, when $0 < \frac{(1+\delta)\tau}{k^2} \leq 1$, original creators' maximum tolerable counterfeiting level is $\sqrt{\frac{(1+\delta)\tau}{k^2\gamma}}$. When $\frac{(1+\delta)\tau}{k^2} > 1$, the maximum tolerable level is $\sqrt{\frac{\tau}{\gamma}}$.

Numerical simulation illustrates original creators' profit function trends across counterfeiting levels. Assuming $\gamma = 1$, $\tau = 4$, and $k = 3$, with cross-benefit coefficients $\delta = 5, 10, 20, 50, 100$, the results are shown in [Figure 5: see original paper].

[**Figure 5: see original paper**] Simulation results show original creators' profit first increases then decreases with counterfeiting level, with an extremum point representing maximum tolerable counterfeiting level. Given other parameters, profit first decreases then increases with δ, while maximum tolerable level σ^* increases with δ. Similar simulations verify relationships between tolerable level σ^* and other parameters in .

** Relationship Between Tolerable Counterfeiting Level σ^* and Other Parameters**

Parameter Change	Maximum Tolerable Level σ^* Change
$\delta \uparrow$	$\sigma^* \uparrow$, π_O first $\downarrow$ then $\uparrow$
$\tau \uparrow$	$\sigma^* \uparrow$, π_O first $\downarrow$ then $\uparrow$
$\gamma \uparrow$	$\sigma^* \downarrow$, π_O first $\uparrow$ then $\downarrow$
$k \uparrow$	$\sigma^* \downarrow$, π_O first $\uparrow$ then $\downarrow$

Thus, in digital content markets, original creators can adopt appropriate tolerance strategies to constrain counterfeiters while increasing profits:

1. **Increasing δ and τ raises tolerance.** Higher τ increases profit margins, making minor market share losses less concerning. Higher δ means counterfeiting benefits exceed losses, potentially encouraging market expansion.
2. **Increasing γ reduces tolerance.** Higher R&D cost coefficients reduce profitability, making market share losses from counterfeiting more damaging.
3. **Increasing k reduces tolerance.** Higher original creator effort multiples indicate advanced technology creating high barriers for counterfeiters, making original creators more sensitive to counterfeiting.

Conclusion

This evolutionary game analysis of digital content product copyright protection yields three key findings:

1. **Both original creators and counterfeiters are profit-driven bounded rational economic agents.** All strategy choices depend on benefits exceeding costs.
2. **Original creators tolerate low counterfeiting levels** when considering objective and subjective factors, but exhibit zero tolerance for high levels.

3. **High counterfeiting levels create adversarial dynamics.** Original creators gradually intensify supervision until counterfeiters exit the market.

Different initial strategy proportions lead to different evolutionary stable strategies—a natural market mechanism process.

The refined profit function model further reveals that original creators' counterfeiting tolerance level is jointly determined by four factors: counterfeiting cross-benefit coefficient, revenue model constant coefficient, product R&D cost coefficient, and original creators' product R&D effort multiplier. Specifically:

- When $0 < \frac{(1+\delta)\tau}{k^2} \leq 1$, maximum tolerable level is $\sqrt{\frac{(1+\delta)\tau}{k^2\gamma}}$
- When $\frac{(1+\delta)\tau}{k^2} > 1$, maximum tolerable level is $\sqrt{\frac{\tau}{\gamma}}$

These conclusions provide theoretical guidance for original creators to appropriately manage counterfeiting tolerance, implement copyright protection systems timely, and regulate digital content market participant behavior.

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Author Contributions

Zhao Yan: Proposed research ideas and paper framework, collected and organized materials, wrote and revised the paper.

Wang Wenju: Guided model construction and paper writing.

Ni Yuan: Determined research ideas and paper framework, provided revision suggestions.

Note: Figure translations are in progress. See original paper for figures.