The High Cost of Entertainment: Quantifying the Carbon Footprint of Live Concerts in the Post-COVID Era

Jialiang Zhu
jialiang@xmu.edu.cn

Jianuo Xu, Corresponding Author
atoniexu@stu.xmu.edu.cn

Abstract

This study addresses the significant environmental and economic challenges posed by live concerts in the post-COVID era through a detailed analysis of the carbon costs associated with air travel. By examining airline records and concert sales figures, we demonstrate that the top live concert artists contribute an average of approximately 0.067 million metric ton CO2 equivalent (MMT CO2eq.) of greenhouse gas (GHG) emissions per concert solely from air travel. The financial burden of mitigating these emissions is substantial, with the annual cost for airlines averaging $485.5 million – figures that often surpass the revenue generated by the concerts themselves. Notably, the impact varies greatly among artists; the cost of mitigating GHG emissions for Lady Gaga's concerts is 18 times higher as her concert revenue, whereas for Coldplay, it is only 0.4 times. This paper contributes to the cultural economics literature by highlighting the substantial carbon costs from major cultural events.

Keywords: *Live Concerts; GHG Emissions; Abatement Cost*

JEL Classification: *Q51; Q53; R11.*

Conflict of Interests: Competing Interests: Jialiang Zhu declares employment at Xiamen University. Jianuo Xu declares employment at Xiamen University. Funding: Jialiang Zhu acknowledges support from the National Natural Science Foundation of China for this work, under grant number 72133004.

1 Introduction

Cultural amenities significantly enhance the well-being of city inhabitants and serve as a key urban feature that attracts, particularly, educated newcomers. Since the late 1990s, a growing body of literature has explored the role of culture in urban development (Mouate and Travers, 2024). Governments have increasingly recognized the value of cultural investments, as evidenced by rising municipal expenditures on culture, which have been shown to scale with the size of the municipality (Getzner, 2022).

However, the COVID-19 pandemic has profoundly reshaped cultural consumption patterns. Recent studies have indicated a substantial decline in public participation in cultural and arts activities, with a decrease of 15 to 17 percentage points for venue-based activities and 24 to 25 percentage points for outdoor events in South Korea (Shin, 2024). Despite these challenges, the United States has witnessed a remarkable resurgence in live concerts, reaching record highs. Live Nation reported unprecedented performance in 2023, continuing into the first quarter of 2024 with robust ticket sales and confirmed bookings.[1] According to PwC, industry revenue in the U.S. is projected to reach \$9.5 billion in 2023 and could ascend to \$10.5 billion by 2027.[2] This resurgence is fueled by post-pandemic pent-up demand, contributing to a boom in music tourism and a burgeoning fanbase, as exemplified by Taylor Swift, who was named Time Magazine's Person of the Year.[3]

The cultural economics literature has increasingly focused on expanding high culture audiences and optimizing ticket pricing strategies to maximize concert revenues, along with understanding factors that influence attendance at live performances (Chen and Tang, 2021; Thompson, 2024; Gutierrez-Navratil et al., 2024). Yet, this burgeoning sector also imposes significant demands on the capacities of host cities. While other economic studies have addressed the impacts of mega-events on local economies, including traffic congestion and environmental pollution (Collins et al., 2009; Du and Zhang, 2022), surprisingly little attention has been paid to the frequent and populous live concerts. Recent shifts in focus include the greenhouse gas (GHG) emissions associated with such events, a critical area still under-explored for live concerts, which are more recurrent than many other mega-events (Zhang et al., 2022).

Therefore, this paper aims to bridge this gap by quantifying the carbon costs associated with live concerts. Employing a fixed-effects model with comprehensive airline data, we estimate the additional GHG emissions generated by concertgoers. Our findings reveal that the top live concert artists are responsible for an average of approximately 0.067 MMT CO2eq. of GHG emissions per concert, due to increased air travel to host cities. Based on the hyperbolic productive efficiency model outlined by Faere et al. (1989), we calculate the

[1] For further details on the recent surge in ticket sales, refer to Live Nation's official announcement at Live Nation Entertainment. See url: https://www.livenationentertainment.com/2023/05/live-nation-announces-annual-concert-week-25-all-in-tickets-to-over-3800-shows-this-year-2/

[2] Additional information on projected industry revenue can be found in the PwC report, "Perspectives from the Global Entertainment & Media Outlook 2023–2027, Resetting expectations, refocusing inward and recharging growth."

[3] For details on Taylor Swift being named Time Magazine's Person of the Year, see the article at Time Magazine, "Taylor Swift Makes History as Person of the Year. Here's How".

Marginal Abatement Cost (MAC), which averages about $895.5 per ton. Thus, the costs to mitigate these emissions typically amount to about twice the revenue generated from these concerts. In addition, we find that the impact varies greatly among artists. The cost of mitigating GHG emissions for Lady Gaga's concerts is 18 times higher as her concert revenue, whereas for Coldplay, it is only 0.4 times.

While existing literature has primarily focused on enhancing audience engagement and optimizing revenue strategies for high culture events, this paper contributes to the culture economics literature by introducing a critical examination of the carbon costs associated with these live concert gatherings. We provide concrete estimates of greenhouse gas emissions driven by concert-related travel and activities, highlighting a substantial carbon costs that contrast sharply with the occasional nature of other large-scale events. Our findings emphasize the need for innovative technological interventions to mitigate the carbon footprint of these culturally significant but environmentally costly events. By expanding the discourse in cultural economics to include environmental considerations, our study not only enriches existing academic discussions but also offers practical insights for policymakers aiming to balance cultural enrichment with environmental sustainability.

The structure of this paper is as follows: Section 2 briefly discusses the resurgence of the live concert industry and its associated GHG emissions; Section 3 details the data utilized in our analysis; Section 4 discusses the estimation of additional GHG emissions attributed to live concerts in hosting cities; Section 5 describes our methodology for calculating the MAC of GHG emissions and presents the findings; Section 6 provides our conclusions.

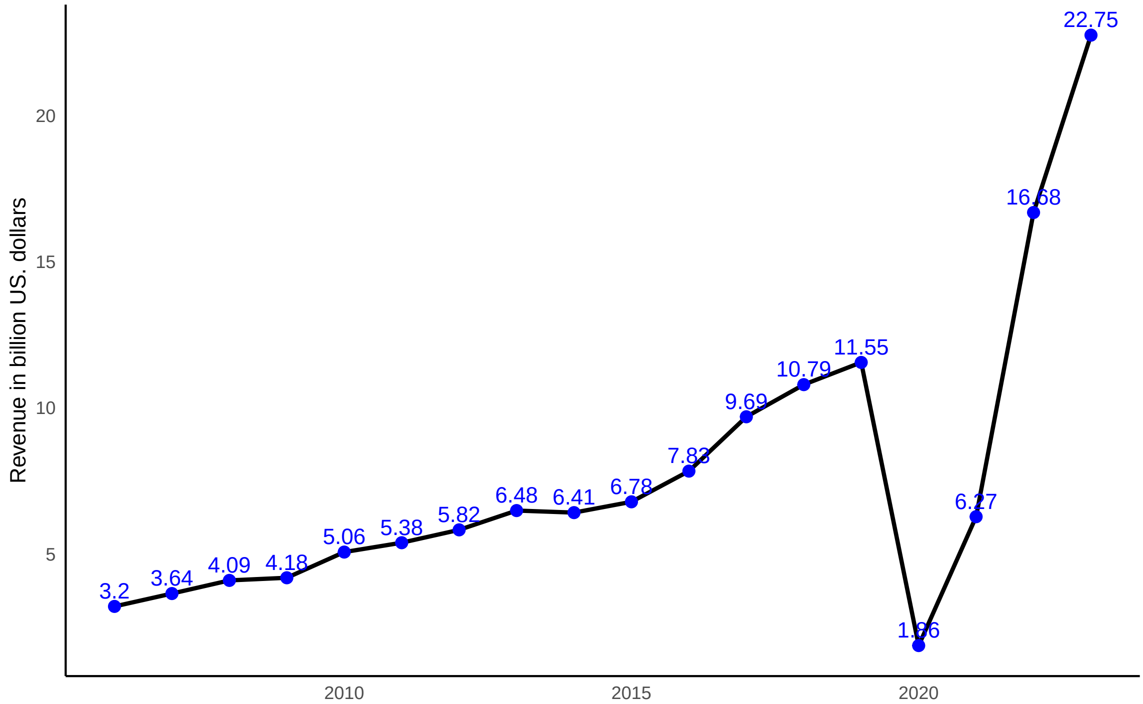
2 Resurgent Live Concerts and Indirect GHG Emissions

The live concert industry was severely impacted during the COVID-19 pandemic, forcing people to stay home and leading to a significant drop in industry revenue. As depicted in Figure 1, the revenue from Live Nation Entertainment gradually increased over the years but experienced a sharp decline in 2020. However, revenue rebounded in 2022 and soared even higher in 2023. Industry analysis indicates that digital ticketing platforms and social media have opened new avenues for reaching audiences and expanding market reach, while post-pandemic conditions have reignited public interest in live events. This resurgence in live entertainment has resulted in unprecedented ticket sales and fully booked venues. Revenue ultimately grew at a compound annual growth rate (CAGR) of 4.2% over the years to 2024, including an increase of 2.6% in that year alone, totaling $56.0 billion.[4]

Figure 2 displays the gross sales of the top 10 artists and their corresponding attendance in 2023. Despite the higher prices for concert and event tickets, fans remain undeterred. The rapid rise in live concert industry revenue is beneficial for business and cultural consumption. However, it also leads to significant pressure on local traffic systems and

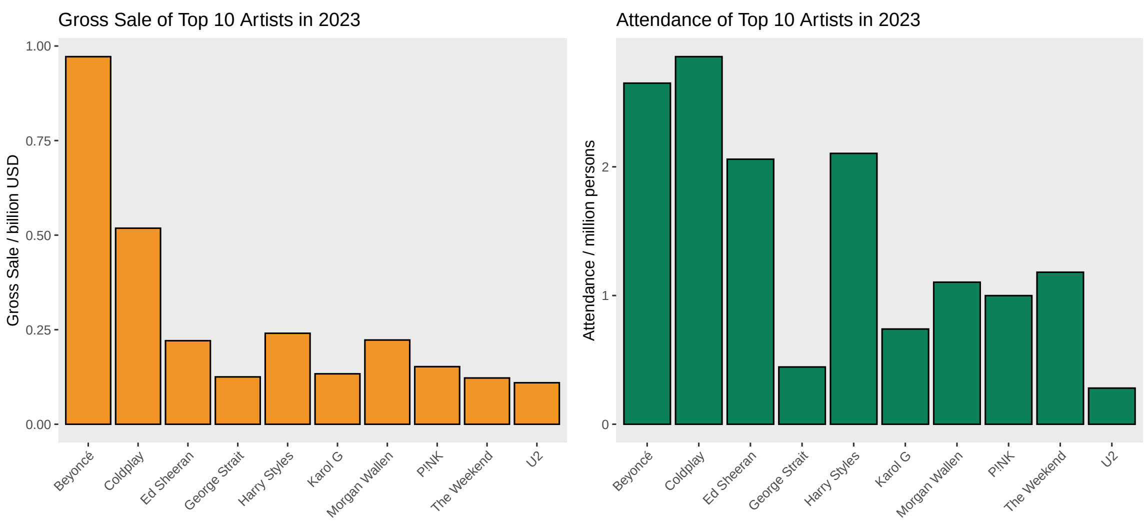
[4]For additional details on industry reports, refer to the IBISWorld Market Research Report titled "Concert & Event Promotion in the US (2014-2029)."

Figure 1: Revenue Live Nation Entertainment from 2006 to 2023



Notes: Figure 1 charts the revenue trends of Live Nation Entertainment from 2006 to 2023. Notably, the revenue sharply declined in 2020, reflecting the severe impact of the COVID-19 pandemic on the. industry. Data sourced from Statista

Figure 2: Gross sales of the top 10 artists and their corresponding attendance in 2023



Notes: Figure 2 illustrates the gross sales and corresponding attendance for the top 10 artists in live concerts for the year 2023. Data sourced from Pollstar.

generates indirect greenhouse gas emissions due to the massive influx of fans into cities.[5]

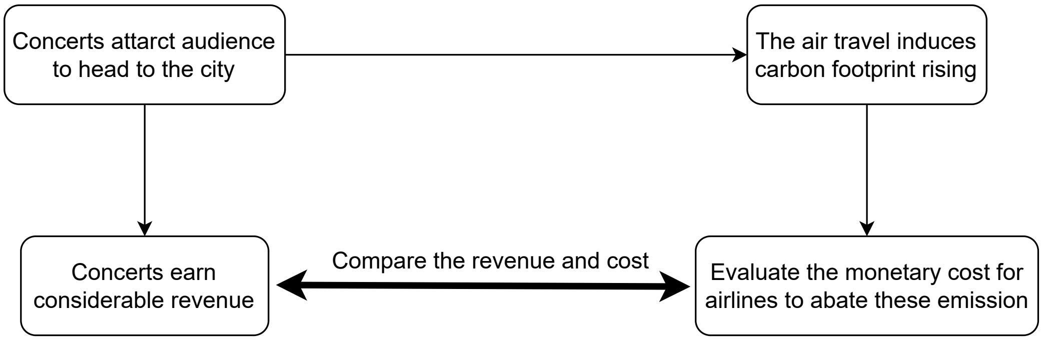
Therefore, this paper seeks to estimate a lower bound of the GHG emissions from these resurgent live concerts in the US by examining air travel data from cities hosting

[5]For more information on indirect emissions from events and conferences, including travel, hotel stays, and venue usage, see the Environmental Protection Agency's report at EPA Climate Leadership.

live concerts. We aim to calculate the MAC for the corresponding airlines to reduce these emissions and the total pecuniary cost of mitigating this additional GHG emission.

Figure 3 outlines the framework used in the paper to analyze the revenues and carbon costs of live concerts. It starts by depicting how concerts attract audiences to its base, leading to significant revenue generation. Subsequently, the framework addresses the carbon costs by evaluating the monetary expenditure required for airlines to mitigate the increased carbon emissions induced by air travel.

Figure 3: Economic and Environmental Impacts of Live Concerts



Notes: This diagram outlines the framework used in the paper to analyze the economic and environmental impacts of live concerts. It details the sequence of assessing the revenue generated, the associated rise in carbon footprint due to air travel, and the monetary costs involved in mitigating these emissions.

3 Data

The data employed in this study originates from two principal sources: aviation travel statistics and concert sales figures. For aviation data, we utilized comprehensive records from the Bureau of Transportation Statistics, part of the United States Department of Transportation. This dataset encompasses monthly records from January 2022 through December 2023, detailing the origin and destination cities, number of passengers, freight, mail enplaned, and flight distances. This information is provided by certificated U.S. and foreign air carriers.

To accurately estimate the GHG emissions associated with each flight, we adopted conversion factors from the "2022 Government Greenhouse Gas Conversion Factors for Company Reporting: Methodology Paper".[6] For example, consider a scenario where a civil airliner enplanes 400 passengers for a 4000-kilometer flight. Multiplying the GHG conversion factor for short-haul flights (distances greater than 1100 kilometers and up to

[6]The "2022 Government Greenhouse Gas Conversion Factors for Company Reporting: Methodology Paper," jointly published by the United Kingdom's Department for Business, Energy and Industrial Strategy (BEIS) and the Department for Environment, Food and Rural Affairs (DEFRA), provides detailed GHG emission conversion factors. Although primarily intended for UK-based and international organizations, these factors are also applied by entities worldwide, including U.S. airlines, to report and manage their GHG emissions. For more information, visit BEIS/DEFRA.

4700 kilometers) at 75.2 gCO2eq. per passenger kilometer, the total GHG emissions for this flight are calculated as 0.120 MMT CO2eq.. It is important to note that flights solely dedicated to cargo are excluded from this analysis.

Regarding the concert data, we select the top 10 artists based on gross sales figures provided by Pollstar's Year-End TOP300 Concerts Grosses for 2022 and 2023.[7] Since there are several artists dominated in both 2022 and 2023, our list contains 16 artists' names finally. In addition, Pollstar also details information about specific venues and dates of concerts, so that we are enabled to match concert events with air travel data according to the hosting city and month of the event precisely.

Table 1 below provides a summary statistic of the aviation specifications collected for this paper.

Table 1: Panel A: Summary Statistic of Aviation Specifications

Statistic	Unit	N	Mean	Min	Max
Passengers	10^3 persons	13761	99.984	0.001	1839.895
Distance	10^3 kilometers	13761	98.661	0.027	1151.917
CO2	MMT CO2eq.	13761	0.047	0.000	0.963
N2O	MMT CO2eq.	13761	0.000	0.000	0.009
CH4	MMT CO2eq.	13761	0.000	0.000	0.000
Total GHG	MMT CO2eq.	13761	0.047	0.000	0.972

Note: GHG emissions by airplanes are estimated by multiplying the number of passenger by distance traveled, with conversion factors in turn. Conversion factors are detailed in the "2022 Government Greenhouse Gas Conversion Factors for Company Reporting: Methodology Paper."

4 Empirical Specification

To quantify the additional GHG emissions generated by live concerts in host cities, we employed a fixed-effects model. The model specification is as follows:

$$y_{i,t} = \alpha \cdot Concert_{i,t} + \mu_i + \nu_t + \epsilon_{i,t}, \tag{1}$$

where $y_{i,t}$represents the variables that specify airline activities and their corresponding carbon footprint, including CO2, N2O, CH4, and their totals. $Concert_{i,t}$ is a binary indicator equal to 1 if a concert is held in the destination city i in month t, and 0 otherwise; the coefficient α measures the incremental effect of hosting a concert in city i during month t. The fixed-effect indicator μ_i is set to 1 if city i has hosted at least one concert during the observation period, and 0 otherwise; ν_t represents time fixed effects, set to 1 after the first concert is held; $\epsilon_{i,t}$ is the error term. The data we use spans from 2022 to 2023.

[7]The concert data sourced from Pollstar's Year-End TOP300 Concert Grosses provides in-depth details on each artist's live performances, including venue locations, audience sizes, and saless. It is important to note that Taylor Swift's concert data is excluded, as her management has opted not to release official box-office numbers for her tours. For further details, visit Pollstar.com.

Table 2: Baseline Regression on All Concerts

	(1) Passengers	(2) Distance	(3) N2O	(4) CO2	(5) CH4	(6) Total GHG
Concert	32.433***	6.899	0.000***	0.021***	0.000	0.021***
	(11.291)	(9.555)	(0.000)	(0.006)	(0.000)	(0.006)
Observations	13,761	13,761	13,761	13,761	13,761	13,761
R^2	0.208	0.235	0.174	0.174	0.053	0.174
Adjusted R^2	0.208	0.235	0.174	0.174	0.052	0.174
Residual Std. Error	178.365	150.951	0.001	0.096	0.000	0.096

Notes: This table displays the results from equation (1), evaluating the impact of concerts on air travel and greenhouse gas emissions. Column (1) reports the additional passengers, showing that concerts attract over 32,000 additional air travelers on average. Columns (2) through (6) analyze the distance traveled and emissions (N2O, CO2, CH4, and total GHG), respectively. Notably, while the distances traveled by these passengers do not vary significantly, the emissions metrics, particularly for N2O and total GHG, are significantly higher when a concert occurs in a city. The total GHG emissions associated with these concerts average about 0.02 MMT CO2eq.. Standard errors are in parentheses below the coefficients, with significance levels indicated by asterisks: *** ($p<0.01$), ** ($p<0.05$), * ($p<0.1$).

Table 2 presents the results from Equation (1). Column (1) shows that on average, live concerts attract more than 32,000 passengers traveling by air. While there is no significant difference in the traveling distances of passengers, the emissions of N2O, CO2, and total GHG are significantly higher if the city hosts a concert. On average, air travel associated with concerts results in approximately 0.02 MMT CO2eq. of GHG emissions.

Furthermore, to examine the impacts of different artists' popularity and influence, we analyze the heterogeneous effects corresponding to various artists. We estimate the following equation:

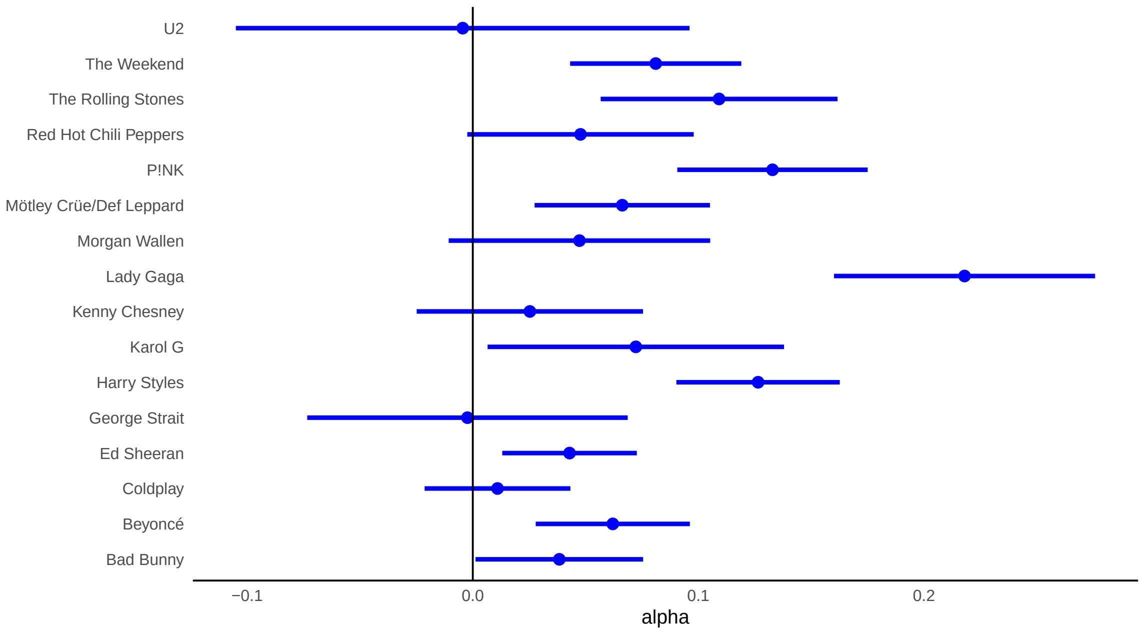
$$GHG_{i,t} = \alpha_j \cdot Concert_{i,j,t} + \mu_{i,j} + \nu_{t,j} + \epsilon_{i,j,t}, \tag{2}$$

where 2, concerts are categorized by their hosts, $Concert_{i,j,t}$ equals to 1 if there's an concert by artist j held in the destination city i during month t, and 0 otherwise.

Figure 4 displays the regression results, highlighting the additional GHG emissions contributed by each artist to the host cities on a monthly basis. Notably, Lady Gaga's concerts generate an additional 0.218 MMT CO2eq. of GHG emissions in host cities. Similarly, P!NK is responsible for an additional 0.133 MMT CO2eq., whereas concerts by Coldplay lead to a smaller increase of just 0.011 MMT CO2eq. in GHG emissions.

To ensure the robustness of our findings, we employ various fixed-effect specifications in our model. We apply city-specific fixed effects, followed by month-specific fixed effects, respectively. Both sets of robustness checks yield consistent results. For detailed outcomes, please refer to the Robustness Checks section provided in the Appendix.

Figure 4: Impact of Live Concerts on GHG Emissions by Top Artists



Notes: Figure 4 visually represents the regression results, illustrating the additional GHG emissions attributed to each artist's live concerts on a monthly basis in host cities. Each horizontal bar indicates the point estimate of the emission increase, with the lines representing the 90% confidence intervals.

5 Abatement Cost Estimation

5.1 Hyperbolic Productive Efficiency Model

To estimate airline's MAC, we apply the shadow cost approach, incorporating the non-parametric production model and enhanced hyperbolic productive efficiency measures as proposed by Faere et al. (1989). The primary step in this methodology involves the construction of a production function, defined as follows:

$$P(\mathbf{x}) = \{(\mathbf{y}, \mathbf{u}) : \mathbf{x} \text{ can produce } (\mathbf{y}, \mathbf{u}), \mathbf{x} \in \Re_+^N, \tag{3}$$

where $\mathbf{x} = (x_1, ..., x_N) \in \Re_+^N$ represents input vectors, $\mathbf{y} = (y_1, ..., y_M) \in \Re_+^M$ represents desirable outputs, and $\mathbf{u} = (u_1, ..., u_J) \in \Re_+^J$ represents undesirable outputs by products (e.g. CO_2).

Following Faere et al. (1989), outputs are weakly disposable if

$$u \in P(x) \Rightarrow \theta u \in P(x) \text{ for all } 0 \leq \theta \leq 1. \tag{4}$$

Or strongly disposable if

$$u' \leq u \in P(x) \Rightarrow u' \in P(x). \tag{5}$$

We assume desirable outputs are strongly disposable while undesirable outputs are weakly disposable. Therefore, we have

$$(y, u) \in P(x) \Rightarrow (y', u) \in P(x) \text{ for } y' \leq y. \tag{6}$$

Suppose there are $k = 1, ..., K$ producers (airlines) using x^k to produce outputs (y^k, u^k). Denote the N $\times$ K matrix of observed inputs by **X**, the M $\times$ K matrix of observed desirable outputs by **Y**, and J $\times$ K matrix of observed undesirable outputs by **U**. **X**, **Y** and **U** are non-negative matrices having strictly positive row sums and column sums.

The weak disposal reference technology, associated with observed data **X**, **Y**, **U** defines the output set:

$$P^w(x) = \{(y, u) : Y \leq Yz, U = Uz, Xz \leq x, z \in \Re^K_+\} \tag{7}$$

where z is a $K \times 1$ vector of intensity variables. In contrast, the strong disposal reference technology is defined by the output set:

$$P^s(x) = \{(y, u) : Y \leq Yz, U \leq Uz, Xz \leq x, z \in \Re^K_+\} \tag{8}$$

Consistent with Faere et al. (1989) 's methodology, the enhanced hyperbolic productive efficiency measure is defined as:

$$H^w_P(y^k, u^k, x^k) = \text{max } \{\lambda : (\lambda y^k, \lambda^{-1} u^k) \in P^w(\lambda^{-1}, x^k)\} \tag{9}$$

The hyperbolic output efficiency measure H^w_P can be computed for airline k by solving the nonlinear programming problem

$$\begin{aligned} H^w_P(y^k, u^k, x^k) &= \max \lambda \\ \text{s.t.} \\ \lambda y^k &\leq Yz \\ \lambda^{-1} u^k &= Uz \\ Xz &\leq \lambda^{-1} x^k \\ z &\in \Re^K_+ \end{aligned} \tag{10}$$

The efficiency model can be linearized by approximating the nonlinear constraints $\lambda^{-1} u^k = Uz$ and $Xz \leq \lambda^{-1} x^k$ around $\lambda = 1$, leading to:

$$
\begin{aligned}
H_P^w(y^k, u^k, x^k) = \max \lambda \\
\text{s.t.} \\
\lambda y^k \leq Yz \\
(2-\lambda)u^k = Uz \\
Xz \leq (2-\lambda)x^k \\
z \in \Re_+^K.
\end{aligned} \tag{11}
$$

The comparison of efficiency measures obtained using $P^w(x)$ and $P^s(x)$ assesses the technology's compliance with strong disposability of all outputs, both undesirable and desirable. This analysis offers insights into the extent regulations or other external factors inhibit the strong disposability of undesirable outputs. For example, by imposing strong disposability of all outputs on the technology, we can measure the potential regulatory impact:

$$
\begin{aligned}
H_P^s(y^k, u^k, x^k) = \max \lambda \\
\text{s.t.} \\
\lambda y^k \leq Yz \\
\lambda^{-1}u^k \leq Uz \\
Xz \leq \lambda^{-1}x^k \\
z \in \Re_+^K.
\end{aligned} \tag{12}
$$

Therefore, for producer k, the revenue loss due to non-compliance with strong disposability is quantified as:

$$
Loss_k = \sum_i r_i^k y_i^k (H_P^s - H_P^w), k = 1, ..., K \tag{13}
$$

Here, r_i^k represents the market price of output i. The MAC is estimated as:

$$
MAC_{k,j} = \frac{\partial Loss_k}{\partial u_j} \tag{14}
$$

Practically, we approximate MAC using finite differences: $\frac{\Delta Loss_k}{\Delta u_j}$.

5.2 Results

To estimate MAC, we employ comprehensive airline financial data sourced from Bloomberg. We successfully match data for 13 airlines both in 2022 and 2023. This dataset includes critical inputs such as the number of aircrafts and the total number of employees. For outputs, we consider airline revenue as the desirable output and emissions of CO2, N2O, and CH4 as undesirable outputs.

Table 3 provides a detailed summary of the statistics for these variables.

Table 3: Panel B: Airline Data Summary for MAC Estimation

Variable	Description	Unit	Obs.	Mean	Min	Max
x_1	Planes	plane	26	346.115	28.000	967.000
x_2	Employees	thousand person	26	32.168	1.641	103.300
y	Revenue	billion USD	26	25.631	0.227	343.197
u_1	CO2	MMT CO2	26	2.247	0.008	15.449
u_2	N2O	MMT CO2eq.	26	0.021	0.000	0.148
u_3	CH4	MMT CO2eq.	26	0.000	0.000	0.000

Notes: This table summarizes key statistics for 26 airlines from data compiled in 2022 and 2023, sourced from Bloomberg. It details the number of planes, employee count, and revenue in billions of USD. It also includes emissions data for CO2, N2O, and CH4 estimated by the same approach presented in Table 1. This data forms the basis for estimating the MAC associated with each airline, considering CO2 and other GHG emissions as undesirable outputs.

We calculate the MAC for each airline and derive a weighted average of MAC based on the proportion of their number of enplaned passengers in the total market. The weighted average of MAC was $895.51 per ton in 2022 and $895.45 per ton in 2023. These values align with findings within existing literature, highlighting the broad spectrum of MAC estimates, which range significantly—from as low as $10 per ton to over $1,000 per ton (Gillingham and Stock, 2018). Notably, Liu and Jiang (2023) have observed that shadow prices typically range around $398.40 per ton, with Japan Airlines' emission reduction costs notably exceeding $1,000 per ton. Additionally, Wei et al. (2021) have identified an average marginal abatement cost for CO2 emissions within China's transport sector to be approximately $1,009 per ton, further affirming the relevance of our estimates.

Table 4 displays the total abatement costs for live concerts. The parameter α represents the additional GHG emissions attributed to artist j in host city i during month t, as per our specified equation (2). The total abatement cost is calculated as the product of the number of concerts, the additional GHG emissions, and weighted average of MAC (we apply the mathematical average of weighted average MACs in 2022 and 2023 here, it equals to $895.48). Remarkably, the costs associated with mitigating these emissions far exceed the sales generated by high-profile artists, reflecting a significant economic and environmental challenge. Specifically, the total abatement cost for artists like Lady Gaga was up to eighteen times higher than her concert sales, underscoring the pressing need for effective strategies to manage the environmental impact of such large-scale events without undermining their economic viability.

Table 4: GHG Abatement Costs and Sales for Top Live Concerts

Artist	# of Concerts	α	Total Abatement Cost	Sales	$\frac{\text{Total Abatement Cost}}{\text{Sales}}$
Bad Bunny	22	0.038	748.643	365.724	2.047
Coldplay	29	0.011	285.666	709.934	0.402
Ed Sheeran	34	0.043	1309.230	466.488	2.807
Harry Styles	23	0.126	2595.176	417.809	6.211
Kenny Chesney	12	0.025	268.652	103.253	2.602
Lady Gaga	9	0.218	1756.982	93.630	18.765
Mötley Crüe/Def Leppard	20	0.066	1182.068	130.328	9.070
Red Hot Chili Peppers	12	0.048	515.811	158.475	3.255
The Rolling Stones	11	0.109	1073.711	136.141	7.887
The Weekend	21	0.081	1523.255	253.115	6.018
Beyoncé	26	0.062	1443.555	971.902	1.485
George Strait	6	-0.002	-10.746	125.152	-0.086
Karol G	7	0.072	451.335	143.497	3.145
Morgan Wallen	9	0.047	378.799	247.211	1.532
P!NK	17	0.133	2024.739	152.305	13.294
U2	3	-0.004	-10.746	109.752	-0.098
Average	16.31	0.07	970.98	286.54	4.90

Notes: This table displays the total GHG abatement costs and sales for live concerts by top artists during whole observation period. The total abatement cost is calculated as the product of the number of concerts, the α coefficient (representing the incremental GHG emissions per concert) from equation (2), and the weighted average MAC of \$895.48 per ton. The units of abatement costs and sales are both presented in million US dollars.

6 Conclusion

This paper has provided a comprehensive analysis of the environmental costs of live concerts, specifically through the lens of cultural economics. By quantifying the carbon costs associated with these events, our research highlights significant GHG emissions primarily driven by increased air travel to host cities. The estimated emissions from the top live concert artists average about 0.067 MMT CO2eq. per concert, with the MAC for airline operations associated with these events estimated at approximately \$895.5 per metric ton of CO2.

Our findings reveal a critical tension between the cultural value generated by live concerts and their substantial environmental costs. For instance, the abatement costs associated with concerts by major artists, such as Lady Gaga, can dramatically exceed the revenues they generate. This discrepancy calls for an urgent reassessment of how live concerts are planned and executed within the cultural sector.

This study extends the discourse in cultural economics by framing the environmental costs of live concerts as a crucial aspect of cultural policy and management. It underscores the need for sustainable practices that reconcile the economic benefits of cultural events with their environmental impact. To this end, we advocate for a shift towards integrating more advanced technological solutions that can reduce GHG emissions without diminishing the cultural and economic value of these events.

In conclusion, while live concerts remain a potent cultural and economic force, their environmental implications pose significant challenges. We call for ongoing research into innovative strategies that can help minimize the carbon footprint of live events, thus ensuring their sustainability alongside their vibrant contributions to cultural life and economic vitality.

References

Chen, G., & Tang, P. (2021). Similar but special: An econometric analysis of live performing arts attendance in mainland china. *Journal of Cultural Economics*, *45*, 459–490.

Collins, A., Jones, C., & Munday, M. (2009). Assessing the environmental impacts of mega sporting events: Two options? *Tourism management*, *30*(6), 828–837.

Du, R., & Zhang, J. (2022). Super bowl participation and the local economy: Evidence from the stock market. *Growth and Change*, *53*(4), 1513–1545.

Faere, R., Grosskopf, S., Lovell, C. A. K., & Pasurka, C. (1989). Multilateral productivity comparisons when some outputs are undesirable: A nonparametric approach. *The Review of Economics and Statistics*, *71*(1), 90–98. Retrieved June 5, 2024, from http://www.jstor.org/stable/1928055

Getzner, M. (2022). Socio-economic and spatial determinants of municipal cultural spending. *Journal of Cultural Economics*, *46*(4), 699–722.

Gillingham, K., & Stock, J. H. (2018). The cost of reducing greenhouse gas emissions. *Journal of Economic Perspectives*, *32*(4), 53–72.

Gutierrez-Navratil, F., Perez-Villadoniga, M. J., & Prieto-Rodriguez, J. (2024). Attracting new audiences to high culture: An analysis of live broadcasted performing arts at cinema theaters. *Journal of Cultural Economics*, 1–18.

Liu, X., & Jiang, P. (2023). How does civil aviation achieve sustainable low-carbon development?—an abatement–cost perspective. *Heliyon*, *9*(10).

Mouate, O., & Travers, M. (2024). The impact of cultural amenities on inter-urban location: A discrete choice experiment on french students. *Journal of Cultural Economics*, 1–40.

Shin, S. (2024). The impact of covid-19 on cultural and arts activities: Evidence from a large-scale micro-level survey in south korea. *Journal of Cultural Economics*, 1–37.

Thompson, D. (2024). Front row or backstage? evidence on concert ticket preferences from a discrete choice experiment. *Journal of Cultural Economics*, 1–29.

Wei, X., Chang, Y.-T., Kwon, O.-K., & Zhang, N. (2021). Potential gains of trading co2 emissions in the chinese transportation sector. *Transportation Research Part D: Transport and Environment*, *90*, 102639.

Zhang, C., Zhou, X., Zhou, B., & Zhao, Z. (2022). Impacts of a mega sporting event on local carbon emissions: A case of the 2014 nanjing youth olympics. *China Economic Review*, *73*, 101782.

A Robustness Check

To evaluate the stability of our model under different contexts, we tested various specifications of fixed effects. Table A1 presents results estimated using equation (1). The key difference from the estimations presented in Table 2 is that the individual fixed effects (μ_i) were adjusted to the city-specific level. Additionally, Table A2 modifies the time fixed effects (ν_t) from the analysis in Table A1 to a month-based level.

Table A1: Regression on All Concerts

	(1) Passengers	(2) Distance	(3) N2O	(4) CO2	(5) CH4	(6) Total GHG
Concert	46.498***	19.250***	0.000***	0.027***	0.000***	0.027***
	(6.281)	(5.020)	(0.000)	(0.003)	(0.000)	(0.004)
Observations	13,737	13,737	13,737	13,737	13,737	13,737
R^2	0.772	0.803	0.744	0.744	0.891	0.744
Adjusted R^2	0.755	0.789	0.726	0.726	0.883	0.726
Residual Std. Error	99.227	79.300	0.001	0.055	0.000	0.056

Notes: Table A1 presents the robustness results for Equation (1), applying city-specific fixed effects to evaluate the impact of concerts on air travel and GHG emissions. Standard errors are in parentheses below the coefficients, with significance levels indicated by asterisks: *** ($p<0.01$), ** ($p<0.05$), * ($p<0.1$).

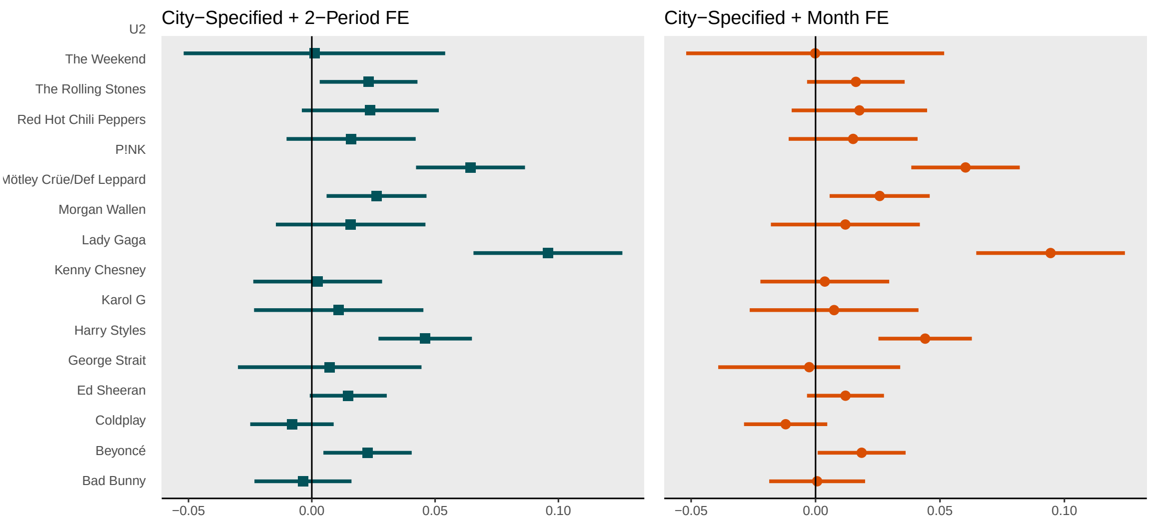
Table A2: Regression on All Concerts

	(1) Passengers	(2) Distance	(3) N2O	(4) CO2	(5) CH4	(6) Total GHG
Concert	32.433***	6.899	0.000***	0.021***	0.000	0.021***
	(11.291)	(9.555)	(0.000)	(0.006)	(0.000)	(0.006)
Observations	13,761	13,761	13,761	13,761	13,761	13,761
R^2	0.208	0.235	0.174	0.174	0.053	0.174
Adjusted R^2	0.208	0.235	0.174	0.174	0.052	0.174
Residual Std. Error	178.365	150.951	0.001	0.096	0.000	0.096

Notes: Table A2 presents the robustness results for Equation (1), applying city-specific fixed effects and month-specific time fixed effects to evaluate the impact of concerts on air travel and GHG emissions. Standard errors are in parentheses below the coefficients, with significance levels indicated by asterisks: *** ($p<0.01$), ** ($p<0.05$), * ($p<0.1$).

Similarly, applying changed FE variables in equation (2) could obtain results presented below. The left figure demonstrates results from estimation with city-specified individual FE. The right one presents estimation with city-specified individual FE and month level time FE.

Figure A1: Robustness check by replacing Fixed-Effect Standard



Notes: Figure A1 presents the robustness results for Equation (2), applying city-specific fixed effects (left panel), and month-specific time (the right panel) fixed effects to evaluate the impact of different artists' concerts on air travel and GHG emissions.