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Tripartite Evolutionary Game Analysis of Governance for Magic Performances Involving Animals in Digital Media: Interactions among Magicians, Exposers, and Content Platforms

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Abstract: Digital platforms have transformed magic performances involving animals from largely stage-bound practices into recordable, distributable, and publicly contested content. This transformation creates interdependent tensions among animal-welfare oversight, the protection of magic secrets, short-term traffic incentives, creator interests, and the long-term governance objectives of content platforms. This study develops a tripartite evolutionary game model involving magicians, content publishers who expose magic-related information (hereafter, exposers), and content platforms. Magicians choose between animal-friendly innovative magic and traditional live-animal magic; exposers choose between public exposure and compliance with professional and platform norms; and platforms choose between active content governance and traffic-oriented recommendation. Replicator dynamics and Jacobian-based stability analysis are used to characterize the evolutionary equilibria, followed by numerical simulations under different initial strategy probabilities, platform-governance benefits, penalty intensities, and exposure-related losses. The results show that the animal-friendly governance equilibrium is asymptotically stable when the payoff from public exposure is lower than the combined non-platform constraint, long-term compliance benefit, and platform penalty, and when the platform's governance benefit exceeds its governance cost plus the baseline recommendation benefit available under non-governance. Numerical analysis further shows that platform-governance benefits can change the evolutionary destination, whereas penalty intensity primarily affects convergence speed and exposure-related losses mainly influence the transient behavior of magicians. These findings connect animal-welfare assessment, professional norms in magic, and platform governance within a unified incentive-based framework and suggest that sustainable governance depends more on reshaping long-term payoff structures than on punishment alone.

Keywords: Magic performances involving animals, animal welfare, digital media, platform governance, tripartite evolutionary game.

1. Introduction and Literature Review

The use of live animals in magic has a long history. Doves, rabbits, and other animals have commonly been incorporated into appearance, disappearance, transformation, and related stage effects because of their visual salience and inherent unpredictability. However, live animals cannot be evaluated merely as performance props. Contemporary animal-welfare frameworks have moved beyond the prevention of obvious injury and increasingly consider nutrition, physical environment, health, behavioral opportunities, and mental state. Welfare assessment therefore requires attention not only to negative experiences but also to opportunities for positive welfare states [1, 2].

Evidence from circus and related entertainment settings provides an important basis for evaluating animal use in magic. Research has identified potential welfare concerns associated with frequent transportation, restricted housing, social isolation, limited behavioral expression, and repeated exposure to unfamiliar environments [3–5]. Work on animal ethics in tourism has similarly emphasized that entertainment value does not, by itself, negate the ethical costs associated with animal suffering [6, 7]. Although these studies were not conducted specifically in magic performances, the underlying concerns are relevant to transportation, housing, backstage waiting, training, lighting, noise exposure, handling, and performance conditions in animal-based magic.

A further difficulty is that stakeholders do not necessarily agree on what constitutes acceptable welfare. Research involving circus professionals, veterinarians, and animal-rescue personnel has shown that stakeholders may all acknowledge the importance of welfare while reaching different conclusions about whether animals enjoy performance, whether existing care is adequate, and whether entertainment purposes justify animal use [5]. Similar disagreements can arise in magic. Performers may emphasize long-term husbandry experience, artistic tradition, and established human–animal interaction, whereas members of the public or animal-welfare organizations may place greater emphasis on less visible costs associated with training, transport, waiting conditions, and stress. Magic involving animals should therefore be understood not only as a technical form of stage entertainment but also as a governance issue involving performers, audiences, professional communities, welfare experts, and digital intermediaries.

Digital media substantially alter this governance environment. Short-video platforms, livestreaming services, and social media reduce the cost of recording, distributing, commenting on, and reporting performance practices. Social media can disseminate conservation information, mobilize public participation, and contribute to organizational or policy responses, but it can also amplify misinformation, sensationalized animal content, and exploitative

representations [8]. Survey evidence concerning animal videos on social media further indicates that suffering may sometimes be obscured by narratives of entertainment or cuteness, while many viewers support warning labels for content involving animal distress [9]. Hashtags, sharing, and user mentions can connect citizens, advocacy organizations, media actors, and industry participants into networked issue publics [10, 11].

Content publishers who expose magic-related practices therefore cannot be treated as a homogeneous group. Visual evidence may support legitimate animal-welfare oversight, but exposure can also be packaged through moralized headlines, decontextualized clips, or sensational claims to maximize attention. In this study, public exposure refers specifically to unregulated or traffic-oriented exposure, including the unnecessary disclosure of secret methods or the sensational amplification of unverified allegations. By contrast, compliance includes evidence-based reporting through appropriate channels, authorized educational content, professional commentary, and other forms of responsible disclosure.

Magic also differs from many other animal-based performances because secrecy is part of the product itself. Artistic value can depend on apparatus design, operational methods, misdirection, and narrative timing. Digital culture has weakened professional control over the boundaries of knowledge circulation, increasing reliance on professional ethics, peer reputation, and community norms to protect creative work [12]. At the same time, exposure is not inherently uniform in its consequences. Its legitimacy depends on its purpose, evidence, target, authorization, scope, and level of technical detail [13]. Research on science-of-magic communication further suggests that explaining selected principles does not necessarily reduce appreciation of magic and may, in appropriate educational contexts, increase interest [14]. Responsible welfare disclosure, authorized teaching, and professional criticism should therefore be distinguished from indiscriminate disclosure designed primarily for copying, sensationalism, or traffic monetization.

Content platforms are not neutral channels in this process. Through ranking, recommendation, warning labels, down-ranking, removal, account restrictions, and monetization controls, platforms determine the visibility and economic value of content. Algorithmic visibility can directly affect creators' income, collaboration opportunities, and self-censorship, while governance rules may be experienced as opaque or inconsistently enforced [15]. More broadly, content moderation is an institutional process through which platforms define acceptable expression and allocate public visibility [16].

For magic involving animals, platforms face competing incentives. Controversial exposure content may produce short-term interaction and advertising value, whereas insufficient governance can generate regulatory risk, reputational loss, creator attrition, and deterioration of the broader content ecosystem. Excessive or inaccurate moderation can also generate costs by amplifying unverified accusations or unnecessarily damaging performers' reputation and incentives to innovate. Platform strategy therefore mediates the relationship between animal-welfare oversight and the protection of legitimate creative activity.

Against this background, this study addresses three related questions. First, how do changes in payoffs and costs affect magicians' transition from traditional live-animal performances to animal-friendly innovative performances? Second, how do professional constraints, long-term reputation-related benefits, and platform penalties affect exposers' choices between traffic-oriented public exposure and compliance? Third, how do governance benefits, governance costs, and traffic-related returns affect platform strategy and the stable states of the overall system?

These questions are suited to evolutionary game analysis because the three populations do not possess complete information or determine globally optimal strategies in a single interaction. Instead, strategies adjust over time in response to observed traffic outcomes, public reactions, professional evaluation, platform enforcement, and accumulated returns.

This study contributes in three respects. First, it integrates animal-welfare concerns, the professional secrecy of magic, and platform governance into a unified tripartite framework. Second, it distinguishes responsible welfare-oriented disclosure from traffic-driven exposure rather than treating all disclosure as either inherently beneficial or inherently harmful. Third, it identifies the payoff conditions under which animal-friendly innovation, compliant disclosure behavior, and active platform governance can become evolutionarily stable and evaluates how major parameters influence both long-run equilibria and transient evolutionary paths.

2. Evolutionary Game Framework

Evolutionary game theory relaxes the assumptions of complete information and perfect rationality that characterize many classical game models. Actors are treated as boundedly rational and adjust their behavior through repeated interaction, learning, imitation, and payoff comparison. A strategy that generates a payoff above the relevant population average tends to become more prevalent, whereas a less rewarding strategy declines.

This framework is appropriate for the present setting. Magicians balance the returns from established live-animal routines against the costs and benefits of animal-friendly innovation. Exposers balance short-term traffic returns against professional constraints, platform penalties, and longer-term opportunities associated with compliant content production. Platforms balance the costs of governance against benefits such as regulatory compliance, creator trust, reputation, and ecosystem quality, while also considering traffic generated by controversial content.

Because magicians, exposers, and platforms occupy distinct functional roles and face different payoff structures, the model is an asymmetric tripartite evolutionary game. Let x, y, and z denote the proportions of the respective populations adopting the following strategies:

x: animal-friendly innovative magic; $1-x$: traditional live-animal magic;

y: public exposure; $1-y$: compliance;

z: active content governance; $1-z$: traffic-oriented recommendation. The tripartite interaction structure is shown in Figure 1.

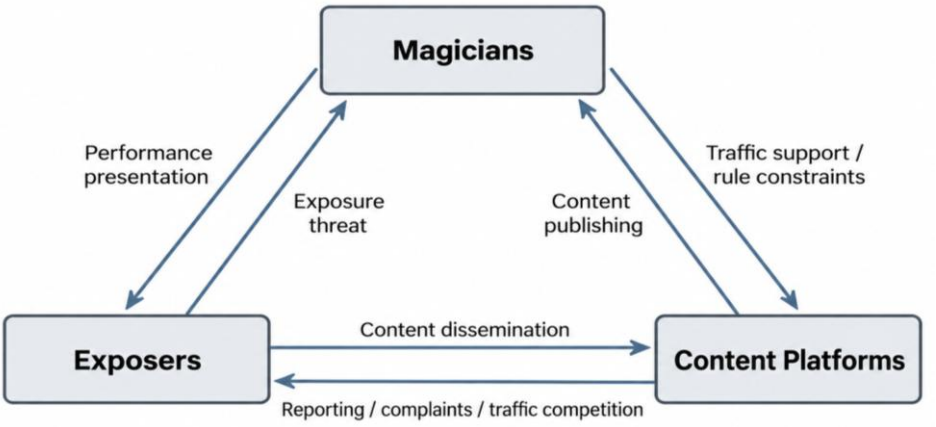


Figure 1. Decision interactions among magicians, exposers, and content platforms in the governance of magic performances involving animals.

3. Model Formulation

3.1. Magician Strategies

The magician population chooses between animal-friendly innovative magic and traditional animal magic. Traditional animal magic refers to conventional routines involving live animals. Animal-friendly innovative magic refers to animal-free alternatives, simulated props, mechanical devices, visual technologies, or other modifications intended to reduce dependence on live animals.

Let x be the proportion choosing animal-friendly innovative magic and $1-x$ the proportion choosing traditional animal magic.

Animal-friendly innovation may generate additional market attention, novelty, and dissemination value, while also requiring creative and technical investment. Parameter α represents its net incremental payoff relative to traditional animal magic and therefore already reflects the net effect of the additional returns and associated transformation costs.

If a magic method is publicly exposed, traditional magic incurs a baseline loss L. Innovative magic may suffer an additional loss β because newly developed methods can have greater originality and secrecy value.

Platform governance provides a general protection payoff P to magicians and an additional innovation-specific protection or incentive payoff S. When the platform adopts traffic-oriented recommendation, disclosure-related losses can be amplified by algorithmic distribution and user redistribution. This amplification is represented by λ.

Parameter V denotes the baseline recommendation benefit generated by ordinary, non-exposure magic content. In the normalized payoff structure, this recommendation benefit contributes both to the magician's exposure-related return and to the platform's ordinary-content payoff when traffic-oriented recommendation is used.

3.2. Exposer Strategies

The exposer population chooses between public exposure and compliance. Let y denote the proportion selecting public exposure and $1-y$ the proportion selecting compliance.

Public exposure may provide clicks, follower growth, and monetization. Its traffic payoff is represented by R. Exposure also incurs non-platform costs K, including professional norms, ethical constraints, peer evaluation, and reputational consequences. If the platform adopts active governance, an additional penalty F may arise through down-ranking, removal, monetization restriction, suspension, or other platform measures.

Under the compliance strategy, content publishers may obtain longer-term returns through science communication, authorized cooperation, professional commentary, interviews, or evidence-based reporting. The corresponding long-term payoff is represented by H.

3.3. Platform Strategies

Platforms choose between active content governance and traffic-oriented recommendation. Let z be the proportion selecting governance and $1-z$ the proportion selecting traffic-oriented recommendation.

Active governance requires investment in content review, technical detection, human moderation, and rule development, generating a cost C. It can also produce benefits through regulatory compliance, reputation, creator trust, and improvement of content quality; these benefits are summarized by G.

When traffic-oriented recommendation amplifies exposure content, the platform may receive a short-term traffic payoff T, while simultaneously facing a risk-related loss Q associated with regulatory pressure, reputational deterioration, creator attrition, and ecosystem degradation.

Finally, E represents the platform's ecosystem benefit from innovative animal-friendly magic content. The model parameters are summarized in Table 1.

Table 1. Model parameters

Parameter	Definition
α	Net incremental payoff of animal-friendly innovative magic relative to traditional animal magic
L	Baseline loss to traditional animal magic caused by public exposure
β	Additional exposure-related loss of innovative magic relative to traditional magic
S	Additional protection or incentive payoff for innovative magic under platform governance
λ	Amplification factor of exposure-related loss under traffic-oriented recommendation
P	General protection payoff received by magicians under platform governance
V	Baseline recommendation benefit generated by ordinary magic-performance content
R	Traffic payoff obtained by exposers from public exposure
K	Non-platform cost borne by exposers when choosing public exposure
F	Platform-imposed penalty associated with exposure under active governance
H	Long-term payoff obtained by exposers under compliance
G	Platform benefit from active governance
C	Platform governance cost
T	Platform traffic payoff from recommending exposure content
Q	Platform risk-related loss from allowing exposure content to spread
E	Platform ecosystem benefit from innovative animal-friendly magic

4. Payoff Matrix and Replicator Dynamics

The payoff matrix of the tripartite evolutionary game is shown in Table 2.

Table 2. Payoff matrix for magicians, exposers, and content platforms

Strategy combination	Magician	Exposer	Platform
Traditional animal magic, compliance, traffic recommendation	V	H	V
Traditional animal magic, compliance, governance	P	H	$G-C$
Traditional animal magic, public exposure, traffic recommendation	$-\lambda L$	$R-K$	$T-Q$
Traditional animal magic, public exposure, governance	$-L+P$	$R-K-F$	$G-C$
Innovative magic, compliance, traffic recommendation	$\alpha+V$	H	$E+V$
Innovative magic, public exposure, traffic recommendation	$\alpha-\lambda(L+\beta)$	$R-K$	$E+T-Q$
Innovative magic, compliance, governance	$\alpha+P+S$	H	$E+G-C$
Innovative magic, public exposure, governance	$\alpha-L-\beta+P+S$	$R-K-F$	$E+G-C$

4.1. Magician Replicator Dynamics

The payoff to a magician adopting animal-friendly innovative magic is

$$U_{11} = yz(\alpha - L - \beta + P + S) + (1-y)z(\alpha + P + S) + y(1-z)[\alpha - \lambda(L+\beta)] + (1-y)(1-z)(\alpha + V) \quad (1)$$

The payoff to a magician adopting traditional animal magic is

$$U_{12} = yz(-L+P) + (1-y)zP + y(1-z)(-\lambda L) + (1-y)(1-z)V \quad (2)$$

The mean payoff of the magician population is

$$\bar{U_1} = xU_{11} + (1-x)U_{12} \quad (3)$$

The replicator dynamic is therefore

$$F_x = \frac{dx}{dt} = x(1-x)\{\alpha + zS - y\beta[z + \lambda(1-z)]\} \quad (4)$$

Equation (4) shows that animal-friendly innovation is promoted by its net incremental payoff α and by innovation-specific protection S under governance. Public exposure reduces its relative payoff through β, and this effect is stronger when traffic recommendation amplifies exposure losses through λ.

4.2. Exposer Replicator Dynamics

The payoff from public exposure is

$$U_{21} = xz(R-K-F) + (1-x)z(R-K-F) + x(1-z)(R-K) + (1-x)(1-z)(R-K) \quad (5)$$

The payoff from compliance is

$$U_{22} = xzH + (1-x)zH + x(1-z)H + (1-x)(1-z)H \quad (6)$$

The mean payoff is

$$\bar{U_2} = yU_{21} + (1-y)U_{22} \quad (7)$$

The corresponding replicator dynamic is

$$F_y = \frac{dy}{dt} = y(1-y)(R-K-H-zF) \quad (8)$$

Thus, exposure becomes less attractive as non-platform constraints K, the long-term benefits of compliance H, and platform penalties F increase.

4.3. Platform Replicator Dynamics

The payoff to a platform adopting active governance is

$$U_{31} = xy(E+G-C) + x(1-y)(E+G-C) + (1-x)y(G-C) + (1-x)(1-y)(G-C) \quad (9)$$

The payoff under traffic-oriented recommendation is

$$U_{32} = xy(E + T - Q) + x(1 - y)(E + V) + (1 - x)y(T - Q) + (1 - x)(1 - y)V \quad (10)$$

The mean platform payoff is

$$\bar{U}_3 = zU_{31} + (1 - z)U_{32} \quad (11)$$

The platform replicator dynamic is

$$F_z = \frac{dz}{dt} = z(1 - z)[G - C - y(T - Q) - (1 - y)V] \quad (12)$$

Equation (12) indicates that the platform's strategic choice depends on the relative return from governance compared with the alternative returns available through exposure-oriented or ordinary traffic recommendation.

5. Equilibrium and Stability Analysis

The equilibrium points are obtained by jointly solving $F_x = 0$, $F_y = 0$, and $F_z = 0$.

The system has eight pure-strategy equilibria: $E_1 = (0,0,0)$, $E_2 = (0,0,1)$, $E_3 = (0,1,0)$, $E_4 = (0,1,1)$, $E_5 = (1,0,0)$, $E_6 = (1,1,0)$, $E_7 = (1,0,1)$, and $E_8 = (1,1,1)$. The local stability results are summarized in Table 3.

For compactness, define

$$A(y,z) = \alpha + zS - y\beta[z + \lambda(1 - z)],$$

$$B(z) = R - K - H - zF,$$

and

$$D(y) = G - C - y(T - Q) - (1 - y)V.$$

The Jacobian matrix is

$$J = \begin{bmatrix} (1-2x)A & -x(1-x)\beta[z+\lambda(1-z)] & x(1-x)[S-y\beta(1-\lambda)] \\ 0 & (1-2y)B & -Fy(1-y) \\ 0 & z(1-z)(V-T+Q) & (1-2z)D \end{bmatrix} \quad (13)$$

According to the first Lyapunov method for local stability, an equilibrium is asymptotically stable when all eigenvalues of the Jacobian have negative real parts.

Table 3. Local stability conditions of the pure-strategy equilibria

Equilibrium	Eigenvalues	Stability condition
$E_1(0,0,0)$	$\alpha,\ R-K-H,\ G-C-V$	Unstable for $\alpha > 0$
$E_2(0,0,1)$	$\alpha+S,\ R-K-H-F,\ C+V-G$	Unstable for $\alpha+S > 0$
$E_3(0,1,0)$	$\alpha-\beta\lambda,\ K+H-R,\ G-C-T+Q$	$\alpha < \beta\lambda;\ K+H < R;\ G+Q < C+T$
$E_4(0,1,1)$	$\alpha+S-\beta,\ K+H+F-R,\ C+T-Q-G$	$\alpha+S < \beta;\ K+H+F < R;\ C+T < Q+G$
$E_5(1,0,0)$	$-\alpha,\ R-K-H,\ G-C-V$	$R < K+H;\ G < C+V$
$E_6(1,1,0)$	$\beta\lambda-\alpha,\ K+H-R,\ G-C-T+Q$	$\beta\lambda < \alpha;\ K+H < R;\ G+Q < C+T$
$E_7(1,0,1)$	$-\alpha-S,\ R-K-H-F,\ C+V-G$	$R < K+H+F;\ C+V < G$, with $\alpha+S > 0$
$E_8(1,1,1)$	$\beta-\alpha-S,\ K+H+F-R,\ C+T-Q-G$	$\beta < \alpha+S;\ K+H+F < R;\ C+T < Q+G$

The equilibrium $E_7(1,0,1)$ is of particular interest because it represents the combination of animal-friendly innovative magic, compliance by exposers, and active platform governance.

The first stability condition, $R < K + H + F$, means that the short-term traffic payoff from public exposure is insufficient to offset the combined non-platform costs of exposure, the opportunity cost represented by the long-term benefit of compliance, and the additional penalty imposed by platform governance.

The second condition, $C + V < G$, means that the platform's governance benefit must exceed the governance cost plus the baseline recommendation benefit available under non-governance when exposers comply.

Because $\alpha > 0$ and $S \geq 0$ under the model definitions, $-\alpha - S < 0$. Therefore, once exposers predominantly comply and platforms govern actively, animal-friendly innovation has a relative payoff advantage.

The mechanism underlying E_7 is a reinforcing feedback structure. Stronger governance reduces the return from traffic-oriented exposure and raises its expected cost. As exposure declines, magicians face lower innovation-related disclosure losses, strengthening the payoff from animal-free or simulated alternatives. Compliance becomes more attractive to content publishers through longer-term cooperation, commentary, education, and evidence-based reporting. The resulting payoff structure can sustain animal-friendly innovation without eliminating legitimate welfare oversight.

6. Numerical Simulation Analysis

Numerical simulations were conducted using the replicator dynamics in Eqs. (4), (8), and (12). The baseline parameter values were $\alpha = 3$, $L = 1$, $\beta = 5.5$, $S = 2$, $\lambda = 1.6$, $P = 1$, $V = 3$, $R = 6$, $K = 2$, $F = 2.5$, $H = 3$, $G = 7$, $C = 2$, $T = 5$, $Q = 1$, and $E = 2$.

Under these values, $R = 6 < K + H + F = 7.5$ and $C + V = 5 < G = 7$, so $E_7(1,0,1)$ satisfies the analytical local-stability conditions.

6.1. Evolution Under Different Initial Strategy Probabilities

Three initial states were examined: $(0.2, 0.2, 0.2)$, $(0.5, 0.5, 0.5)$, and $(0.8, 0.8, 0.8)$. The corresponding trajectories are shown in Figure 2.

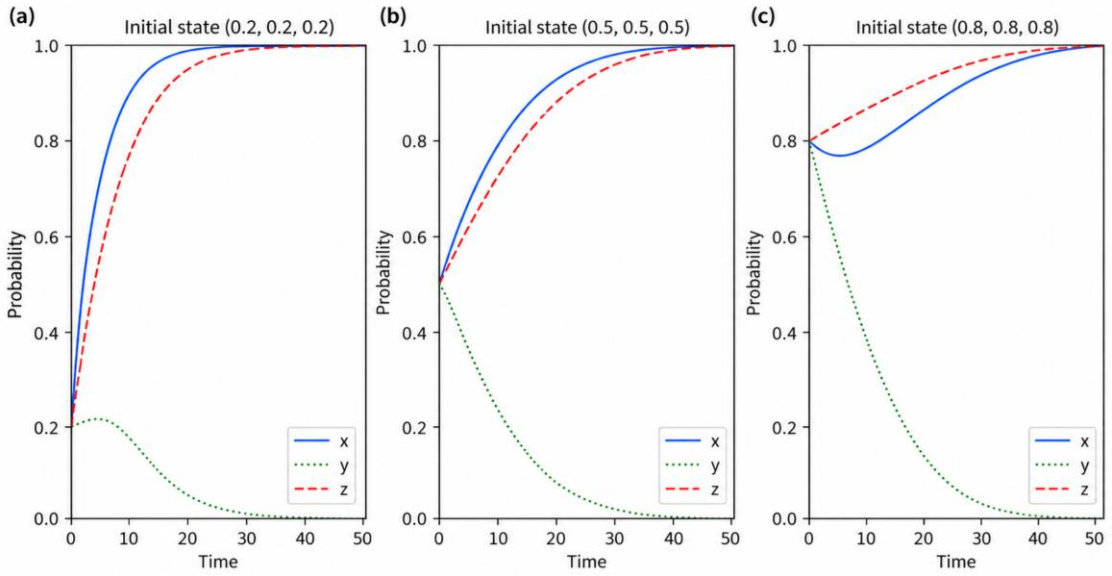


Figure 2. Evolutionary trajectories under different initial strategy probabilities: (a) $(0.2, 0.2, 0.2)$, (b) $(0.5, 0.5, 0.5)$, and (c) $(0.8, 0.8, 0.8)$.

Across all three initial states, the system converges to $E_7(1, 0, 1)$. The proportion of magicians adopting animal-friendly innovative magic approaches 1, the proportion of exposers selecting public exposure approaches 0, and the proportion of platforms adopting active governance approaches 1.

When all initial probabilities are low, y increases slightly during the early stage. At that stage, platform governance remains relatively uncommon, so the net return from public exposure can temporarily remain positive. As z increases, the platform penalty becomes increasingly influential, the payoff advantage of exposure disappears, and y declines toward 0.

For the intermediate and high initial states, governance increases continuously while exposure declines. At the high initial state, x exhibits a small transient fluctuation, but as exposure falls and governance rises, animal-friendly innovation becomes increasingly advantageous and x converges toward 1.

The common long-run destination across the three tested initial states is consistent with the local-stability analysis under the baseline parameters. Within these simulations, convergence toward animal-friendly innovation does not require an unusually favorable initial strategy distribution.

6.2. Evolution Under Different Platform-Governance Benefits

The platform-governance benefit was varied as $G = 1.5$, 3.5, 5.5, and 7.5, while the other baseline parameters were retained. The resulting trajectories are shown in Figure 3.

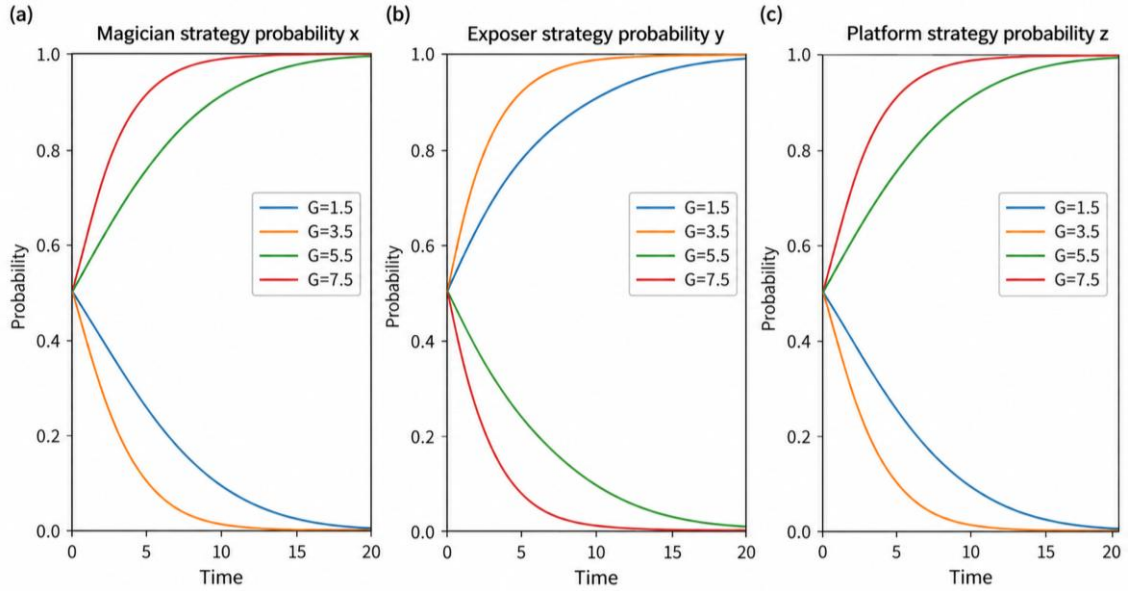


Figure 3. Evolutionary trajectories under different platform-governance benefits $G = 1.5$, 3.5, 5.5, and 7.5.

At $G = 1.5$ and $G = 3.5$, the governance benefit is insufficient to compensate for the platform's governance cost and alternative traffic returns. Consequently, z declines toward 0. Reduced governance weakens the constraints on exposers, causing y to rise toward 1. As exposure becomes increasingly prevalent, the relative return to animal-friendly innovation deteriorates and x declines toward 0.

The resulting trajectory is consistent with $E_3(0, 1, 0)$: traditional animal magic, public exposure, and traffic-oriented recommendation.

At $G = 5.5$, the reported simulation changes direction. Platform governance increases gradually, exposure declines, and animal-friendly innovation rises toward 1. Compared with $G = 7.5$, however, convergence is slower. At $G = 7.5$,

governance rapidly approaches 1, exposure declines quickly, and animal-friendly innovation rises correspondingly.

The analytical conditions clarify this transition. For E_7, the baseline values require $G > C + V = 5$. For E_3, the corresponding platform condition is $G + Q < C + T$, which, under the baseline values, becomes $G < 6$. Thus, the interval $5 < G < 6$ permits local stability of both E_3 and E_7 under the remaining baseline conditions. The trajectory observed at $G = 5.5$ therefore demonstrates convergence to E_7 from the simulated starting state, rather than global convergence from every possible initial state. This overlap identifies a region in which evolutionary history and initial conditions can matter.

Overall, increasing G changes not only the speed of governance adoption but, outside the overlapping stability region, the long-run strategic structure of the system.

6.3. Evolution Under Different Penalty Intensities

The platform penalty applied to public exposure under governance was varied as $F = 1.5$, 2.5, 3.5, and 4.5. The resulting trajectories are shown in Figure 4.

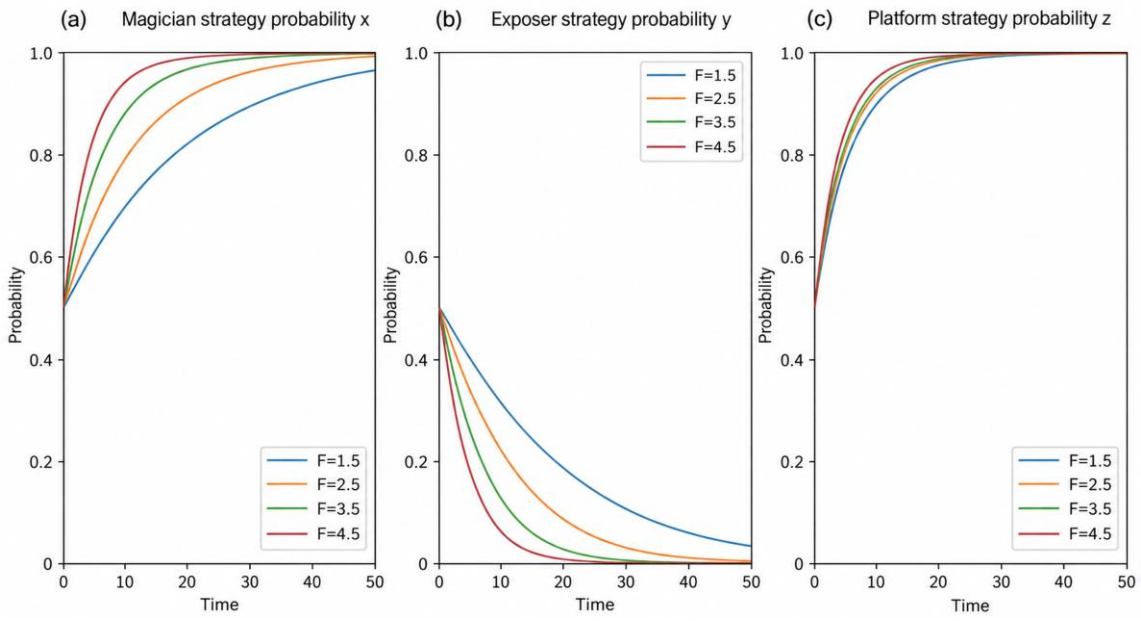


Figure 4. Evolutionary trajectories under different platform penalty intensities $F = 1.5$, 2.5, 3.5, and 4.5.

Across all four values, the system converges to $E_7(1, 0, 1)$. This is consistent with the analytical stability condition $R < K + H + F$. Under the baseline values, this condition becomes $6 < 5 + F$, or $F > 1$. All four simulated values satisfy this requirement.

The principal effect of F is therefore on the speed and transient path of convergence. At $F = 1.5$, exposure remains relatively attractive during the early stage and y declines more slowly. As F increases to 2.5, 3.5, and 4.5, the net return to exposure falls more rapidly and y approaches 0 sooner.

This change indirectly affects magicians. When exposers abandon the public-exposure strategy more rapidly, the innovation-specific loss represented by β becomes less influential, allowing x to rise more quickly. By contrast, the platform trajectory changes relatively little across the four cases because the platform-governance benefit remains high and Eq. (12) does not contain F directly.

The results therefore indicate that penalties can accelerate the exit of traffic-driven exposure from the system, but penalty intensity is not the sole determinant of the long-run equilibrium. Governance benefits, compliance incentives, review standards, and reporting mechanisms remain structurally important.

6.4. Evolution Under Different Exposure-Related Losses

The additional exposure-related loss suffered by innovative magic was varied as $\beta = 1.5$, 3.5, 5.5, and 7.5. The resulting trajectories are shown in Figure 5.

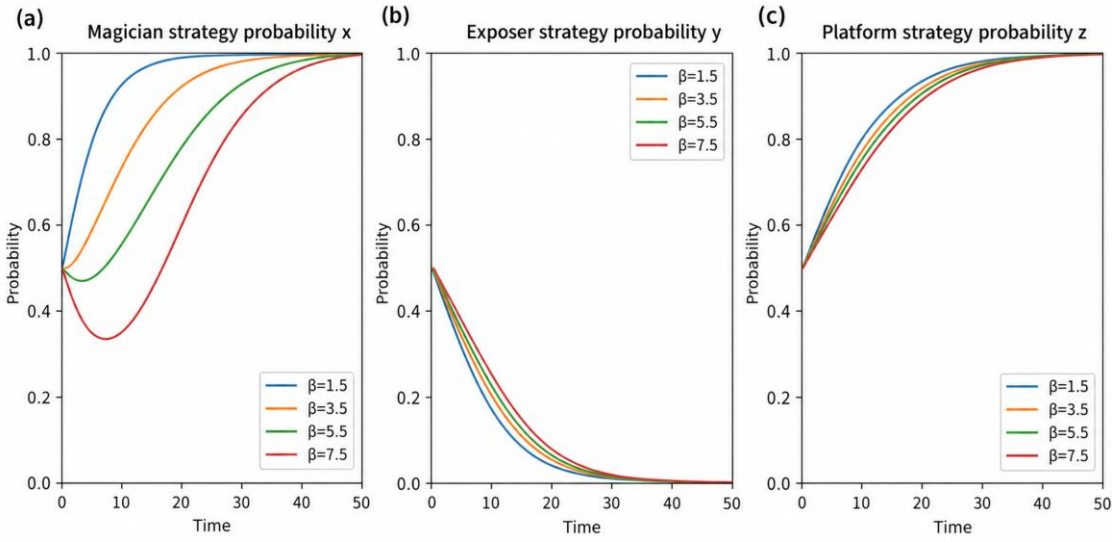


Figure 5. Evolutionary trajectories under different exposure-related losses $\beta = 1.5,\ 3.5,\ 5.5,$ and 7.5.

For all four values, the system converges to $E_7(1,0,1)$. This result follows directly from the structure of the equilibrium: when $y = 0$, the β-dependent exposure term disappears from the magician replicator dynamic. Accordingly, the eigenvalue governing the magician dimension at E_7 is $-\alpha - S$, which does not depend on β.

Nevertheless, β has a clear influence on transient dynamics when $y > 0$. At $\beta = 1.5$, the cost of exposure to innovative magic is relatively small, and x rises rapidly. At $\beta = 3.5$ and 5.5, the increase in x becomes slower. At $\beta = 7.5$, x initially declines before recovering as governance rises and exposure falls.

By contrast, the trajectories of y are similar across the four values because β does not appear in Eq. (8). Likewise, z remains comparatively insensitive to β because it does not appear directly in Eq. (12).

The role of exposure-related damage is therefore primarily transitional: greater potential damage can temporarily discourage animal-friendly innovation while exposure remains prevalent, but it does not change the long-run E_7 equilibrium under the baseline governance and compliance incentives.

7. Discussion

7.1. Main Findings and Underlying Evolutionary Mechanism

The central finding of this study is that the governance of magic performances involving animals is not determined by the behavior of a single actor. The long-run outcome emerges from the interaction among three linked payoff structures: the relative attractiveness of animal-friendly innovation for magicians, the balance between short-term exposure traffic and longer-term compliant behavior for content publishers, and the balance between governance returns and traffic-related returns for platforms.

The stability analysis gives this mechanism an explicit form. At $E_7(1,0,1)$, public exposure declines when $R < K + H + F$, while active platform governance remains stable when $G > C + V$. These conditions show why punishment alone is insufficient. Raising F can reduce the attractiveness of traffic-oriented exposure, but the platform itself must also have a sustainable reason to continue governing. If governance produces insufficient compliance, reputation, creator-trust, or ecosystem value relative to its cost and alternative recommendation returns, the platform can move away from governance even when formal rules exist.

This distinction is supported by the simulation results. Varying F over the tested range changes convergence speed without altering the long-run equilibrium because every tested value remains above the analytical threshold required for E_7. By contrast, changes in G cross stability boundaries and can alter the strategic destination of the system.

The analysis of β reveals another important mechanism. Greater damage from exposure can suppress innovation during the transition, but it does not affect the local stability of E_7 once exposure has disappeared from the equilibrium. This explains why high exposure-related losses generate short-term hesitation among magicians without necessarily preventing eventual convergence to animal-friendly innovation when governance and compliance incentives remain sufficiently strong.

7.2. Relationship with Animal-Welfare Research

The model complements existing animal-welfare research by showing how welfare concerns can become embedded in an incentive system rather than remaining an external ethical recommendation. The Five Domains framework emphasizes that welfare cannot be reduced to visible injury and should include environment, health, behavior, mental state, and opportunities for positive experience [1, 2]. Evidence from circus settings similarly points to transport, restricted environments, social conditions, and behavioral limitation as relevant welfare considerations [3–5].

These findings imply that platform governance of animal-related performance content should not rely solely on easily visible signs of physical injury. A governance system based only on highly explicit abuse can miss conditions related to stress, handling, transport, repeated exposure, or behavioral restriction. At the same time, the present model does not imply that every use of a live animal constitutes welfare harm. Rather, it analyzes how welfare concerns, reputational incentives, professional practices, and digital dissemination interact when such concerns arise.

The results therefore support a multidimensional review approach. Animal-welfare evaluation should be evidence-based and sufficiently specific to distinguish legitimate care and performance practices from situations that warrant

intervention.

7.3. Responsible Disclosure Versus Traffic-Driven Exposure

An important conceptual result is the need to separate welfare-oriented disclosure from indiscriminate exposure of magic secrets.

Research on professional magic has shown that digital culture has altered the way knowledge and professional boundaries are maintained [12]. Theoretical work on exposure likewise emphasizes that disclosure differs according to purpose, scope, evidence, audience, authorization, and level of detail [13]. In addition, science-of-magic research indicates that educational explanation is not necessarily incompatible with audience appreciation [14].

These studies support the binary strategy distinction used in the model only when its meaning is interpreted carefully. The strategy $y = 1$ should not be understood as all forms of reporting or public criticism. It represents traffic-oriented, inadequately regulated exposure in which secrecy or welfare allegations are exploited primarily for visibility. Conversely, $y = 0$ does not require silence. Compliance can include authorized explanation, professional criticism, evidence-based welfare reporting, confidential reporting, and public discussion that avoids unnecessary disclosure of reproducible secret methods.

This distinction is especially important for animal welfare. A governance system that protects magic secrets by suppressing legitimate evidence of animal harm would be inconsistent with the welfare objective of the model. The sustainable equilibrium instead depends on creating channels through which credible concerns can be reported without turning unnecessary technical exposure into a traffic commodity.

7.4. Platform Governance as an Incentive Mechanism

The results are also consistent with research emphasizing the central role of platforms in determining visibility and creator incentives. Social-media creators may experience algorithmic visibility and invisibility as direct economic and professional constraints [15], while platform moderation more broadly determines what content becomes visible and monetizable [16].

In the present model, this influence appears through both F and G. Parameter F changes the expected return of exposure content, whereas G determines whether governance remains attractive to the platform itself. This difference helps explain why the simulations show stronger structural effects from G than from increases in F once the penalty threshold has already been crossed.

The overlap of local stability conditions at intermediate G values is also important. Under the baseline values, both E_3 and E_7 can be locally stable when $5 < G < 6$. Such coexistence means that modest improvements in governance returns do not necessarily guarantee a unique long-run outcome. When the system lies near a boundary between governance regimes, initial conditions and the previous evolutionary path can affect which equilibrium is reached.

For practical governance, this suggests that temporary campaigns may be less effective than durable changes to the platform's reward structure. If compliance quality, creator trust, animal-welfare reputation, and regulatory alignment generate persistent value, governance becomes less dependent on short-term enforcement campaigns.

7.5. Governance Implications

The results support three complementary governance directions.

First, the magic industry can develop operational welfare standards covering animal sourcing, transport, backstage waiting, housing, training, exposure to intense light and noise, handling, and emergency procedures. Where live animals remain part of a performance, the necessity and welfare conditions of their use can be subject to stronger review. Professional competitions, commissioning practices, and platform promotion can also provide positive incentives for mechanical, simulated, or other animal-friendly alternatives.

Second, platforms can incorporate animal-performance content into specialized review procedures. Review should not depend solely on obvious violence-related keywords. Where technically feasible, evidence may also be evaluated for forced postures, dangerous interactions, apparent stress, uncertain sourcing, and risks associated with repeated imitation. Content with incomplete evidence can be subject to contextual labeling or human review before stronger measures are taken. Confirmed harmful content or content that intentionally exploits harm for traffic can then be addressed through down-ranking, removal, monetization restrictions, or account-level enforcement, with appropriate appeal and evidence-submission procedures.

Third, animal-welfare reporting and the protection of magic secrets should be handled through partially separate channels. Confidential reporting mechanisms can allow welfare concerns to be assessed by personnel with relevant animal-behavior or veterinary expertise. Public communication can focus on welfare facts, risks, and corrective measures without unnecessarily revealing reproducible apparatus designs or operational details. Such an arrangement can preserve legitimate oversight while reducing incentives for sensationalized exposure.

7.6. Limitations and Future Research

Several limitations define the appropriate interpretation of the findings.

First, the model aggregates heterogeneous animals, performance intensities, and welfare risks into a limited number of payoff parameters. It does not distinguish, for example, between commonly used domestic species and species with substantially different husbandry, behavioral, or stress-related requirements. The model should therefore not be used as a substitute for species-specific welfare assessment.

Second, the parameter values used in the numerical analysis are theoretical payoff settings rather than empirically calibrated effect sizes. The simulations establish the internal dynamic behavior of the model under the stated parameter combinations, but they do not establish empirical causal magnitudes for real platforms, performers, or audiences.

Third, each stakeholder group is represented by two broad strategies. Real practices are more heterogeneous. Exposure may range from unauthorized technical disclosure to responsible whistleblowing, while platform governance may include labeling, down-ranking, demonetization, removal, account sanctions, or expert review. These measures can have different costs and effects.

Fourth, the model treats population strategies through replicator dynamics and does not explicitly represent network structures, cross-platform migration, repeated creator-specific

histories, or heterogeneous recommendation algorithms.

Future research can address these limitations by empirically calibrating model parameters using coded platform content, moderation records where access is permitted, public-comment data, and interviews with relevant practitioners. Further extensions could distinguish animal species and welfare-risk categories, incorporate professional animal-welfare organizations or audience-reporting behavior as additional actors, and model differences among platform recommendation and moderation systems. Such extensions would strengthen external validity while preserving the incentive-based structure developed here.

8. Conclusion

This study developed a tripartite evolutionary game framework to examine how magicians, exposers, and content platforms jointly shape the governance of magic performances involving animals in digital media. The model links animal-friendly innovation, disclosure behavior, and platform governance through boundedly rational strategy adjustment and payoff feedback.

Analytical stability results identify $E_7(1,0,1)$—animal-friendly innovative magic, compliant disclosure behavior, and active platform governance—as an asymptotically stable equilibrium when short-term exposure returns are lower than the combined constraints, compliance benefits, and platform penalties associated with exposure, and when the platform's governance benefit exceeds its governance cost and baseline non-governance recommendation benefit. Numerical simulations are consistent with these analytical conditions. Platform-governance benefits can change the long-run evolutionary direction, penalty intensity mainly changes the speed at which traffic-driven exposure declines once the stability threshold is satisfied, and exposure-related losses chiefly affect the transient willingness of magicians to adopt animal-friendly innovation.

The broader implication is that sustainable governance cannot be achieved solely by increasing penalties or suppressing disclosure. It requires a payoff structure in which animal-friendly creative practice remains worthwhile, responsible reporting has a viable long-term return, and platforms obtain durable value from credible governance. Within its theoretical scope, the framework provides a structured basis for coordinating animal-welfare oversight, professional norms in magic, and digital-platform governance. Further empirical calibration can extend the model to species-specific welfare conditions, heterogeneous platforms, and more differentiated forms of disclosure and moderation.

Ethics Statement

Not applicable.

Data Availability Statement

No external empirical dataset was used in this study. The numerical results reported in the simulation analyses and figures were generated by the authors from the evolutionary-game model and the parameter settings reported in the manuscript.

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