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Sequential innovation and contribution distribution: measurement from game live-streaming industry

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Profit distribution in sequential innovation is a crucial yet relatively unexplored area of empirical research. With novel cross-section data from the game live-streaming industry, we are the first to assess the contribution shared by initial and follow-on innovators empirically. Unlike the complex innovation paths of patents, the copyright structure within the game live-streaming industry is clear and concise, enabling direct measurement of innovation value. At the industry's average level, the share stands at 1:2 between game producers and streamers. This measurement remains robust even after controlling for income levels and distinguishing between professionals and amateurs. Nevertheless, significant heterogeneity exists across different game genres. We suggest that a balanced distribution scheme between initial and follow-on innovators should seriously consider their contribution shares.

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Introduction

Sequential innovation, or cumulative innovation, is a prevalent phenomenon in industries where intellectual property (IP) advancements build upon one another, with subsequent innovators benefitting from the progress of their predecessors (Scotchmer, 1991). Nonetheless, determining an equitable distribution of profits arising from follow-on innovations between the initial innovator and the subsequent innovator poses a complex challenge (Chen and Sappington, 2018; Gilbert and Katz, 2011; Green and Scotchmer, 1995; Llanes and Trento, 2012; O'Donoghue, 1998; O'Donoghue et al. 1998; Parra, 2019). On one hand, allocating insufficient profits to the initial innovator can dampen their incentive (Brüggemann et al. 2016). On the other hand, assigning all profit generated by subsequent innovations to the initial innovator can discourage further innovation by subsequent creators, resulting in significant deadweight loss, particularly when followers' contributions are substantial or when the cost of negotiation is high between followers and the initial innovator (Kwon and Marco, 2021).[1]

Apart from the patent field typically focused on in literature, the field of copyright, specifically the game live-streaming industry, offers an opportunity to shed light on this issue. Game live-streaming involves streamers broadcasting their gameplay to online audiences. The creation process of a game live-streaming is a typical example of sequential innovation with a clear and concise path, enabling empirical measurement of the contribution of initial and follow-on creators: game producers and streamers. In a game live-streaming, the game producers establish the static framework of frames while streamers bring it to life. Streamers fulfill viewers' needs for entertainment and socialization by showcasing their talents, engaging with viewers, and implementing various strategies. Viewers tip their favorite live streams to recognize streamers' significant contribution to live-streaming creation, providing an excellent opportunity to characterize the value of streams.

With cross-section data from the game live-streaming industry, this article presents three primary empirical findings. First, it quantitatively measures the contribution ratio between initial and subsequent innovators in sequential innovation, representing a pioneering endeavor in intellectual property. Across the entire game live-streaming industry, the study measures a contribution ratio of approximately 2:1 for streamers and game producers. Second, the contribution share remains relatively consistent as the stream income level increases. As depicted in Table 1, considering the industry, the contribution shares for streams at the top 25%, 50%, and 75% income levels hover around two-thirds. In the case of streams produced by professionals, these ratios slightly increase. Third, substantial variations are observed across different games. Streamers' contribution ratio is nearly zero in less popular games, whereas the correlation between streamer ability and stream income is significant in popular games.

Table 1 Streamers' Shares for the Game Live Streaming Industry.

	Overall		
Overall industry	**64.3–65.5%**		
	K-means	**Wards Linkage**	**Average Linkage**
Professional streamers	67.5–70.3%	82.1–86.5%	67.0–69.5%
	Top−75%	**Top−50%**	**Top−25%**
Overall industry	59.2–65.1%	64.0–66.8%	65.1–66.4%
Professional streamers	71.3–73.0%	73.1–75.8%	65.0–66.5%

The stream data are from a Chinese mobile live-streaming platform, "Huoshan," developed by ByteDance, which focuses on delivering high-quality game streams. Combining this data with game-related information from QuestMobile and AppAnnie, we construct a balanced cross-sectional dataset that controls for game type and temporal effects. The study utilizes streamers' aggregated fan base and average monthly income per fan over four months as proxy variables for streamer abilities, enabling the estimation of how streamer capability and game type correlate with stream income. While the data encounters challenges in eliminating individual effects for causal analysis, it is adequate for performing a correlation analysis to capture contributors' shares.

The paper comprises seven sections. Section 2 discusses the literature. Section 3 furnishes an overview of game live-streaming and related copyright disputes. Section 4 details the dataset used in the study. Section 5 estimates the contribution share between streamers and game producers and explores heterogeneity among game genres. Section 6 extends the analysis to encompass professional streamers. Section 7 discusses the role of the platform and its limitations. Section 8 concludes.

Literature review

This paper contributes to both existing literature and policy-making in three primary ways.

Measurement of contribution in sequential innovation. First, it introduces an empirical measurement of the contribution shares within sequential innovation using data from the game live-streaming industry. The analytical framework and findings not only offer guidance to industry stakeholders but also provide insights for legislative and regulatory considerations in other sectors (e.g., semiconductors and intelligent devices).

As of our current knowledge, there is a dearth of empirical measurements concerning contribution shares in the presence of sequential innovation. Two significant challenges underpin this scarcity. First, technological development paths are intricate and interconnected (Ziedonis and Galasso, 2019). Due to widespread knowledge sharing, a typical end product now involves numerous patents, making it exceedingly laborious to discern the precise role of each patent within patent thickets and accurately gauge their contributions. Secondly, estimating the exact value of follow-on innovations proves even more formidable. Consequently, much empirical research resorts to using the number of sequential research projects as a proxy (Galasso and Schankerman, 2015; Murray and Stern, 2007; Murray et al. 2016; Williams, 2013; Woo et al. 2015).

The game live-streaming industry data deals with these challenges in two ways: first, the innovation trajectory within this industry is transparent and concise. Streamers primarily require copyright licenses from game producers, as there is no prevalent occurrence of "patent thickets" or "cross-licensing" (Galasso, 2012). Typically, no other innovators are involved, and the value of game streams is shaped solely by game producers and streamers. Second, the value of streams can be directly and accurately quantified. Numerous streaming platforms allow viewers to tip streamers using virtual currency, exchangeable for real money at a fixed rate. Additionally, game streams compete to a limited extent with the actual games, ensuring that follow-on innovation does not undermine the interests of initial innovators. This simplified analysis aligns with assumptions in classic theoretical models (Green and Scotchmer, 1995). A

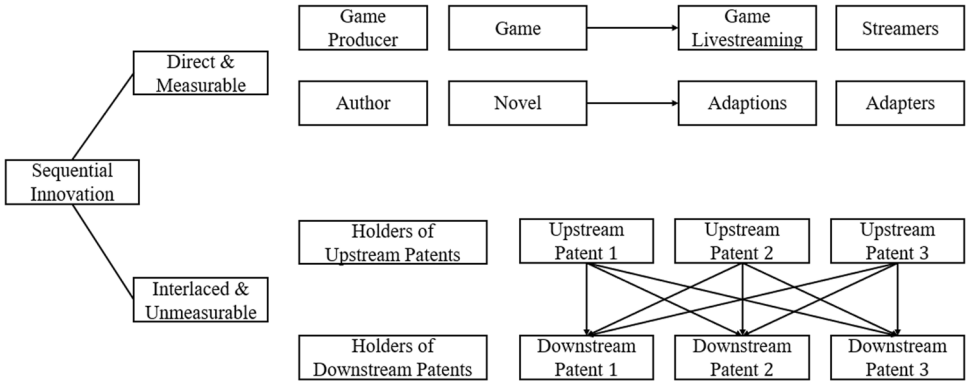

Fig. 1 Sequential Innovation in the Fields of Copyright and Patent. This figure illustrates the different characteristics and structures of sequential innovation in the field of copyright and patent.

comparison of sequential innovation in copyright and patent contexts is illustrated in Fig. 1.

Research and debate on copyright. Second, this paper expands the scope of copyright research from examining the effectiveness of copyright protection to limitations in copyright and sheds light on the distribution of rights of derivative works from the perspective of empirical analysis.

While much research concentrates on intellectual property through patents due to frequent and varied policy shifts, copyright has seen limited cross-sectional or temporal variation over the past century. Consequently, empirical research on copyright remains sparse. Existing studies often investigate historical reforms, such as Giorcelli and Moser (2020) and Bradley and Kolev (2023). The former examines evidence from Italian opera to explore the correlation between copyright and the quantity and quality of creative output, and the latter researches a 2001 technological shock in software piracy. This paper aims to broaden the scope and subjects of copyright research by highlighting the significance of establishing a balanced profit distribution scheme among innovators to foster innovation, addressing the issue of limited policy variation.

Also, the paper endeavors to provide more evidence for the copyright disputes concerning derivative works and challenges the conventional notion of absolute copyright exclusivity. Game live-streaming exemplifies a derivative work derived from games, raising debates over whether streamers, as creators, can claim copyright and monetary benefits (Matsui, 2016; Qui, 2017). While "fair use" is a standard clause in copyright law in various countries, commercial use remains stringently regulated, particularly in conservative jurisdictions like China and Japan. Nevertheless, unauthorized large-scale uploads of game streams often go unchallenged by game copyright holders and producers due to the high costs of asserting rights and the potential benefits of exposure. Matsui (2016) refers to this phenomenon as "tolerated infringement." This paper advocates for its legalization, offering evidence from a contribution perspective.

Gaming and game live-streaming platform. Third, this paper significantly contributes to the evolving gaming and game live-streaming platform literature. Prior research in gaming has highlighted the distinct purposes of gaming and game live-streaming, emphasizing their roles in entertainment and socialization (Vosmeer et al. 2016). In contrast to the content topic (game genre) of a game live-stream, the archetypal structure (streamed content) is a more pivotal factor in gaining viewers' gratification (Sjöblom et al. 2017). These insights prompt our exploration of the balanced distribution of benefits between game producers and streamers.

Earlier studies underscore the substantial differences in incentive structures and behavior patterns between professional players and amateurs, with the former investing considerably more time and effort in playing. To differentiate between these two groups, we employ playing frequency and playing duration as indicators, drawing inspiration from the works of Bányai et al. (2020) and Nagorsky and Wiemeyer (2020), using a clustering method as outlined by Hedlund (2023). According to the wide-range survey by Nagorsky and Wiemeyer (2020), esports players' average weekly gaming hours stand at approximately 20, with one-third dedicated to professional training. This aligns with our findings, indicating that professional streamers make substantial contributions, warranting considerations for copyright schemes that favor professionals, especially in the game live-streaming industry.

Our paper also strongly correlates with the existing literature on game live-streaming platforms. As noted by Li et al. (2020), viewers' behavior in watching game live-streams is influenced not only by their demands and interactions with streamers but also by the platform's impact. Effective gamification mechanisms and socialization features fulfill viewers' social needs, and the overall digital experience of live-streaming influences viewers' willingness to provide tips. While our study lacks panel data at an individual level across different platforms, this limitation does not undermine its significance. Copyright rewards direct contributors, and various measures are available for viewers and streamers to compensate platforms for their utility in bringing content. A more in-depth discussion on the role of platforms is presented in Section 7.1.

Game live-streaming and its copyright dispute

Game live-streaming refers to the activity of streamers playing games and broadcasting their gameplay over the internet to viewers.

Industry background. The origins of game streaming can be traced back to interactions among game players. Initially, game platforms introduced voice communication systems that facilitated player interaction and idea sharing during games. Over time, it became increasingly convenient for players to share their experiences and broadcast their gameplay to friends. The surge in the gaming market in 2013 led to a flood of new players. These newcomers sought novel ways to learn strategies and share techniques without comprehensive guidance from game

producers. Coupled with advancements in communication systems, this gave rise to the game live-streaming industry.

The growth of the game live-streaming sector has been remarkable. In China, improvements in internet speed and the acquisition of Twitch.TV in the United States has driven the rapid expansion of this industry. By 2020, China's game live-streaming market had generated about 5 billion dollars in total revenue, experiencing an annual growth rate exceeding 50 percent over the past three years. Viewer numbers reached 350 million in 2020, with a nearly 17 percent annual increase between 2018 and 2020.[2]

Earnings from streaming. The primary income source for game live-streaming comes from viewer tips. While viewers typically do not pay to watch streams on streaming platforms, many tip streamers as a reward for their engaging gameplay and commentary. This practice also encourages streamers to produce more high-quality content. Viewers often offer tips by sending virtual gifts, the prices of which are predetermined and convertible into real currency at fixed exchange rates. After deducting a small platform service fee, the tips are directly transferred to the streamers. In 2018, tipping accounted for more than 88.7% of streamers' income. Notably, game producers rarely offer permanent positions to streamers. Therefore, this paper considers tipping as a form of streaming income. As the competition among streamers intensifies, various methods are employed to attract viewers and encourage tips, including improving gaming skills, providing humorous commentary, or showcasing additional talents such as singing while playing.

With increasing recognition of games and streaming, viewers have become more inclined to make payments. More viewers perceive tipping as worthwhile, contributing to the industry's long-term development.

Copyright disputes in game live-streaming. Whether game live-streaming constitutes a "work" under copyright law has been debated. Green (2017) argues that the frames in game live-streaming qualify as derivative works based on games and are protected as audio-visual works under the U.S. Copyright Act.[3] Nevertheless, disputes concerning the rightful copyright holder of game live-streaming persist.

Game producers contend that streamers contribute minimally to live-streaming as most frames consist of static elements stored within the game programs. Irrespective of the streamer's skill level, live-streaming essentially involves presenting and recording these pre-existing elements. In contrast, streamers maintain that games are akin to sports, with game producers establishing the rules while players bring these rules to life. For instance, consider whether attributing all profits from broadcasting a basketball game should solely go to James Naismith. Although game producers hold copyright over intricate static frames, viewers place a more comprehensive value on the streaming experience. Streamers argue that their engaging gameplay, entertaining commentary, and interactive engagement capture viewer interest and sustain their enjoyment. Copyrights protect streamers' work against abuse and the "free-riding" problem, enhancing their bargaining power over game producers and platforms. Without the safeguard of copyrights, streamers would have little incentive to create more content, which is undoubtedly unfavorable to the industry's long-term growth.

From our perspective, game live-streaming constitutes a derivative work, entitling game producers and streamers to claim copyright. Current cases underscore the complexity of devising a uniform rule, given the diverse contributions of both parties. Entertaining streamers can amass large followings by playing content-oriented games, while less skilled streamers can attract viewers by broadcasting visually appealing frame-oriented games, even with minimal original input. Thus, addressing these issues case-by-case and incrementally formulating flexible standards based on judicial precedents and research appears prudent.

As demonstrated by a well-known case, "a single patent policy and patent law are unsuited to the range of scientific and commercial activity in today's economy."[4] Similarly, copyright law has lagged behind the rapid advancements of the digital economy. While concepts like "fair use" and "transformative use," which govern the unauthorized use of copyrighted works, are gaining traction even in conservative legislative environments, mainstream copyright protection still adheres to the traditional framework of exclusive rights that cannot be divided among multiple entities. However, this approach might not be economically efficient from a societal perspective. This paper proposes a preliminary numerical distribution scheme that judicial bodies can consider. The aim is to stimulate further discussions on copyright legislation and regulation, especially for digitally-based works.

Data description

Our empirical analysis relies on two primary datasets: stream-level data extracted from the Chinese mobile live-streaming platform "HuoShan" and game-related data obtained from QuestMobile and AppAnnie.

Stream-level data from HuoShan. Launched in 2017, HuoShan is a medium-sized live-streaming platform that aims to provide users with a comprehensive array of high-quality mobile game entertainment services. Developed by ByteDance, a prominent Chinese internet corporation, ByteDance manages several mobile applications (APPS) for live-streaming. As a dominant content provider in the Chinese live-streaming landscape, ByteDance reported revenue exceeding 17 billion U.S. dollars in 2019.

The stream-level data from HuoShan spans from July 22 to August 20, 2019, encompassing all game streams that generated income on the platform during this period. Each data entry represents an individual stream, identifiable through a unique ID that facilitates cross-database matching. The empirical analysis draws on the following variables:

Current income. This denotes the value of gifts a streamer receives during each streaming session. Gift values are measured in "diamonds", HuoShan's virtual currency, which can be converted to Chinese Yuan at a fixed official rate. It serves as a dependent variable in regression analysis.

Former fans. Represented as the logarithm of each streamer's average monthly fan count from March to June 2019. This variable serves as a proxy for streamer abilities and constitutes an independent variable in regressions.

Former AMIPF (Average Monthly Income per Fan). This logarithmically scaled variable signifies each streamer's average monthly income per fan from March to June 2019. Computed by dividing streamers' monthly income by their monthly fan count and calculating the average, it also acts as a proxy for streamer abilities in regression models.

Dates/Hours. These dummy variables indicate each stream's starting date and time, serving as control variables in regressions.

Game-related data. We gather game-related data from prominent online data providers QuestMobile and AppAnnie to assess each game type. These indicators help gauge the comprehensive

capacity of mobile game applications to attract players and generate revenue. The indicators include daily average users (DAU), average usage time per user, and daily in-app income.

Daily average users (DAU). This corresponds to the count of distinct APP users within a single day.

Average daily usage time per user. Denotes each user's daily mean time on the APP.

Daily in-app income. Represents the revenue generated by the APP from user activities within the application.

These variables can be roughly categorized into two groups. "Average daily usage time per user" and "Daily in-app income" are proxies for player engagement and game popularity, while "Daily average users (DAU)" indicates the player base. Due to their strong positive correlations, we include one or two of these proxy variables in each regression.

For specific game types with similar visual characteristics (e.g., shooting games), distinguishing them using the content-identification system is challenging. Consequently, we approximate the game-related data for specific game types by aggregating data from two, three, or four leading applications in Mobile Application Stores. Weighted averages are calculated based on the daily average of users for each application.

Descriptive statistics. Table A1 in the online appendix provides descriptive statistics for the main variables. The dataset comprises 11,202 valid observations. Substantial disparities between means and medians and the large standard deviations of dependent and independent variables indicate the long-tailed distributions of game streamer abilities and stream income. Moreover, there is noticeable heterogeneity among games. Streams associated with popular games tend to yield higher income, exhibiting a more substantial manifestation of the "Matthew Effect," where the share of streamers' contributions increases with their income levels. This underscores the rational decision-making of streamers in game selection and effort allocation.

Overall industry analysis

Cross-section estimates. To offer a preliminary overview of the game-streaming industry, we begin by conducting simple cross-section estimates. We focus on the coefficients of aggregated fans and average monthly income per fan, representing the overall relationship between streamer ability and stream income. The examination of heterogeneous effects across games on streamers will be discussed in Section 4.3.

For each stream's performance (i), we estimate the following equation:

$$(\text{Current income})_i = \beta_1(\text{Streamer})_i + \beta_2(\text{Game})_i + \lambda(\text{Covariates})_i + \alpha + \epsilon_i$$

In our regression models, we employ the natural logarithmic form of both dependent and independent variables for two main reasons: first, many variables exhibit long-tail distributions (Online Appendix Table A1); logarithmic transformations can partially mitigate the impact of heterogeneity. Second, since there's no definitive criterion for measuring abilities and we can only gauge relative abilities, logarithmic transformation allows for relative comparisons. The contribution share of streamers is calculated by $\beta_1/(\beta_1+\beta_2)$, while the share of game producers is $\beta_2/(\beta_1+\beta_2)$.

Table 2 presents our Ordinary Least Squares (OLS) estimates and heteroskedasticity-robust standard errors.[5] Column 1 showcases results without controlling for game-related variables. In contrast, columns 2-4 progressively include various combinations of game-related variables as controls.[6] One percent increase in former fans and average monthly income per fan averagely links to an increase of stream income by approximately 0.35 and 0.37, respectively. Including game-related variables together, these influences range from 0.38 to 0.40. This suggests a contribution share between streamers and game producers of approximately 2:1.[7]

Table 2 Cross-Section Estimates: Relationship between Streamers' Ability and the Stream Income.

	(1)	(2)	(3)	(4)
Dependent Variable	**Stream Income**	**Stream Income**	**Stream Income**	**Stream Income**
ln(fans)	0.334***	0.352***	0.352***	0.347***
	(0.008)	(0.009)	(0.009)	(0.009)
ln(AMIPF)	0.364***	0.374***	0.374***	0.375***
	(0.007)	(0.008)	(0.008)	(0.008)
ln(usage time)		0.379***	0.386***	0.420***
		(0.060)	(0.069)	(0.061)
ln(DAU)			-0.004	
			(0.020)	
ln(daily income)				−0.019***
				(0.007)
Time Effects	Yes	Yes	Yes	Yes
Observations	11,202	10,750	10,750	10,750

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors are reported in parentheses. According to columns 3 and 4, the contribution shares of streamers are $(0.352+0.374)/(0.352+0.374+0.386-0.004) \approx 65.5\%$ and $(0.347+0.375)/(0.347+0.375+0.420-0.019) \approx 64.3\%$. Similar calculations apply to Tables 3 and 4.

Quantile regressions. Given the highly asymmetric distribution of streamer ability and stream income, we conduct quantile regressions to ensure the robustness of our findings. The specification for these regressions is as follows:

$$(\text{Current income})_{q,i} = \alpha_q + \beta_q(\text{Streamer})_i + \lambda_q(\text{Game})_i + \gamma_q(\text{Covariates})_i + \epsilon_{q,i}$$

Table 3 presents quantile regressions for various conditional quantiles of current income levels (10, 25, 50, 75, and 90 percent) using two different sets of game-related variables. The results affirm that streamer ability and game attractiveness significantly correlate with streaming income. Notably, the magnitude of the correlation between streamer ability and stream income increases as the stream income level rises. For instance, at the upper quartile income level of stream incomes, a one percent increase in streamer ability links to an average increase of about 0.85 percent, roughly 1.5 times the magnitude at the lower quartile income level. These findings align with the intuitive understanding that streamers with higher skill levels reflected by higher incomes and more engaging styles significantly correlate with stream income. Additionally, coefficients of game-related variables remain insignificant for streams at the bottom income level, whereas streamer-related variables show strong significance. This reinforces the notion of allocating a larger share of income to streamers at lower income levels.

As demonstrated in Table 1, the estimated contribution ratios for streams at top-, mid-, and bottom-quartile income levels range from approximately 59.2% to 65.1%, 64.0% to 66.8%, and 66.4% to 65.1%, respectively. The contribution share between streamers and game producers is roughly 2:1 across all stream income levels. From an industry-wide perspective, this suggests that streamers' contributions predominate at all income levels.

For further robustness and intuitive results, the trends of the main coefficients are observed in bootstrapped quantile regressions, along with a comparison to OLS estimates (Online Appendix Figure A5). Regardless of whether daily usage time

Table 3 Quantile Regression: Relationship between Streamers' Ability and the Stream Income.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS		Q10		Q25		Q50		Q75		Q90	
DV	Stream Income		Stream Income		Stream Income		Stream Income		Stream Income		Stream Income	
ln(fans)	0.352***	0.347***	0.075***	0.072***	0.262***	0.256***	0.384***	0.377***	0.426***	0.422***	0.408***	0.402***
	(0.009)	(0.009)	(0.020)	(0.016)	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)	(0.013)
ln(AMIPF)	0.374***	0.375***	0.091***	0.091***	0.307***	0.311***	0.436***	0.438***	0.428***	0.428***	0.367***	0.366***
	(0.008)	(0.008)	(0.022)	(0.013)	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.011)
ln(usage time)	0.386***	0.420***	0.081	0.130	0.170	0.365***	0.383***	0.468***	0.525***	0.466***	0.549***	0.498***
	(0.069)	(0.061)	(0.077)	(0.114)	(0.108)	(0.097)	(0.104)	(0.090)	(0.098)	(0.084)	(0.103)	(0.095)
ln(DAU)	-0.004		0.024		0.135***		0.025		−0.067**		-0.049*	
	(0.020)		(0.021)		(0.030)		(0.029)		(0.027)		(0.028)	
ln(daily income)		−0.019***		0.001		0.025**		−0.010		-0.036***		−0.027**
		(0.007)		(0.013)		(0.011)		(0.010)		(0.009)		(0.011)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,750	10,750	10,750	10,750	10,750	10,750	10,750	10,750	10,750	10,750	10,750	10,750

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors are reported in parentheses.

length per user and DAU or daily usage time length per user and daily income within the application are included as controls, the trends remain consistent. Compared to the trend of monotonically increasing magnitude of the correlation between game-related variables and stream income, the magnitude of the correlation between streamer ability and income initially rises as the stream income level increases, then plateaus when the stream income level approaches the top 30 percent. This observation suggests a bottleneck in stream income. Initially, streamers can significantly enhance their income by improving their abilities, but the marginal returns decrease as they reach higher skill levels. This phenomenon suggests that competition among streamers at the top income level is fierce, and further improvements in skill might yield diminishing returns.

Heterogeneity across games. To explore heterogeneity across different games, we present bootstrapped quantile regression estimates for each game at different stream income levels in Fig. 2. The trends of coefficients for game-related variables generally remain horizontal and close to zero, indicating that the correlation between game genres and stream income is insignificant for most games.

Differences between the trends of streamer-related coefficients are noticeable across games. Games like "BuildTopia", "Mini World", "Game for Peace", and "Dou Dizhu" exhibit an increasing trend of streamer ability coefficients with higher stream income levels, reflecting a strong Matthew Effect. This suggests that the positive correlation between streamer ability and stream income grows significantly for these games. Consequently, streamers are incentivized to improve their skills and invest in self-improvement. In contrast, games like "Chinese Chess", "Tom & Jerry", "Identity V", "Sausage Party", "QQ Speed", and "Shuffle" show nearly horizontal trends for streamer-related coefficients, indicating a weaker Matthew Effect.

This analysis provides deeper insights into the popularity of streams for various games. Some games, like "Game for Peace" and "Dou Dizhu", experience a strong Matthew Effect, with streamer ability substantially correlating with income. In such cases, streamers are motivated to improve their skills and invest in growth, even when competing at the top income level. These observations contribute to a richer understanding of the dynamics within the game-streaming industry.

Professional streamers

Numerous players transition into becoming full-time professionals who sustain themselves through streaming, leading to heightened dedication and motivation for self-improvement compared to amateurs. Consequently, we posit that professionals' abilities correlate more substantially with stream income. However, a clear quantitative distinction between professionals and general streamers is absent. Nevertheless, streaming frequency, duration of streams, and stream income can offer some insights. To tackle this ambiguity, we adopt a clustering methodology to categorize streams most likely representative of professional work.

We apply K-means clustering to segment the observations into three groups (Online Appendix Figure A6 (1)). Streams generated by prolific and high-income streamers are identified as professional streams, as highlighted in blue in Online Appendix Figure A6. To ensure robustness, we additionally employ two commonly used hierarchical clustering techniques-average linkage and Ward's linkage (Online Appendix Figure A6 (2) and (3)). The results from these supplementary analyses align closely with the initial K-means clustering.

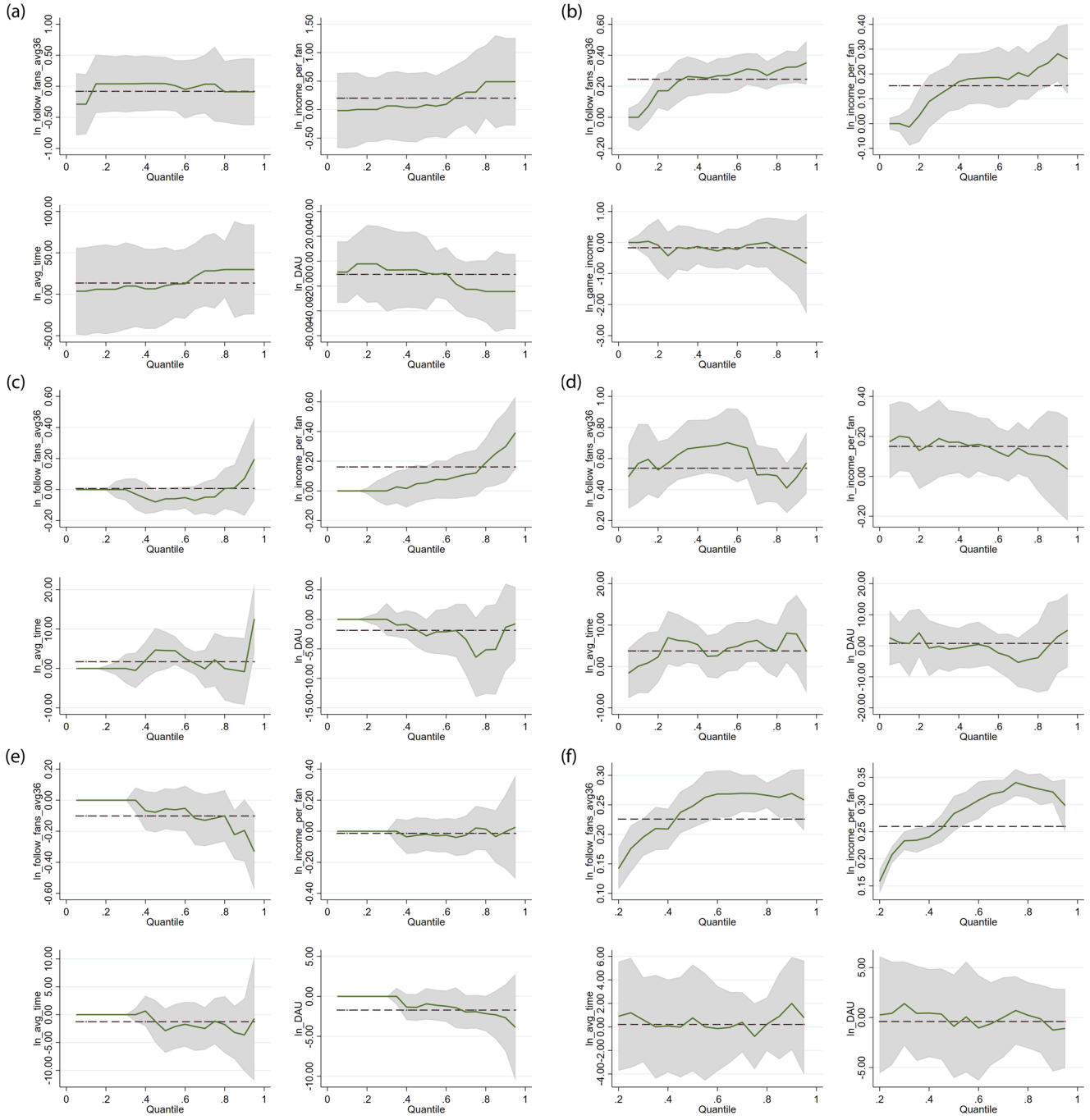

Fig. 2 Bootstrapped Quantile Regression Across Games (Overall Industry). The green line represents estimates of coefficients, the shadowed area represents a 95% confidence interval, and the dotted line represents point estimation.

Following a similar approach as in Section 4.1, we perform OLS estimations. Columns 1 and 2, 3 and 4, 5 and 6 of Table 4 showcase the estimates for streams attributed to professionals, as determined by K-means, Ward's linkage, and average linkage, respectively. The corresponding contribution shares amount to 67.5% - 70.3%, 82.1% - 86.5%, and 67.0% - 69.5%. This shows a slight increase compared to the findings in Table 2, albeit not significantly higher. Moreover, the coefficients for streamer-related and game-related variables are smaller than those in columns 3 and 4 of Table 2. Specifically, a unit percent increase in streamer-related variables now suggests an average increase of around 0.4, while it was 0.7 for the overall industry. This indicates the intense competition among professional streamers. Boosting income by refining streamer abilities or selecting popular and captivating games has become progressively challenging.

It's worth noting that while the coefficient of DAU was insignificantly negative in column 3 of Table 2, it is now significantly negative. This reflects streamers' trade-offs when deciding whether to stream a popular game. A game with a more extensive active user base implies a broader pool of potential viewers and more potential earnings, but it also signifies heightened competition. In the broader industry context, opportunity and competition tend to balance each other out, whereas intensified competition exacerbates its negative correlation with income among professionals.

Table 4 Cross-Section Estimates: Relationship between Professional Streamers' Ability and the Stream Income.

	(1)	(2)	(3)	(4)	(5)	(6)
Clustering Method	**K-means**		**Ward's Linkage**		**Average Linkage**	
Dependent Variables	**Stream Income**	**Stream Income**	**Stream Income**	**Stream Income**	**Stream Income**	**Stream Income**
ln(fans)	0.233***	0.232***	0.228***	0.227***	0.216***	0.215***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)
ln(AMIPF)	0.215***	0.215***	0.203***	0.204***	0.188***	0.188***
	(0.013)	(0.013)	(0.014)	(0.014)	(0.010)	(0.010)
ln(usage time)	0.308***	0.225***	0.186**	0.104	0.266***	0.203***
	(0.076)	(0.074)	(0.074)	(0.074)	(0.071)	(0.068)
ln(DAU)	−0.092***		−0.092***		−0.067***	
	(0.021)		(0.020)		(0.019)	
ln(daily income)		−0.036***		−0.037***		−0.026***
		(0.007)		(0.007)		(0.007)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3281	3281	2583	2583	3472	3472

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors are reported in parentheses.

Similar to Section 4.2, we utilize bootstrapped quantile regressions to investigate heterogeneity among professional streams. Online Appendix Tables A6–A8 present the quantile estimates using K-means, Ward's, and average linkage clustering. The magnitude and significance of streamer- and game-related variables in these tables demonstrate remarkable similarity. Notably, the coefficients of game-related variables for streams at the middle-income level when employing Ward's linkage clustering are smaller than those using K-means clustering. Consequently, the contribution share of streamers shifts from approximately 73.1–75.8% with K-means clustering to 92.5–96.4% with Ward's linkage clustering. In general, adopting Ward's Linkage clustering to identify streams produced by professionals yields substantially higher contribution share measurements. Meanwhile, average linkage clustering yields measurements akin to K-means clustering. Panel B of Online Appendix Table A5 provides a comparative analysis of measurements using different clustering methods.

The coefficient trends of quantile regressions remain consistent when utilizing the K-means, Ward's linkage, and average linkage methods for stream identification (Online Appendix Figure A8). The "inverted-L" shape curve characterizing the relationship between streamer ability and stream income suggests that its magnitude reaches a bottleneck as streams ascend to the top 60% income level. This trend is indicative of fierce competition among the highest-income streams. The trends for game-related variables exhibit near-horizontal patterns. Notably, daily average usage time per user emerges as a stronger explanatory variable than DAU and daily income within game applications across all stream income levels.

Discussions

The role of platforms. An essential aspect insufficiently addressed in our paper pertains to the important role of platforms in the game live-streaming industry. Platforms connect the viewers with streamers and provide an essential environment for live-streaming. Various researchers have highlighted the significant impact of environmental stimuli on viewers' participation through cognitive and emotional channels (Li et al. 2020; Xu et al. 2021). Nevertheless, we explain why the current paper does not assign great importance to the contribution of platforms.

Most importantly, this paper aims to discuss how copyrights should be attributed among creators according to creators' contribution share instead of how copyrights are distributed among related entities in reality. Copyright inherently rewards direct contributors specific to the creation, even though multiple interested parties may contribute to the creation process. Let us consider another platform type, exhibition, which connects initial innovators, subsequent creators, and viewers/consumers/users with various high-quality exhibits. For example, the Great Exhibition in 1851, held in London, provided a significant opportunity for innovators to showcase their innovations to potential users. Many displayed for the first time at the Great Exhibition were "sequential innovations" built upon previous patents (e.g., steam engines, automated spinning machines, and water pumps). Moreover, the exhibits also motivated re-creations, which are displayed in the following exhibitions. It is widely acknowledged that the exhibition, serving as a platform that forms an ecosystem of the supply and demand sides, is crucial in value realization. However, the consensus is that a patent should not be granted to the Great Exhibition. The same rationale applies to game live-streaming.

Analogously, in a "commissioned work/work made for hire," the copyright is generally attributed to employees rather than employers, despite the latter providing diverse conveniences to the creation process. In comparison to platforms that mainly focus on driving aggregated traffic to themselves, the contributions of streamers and game producers are more focused and specific to the creation of streams, addressing viewers' diverse needs for affective gratifications and tension release through various stream types (competitive, let's play, casual, speedruns, talk shows, how-to-play, and reviews) (Sjöblom et al. 2017). Streamers design intellectual playing strategies, show talented playing skills, look for suitable background music, and engage with viewers actively (Wulf et al. 2020). Simultaneously, game producers must promptly cater to players' needs, fixing bugs to provide a seamless gaming experience.

Second, the motivation behind copyright is to balance creators' incentives to create further and the widespread propagation of works (Sterk, 1995). In a scenario where streaming platforms exert substantial control over streamers (Quintais et al. 2023) and wield market power over viewers, granting platforms a share of copyright could exacerbate imbalances within the game live-

streaming industry. This imbalance may dampen streamers' incentives and hinder the industry's long-term growth.

Third, there are practical and efficient ways to reallocate rewards between platforms and streamers or platforms and game producers. In the highly distributed user-generated content industry of game live-streaming, which connects thousands of game producers and millions of streamers, the communication cost is prohibitively high for a case-by-case arrangement of copyright issues. However, this is not a concern for platforms with personalization capabilities. Platforms can enter contracts with streamers/platforms to secure specific shares from their total income or deduct a portion of viewers' tips, given their control over payment channels. Considering the perspectives discussed above, we assert that it may be unnecessary to consider granting platforms a specific share in the initial allocation of copyright.

With mixed perspectives above in mind, we contend that assigning less importance to platforms in our analysis does not alter our analytical framework of the copyright distribution scheme between streamers and game producers.

Limitations and future research. This paper acknowledges several limitations. First, our data covers only one month, and the highly uneven stream frequency distribution impedes identifying individual fixed effects. Future research using panel data with a more extended time range is warranted to characterize the causal effects in the creation of game live-streamings. Second, our data is derived from a single medium-sized platform, posing challenges in discussing the role of platforms comprehensively. Subsequent research should encompass data from more platforms to enhance representativeness and leverage differences in sensitivity between large and small platforms for difference-in-difference analysis. Data from more dimensions can also allow future research to take factors (e.g., intra-/inter-platform competition, paid prominence, advertisement, self-preferencing, and platform strategies related to ecosystem governance) that may also influence viewers' tipping into consideration. Third, while our analysis establishes a benchmark for sequential innovation measurement, there may be considerable diversity between game live-streaming and other work and patents. More sophisticated methods are needed to identify the value of innovation and the contribution shares of innovators. Last, this paper provides limited discussion on streamers who sign contracts with platforms, constituting a small proportion of all streamers. Their creation logic follows a "reward system" instead of copyright, resembling corporate works (Shavell and Van Ypersele, 2001). Further research is encouraged to delve deeper into this aspect.

Conclusions

In this paper, we estimate the relationship between streamer ability and games and the income of game live streams with stream-level data from a Chinese mobile live-streaming platform. The paper uncovers important insights that shed light on income distribution in this emerging industry by combining OLS estimates and quantile regressions.

Three key findings emerge from the study. First, the contribution share between streamers and game producers is approximately 2:1, with streamers holding the larger portion. This result holds across different income levels of streams and when considering professional streamers, indicating that streamers may correlate more closely with the stream income than game genres. Second, the Matthew Effect, wherein high-income streams accumulate more income, is significant in the industry. Certain popular games exhibit an exceedingly large Matthew Effect, suggesting that successful streams of these games have a higher potential for amassing greater income. This underscores the importance of not only streamer ability but also the choice of games in determining income. Last, the study highlights the considerable heterogeneity across different types of games. The relationship between streamer ability and income varies widely across games, influencing streamers' preferences in selecting games to stream. This implies that a one-size-fits-all approach is inadequate for determining the contribution share of streamers and game producers.

The paper's insights have implications for the distribution of copyright and income in the game live-streaming industry. We argue that streamers' contributions are paramount and recommend a more flexible approach to copyright, particularly in digital audiovisual works. Furthermore, the study underscores the need for nuanced legal frameworks that recognize the diverse dynamics between streamers and game producers in different contexts.

Data availability

Due to the protection of individual privacy and trade secrets, the datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Notes

1 Certain theoretical models treat the distribution of profit shares as externally determined to simplify the models (Bessen and Maskin, 2009; Green and Scotchmer, 1995), but these considerations remain fundamental.
2 See "2020 China Mobile Game Industry Research Report" by iResearch Inc.
3 Copyright Act, 17 U.S.C. §§101-1332 (2012).
4 Water Techs. Corp. v. Calco, Ltd., 850 F.2d 660 (Fed. Cir. 1988).
5 It is imperative to note that OLS estimates may not adequately capture causal effects due to the potential for endogeneity issues arising from omitted variables, measurement errors, or simultaneity. For instance, both the dependent and main explanatory variables could depend on streamers' unobservable ability traits. Such issues can lead to biased or inconsistent estimates. A more comprehensive discussion on this matter is provided in Section 7.2.
6 Due to the absence of DAU and daily usage time length per user data for the game "BuildTopia", these variables are not included in regressions for columns 2-4.
7 To be precise, the calculated contribution proportions are approximately 1.901 and 1.801.

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Author contributions

HJL and XDX collected the original data and performed the initial data analysis. HJL, XDX, and XZH conceived and wrote this paper. All authors read and approved the final manuscript. The authors contribute equally to the paper, and authors are ordered alphabetically.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

Informed consent was not required as the study did not contain any studies with human participants performed by any of the authors.

Additional information

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