Marketing Science

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Abstract. Many have speculated that the recent outbreak of COVID-19 has led to a surge in the use of online streaming services. However, this assumption has not been closely examined for music streaming services, the consumption patterns of which can be different from video streaming services. To provide insights into this question, we analyze Spotify's streaming data for the weekly top 200 songs for two years in 60 countries between June 2018 and May 2020, along with varying lockdown policies and detailed daily mobility information from Google. Empirical evidence shows that the COVID-19 outbreak significantly reduced music streaming consumption in many countries. We also find that countries with larger mobility decreases saw more notable downturns in streaming during the pandemic. Further, we reveal that the mobility effect was attributable to the complementarity of music consumption to other activities and likely to be transient rather than irreversible. Alternative mechanisms, such as unobservable Spotify-specific factors, a demand shift from top-selling songs to niche music, and supply-side effects, did not explain the decline in music consumption.

1. Introduction

The spread of the novel coronavirus (COVID-19) has had an unprecedented impact on public health—1.6 million people have died from COVID-19 worldwide as of December 14, 2020 (European Centre for Disease Prevention and Control 2020). To limit the spread of the outbreak, governments have enacted various social distancing policies, such as reducing transportation, halting nonessential activities, and issuing shelter-in-place orders. The pandemic has impacted the economy as well. The sudden downturn caused by COVID-19 has affected almost every aspect of economic endeavors on both demand and supply sides (Bonaccorsi et al. 2020). Many industries have been adjusting to the new norms, and every component of their value chains—from production and distribution channels to consumers—has been shaken.

Although COVID-19 has exposed many players to risk, it has not posed a threat to all. Amid the market meltdown, many anticipated that digital streaming services would see a surge in demand since many people have been forced to stay at home and work remotely (Beech 2020, Nielsen 2020). During this time, people may spend more time online via their digital devices, which may increase media content consumption. As theaters have remained closed, consumers are likely to turn to video content at home. In this regard, COVID-19 shutdowns have accelerated the transition toward on-demand streaming services and away from ownership-based models.[1] In line with this growth, Netflix's and Spotify's shares were up 32.2% and 27.1%, respectively, from the beginning of the year through May 21, 2020, whereas S&P 500's dropped 9.5% over the same period.[2]

Although it has been reported that people's increased time at home has significantly benefited visual forms of entertainment (e.g., live video streaming), audio consumption went in the opposite direction.[3] A possible reason for this disparity is that music is often consumed as a complement to other activities rather than as stand-alone entertainment. For instance, music can serve as a source of distraction while in traffic—almost 29% of all music consumption takes

place in the car (Nielsen 2017). Similarly, music listening during work or while doing chores accounted for a combined total of about 30% of all consumption (Nielsen 2015), and 54% of consumers listened to music while commuting (IFPI 2018).

This evidence suggests that the adverse impact on such music-friendly activities will likely be reflected in lower music consumption levels. This is because music is less intrusive than other media forms and has complementary properties; that is, the pandemic might reduce music consumption by restricting travel and cutting down music-friendly activities. This hypothesis can only be substantiated if various socioeconomic aspects and pandemic-related policies are thoroughly studied together. To gain insights into the impact of the pandemic on streaming music consumption, we combine and analyze music streaming data, COVID-19 statistics, policy measures from the government, as well as mobility data from major tech companies, broken down by countries.

Specifically, we analyze Spotify's streaming data for the weekly top 200 songs for two years in 60 countries. Our assumption-free statistical test and model-based inference reveal that in more than two-thirds of countries that enforced lockdowns, music streaming volume significantly decreased after the lockdowns took effect. On average, music consumption decreased by 12.5% after the World Health Organization's (WHO) pandemic declaration on March 11, 2020. Analyzing the Spotify streaming data together with people's mobility patterns suggests that reduced commuting time is strongly correlated to the decline in music consumption. Our analysis of movement patterns also shows that the downturn in music consumption was more noticeable in countries where time spent on commuting and movement drastically plummeted.

Our additional analysis further confirms how the complementarity of music listening led to the demand decline during the pandemic. We find that video-based music consumption via YouTube went up when the COVID-19 cases were high, lockdown policies were restrictive, and more time was spent at home, which suggests that such music streaming did not decrease when it is not complementary to other activities. Besides, we find that music consumption was more affected by commuting than general mobility. Importantly, a noticeable rebound of music consumption in countries with a temporary ease of COVID-19 implies that such effects are transient rather than irreversible. We also provide evidence that our findings were very unlikely to be driven by the consumers shifting toward a niche market or unobservable Spotify-specific factors. We also observe that popular artists did not significantly change their music release decisions during the pandemic, suggesting

that the supply level of popular artists has not driven the reduced music consumption.

Our study makes several important contributions. To the best of our knowledge, this study provides the first empirical evidence of the impact of COVID-19 on digital streaming consumption in a global context. First, despite the common expectation that the pandemic would universally benefit online media platforms, we show that it has adversely impacted music streaming services. Our study highlights that music consumption can decline due to its complementary nature. Second, our discussion on the pandemic and digital consumption implies that the substantially changing media consumption environment can put streaming music in a fiercer competition against other media forms, for example, visual media offering more dynamic and vivid experiences to consumers (Kumar and Tan 2015). These findings demonstrate the significance of contextual preference in media consumption.

2. Data

To examine the impact of COVID-19 on music consumption, we use Spotify's weekly streaming data for the top 200 weekly music charts during 104 consecutive weeks between June 2018 and May 2020 across 60 countries listed in Table A1 in Online Appendix A. Spotify is the world's largest subscription music streaming service with 96 million paid subscribers and 74 million free users, offering unlimited free streaming with advertisements, as well as paid premium services (Field 2020). The weekly streaming volume of a song refers to the number of times it was played by legitimate paid-for or free service users each week. We aggregated weekly streaming counts of the top 200 songs for each country and built the country-week level for 104 weeks of 60 countries, for a total of 6,240 observations.

We combine music consumption data with COVID-19 case statistics from the European Centre for Disease Prevention and Control (ECDC). The ECDC provides daily updated panel data of COVID-19 cases and deaths by country, except Hong Kong.[4] To make these statistics comparable across countries, we calculate the number of COVID-19 cases and deaths per million people using national population data from the World Bank. We utilize data on enforced social distancing measures by the governments from the Oxford COVID-19 Government Response Tracker (Petherick et al. 2020). The data contain various government responses to COVID-19, such as shelter-in-place orders at the country-day level. In the Spotify data set, 59 out of 60 countries are matched to such enforcement data. Lastly, we use country-day-level data on individuals' time allocation changes (for activities) since the COVID-19 outbreak from Google's COVID-19 Community Mobility Reports

(Google 2020). The data report daily percentage changes in the number of visits by place category (e.g., transit stations, workplaces, and residential) with respect to the baseline average of visits on the corresponding day of the week during the five-week prepandemic reference period (for more details, see Online Appendix A). Table 1 presents variable descriptions and summary statistics.

Figure 1 presents streaming trends by country during our research period. The bright green (dark purple) line indicates the weekly streaming volume when no (one or more) government restriction was in effect, according to the Oxford COVID-19 Government Response Tracker. Although we observe downward shifts in demand after restrictions, such fluctuations might be attributed to market trends and seasonality, while overall trends and seasonality substantially vary across countries. To statistically assess whether such shifts could have occurred without the COVID-19 outbreak, we conduct a distribution-free statistical test using simple A/B testing and empirical reference distributions (Box et al. 2005, pp. 68–71). We find that music streaming volume significantly decreased after the lockdowns took effect in more than two-thirds of countries that enforced lockdown (see Online Appendix C).

3. Econometric Analysis and Results
3.1. Impact of COVID-19 Outbreak on Music Consumption

To account for the growth and seasonality of the streaming demand, we compare weekly streams of each week with those of a comparable week a year ago in each country (e.g., Chen et al. 2020, Fang et al. 2020). This approach allows us to comprehensively capture various components of the COVID-19 effect—such as individuals' preventive efforts to avoid exposure to the virus, as long as the parallel pretrend assumption is satisfied (Fang et al. 2020).

Figure 2 illustrates this procedure. We divide our research period into two one-year-long periods. The first year spans 52 weeks from June 1, 2018, to May 30, 2019. The second year covers the following 52 weeks from May 31, 2019, to May 28th, 2020. The first week of the first year (June 1–7, 2018) corresponds to the first week of the second year (May 31–June 6, 2019). By subtracting the earlier streams from the later ones, we examine whether and to what extent the difference between the two years widened after WHO declared the outbreak a pandemic on March 11, 2020.

Figure 3 presents the streaming trends in the first year and the second year at the global level. We observe that the trends were sufficiently parallel between the two years before the pandemic declaration. However, after the declaration, the two trends began to part drastically; in April and May 2020, the second year's trend deviated from the parallel line by approximately 0.4 billion streams per week. We formally test this assumption by estimating the relative time model that leverages leads and lags of the treatment (Autor 2003, Burtch et al. 2018) and find that such differences were unlikely to appear without the COVID-19 outbreak (see Online Appendix C).

To quantify the differences, we employed a difference-in-differences (DID) approach that leverages observations in the first year as a control group and

Table 1. Variable Description and Summary Statistics

Variables	Description	Number of observations	Mean	Standard deviation	Min	Max
Streams	Total streaming counts of the weekly top 200 songs	6,240	4.49e+07	8.64e+07	697,435	7.77e+08
Treated	1 if a year is the treated year (i.e., year 2), 0 otherwise (i.e., year 1)	6,240	0.500	0.500	0	1
After	1 if a week of the year is later than March 11, 2019 (March 11, 2020) for the control year (the treated year), and 0 otherwise	6,240	0.231	0.421	0	1
COVID-19 cases	Number of newly confirmed COVID-19 cases (per million people)	6,240	16.34	91.92	0	1,847
COVID-19 deaths	Number of newly confirmed COVID-19 deaths (per million people)	6,240	0.976	6.940	0	169.8

Figure 1. (Color online) Music Streaming Trends by Country

Note. The bright green line indicates weekly streams with no government restriction, whereas the dark purple line indicates weekly streams after at least one restriction.
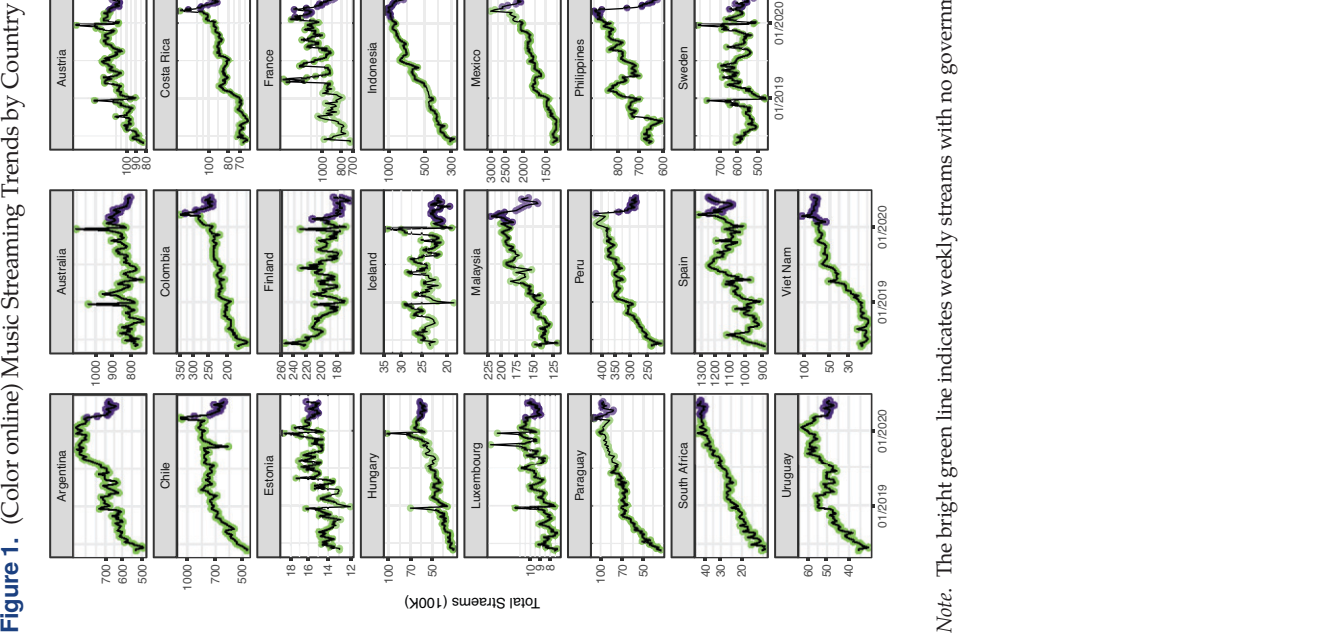
Figure 2. (Color online) Research Period and Econometric Setting
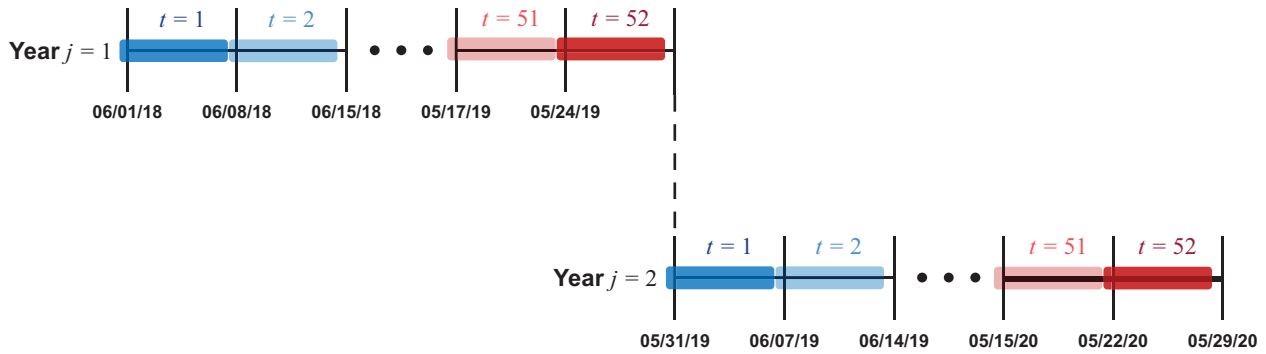
those in the second year as a treated group. This can be expressed as

$$\ln\left(Streams_{ijt}\right) = \alpha_i + \beta_1 \cdot Treated_j + \beta_2 \cdot After_t$$
$$+ \beta_3 \cdot Treated_j \cdot After_t + \sum_t \delta_t + \varepsilon_{ijt}, \quad (1)$$

$$\ln\left(Streams_{ijt}\right) = \alpha_i + \beta_1 \cdot Treated_j + \beta_2 \cdot After_t$$
$$+ \beta_3 \cdot Treated_j \cdot After_t + \sum_i \sum_j \alpha_i \cdot \gamma_j$$
$$+ \sum_i \sum_t \alpha_i \cdot \delta_t + \varepsilon_{ijt}, \quad (2)$$

where $i = 1, \ldots, n$ indexes countries; $j = 1, 2$ indexes the two-year period; $t = 1, \ldots, 52$ indexes the week of the year; $Streams_{ijt}$ is the weekly total streaming count of the top-200 charts in country i, year j, and week t; $Treated_j$ indicates 1 if $j = 2$ (the treatment year), and 0 otherwise (the control year); $After_t$ indicates 1 if week of the year t is later than March 11, 2020, corresponding to the pandemic declaration date, and 0 otherwise; α_i is a set of country fixed effects; δ_t is a week-of-the-year dummy variable; $\alpha_i \cdot \gamma_j$ is the product of the country dummy and the period dummy; $\alpha_i \cdot \delta_t$ is the product of the country dummy and the week-of-the-year dummy; and ε_{ijt} is an error term clustered at the country level to take account of autocorrelation in the data (Bertrand et al. 2004).

The impact of the COVID-19 outbreak on streaming demand is captured by β_3. In Equation (1), $\sum_t \delta_t$ controls for week-of-the-year fixed effects. In Equation (2), $\sum_i \sum_j \alpha_i \cdot \gamma_j$ captures country-specific period fixed effects that control for heterogeneous annual growth of demand; $\sum_i \sum_t \alpha_i \cdot \delta_t$ captures country-specific week-of-the-year fixed effects that reflect heterogeneous seasonality and cancels out $\sum_t \delta_t$, which picks up common week-of-the-year fixed effects.

As seen from the results in Table 2, the coefficients of $Treated_j \cdot After_t$ are negative and significant, and the

magnitudes of these coefficients remain unchanged across models. These results suggest that streaming demand decreased by 12.5% after the pandemic declaration. The results are also qualitatively consistent across sample selection criteria (e.g., continents and rank ranges) and functional forms (e.g., count models and disaggregated country-rank level data) (see Online Appendix C).

Although the pandemic declaration is a useful indicator of the COVID-19 outbreak, it does not reflect heterogeneity in the timing and severity of COVID-19 across countries. Furthermore, one might raise a concern that the decline in streaming might be attributable to a common trend in Spotify demand. To address this concern, we use the country-specific number of confirmed cases and deaths as independent variables and include a set of common time fixed effects that absorb any Spotify-specific demand shock. The results show that 1,000 COVID-19 cases per million people each week were associated with a 14.4% decline in streaming consumption, supporting the validity of our findings (see Table C4 in Online Appendix C).

3.2. Lockdown Restrictions, Movement, and Music Consumption

During the pandemic, media consumption contexts may dramatically change as commuting and traveling are restricted. Specifically, government responses to the COVID-19 outbreak, such as shelter-in-place orders, can reduce time spent on transportation. This could discourage the consumption of streaming music. To explore this hypothesis, we obtain information on various types of government policies from the Oxford COVID-19 Government Response Tracker (Petherick et al. 2020). The data specify eight types of containment and closure policies, and the details are provided in Table A2 in Online Appendix A. We observe that a substantial number of countries did not enforce restrictions on public transport, shelter-in-place, and internal movement, and many countries

Figure 3. (Color online) Global Streaming Trends by Research Year
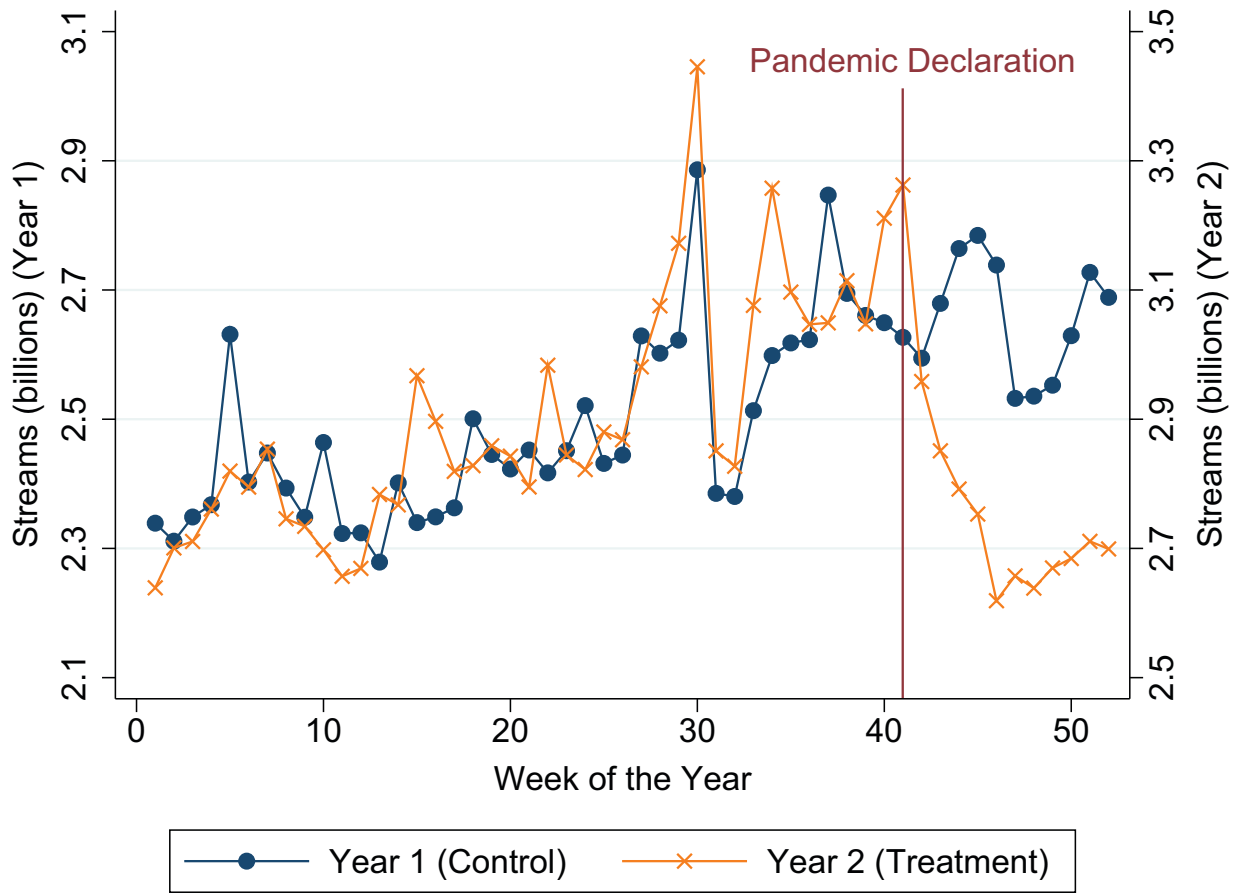
released these restrictions over time. We leverage this variation to estimate the following model:

$$
\ln\left(Streams_{ijt}\right) = \alpha_i + \tau \cdot Restriction_{ijt} + \theta_1 \cdot Cases_{ijt}
$$
$$
+ \theta_2 \cdot Deaths_{ijt} + \sum_i \sum_j \alpha_i \cdot \gamma_j
$$
$$
+ \sum_i \sum_t \alpha_i \cdot \delta_t + \sum_j \sum_t \gamma_j \cdot \delta_t + \varepsilon_{ijt},
$$

$$(3)$$

where $Restriction_{ijt}$ indicates 1 if country i enforced a lockdown policy in period j and week of the year t; $Cases_{ijt}$ and $Deaths_{ijt}$ control for the weekly number of confirmed COVID-19 cases and deaths per million people in each country, respectively; and $\sum_j \sum_t \gamma_j \cdot \delta_t$ is a set of common time fixed effects that absorb Spotify-specific demand shocks.

Table 3 shows the estimates for each restriction type. Most policies significantly decreased streaming demand, except for schools' closings and limits on private gatherings. These results indicate that restricted movement seemed to notably contribute to this demand shrinkage. We find qualitatively similar results

when we use ordinal measures of government restrictions and include/exclude COVID-19 cases and deaths (see Tables C5–C7 in Online Appendix C).

To dive deeper into how one of the complementary activities, namely, mobility, affected streaming demand, we combined the previous data set with country-specific data on time allocation changes from Google's COVID-19 Community Mobility Reports (Google 2020). Figure 4 depicts the changes in time spent on the residence and streaming demand from the reference period in the data (between January 3, 2020, and February 6, 2020). It is clearly seen that residential time surged during the pandemic, and the rise in residential time accompanied a drop in streaming demand in most countries.

Motivated by these exploratory findings, we quantify how much the reshaped mobility patterns were associated with streaming demand using the following model:

$$
\ln\left(Streams_{it}\right) = \alpha_i + \pi \cdot \Delta Time_{it} + \tau \cdot Restriction_{it}
$$
$$
+ \theta_1 \cdot Cases_{it} + \theta_2 \cdot Deaths_{it}
$$
$$
+ \sum_t \delta_t + \varepsilon_{it},
$$

$$(4)$$

Table 2. Effects of COVID-19 Pandemic Outbreak on Demand for Streaming Music

Dependent variable = ln(*Streams*)	(1)	(2)	(3)
Treated	0.283***	0.283***	Absorbed
	(0.0319)	(0.0320)	
After	0.142***	Absorbed	Absorbed
	(0.0174)		
Treated × After	−0.134***	−0.134***	−0.134***
	(0.0169)	(0.0170)	(0.0169)
Country fixed effect	Yes	Yes	Yes
Week-of-the-year fixed effect	No	Yes	Absorbed
Country-specific growth fixed effect	No	No	Yes
Country-specific week-of-the-year fixed effect	No	No	Yes
Number of countries	60	60	60
Number of observations	6,240	6,240	6,240
Within R^2	0.385	0.481	0.940

Note. Standard errors, in parentheses, are robust and clustered at the country level.

***$p < 0.01$.

where $\Delta Time_{it}$ indicates the percentage changes in time allocation to a certain place category compared with those of the five-week reference period between January and February 2020; other variables are equivalent to those defined in Equation (4). Since Google's data began in February 2020, we do not include country-specific growth and seasonality terms.

The estimated results are reported in Table 4. We find that the more time spent on outdoor activities (e.g., grocery/pharmacy, parks, and transit stations) was positively related to music consumption. In contrast, more residential time had a negative relationship with music consumption. Specifically, a 10% increase in residential time accompanied an 8.1% decline in demand for music streaming. In addition, we find consistent results by using Apple's COVID-19 Mobility Trends Reports (see Table C8 in Online Appendix C).

4. Discussions
4.1. Additional Insights on Mobility and Music Consumption

We have discussed that decreased time spent moving to different locations (e.g., commuting to work, driving to restaurants) during the pandemic led to a decline in music consumption, as music listening is often nonintrusive and complementary to such activities. If this argument is true, then such declines will not happen in the consumption of other media forms. To see this, we examine how video-based music consumption at YouTube has been affected by the pandemic by using the data from Soundcharts' API (see Online Appendix B). We find that video consumption for music is positively associated with the severity of COVID-19, lockdown policies, and time spent at home. In contrast, it is negatively associated with time spent on outdoor activities. This suggests that the decline in music streaming was

indeed attributable to the audio-based nature and its complementarity with mobile activities.

Complementarity of music may also vary across mobility contexts; for instance, commuting—during which people are under a high level of stress (Ghose et al. 2019)—may motivate individuals to listen to music to relieve stress. To better understand the role of heterogeneous complementarity, we investigate whether music consumption was more influenced by commuting than general mobility. For this, we consider two approaches. First, we examine how the decrease in music consumption is associated with commuting time in European countries (see Online Appendix B). We observe that the estimated decline was more pronounced in countries with longer commuting times. Second, we investigate the contingent effects of COVID-19 on top-200 streaming in Spotify by day of the week. We find that the effect was more prominent on weekdays than weekends, and this pattern was consistent with time allocation changes in workplaces and residences than those of transit stations. These results may imply that music tends to be more complementary to stressful situations, as it helps relieve stress (Oldham et al. 1995).

It is also important to check whether such influences are transient or irreversible. If the decline in streaming volume is transient, then we would see that the demand returns to pre-COVID levels as restrictions are lifted. We find that the temporary ease of COVID-19 during late April and May 2020 led to a noticeable rebound of consumption in countries with a decrease in confirmed cases, in line with Spotify's statement (Perez 2020). Likewise, we find that the reduction in residential time was highly associated with the recovery of the streaming volume (see Online Appendix B). Despite this observation, the recent resurgence of cases might lead to a "new normal" that sets working from home and social distancing as a norm

Table 3. Effects of Government Restrictions on Demand for Streaming Music

Dependent variable = ln(Streams)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Government restrictions (binary)							
Schools	−0.0185 (0.0243)							
Workplaces		−0.0624** (0.0243)						
Public Events			−0.0897*** (0.0206)					
Private Gatherings				−0.00959 (0.0452)				
Public Transport					−0.0709** (0.0300)			
Shelter-in-Place Orders						−0.0795*** (0.0248)		
Internal Movement Between Cities/Regions							−0.0842*** (0.0220)	
International Travel								−0.0348** (0.0158)
	COVID-19 statistics (per million people)							
Cases (current week)	−0.000152** (5.93e-05)	−0.000140** (5.93e-05)	−0.000147** (5.88e-05)	−0.000153** (5.99e-05)	−0.000153** (5.90e-05)	−0.000126** (5.31e-05)	−0.000136** (5.26e-05)	−0.000158** (5.97e-05)
Deaths (current week)	0.000430 (0.000951)	0.000373 (0.000955)	0.000452 (0.000950)	0.000437 (0.000949)	0.000367 (0.000934)	0.000520 (0.000900)	0.000234 (0.000903)	0.000489 (0.000951)
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific growth fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific week-of-the-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common week fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	59	59	59	59	59	59	59	59
Number of observations	6,136	6,136	6,136	6,136	6,136	6,136	6,136	6,136
Within R^2	0.950	0.951	0.951	0.950	0.951	0.952	0.952	0.951

Notes. Standard errors, in parentheses, are robust and clustered at the country level. In this analysis, Malta was excluded due to a lack of relevant data in the Oxford COVID-19 Government Response Tracker.
**$p < 0.05$; ***$p < 0.01$.

Figure 4. (Color online) Residential Time and Streaming Change by Country
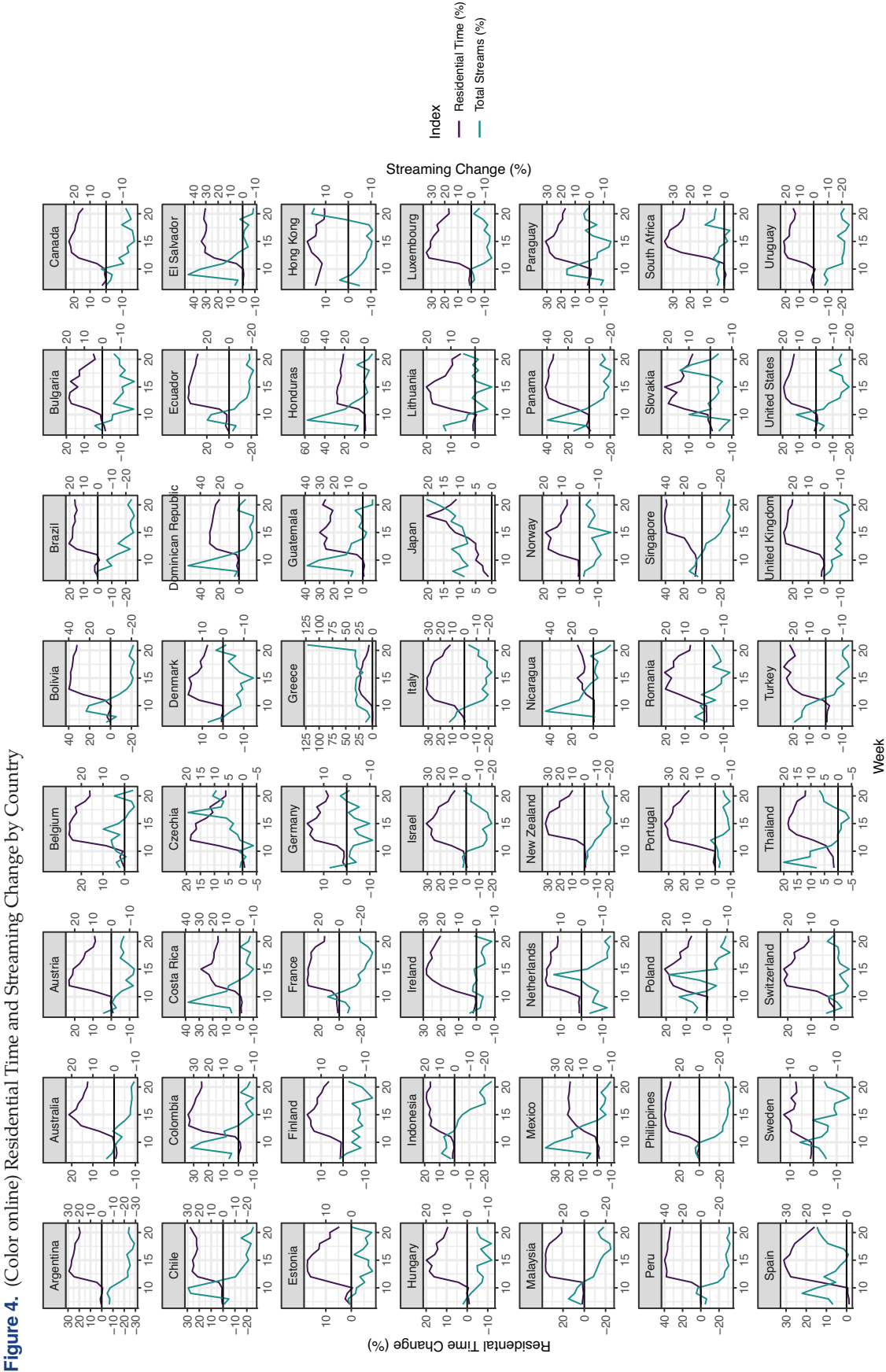
Note. Residential time change and streaming change are the ratios of value in the current week to that in the reference period (January 3–February 6, 2020).

Table 4. Time Allocation Changes and Demand for Streaming Music

Dependent variable = ln(*Streams*)	(1)	(2)	(3)	(4)	(5)	(6)
	Difference in time spent on (%)					
Retail/Recreation	0.00216***					
	(0.000426)					
Grocery/Pharmacy		0.00293***				
		(0.000461)				
Parks			0.00132***			
			(0.000203)			
Transit Stations				0.00299***		
				(0.000509)		
Workplaces					0.00330***	
					(0.000502)	
Residence						−0.00849***
						(0.00114)
Government restrictions controls	Yes	Yes	Yes	Yes	Yes	Yes
COVID-19 statistics controls	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Common week fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	58	58	58	58	58	58
Number of observations	870	870	870	870	870	870
Within R^2	0.522	0.553	0.550	0.543	0.547	0.577

Notes. Standard errors, in parentheses, are robust and clustered at the country level. Malta was excluded in this analysis due to a lack of relevant data in the Oxford COVID-19 Government Response Tracker. Iceland was excluded from Google's data set.

***$p < 0.01$.

for the foreseeable future. As such, less commuting and more working from home will persist for a while, which will keep the music streaming demand at a low level until regaining normalcy.

4.2. Alternative Explanations and Robustness Checks

It is imperative to conduct an extensive set of robustness checks to rule out alternative explanations, as we are examining complex social phenomena. We briefly provide results in this section as summarized in Table 5, with the full details provided in Online Appendix C. First, we test whether the functional form of our model drives our findings. We thus conduct a nonparametric test and fit a Poisson regression model, showing consistent results. Second, we examine the possibility that outliers might have driven the main effects by conducting a subgroup analysis by continent or range of the rank position. We observe significant declines across different continents and rank positions. Third, we formally test if the parallel pretrend assumption is violated by estimating a relative time model (Autor 2003, Burtch et al. 2018) and find supporting evidence of our identification assumption.

Fourth, we examine the possibility that our findings were solely caused by the unobservable Spotify-specific factors that were not related to the pandemic. To assess this, we first thoroughly review Spotify's updating posts during the research period and find no abnormal difference in service updates and promotions that could induce a noticeable drop in streaming in the period after the pandemic. We also

collect nationwide music streaming data of the weekly top 400 songs in South Korea, where Spotify had not yet launched but is one of the largest music markets in the world. We observe that music streaming dropped by 12.0% after its initial surge in the number of cases and restrictive measures that followed. The magnitude of the estimated coefficient from the South Korea data are consistent with our main finding from Spotify data, suggesting that Spotify-specific factors did not drive the plummeting demand for streaming music during the pandemic.

Fifth, since our main analysis covers the weekly top 200 songs, one may ask whether the observed decline reflects an internal shift from popular songs to lesser-known ones such as chill or instrumental music (Spotify 2020), rather than a reduction in total consumption. Although our main estimates are highly comparable to the decline in year-over-year growth rates in Spotify's revenue, it may not be suitable to draw a conclusion directly from comparing the revenues and consumption.[5] We also provide back-of-the-envelope calculations on how significantly consumers should increase consumption of songs below the top 200 to compensate for the decline in top-200 consumption in Online Appendix C, but this still does not answer whether the internal shift occurred or not. To directly examine the possibility of demand shift, we obtain panel data of the daily number of followers from 1,500 playlists with over 75,000 unique songs.[6] Our main findings suggest that the growth of playlist followers was significantly decelerated after the

Table 5. Summary of Additional Analyses

Question	Analysis	Result	Location
Additional analysis of mobility and music consumption			
Does the complementary nature of audio consumption matter?	• Analysis of video consumption for music in YouTube	• Video-based music consumption increased (decreased) with the severity of COVID-19, lockdown policies, and time spent on outdoor activities (residence).	Tables B1–B3
When is the complementarity more influential?	• Analysis of heterogeneous commuting time among European countries	• The decline was more significant in countries with longer commuting time.	Tables B4–B5
	• Contingent effects on music streaming and time allocation by day of week	• The effect was more prominent on weekdays than weekends and more consistent with effects on time spent on workplaces and residence than that on transit.	Tables B6–B7
Will the decline in music consumption last?	• Analysis of the temporary ease of COVID-19 during April and May 2020	• A rebound in countries with decreasing cases • The reduction in residential time was highly associated with the recovery of streaming volume.	Figures B2–B3
Alternative explanations and robustness checks			
Does using a specific functional form drive our results?	• A distribution-free statistical test using empirical reference distributions	• Two-thirds of countries experienced an unprecedented decline after the pandemic.	Figure C2
	• Poisson regressions	• Consistent with main results	Table C2
Do outliers drive our results?	• Subgroup analysis by continent	• The decline was consistent across continents.	Table C1
	• Subgroup analysis by rank position	• The decline was consistent across rank positions.	Table C3
Is the parallel pretrend assumption violated?	• Estimating the relative time model with leads and lags of the treatment	• Streaming differences are mostly indistinguishable across weeks-of-year before the pandemic declaration.	Figure C3
Are Spotify-specific unobservables responsible for the findings?	• Estimating a model with the number of confirmed cases and deaths and common time fixed effects	• 1,000 COVID-19 cases per million in each week were associated with a 14.4% decline in streaming consumption.	Table C4
	• Analysis of Spotify's updates	• No distinct updates after the pandemic declaration	Table C9
	• Analysis of the Korean market	• Music streaming decreased in the absence of Spotify.	Table C15
Does demand shift from superstars to underdogs explain the results?	• Follower trends of 1,500 playlists (top 500 for each provider type) in Spotify	• Significant deceleration of the number of followers after the pandemic and no evidence of demand shift	Tables C15–C16
Is the supply-side effect responsible for the decline?	• Analysis of music releases of recently successful artists in Spotify	• No evidence that popular artists reduced new music releases significantly	Table C18
Is the decline attributable to the promotion of new releases?	• Analysis of chart entrance and rank positions of newly released songs	• Fewer newly released songs appeared on the top-200 charts, and their rank positions were lower. • This effect was more prominent among superstars.	Tables C19–C20

COVID-19 outbreak. Moreover, we find no evidence that instrumental, contextual, and other types of music playlists experienced significant follower gains that could compensate for the loss of popular music. Our analyses of playlist followers are still implicative because the number of followers is not identical to active listeners.

Sixth, we examine the possibility that supply-side dynamics might affect music consumption. Using data collected from Spotify's API, we reveal that top-tier artists have not significantly reduced new songs' releases measured by the number of new albums and tracks.

Seventh, we check if newly released songs were less successful during the pandemic by comparing songs' chart entrances and rank positions. We find that there is a tendency that fewer newly released songs made it to the top-200 charts, and they landed lower in the chart, which suggests that new releases were less successful during the pandemic.

5. Implications, Limitations, and Future Research

Spotify's recent financial reports indicate that the firm's revenues of the first three quarters of 2020 were 5.712 billion EUR. If the year-over-year growth rate was maintained as in the same period of 2019, then the revenue would be 6.404 billion EUR, suggesting that Spotify has lost about 692 million EUR in the first three quarters of 2020 with the pandemic outbreak. This financial outcome is consistent with our main findings. Our study further demonstrates that the pandemic-led decline is commonplace across countries, and possible impacts other than COVID-19 would be limited. More importantly, our research reveals that the notable shift of music demand is associated with consumers' behavioral patterns, particularly restricted mobility. When the pandemic is more widespread, people are more likely to stay at home. Our study shows that this behavioral shift has led to the reduction of music consumption.

Encountering this decline, digital music platforms may need to consider new strategic approaches to boost fans' engagement during and after the pandemic, which has already been happening lately. For example, Spotify introduced a new group session feature in May 2020, "Listening Together," with which users can share their own playlists and podcasts and simultaneously listen with other people. Also, enhanced video features that allow real-time interactions between artists and listeners can be considered, which Spotify also introduced in July 2020. Offering such video podcasts and live concerts features exclusively to premium users would increase consumers' willingness to pay for the premium subscription, which could compensate for the recent decline in revenue

per premium user. Platforms can also consider closer collaboration with artists and music labels to compete with the online video platform to retain current users and attract more new subscribers.

Music labels and artists may counteract this decrease by reconsidering new album release timelines and promotion strategies. For instance, they might reallocate more promotion budgets to online video channels. With COVID-19, it is critical to recouping the lost revenues from live concerts, a major revenue source for artists in recent years. Thus, they may need to find alternative channels to connect with their audience and fans to generate revenues and maintain a close relationship with them for the post-COVID era. Popular artists can consider virtual live-streamed concert events under the new reality of life with social distancing. For example, in a recently held pay-per-view online concert, BTS, a popular K-pop group, drew nearly 760,000 viewers worldwide and generated $20 million in ticket sales in June 2020. The success led them to hold an additional two-day live-streamed concert in October that attracted nearly 1 million viewers from 191 countries (Stassen 2020).

Our study provokes three main questions that could pave the way for future research. First, our study only looked at the top 200 songs on the chart in each country. There is a possibility that the consumption of songs beyond the ranking chart can be affected differently, which provides a meaningful avenue for future research. Although Spotify's financial reports, playlist analysis, and many other results also suggested the overall decline in music consumption, the magnitudes of such decline might have substantially varied across artists. For example, the top 10 songs were most affected among the weekly top 200 songs (see Table C3 in Online Appendix C). This might imply that the consumption in Spotify became more evenly distributed among musicians during the pandemic than it was before. Future research may provide more profound insights from revealing the uneven effects of COVID-19 on artists and underlying mechanisms.

Second, despite the extensive efforts to explore underlying mechanisms, there still exists a gap toward a more comprehensive understanding of all potential drivers of this phenomenon. Hence, future studies should be directed toward exploring additional factors affecting music consumption during the pandemic. For instance, fewer successes of new releases can be attributed to different causes: live event cancellations, promotion changes, or shift in the demand side. Future research should investigate why new releases had less success during the pandemic than they did before. Likewise, the impacts of COVID-19 on various public mental health issues, such as high loneliness rates (Groarke et al. 2020), could be examined as potential drivers of the pandemic-induced decline in music streaming.

Third, future research should evaluate the effectiveness of firm interventions to mitigate the decline of music consumption—some of which we have suggested but could not directly examine. For instance, although Spotify's year-to-year revenue continued to decline in the third quarter of 2020, their recent efforts might have regained some listeners. It is also interesting to examine how artists' different actions led to varying outcomes, as some artists might have benefited from the pandemic. Relatedly, our research period is limited to three months from the pandemic declaration. Future research might benefit from investigating how firms should respond to the changes from the gradual rebound in mobility as we slowly recover from the pandemic.

Acknowledgments

Endnotes

[1] Even before the pandemic, consumers had started shifting toward music subscription services over individual purchases (Li et al. 2020). The music industry was one of the first to be noticeably affected by this trend and has served as a compelling example of the post-ownership economy. By using music streaming services, users can replace a traditional music collection with a virtual playlist, listen to unlimited music, and conveniently discover new music (Datta et al. 2017, Aguiar and Waldfogel 2018). Such services became the main driver of the market after a 15-year consecutive decline since 1999. By 2019, global streaming revenue had grown by 22.9%, to $11.4 billion, and accounted for more than half (56.1%) of global recorded music revenue for the first time (IFPI 2020).

[2] These are computed by the stock prices of each company on the given days, obtained from Yahoo! Finance.

[3] Many outlets focused on the surge in Spotify's paid subscribers and higher podcast uploads (e.g., Lee 2020, Nicolaou 2020), whereas some pointed out the declining number of streaming counts in a few countries (e.g., Grant 2020, Korzeniowska and Wyborcza 2020). In particular, Korzeniowska and Wyborcza (2020) wrote, "Those confined and working from home have more time to watch, listen and read. Music services should benefit from this, but the data suggests the opposite," implying that it might be unexpected to investors and field experts.

[4] We supplement the data with COVID-19 statistics released by the Government of the Hong Kong Special Administrative Region.

[5] Based on the publicized information obtained from Spotify's financial reports, we find that Spotify's year-over-year revenue growth rates decreased by 10.4 to 17.6 percentage points during the first three quarters of 2020, which are comparable to our main estimate—a 12.5% decline after the WHO's pandemic declaration. However, such results should be interpreted with caution, because revenues are also related to subscription fees and advertisers' willingness to spend.

[6] The source of the data is Soundcharts, a subscription-based music data provider. Since we rely on the top-500 playlists on October 22, 2020, for each of three provider types (Spotify, major providers, and third parties), our results might have been affected by selecting survivors. However, it is worth noting that this selection is likely to induce upward bias, shifting the results toward an increase in playlist followers after the COVID-19 outbreak. Thus, the observed deceleration of increase in playlist followers can be considered as conservative outcomes.

References

Aguiar L, Waldfogel J (2018) As streaming reaches flood stage, does it stimulate or depress music sales? *Internat. J. Indust. Organ.* 57: 278–307.

Autor DH (2003) Outsourcing at will: The contribution of unjust dismissal doctrine to the growth of employment outsourcing. *J. Labor Econom.* 21(1):1–42.

Beech M (2020) COVID-19 pushes up internet use 70% and streaming more than 12%, first figures reveal. *Forbes* (March 25), https://www.forbes.com/sites/markbeech/2020/03/25/covid-19-pushes-up-internet-use-70-streaming-more-than-12-first-figures-reveal/#623baadf3104.

Bertrand M, Duflo E, Mullainathan S (2004) How much should we trust differences-in-differences estimates? *Quart. J. Econom.* 119(1):249–275.

Bonaccorsi G, Pierri F, Cinelli M, Flori A, Galeazzi A, Porcelli F, Schmidt AL, Valensise CM, Scala A, Quattrociocchi W (2020) Economic and social consequences of human mobility restrictions under COVID-19. *Proc. Natl. Acad. Sci. USA* 117(27): 15530–15535.

Box GE, Hunter WH, Hunter S (2005) *Statistics for Experimenters*, 2nd ed. (Wiley, New York).

Burtch G, Carnahan S, Greenwood BN (2018) Can you gig it? An empirical examination of the gig economy and entrepreneurial activity. *Management Sci.* 64(12):5497–5520.

Chen H, Qian W, Wen Q (2020) The impact of the COVID-19 pandemic on consumption: Learning from high frequency transaction data. Preprint, submitted April 6, https://dx.doi.org/10.2139/ssrn.3568574.

Datta H, Knox G, Bronnenberg BJ (2017) Changing their tune: How consumers' adoption of online streaming affects music consumption and discovery. *Marketing Sci.* 37(1):5–21.

European Centre for Disease Prevention and Control (2020) Download today's data on the geographic distribution of COVID-19 cases worldwide. Accessed March 17, 2021, https://www.ecdc.europa.eu/en/publications-data/download-todays-data-geographic-distribution-covid-19-cases-worldwide.

Fang H, Wang L, Yang Y (2020) Human mobility restrictions and the spread of the novel coronavirus (2019-nCoV) in China. *J. Public Econom.* 191:104272.

Field M (2020) The best music streaming services: Apple Music, Spotify, YouTube Music and Amazon Music compared. *Telegraph* (April 30), https://www.telegraph.co.uk/technology/0/best-music-streaming-services-apple-music-spotify-amazon-music/.

Ghose A, Kwon HE, Lee D, Oh W (2019) Seizing the commuting moment: Contextual targeting based on mobile transportation apps. *Inform. Systems Res.* 30(1):154–174.

Google (2020) COVID-19 Community Mobility Reports. Accessed July 16, 2020, https://www.google.com/covid19/mobility/.

Grant KW (2020) The future of music streaming: How COVID-19 has amplified emerging forms of music consumption. *Forbes* (May 16), https://www.forbes.com/sites/kristinwestcottgrant/2020/05/16/the-future-of-music-streaming-how-covid-19-has-amplified-emerging-forms-of-music-consumption/#17b570e0444a.

Groarke JM, Berry E, Graham-Wisener L, McKenna-Plumley PE, McGlinchey E, Armour C (2020) Loneliness in the UK during the COVID-19 pandemic: Cross-sectional results from the COVID-19 Psychological Wellbeing Study. *PLoS One* 15(9):e0239698.

IFPI (2018) Music consumer insight report. Accessed July 17, https://www.ifpi.org/wp-content/uploads/2020/07/091018_Music-Consumer-Insight-Report-2018.pdf.

IFPI (2020) Global Music Report: The Industry in 2019. Accessed June 29, https://www.ifpi.org/news/IFPI-issues-annual-Global-Music-Report.

Korzeniowska K, Wyborcza G (2020) How the pandemic is affecting Spotify use. *VoxEurop* (April 28), https://voxeurop.eu/en/how-the-pandemic-is-affecting-spotify-use/.

Kumar A, Tan Y (2015) The demand effects of joint product advertising in online videos. *Management Sci.* 61(8):1921–1937.

Lee W (2020) How the coronavirus crisis has helped Spotify's podcast business. *Los Angeles Times* (April 27), https://www.latimes.com/entertainment-arts/business/story/2020-04-27/coronavirus-podcasts-spotify-finneas.

Li S, Luo Q, Qiu L, Bandyopadhyay S (2020) Optimal pricing model of digital music: Subscription, ownership or mixed? *Production Oper. Management* 29(3):688–704.

Nicolaou A (2020) Music streaming during pandemic boosts Spotify paying users. *Financial Times* (April 29), https://www.ft.com/content/354f05c7-8418-4d2b-bd56-3d8dd65d2bde.

Nielsen (2015) 2014 Nielsen Music U.S. report. Accessed December 9, 2020, https://www.nielsen.com/us/en/press-releases/2015/2014-nielsen-music-report/.

Nielsen (2017) Nielsen Music U.S. music 360—2017 highlights. Accessed December 12, 2020, https://www.nielsen.com/us/en/insights/report/2017/music-360-2017-highlights/.

Nielsen (2020) Streaming consumption rises in U.S. markets with early stay-at-home orders during COVID-19. Accessed June 30, 2020, https://www.nielsen.com/us/en/insights/article/2020/streaming-consumption-rises-in-u-s-markets-with-early-stay-at-home-orders-during-covid-19/.

Oldham GR, Cummings A, Mischel LJ, Schmidtke JM, Zhou J (1995) Listen while you work? Quasi-experimental relations between personal-stereo headset use and employee work responses. *J. Appl. Psych.* 80(5):547–564.

Petherick A, Kira B, Angrist N, Hale T, Phillips T (2020) Variation in government responses to COVID-19. Working paper 31, Blavatnik School of Government, University of Oxford.

Perez S (2020) Spotify users are streaming again, but ad revenues still suffer due to COVID crisis. *TechCrunch* (July 29), https://techcrunch.com/2020/07/29/spotify-users-are-streaming-again-but-ad-revenues-still-suffer-due-to-covid-crisis/.

Spotify (2020) How social distancing has shifted Spotify streaming. Accessed November 8, 2020, https://newsroom.spotify.com/2020-03-30/how-social-distancing-has-shifted-spotify-streaming/.

Stassen M (2020) Despite the pandemic, Big Hit Entertainment generated revenues of $436M in the first 9 months of 2020. *Music Business Worldwide* (November 16), https://www.musicbusinessworldwide.com/despite-the-pandemic-big-hit-entertainment-generated-revenues-of-436m-in-the-first-9-months-of-2020/.