DISCUSSION PAPER SERIES

DP16006

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INDUSTRIAL ORGANIZATION

CEPR

ISSN 0265-8003

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Discussion Paper DP16006
Published 04 April 2021
Submitted 30 March 2021

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www.cepr.org

This Discussion Paper is issued under the auspices of the Centre's research programmes:

- Industrial Organization

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## Abstract

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JEL Classification: D12, L82, O33

Keywords: Music industry, Music consumption, Digitization



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Acknowledgements
We are grateful for the financial and intellectual support we received from the Département des Etudes, de la Prospective et des Statistiques (DEPS) from the French Ministry of Culture. We thank Tobias Kretschmer, Johannes Loh, and Yann Nicolas, as well as seminar participants at the AFREN's Digital Summer School in La Rochelle (2019) and ISTO's Research Days in Munich (2019) for their useful comments and suggestions.

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**Abstract**

Do new digital consumption channels of music depress sales in old physical ones, or are they complementary? To answer this question, we exploit product-level variations in prices of about 30 million sales and streams of over 300 thousand products observed weekly between 2014 and 2017 for the entire French market. At the track-level, we find that streaming displaces digital sales. Similarly, at the album level, digital sales displace physical sales. At the more aggregate artist-level, digital sales displace physical sales, but streaming implies a promotional effect on physical sales. This complementarity is driven by popular genres, i.e., Pop and Urban Music. Most of our findings are robust to whether we consider the hits or include the products that belong to the long tail.

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# 1 Introduction

After more than a decade of falling revenue, the music industry is returning to growth. Since 2015, its global revenues are increasing again, and, since 2017, the biggest part of its revenues originate from streaming services, which timidly started in 2005. [1] This industry has gone through significant transformations since the early 2000s. Digitization drastically accelerated these transformations, by simultaneously affecting the nature of the products, their distribution and the way they are consumed. These transformations are shared by many media industries (films and videogames) and attract a strong and sustained attention from researchers in various fields. In economics, the main questions revolve around prices, revenue sharing, and in particular the substitution between consumption channels. Even though there is now a flourishing literature aiming to shed light on the question of substitution between channels, there exists no systematic approach so far. In this paper, we aim at providing one.

It is also a contribution to economic policy as it touches upon questions related to the aggregate demand and producers' revenue, the market structure, and the revenue sharing of this industry. Indeed, the replacement of some products by other products – and some distribution channels by others – can yield significant changes in the aggregate demand and producers' revenue.[2] In terms of market structure, both the distributors of music and the artists are affected by these changes. While the majors and the large retailers were the heart of the recorded music industry before the digitization – now a few dominant platforms (Youtube, Spotify, Apple) are occupying the economic space and concentrate a large part of the revenue generated.[3] When considering the artists, the digitization is often described as having favored the 'stars', even though it enables a large number of 'niche' artists to get known and to sell their products in limited volumes. In terms of revenue sharing, digitization has increased the number of artists who are tied to a record company (especially a major) with a license contract, in which the producer (i.e., the record company) is in charge of the recording but not the promotion of the music, as opposed to a more traditional form of contract, in which the record company takes in

[1] Source: International Federation of the Phonographic Industry (IFPI).
[2] See for example Datta, Knox and Bronnenberg (2018).
[3] See for example SNEP (2019).

charge of promotion of the music that it produces (See Bearing Point (2017)). More and more artists use the streaming platforms as the principle promotion channels of their work nowadays. It remains unclear, however, whether this change in promotion method of music benefits the artists or not. Highlighting how the digitization impacts the popularity of artists (as measured by the consumption of their music) across the various channels helps to shed light on this question. Finally, highlighting the heterogeneity across genres is important to understand how the variety of consumption of cultural products is affected by the digitization.

Using a unique dataset that covers virtually the whole French market for recorded music between 2014 and 2017, we ask whether there is displacement or complementarity between old and new ways of listening to recorded music - what we will name consumption channels thereafter. The old consumption channels correspond to physical sales (CDs and Vinyls), while the new ones to digital sales (downloads) or streaming.

We exploit variation in prices to estimate the impact of streaming on the digital sales channel, and the impact of each of the two new consumption channels (download and streaming) on the old physical sales one. At the product level, i.e., for tracks and albums, we show that there exists a substitution effect between the new and old channels, which has already been documented by other researchers. At the artist-level, we find a substitution effect between digital downloads and physical sales. At the same time, however, there is a complementarity effect between streaming and physical sales, that is mostly driven by the genres Pop and Urban Music. This suggests that artists who are positioned in specific "segments" benefited from the introduction of the streaming channel (at least in terms of units consumed). That finding complements some recent evidence in the literature. Finally, at the market-level, our results remain inconclusive.

Our paper relates to the literature studying the impact of digitization. On the supply side, prior work suggests that digitization led to increased quality (Waldfogel, 2012, Aguiar and Waldfogel, 2018a) and an increased variety of offered content (Luca and McFadden, 2016, Aguiar and Walfogel, 2018c). On the demand side, some papers highlight how the digitization of content and new consumption channels led to an increase in quantity consumed (Datta et al. 2018), although some other papers argue that the market is not expanding. Some empirical evidence suggests there has been an increase in consumed variety (Luca and Mc Fadden, 2016,

Datta et al. 2018), while another work is ambiguous on this point (Kretschmer and Peukert (2020)). Our paper contributes more specifically to the growing body of literature that focuses on the substitution between music consumption channels: substitution between traditional and new channels (e.g., physical and digital sales) or substitution between digital channels (e.g., per-purchase versus on-demand) . First, several papers document the impact of unlicensed content (together with piracy). Curien and Moreau (2009) find that unlicensed content had a negative impact on the traditional market. Aguiar and Martens (2016) do not find evidence that unlicensed content had a negative impact on licensed digital content, and even find a small complementarity in some countries. A large literature however observes significant displacement effect of unlicensed content (e.g., Liebowitz, 2016). Second, a more recent literature analyzes the impact of streaming services on non-digital sales. Wlömert and Papies (2016) highlight the existence of cannibalization between streaming (free and paid services) and revenue from hard copies. Hiller (2016) finds a strong substitution effect of YouTube on physical sales (with YouTube views replacing about a quarter of album sales). In contrast, Kretschmer and Peukert (2020) find that YouTube has generated positive externalities on physical sales (with 20 percent extra revenues from songs available on the platform).[4] Our work relates perhaps most closely to the analysis of streaming by Aguiar and Waldfogel (2018b). They estimate displacement based on weekly data on digital track sales and streams in over 21 countries, between April and December 2013. However, their streaming data covers the top 50 only. They also exploit aggregate sales of tracks and albums, both in digital and physical format, for the period 2012-2013 for the U.S. which is prior to the true boom of streaming consumption. In France, this boom took place in 2015, which is covered by our own data set.

In sum, this overview indicates that there is a large but somewhat fragmented literature studying the question of displacement in the music industry. The conclusions from this literature are sometimes contradictory, which may in part be due to the consideration of different time periods or different adopted methodologies. With our data, we can analyze the market, encompassing physical and digital sales, as well as streaming, which has been rarely possible in

[4]When looking at the level of the entire market, Wlömert and Papies (2016) and Hiller (2016) conclude that industry revenues remain unchanged, whereas Kretschmer and Peukert (2020) find market expansion.

the literature. Furthermore, our analysis does not need to focus only on the hits; we can also include the products belonging to the long tail.

In terms of empirical strategies, prior work can be classified in three categories: (i) papers based on individual data from music consumers, (ii) papers, and (iii) papers using data aggregated at the product and artist levels. First, a strand of literature exploits the availability of individual-level data. Waldfogel (2010) uses survey data to assess consumers' willingness to pay for illegal and legal products and finds that the rate of the sales displacement ranges between -0.15 and 0.3 which means that an additional stolen song reduces purchase between a third and a sixth of a song. Wlömert et Papies (2015) use a quasi-experimental design and periodic survey for a large population of music consumers, enabling them to incorporate individual fixed effects in their empirical analysis. Aguiar and Martens (2016) exploit individual clickstream data and estimate a panel OLS model with individual and country fixed effects.

Second, several papers have used aggregate sales data and exploit exogenous shocks to estimate difference-in-differences models. Hong (2013) uses the introduction of Napster in 1999 – that was a pioneering peer-to-peer file sharing internet software which remained dominant until being shutdown in 2001 after running into legal difficulties over copyright infringement. Hiller (2016) uses the Warner shock in 2009, during which all the content produced by Warner was suddenly withdrawn from Youtube for a period of nine months. Kretschmer and Peukert (2020) use the GEMA shock in 2009. This year, a legal dispute occurred between the royalty collection society that represent artists in Germany and Youtube. It resulted in almost all music video being blocked in this country for several months.

Third, some papers have relied on aggregate sales data at the product and artist levels. In particular, Aguiar and Waldfogel (2018b) have data at the song and artist level for multiple countries. This enables them to estimate the impact of streaming on other music channels using song-time and country fixed effects, therefore accounting for common shocks in the popularity of songs across countries. Our paper belongs to this third category. We also have detailed data at the song or album level, which allows us to include product fixed effects. However, in contrast to Aguiar and Waldfogel (2018b), we only observe data for a single country, France, so we cannot exploit variation across countries. We therefore suggest an alternative empirical strategy that

relies on variation in prices to identify the impact of new music channels on existing ones.

The remainder of this paper is organized as follows. Section 2 presents the data used in the estimation. Section 3 introduces the econometric framework. Section 4 presents the estimation results. Finally, Section 5 concludes.

# 2 Industry background and data

## 2.1 The recorded music industry

Recorded music products are typically sold in three forms: (i) as physical goods (CD and vinyl) sold by brick-and-mortar or online retailers; (ii) as digital goods, i.e., downloaded music from platforms and websites; (iii) as streams, sold as large bundles of songs through subscription. The market for physical products is relatively fragmented, with many retailers varying widely in terms of size. For example, supermarkets, specialized independent shops and marketplaces such as Ebay and Amazon all serve the physical market. The market for digital products (i.e., downloads) is much more concentrated with only a few platforms serving consumers, such as iTunes, Amazon Music and Soundcloud.[5] The streaming market is even more concentrated: a limited number of companies offer either audio services (Spotify, Deezer, Apple Music, Amazon Music), video services (Youtube) or radio services (Pandora and Napster). As a result, it is much more common to see price variation for physical products across retailers and over time. For digital products we often observe focal prices, such as 1.29€ for a track and 9.99€ for an album in France. Subscription prices for streaming services are also relatively homogeneous over time and across platforms, with a focal price of 9.99€ per month in France.

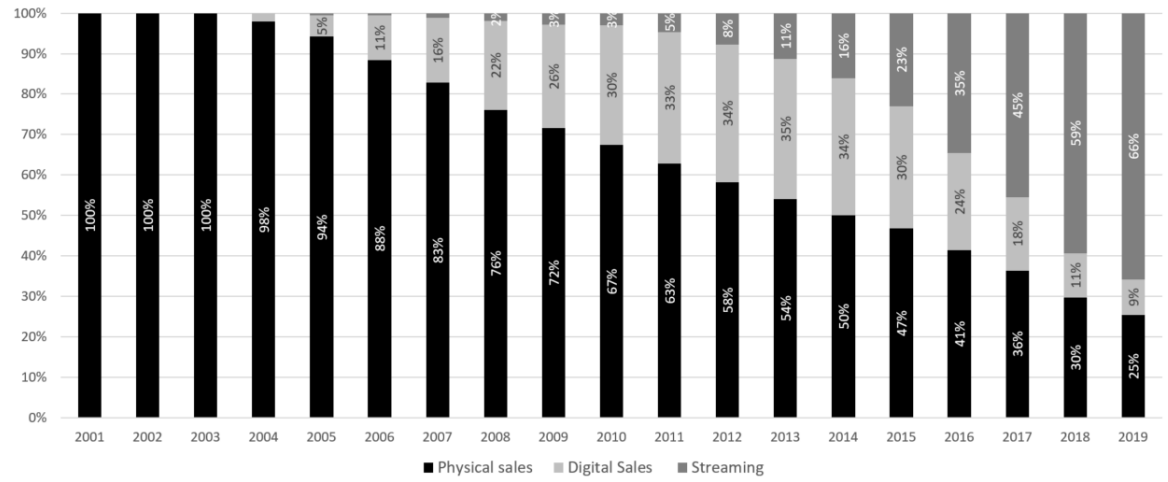
The dark side to this picture of the industry is the illegal consumption channel with piracy (via Peer to Peer (P2P) networks for example). Unfortunately, it is hard to measure it and therefore our study focuses on legal channels for which good and fine-grained data exist.

Figure 1 shows the evolution of the global recorded music revenues per consumption channel. Physical sales (excluding performance rights and synchronization[6]) represented virtually 100

[5]Some smaller players offer differentiated products such as high quality downloads (e.g. Qobuz in France).

[6]Performance rights generate payments for the copyright owner when the song is performed (live or by a sound recording) in a public space such as nightclubs, supermarkets or restaurants. Synchronization rights generate

Figure 1: Global recorded music industry revenues, per channel




Based on IFPI's Global Music Report (2019)

percent of the industry revenues in 2001 and dropped to only a quarter of revenues in 2019. Digital sales began around 2004 and gradually grew to up to 35 percent of industry revenues in 2013; since then, the share of digital sales continuously decreased to about 9 percent in 2019. Streaming timidly started in 2005 to reach a share of 8 percent in 2012; it truly took off in 2016 with a market share of 35 percent and its share subsequently increased by at least 10 percentage points per year, to reach 66 percent of the market in 2019.

More specifically in France, the share of digital sales (downloads and streaming) grew from roughly 30 percent in 2014, to reach almost 50 percent in 2017, based on data published by the SNEP (see Figure A.1). Therefore, the time period of our study covers the 'switch' from a market where the main part of revenue originated from physical sales to a market where digital revenue is predominant. The most recent figures from the SNEP indicate that the share of digital sales almost reached 65 percent in 2019.

## 2.2 Dataset

Our main source of data originates from the market research firm GfK. It contains weekly product level information for the entire French market on physical and digital sales of recorded

payments when a song is used in films, videos, commercials etc.

music, as well as the number of streams generated on audio, video, and radio platforms. The data cover virtually the entire digital music market (about 99 percent for the digital sales and all streaming according to informal discussion with GfK) and also almost completely the physical market (about 95 percent). In addition to sales, the data also include product characteristics such as names of artist, publisher, and label, its main genre and subgenre of music, and its release week.

Physical sales products refer to physical albums and singles, as sold through supermarkets, specialized shops, and online websites. Digital sales are downloads of albums or tracks (i.e., individual songs) that took place on legal platforms such as iTunes and Qobuz. Streams are always at the track-level and originate from audio platforms such as Spotify, Deezer, or Qobuz, and video platforms such as Youtube and Dailymotion.[7] For physical and digital sales, we observe both quantities and revenues, and hence the average price per album or track. Streaming refers to the quantity consumed (at a price of zero), both from users with a subscription plan and from users with a free access interrupted by ads. Even though we observe quantities for each type of streaming (premium audio, free audio and free video streaming), we pool them together as quantities observed are highly correlated with each other.

For physical and digital sales, the original data set covers the period 2006 - 2018. The streaming data starts during the last week of 2014 and ends in 2018. However, GfK does not collect the video streaming numbers since January 2018, so we restrict our analysis to the period 2014 - 2017. The original data consist of a large number of weekly cross-sections, which we combine based on the artist and title names. We remove 56 of the 208 weeks for which the data provided by Gfk was incomplete (because data for a given channel are missing, the basket item appears several times, etc.), leaving a final sample of 152 weeks.

For the physical sales, GfK explicitly codes whether a product is an album or a single. For the digital sales, this information is only partly coded. When missing, we define a product as a track if the price is at most 3€ and as an album if the price is above 4.9€.[8] We remove

[7] We exclude the data for radio streaming because it represents a very small volume and a lot of periods are missing.

[8] Defining a reasonable threshold was a challenge as it does not exist, to the extent of our knowledge, any rule previously used in the literature or reports. Therefore, we based our final choice on our own observations from the digital stores and informal discussion with GfK. One may note that this choice of threshold does not impact

the products priced in between, which represent a negligible number of observations (less than 0.5 percent).[9] Regarding streams, this always refers to tracks in our dataset. We remove a small number of price outliers: products with a price lower than 0.9€ or greater than 60€ on the physical channel (which removes very high-end special editions); and products with a price greater than 30€ for the digital albums and greater than 5e for digital tracks (where this was coded by GfK). Finally, we remove observations with an outlier price variation (beyond +100 percent of the price of a given product).

The creation of the panel data set highlights that some products are not sold or consumed every month since the launch date. GfK confirmed to us that it registers virtually every physical and digital sale. Hence, the absence of sales of a product in a given week indicates a true zero value for the week at which we observe the first sale. For such products with zero sales in some weeks, we do not observe the average price, so we use a simple linear interpolation to impute the missing price information. Regarding streaming, the interpretation of a missing quantity takes another meaning. Indeed, to appear in GfK's panel, a title must be streamed at least 100 times on audio-streaming platforms and at least 1000 times on video-streaming platforms on a given week. All the consumptions below this threshold enter a basket which is provided by GfK. Even though this basket allows us to compute the total number of units consumed on the market, the data is partially censored at the track-level.[10] To deal with that issue, we use a linear interpolation for tracks with missing values and for which we can reasonably assume that the track was available on the market during the week in question and that the observation was possibly censored by the 100/1000 streams threshold rule adopted by GfK. We interpolate at the track-level when possible, at the artist-level otherwise.

Finally, we complement this data with an extensive dataset published by the National Agency of Radio Frequencies (ANFR) that contains information on the number of 2G, 3G, and 4G antennas on the French territory between 1997 to 2019.[11] We use this data to compute the

significantly our final results as more than 99% of our observations clearly belong to one category or the other.

[9] We also verified that our definition based on the price bounds almost always coincides with that of GfK where this was coded.

[10] Nevertheless, the censoring thresholds of 100 and 1000 streams are very mild, and only the least popular products are affected by this censoring issue.

[11] See https://data.anfr.fr/anfr/portail.

weekly number of active 4G antennas between 2014 and 2017 and use it as an instrument in the market-level analysis.

### 2.3 Descriptive statistics

**Number of observations** As shown in Table 1, the final dataset is a panel of 29,625,455 observations, covering 4,333,239 unique products from 895,483 unique artists observed during 152 weeks. Albums make up 32 percent of all products and relate to either physical or digital sales (i.e., not streaming). Tracks make up the remaining 68 percent of the products. They mainly refer to digital sales and streaming. For physical sales, there are also singles, i.e., 2-tracks on CDs or Vinyls, but these make up a very small number of the observations during our sample, so we exclude them from our analysis.

Table 1: Number of observations

| | All | Unique products | Unique artists |
|---|---|---|---|
| Physical albums | 6,509,539 | 442,886 | 136,012 |
| Digital tracks | 19,020,901 | 3,201,891 | 699,847 |
| Digital albums | 5,053,784 | 646,244 | 258,239 |
| Streams | 7,698,617 | 396,251 | 115,771 |
| All products | 29,625,455 | 4,333,239 | 895,483 |

**Volumes and market shares by consumption channel** Since our dataset covers virtually the entire French market between 2014 and 2017, we can provide a comprehensive description of changes in the market shares of each channel: physical sales, digital sales, and streams. Because we do not have an unambiguous measure for the average price per stream, we focus on market shares in volume rather than in value terms. To aggregate sales over tracks and albums, we express album sales in track-equivalent units, assuming there are 10 tracks per album, which is a common assumption in the literature (see for instance Aguiar and Waldfogel (2018c)). Figure A.2 in Appendix shows the evolution of market shares over time.

Table 2 provides information on the absolute numbers behind these market shares. The total volume of digital sales is on average 865,576 track-equivalent units per week. This is indeed considerably lower than the total volume of physical sales of on average 4.2 billion per

Table 2: Track-equivalent volumes at the week-year level

| Variable | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| Track-equivalent physical sales | 4,219,386,789 | 2,308,579,692 | 2,405,653,504 | 17,533,339,648 |
| Track-equivalent digital sales | 865,563 | 159,895 | 607,597 | 1,411,537 |
| Streams | 956,711,454 | 175,692,107 | 644,443,072 | 1,408,501,504 |
| N | | 152 | | |

week, and the total volume of streams of on average 960 million units per week. Compared to the global figures presented earlier, the French market appears to differ, with respect to the number of digital sales that represent a small share of volume every week. Additionally, the physical market still represents an important share of revenues in the country. This has been described as a "French exception" by the National Syndicate of Phonographic Publishing (SNEP, 2018; SNEP, 2019 and SNEP, 2020).

This overview seems to suggest that the economically most relevant phenomenon to study is the impact of streaming on physical sales. However, digital sales still generate some significant industry revenue compared to streaming, so studying the impact of streaming on digital sales is also of economic interest.[12] Note that it is not possible to directly assess the impact of streaming on physical sales at the track-level (because physical sales for tracks are virtually non-existent). We therefore conduct this part of the analysis at the artist-level.

**Sales and price variation** Table 3 presents summary statistics of our main variables. The top panel shows the summary statistics for sales volumes, broken down by channel (physical, digital, and streaming) and format (track and album). These figures confirm that digital sales volume is on average very small, including many zero values. Physical sales and streams volume are much higher on average. While average album sales volume seems to be of a comparable magnitude as streams volume, it is in fact much higher once converted into track-equivalent units (that is to say, after multiplying by 10).

Figure A.3 shows the change over time in the number of sales on the three channels. The total volume of physical sales stays relatively stable, except for the traditional end-of-the-year shocks around Christmas. Total digital sales volume is steadily declining to reach in 2017 half

[12] See Figure 1.

Table 3: Volumes and prices, at the product-level

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| Volumes | | | | | |
| physical albums | 9,851 | 189,906 | 0 | 111,677,352 | 6,509,539 |
| digital tracks | 2 | 18 | 0 | 8,149 | 19,020,901 |
| digital albums | 2 | 24 | 0 | 20,832 | 5,053,784 |
| streamed tracks | 11,047 | 65,417 | 100 | 12,019,576 | 7,698,617 |
| | | | | | |
| Prices | | | | | |
| physical albums | 13.5 | 7 | 0.9 | 60 | 6,509,539 |
| digital tracks | 1.3 | 0.2 | 0.2 | 5 | 190,208,961 |
| digital albums | 10 | 2.1 | 0.5 | 30 | 5,053,783 |

of what it was at the end of 2014. The number of streams is on the rise, starting from about 600 million in 2014 to reach about 1.4 billion in 2017. The shock in the middle of 2016 is due to a change in GfK's data construction method. To account for this event, we include week-year fixed effects in the regressions we comment below.

The top panel of Table 3 presents some statistics on the volumes. On average, a physical album is sold about 9800 times a week, while a digital album is sold twice a week. Songs available on the streaming platforms are streamed 11,000 times a week on average.

The bottom panel of Table 3 shows the summary statistics for prices, which are key factors of sales volumes. The price of a digital track is on average 1.3€, with a standard deviation of 0.2€. The price of a digital album is on average 10e, with a standard deviation of 2.€. The price of a physical album is on average 13.5e, with a standard deviation of 7e. The histograms shown in Figure A.4 provide additional insights into the price variation. The prices of digital tracks and albums appear as 'standard' and do not vary much over products, or time. Indeed, the vast majority of digital tracks and albums are sold at respectively 1.29€ and 9.99€. Nevertheless, there is variation around these price values, especially for albums. The prices of physical products show considerably more variation. While there are focal prices for physical albums at 6.99€, 10€ and 14€, as indicated by the spikes, it remains a considerable variation around these focal values.

Figure A.6 shows the distribution of the percentage change in prices within a given product. This shows that prices often stay relatively stable, but there exists variation for both digital and

physical products. Table A.1 provides further details on the frequency and magnitude of these price changes. On the digital channel, a price change is observed for 20 percent of the product-week observations. On average, this price change is 0.4 percent, which indicates an upward trend. On the physical channel, price changes occur in 95 percent of cases, with an average magnitude of -0.83 percent, which is the sign of a downward trend. At the product level, we observe similar phenomena, with much more variation observed on the physical channel, more significant price changes, and a downward price trend.

**Tops and Genres** Figure A.7 and Table A.2 highlight the significant concentration of sales and streams over a few top tracks and albums. This concentration of consumption on a few very popular products (the Hits) and the existence of a long tail of products with a limited number of sales is typical of various entertainment industries in the Digital Age as discussed in Anderson (2006). The availability of sales information for the products falling in this long tail is rare. This is in contrast with many contributions in the literature which only considers the most popular products. and can potentially moderate the conclusions from the literature, We will therefore exploit this information to see how our results vary whether we consider the top 50, 200, 1000, 5000 or all products, at each level of data aggregation (product level and artist-level).

As shown in Table A.3, almost 25 percent of available products percent belongs to the genre 'Pop'. Five additional genres represent around 7 percent of available products: Rock, Urban Music, Variety, Electro/Dance, and Classical Music. For each level of data aggregation (product-level and artist-level), we will carry out analysis for each of these genres to comment on their heterogeneity.

## 3 Empirical framework

Based on our product-level data by week, we aim to identify the extent to which different music channels imply sales displacement because of substitution, or rather sales enhancement from complementarities (e.g., from the possibility to discover new music, known as the sampling effect). More specifically, we are primarily interested in measuring the impact of the new music channels on the old ones, i.e., (i) the impact of the streaming channel on the digital channel, and

(ii) the impact of the digital and streaming channels on the physical channel. In practical terms, we consider that the two main music formats, i.e., tracks and albums, have a different presence in the three channels, as documented in section 2. Tracks are only available in the digital and streaming channels, whereas albums are only available in the physical and digital channels.

We incorporate this feature of the music market in two alternative ways. First, we consider a product-level analysis, i.e., either at the track-level or album-level. At the track-level, we then focus exclusively on the impact of streaming on digital sales. At the album-level, we focus on the impact of the digital channel on the physical channel. Second, we implement our analysis at the more aggregate artist-level, by considering track-equivalent units for album sales (based on our conversion of one album into 10 tracks). Our artist-level approach enables us to measure the impact of both the digital and streaming channels on the physical channel in an integrated way.

A typical approach to measure the impact of a new music channel on an existing one consists of regressing sales of the existing channel on the sales of the new channel. This entails a typical endogeneity issue: sales of a track (or album or artist) may be subject to the same common shock (an unexpected effect of popularity for instance), so that any positive relationship between the sales on the existing and new channels may simply capture this common shock rather than a complementarity effect between both sales channels. To address this issue, several papers exploited natural field experiments, such as the temporary withdrawal of part of the content from streaming platforms (Hong (2013), Hiller (2016) and Kretschmer and Peukert (2020). Other papers used panel data from different countries and include fixed effects per track and time period to control for the current common international popularity of a track or artist (e.g., Aguiar and Waldfogel (2018c), Aguiar and Martens (2016)). However, these approaches are not always feasible in terms of data requirement as in our case, since our data do not cover a temporary shut-down or a change in the regulation for instance and are available only for France. Furthermore, previous work is still based on certain assumptions (e.g., the assumption that the withdrawal of part of a channel is not correlated with its popularity in the first approach, and the assumption that local sales shocks are not correlated across countries, conditional on the included track-period fixed effects). As an alternative, we exploit the fact that we observe the

price of each product every week to implement an instrumental variable approach to identify the impact of new music channels on existing ones.

More formally, let $q_{it}^c$ denote the quantity of product $i$ sold or streamed at time $t$ on channel $c$. A product $i$ can refer to an individual track or an individual album. In our artist-level analysis, a product $i$ will refer to the artist (and quantities will be total of track-equivalent units across tracks and albums. The channel $c$ can be the physical channel, the digital channel, or the streaming channel. As in other research, we are specifically interested in measuring the impact of sales on the new channel on sales on the older channel. We thus let $c = O, N$, where $O$ and $N$ denote the old and new channels.

In the spirit of other papers such as Aguiar and Waldfogel (2018) and Kretschmer and Peukert (2020), we consider the following linear regression model to estimate the impact of sales in the new channel on sales in the old channel:

$$q_{it}^O = \alpha_0 + \alpha_1 q_{it}^N + \mu_i + \theta_t + \varepsilon_{it}^O \tag{1}$$

where $\mu_i$ is a time-invariant fixed effect for product $i$, $\theta_t$ is a week-year fixed effect, and $\varepsilon_{it}^O$ is the error term. Our main interest is in the coefficient $\alpha_1$. If $\alpha_1 < 0$, this means that the new channel displaces the old channel because of substitution. If instead $\alpha_1 > 0$, the new channel enhances the old channel because of complementary.

In our setting, this regression model can be implemented as follows. If products refer to tracks, then $q_{it}^O$ refers to the quantity on the (older) digital channel and $q_{it}^N$ refers to the quantity of streaming (and we ignore physical tracks (singles) because these are virtually non-existent). If products refer to albums, then $q_{it}^O$ refers to the quantity of the physical channel, and $q_{it}^N$ refers to the quantity of the digital channel (and we ignore streams because these always refer to tracks). Finally, if products refer to aggregate artists, then $q_{it}^O$ refers to the track-equivalent total quantity of the artist on the physical channel, and $q_{it}^N$ is a vector referring to the total quantity of the artist on the digital channel and the total quantity of streaming.

To estimate $\alpha_0$ and $\alpha_1$ in (1), the simplest approach would ignore both the product and time fixed effects (so $\mu_i = \theta_t = 0$) and use ordinary least squares (OLS). This would, however, involve

a severe endogeneity problem because shocks in the demand for the product on the old channel ($\varepsilon_{it}^O$) are likely strongly correlated with demand for the same product on the newer channel ($q_{it}^N$). Including the product and time fixed effects may mitigate this concern, but it is likely that there is a strong remaining conditional correlation between ($\varepsilon_{it}^O$ and $q_{it}^N$ (e.g. a positive coverage of a particular song in French media may induce both more streaming and higher digital sales).[13]

To cope with the endogeneity issue of the variable $q_{it}^N$, we adopt an instrumental variable approach. Good instruments for $q_{it}^N$ would be product and time varying variables that have explanatory power for $q_{it}^N$, but do not directly enter the sales displacement/enhancement regression (1). Natural candidates would be the product prices at the various sales channels (or the determinants of these prices).[14] To see this, we can formulate the two structural linear demand functions underlying regression model (1), for $c = O, N$:

$$q_{it}^c = \beta_0 + \beta_1^O p_{it}^O + \beta_1^N p_{it}^N + \nu_i + \tau_t + \xi_{it}^c \tag{2}$$

where $p_{it}^O$ denotes the price of product $i$ at time $t$ on the old channel $O$, and $p_{it}^N$ the price of this same product on the new channel $N$.

Under the assumption that the prices are uncorrelated with the demand error $\xi_{it}^c$, the parameters of the demand equations can be estimated consistently. From the demand equation of the new channel ($c = N$), one can then compute the predicted sales $\hat{q}_{it}^N$ and use this as an instrument for $q_{it}^N$ in (1). Or equivalently, one can simply use the prices $p_{it}^O$ and $p_{it}^N$ in a two-stage least squares estimator. If prices are instead correlated with the demand error, one can modify the approach and use price instruments instead of prices themselves. In our set-up, the assumption that prices are uncorrelated with the demand error does not appear to be unreasonable. First, we include a rich set of product and time fixed effects. Second, as discussed above, prices tend to be focal around a limited number of values; then the remaining within-product variation tends to be discrete and is not obviously driven by sudden unobserved demand shocks. Hence, these

[13] With panel data on multiple countries, a full set of multiplicative product-time fixed effects ($\mu_{it}$) could be included, as done by Aguiar and Waldfogel (2018).

[14] Additionally, one may use other demand determinants at the channels, such as the number of active 4G antennas. We will use these at our most aggregate model as instruments for streams. Indeed, one can expect this to impact positively the consumption of streaming services, in particular in mobility.

prices are good candidate instruments in our case.

# 4 Estimation Results

As discussed in the previous section, we are interested in estimating the impact of the newer music channels on the older ones based on the commonly used regression model (1). As a benchmark, we first consider the results from OLS and fixed effects regressions. However, our main interest is in the 2SLS regressions, where $p_{it}^O$ and $p_{it}^N$ are used as instruments for $q_{it}^N$.

In the first subsection, we present the results from estimating (1) at the most disaggregate level, where products $i$ either refers to either tracks or albums. Because tracks are available only on the digital and streaming channels, and albums only on the physical and digital channels, this level of disaggregation does not allow us to consider the impact of both digital and streaming on the physical channel. We therefore address it in the second subsection at a more aggregate level of analysis: the artist level, where we sum over tracks and albums by using track-equivalent units, and at the level of the entire French market.

## 4.1 Track-level and album-level analysis

Our first analysis is at the level of individual tracks or individual albums. In both cases, we consider the impact of the newer technology on the older one: the impact of streaming on digital sales in the case of tracks, and the impact of digital sales on physical sales in the case of albums.

**Tracks** Table 4 shows the empirical results at the track-level, where we regress the number of digital sales (i.e. downloads) on the number of streams. As a benchmark for comparison, the first two columns show the results from estimating (1) using OLS and fixed effects. Both regressions would suggest a positive impact of streaming on digital sales. Including the track and time fixed effects does not reduce the estimated positive association. The results from both regressions cannot be interpreted as a finding complementarity between both channels. Instead, the positive relationship may be due to the presence of demand shocks for tracks at certain points in time, which influence both the demand on the digital sales and streaming channels.

Table 4: Product-level estimation results for digital tracks sales

| *Dep. Var* | **Digital tracks sales** | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | OLS | Panel OLS | Panel 2SLS |
| Streams (thousands) | 0.18*** | 0.21*** | -1.13*** |
| | (0.01) | (0.02) | (0.18) |
| Week-Year FEs | Yes | Yes | Yes |
| Track FEs | No | Yes | Yes |
| Instrument | No | No | Yes |
| First stage regression | | | |
| *Dep. Var.* | | | Streams (thousands) |
| Digital track price | | | 6.16*** |
| | | | (0.87) |
| Observations | 6,516,222 | 6,516,222 | 6,516,217 |
| Unique tracks | 237,639 | 237,639 | 237,639 |

Standard errors in parentheses, clustered at the track level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The third column shows the results after we use a price instrument for the number of streams. As expected, the first stage demand specifications show that the volume of streams depends positively on the price of the digital track. Note that the first stage thus includes only the cross-price effect. We cannot include an own-price effect because the marginal price per stream is zero (i.e. consumers pay only a monthly subscription).

We therefore only use the price of digital tracks as an instrument for the number of streams. The first stage regression shows that the price of a digital track has a positive and significant impact on streaming consumption, which is intuitive and indicates the two channels are substitutes. Consistent with this, the 2SLS estimator of our regression (1) shows that streaming has a negative impact on digital track sales. An extra one thousand units of streams leads to 1.1 less digital sales. This confirms the existence of substitution between digital sales and streams, the displacement effect commonly discussed in the literature.

To obtain further insights we repeat our 2SLS analysis for different subsamples: different definitions of top tracks and different genres. Table 5 shows the results when we consider different

Table 5: Product-level estimation results for digital tracks sales (by sample size)

| *Dep. Var* | **Digital tracks sales** | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | All | Top 5000 | Top 1000 | Top 200 | Top 50 |
| Streams (thousands) | -1.13*** | -0.98*** | -1.04*** | -2.28** | -6.13 |
| | (0.18) | (0.16) | (0.20) | (0.98) | (10.32) |
| Week-Year FEs | Yes | Yes | Yes | Yes | Yes |
| Track FEs | Yes | Yes | Yes | Yes | Yes |
| First stage regressions | | | | | |
| *Dep. Var* | | | Streams | | |
| Digital track price | 6.16*** | 29.77*** | 63.96*** | 59.32** | 30.11 |
| | (0.87) | (4.27) | (11.26) | (22.88) | (39.14) |
| Observations | 6,516,217 | 709,444 | 143,515 | 29,207 | 7,390 |
| Unique tracks | 237,639 | 28,868 | 7,810 | 2,372 | 856 |

Standard errors, clustered at the track-level, in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

definitions of top-selling tracks over the sample period: Top 5000, Top 1000, Top 200 and Top 50. This is of interest to assess whether streaming has somehow affected the distribution of sales (towards a longer or shorter tail). Considering the narrower top lists also serves as a methodological robustness analysis, as we have considerably fewer cases of zero sales for these lists. Table 5 shows that we obtain comparable findings across the different subsamples, i.e., streaming tends to displace digital sales. As we consider narrower top lists, the displacement seems to be stronger. For example, for the Top 200 we estimate that one thousand more streams lead to a reduction in digital sales by 2.3 units. However, because the sample size becomes much smaller the estimated standard error also increases. For the Top 50, we obtain a (strong) negative but imprecisely estimated impact.

Table 6 shows the results for different genres. Displacement is estimated to be slightly lower for Pop and especially Urban Music, while it appears to be stronger for Electro and Classical Music. However, because of the reduced sample sizes, the estimates are also less precise, so caution is warranted before concluding there are strong differences between genres. Overall, the findings by genre indicate that displacement is a common phenomenon, and not limited to certain specific genres.

Table 6: Product-level estimation results for digital tracks sales (by genre)

| *Dep. Var* | **Digital tracks sales** | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | Pop | Urban Music | Electro | Rock | Variety | Classical |
| Streams (thousands) | -0.92*** | -0.53*** | -1.51* | -12.42 | -1.20 | -1.24* |
| | (0.21) | (0.16) | (0.73) | (33.55) | (0.73) | (0.50) |
| Week-Year FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| Track FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| First stage regressions | | | | | | |
| *Dep. Var* | Streams | | | | | |
| Digital track price | 9.06*** | 24.90*** | 6.34** | 0.31 | 5.00 | 1.91 |
| | (1.84) | (7.01) | (2.72) | (0.84) | (2.89) | (1.87) |
| Observations | 1,466,503 | 973,624 | 581,193 | 562,177 | 402,217 | 92,088 |
| Unique tracks | 69,948 | 24,653 | 19,700 | 18,650 | 10,838 | 7,353 |

Standard errors, clustered at the track-level, in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Albums** Table 7 shows the results at the album level, where we now regress the number of physical sales on the number of digital sales (download). This regression, therefore, does not include streaming as a regressor because streams are at the track-level in our data set. [15]

OLS and fixed effects estimates again show a positive and significant effect of digital album sales on physical sales, suggesting there would be complementarity between the 'old' and the 'new' channels. However, as in our track-level analysis, this likely reflects the presence of common unobserved shocks that affect both physical and digital sales.

Our instrumental variable approach addresses this by considering a first stage, in which the demand for digital album sales may depend on the price of digital albums and physical albums. This first stage regression indicates that the price of digital albums has a negative and significant effect on the demand for digital albums, whereas the price of physical albums does not show a statistically significant effect. Using both prices as instruments for digital sales, we then estimate a negative and significant effect of digital album sales on the physical ones, implying that there exists a displacement between the digital and physical channels.

[15] Of course, individuals may also consume albums on streaming platforms. However, our data for the streaming channel only consists of tracks. We acknowledge that this may be a limitation of our data, and we address this issue in our further analysis below, which considers displacement by all channels at the artist and country level.

Table 7: Product-level estimation results for physical albums sales

| *Dep. Var.* | **Physical album sales** | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | OLS | Panel OLS | Panel 2SLS |
| Digital album sales | 1989.22*** | 1766.89*** | -18561.21*** |
| | (453.63) | (425.31) | (4788.77) |
| Week-Year FEs | Yes | Yes | Yes |
| Album FEs | No | Yes | Yes |
| Instrument | No | No | Yes |
| First stage regression | | | |
| *Dep. Var.* | | | Digital album sales |
| Physical album price | | | 0.002 |
| | | | (0.004) |
| Digital album price | | | -0.076*** |
| | | | (0.010) |
| Observations | 2,154,036 | 2,154,036 | 2,154,035 |
| Unique albums | 60,697 | 60,697 | 60,697 |

Standard errors in parentheses, clustered at the album level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

To obtain some further insights, we again, as in the track-level analysis, apply the instrumental variable approach on different subsamples: different definitions of top albums and different genres. We report the results from this analysis in Table B.1 of Appendix B. Compared with the track level analysis, we have fewer observations, so the estimates tend to be less precise, but they overall imply comparable conclusions.

For all subsamples except the Top 50, the first stage estimates a negative and statistically significant effect of the digital album price on digital album sales. The point estimates for the displacement effect in the second stage 2SLS regression remain very comparable for the subsamples limited to the Top 5000, Top 1000, and the Top 200, and the estimates also remain statistically significant. Only when we limit the sample to the Top 50, we no longer identify a significant effect. We attribute this to the fact that price is a weak instrument in this case, as indicated by its insignificance in the first stage regression.

Table B.2 shows the results for the different genres. We estimate a negative and statistically significant displacement effect for the genre Pop Music. For the other genres, we obtain negative but insignificant effects.

## 4.2 Aggregate analysis

The track-level and album-level analyses reveal interesting findings on the extent to which newer channels displace older channels. However, they do not allow for a direct comparison of how the digital sales and streaming affect differently the physical sales, because the physical sales of tracks are virtually non-existent, and the streaming of albums is not observed. To allow for such a comparison, we consider an analysis at more aggregate levels of data. We first consider the artist-level, where we convert album sales into track-equivalent sales using the earlier discussed conversion factor of 10 tracks per album (as in Aguiar and Waldfogel (2018)). Such an aggregate analysis is not only informative because it enables us to compare the relative impact of the digital and streaming channel on physical sales. It can also incorporate the impact of any possible spillover effects between different tracks and albums of the same artist. Using a similar approach, we also consider an analysis at the French market level at the end of this section.

**Artist-level analysis** Table 8 shows the results from the analysis at the artist-level. As in our earlier analysis at the track-level and album level, the OLS and fixed effects regressions suggest a positive impact of both the digital channel and streaming on sales in the physical channel.

The third column of Table 8 shows the results based on our price instruments.[16] We now have two first-stage demand regressions: one for digital (track-equivalent) sales, and one for streams. Both demands may depend on the prices of digital products and physical products (and again not on the price of streams, because the marginal price of a stream is zero under the platforms' subscription models). The estimated price effects in both first-stage regressions have the expected sign and are statistically significant. The artists' demand in the digital channel depends negatively on the price in the digital channel, and positively on the price in the physical

[16] To aggregate our price instruments, we use weighted and unweighted average prices for a given artist or week.

channel. Furthermore, the artists' streams depend positively on both the prices in the digital and physical channels.

Table 8: Artist-level estimation results for physical track-equivalent sales

| *Dep. Var* | **Physical track-equivalent sales** | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | OLS | Panel OLS | Panel 2SLS |
| Digital track-equivalent sales | 1407.86 | 1896.35*** | -3888.97* |
| | (866.06) | (525.70) | (1670.29) |
| Streams (thousands) | 2677.83*** | 2110.53*** | 14135.64*** |
| | (759.15) | (575.19) | (3909.26) |
| Week-Year FEs | Yes | Yes | Yes |
| Artist FEs | No | Yes | Yes |
| Instrument | No | No | Yes |
| First stage regressions | | | |
| *Dep. var.* | | Digital track-equi sales | |
| Average price of digital units | | | -14.43*** |
| | | | (1.43) |
| Average price of physical units | | | 3.82*** |
| | | | (0.74) |
| *Dep. var.* | | Streams | |
| Average price of digital units | | | 4.42** |
| | | | (1.38) |
| Average price of physical units | | | 3.40*** |
| | | | (0.69) |
| Observations | 9,777,091 | 9,777,091 | 941,021 |
| Unique artists | 895,596 | 895,596 | 34,164 |

Standard errors in parentheses, clustered at the artist level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on these first-stage results, the 2SLS estimates reveal the following regarding our artist-level analysis. The digital sales channel again has a negative and significant impact on the physical sales channel, similar to the displacement effect we estimated earlier at the album level. Hence, also after accounting for spillover effects between different tracks and albums of the same artist, the digital sales appear to crowd out physical sales. In contrast, the streaming channel

shows a positive impact on sales in the physical channel at the artist level. This points to a complementarity or demand enhancement effect. One interpretation is that streaming of certain songs provides users new information and encourages them to purchase physical products of the same artist (including other tracks or albums than the ones they streamed).

As in the track-level and album-level analysis, we also consider our analysis for different subsamples: different definitions of top artists and different genres. A general message from these extensions is that the effects are estimated less precisely and are often statistically insignificant.

Table B.3 shows the estimated effects of the digital and streaming channel for different definitions of top artists. The estimated price effects in the first stage regressions have the expected sign and are usually significant. This translates in comparable point estimates of the new channels on the physical channel: a negative impact of the digital channel and a positive one for streaming. But the estimates are imprecise, possibly because the price instruments are not sufficiently strong in these much smaller subsamples.

Table B.4 shows the estimated effects of the digital and streaming channels for different genres. The estimated price effects in the first stage regressions again have the expected sign and are usually significant, suggesting that our IV approach also works properly with aggregate data at the artist level. Nonetheless, the estimated impact of the new channels on the physical channels is sometimes imprecisely estimated. In those cases where we do obtain significant estimates, they are in line with the pooled regression across genres: for Urban Music, streaming enhances physical sales; for Rock , digital sales displaces physical sales; and for Variety, digital sales displaces physical sales, while streams enhance physical sales. Note that the positive coefficient on streaming that we obtain for these genres are in line with Kretschmer and Peukert (2020), who also identified a promotional effect of (video) streaming on music sales based on a natural experiment. One of the genres for which we obtain a positive coefficient (Urban Music) is very often described as being the main beneficiary of the emergence of streaming platforms in France. (See the reports by the National Syndicate of Phonographic Publishing (SNEP) in 2018, 2019 and 2020 and the study by Donnat (2018) for the Ministry of Culture.)

**Market-level analysis** For completeness, we also conducted our analysis at the most aggregate level of data: the French market level. Table B.5 shows the results, based on OLS and 2SLS for the 152 weeks in our sample.[17] Both the OLS and 2SLS approaches give insignificant results, and the first stage instruments appear to be weak at this aggregation level.[18] We obtain similar results under different ways for computing the average prices, as shown in Table B.6.

# 5 Conclusions

Using a unique dataset that covers virtually the entire French market for recorded music, we measure the displacement between old and new distribution channels. We exploit variation in prices to estimate the impact of the streaming platform on the digital sales channel, and the impact of these two channels on the physical sales channel.

At the product level, i.e., for tracks and albums, we show that there exists a substitution effect between the new and old channels, consistent with previous literature. At the artist-level, we also find a substitution effect between the digital and physical channels. At the same time, however, there is a general complementarity effect between streaming and physical sales, that is mostly driven by the genres Pop and Urban Music. This suggests that artists who are positioned in specific "segments" benefited from the introduction of the streaming channel.[19] That finding complements some recent evidence in the literature (e.g. Kretschmer and Peukert (2020)). Finally, at the market-level, our results are inconclusive.

Our results are useful for economic policy as it touches upon questions related to the aggregate demand and producers' revenue, as well as on the market structure and the revenue sharing of this industry, which attracted significant attention over the last decade.

[17] Note that a fixed-effects approach is no longer feasible at this aggregation level.

[18] The first stage regressions give no significant results, even though we obtain an intuitive negative coefficient for the price index of physical albums on track-equivalent physical sales.

[19] At least, these benefits are in terms of units consumed. We do not claim that the artists ultimately benefited from it as the revenue sharing may be different across channels, as suggested by several reports.

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# Appendix A: Descriptive Statistics

## Market share

Figure A.1: Market share of revenue in the French Market in Revenue (Data source: SNEP)

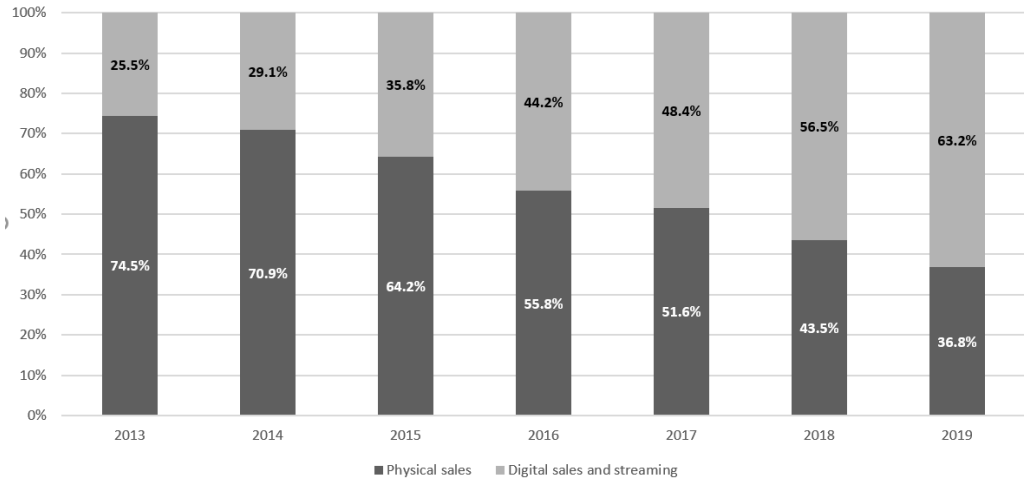
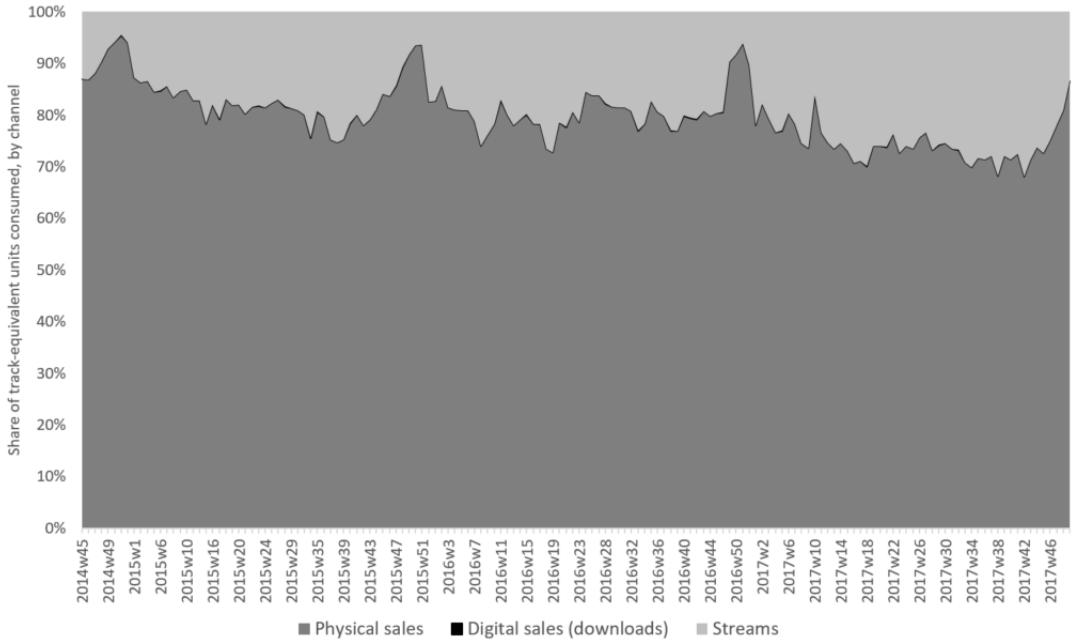
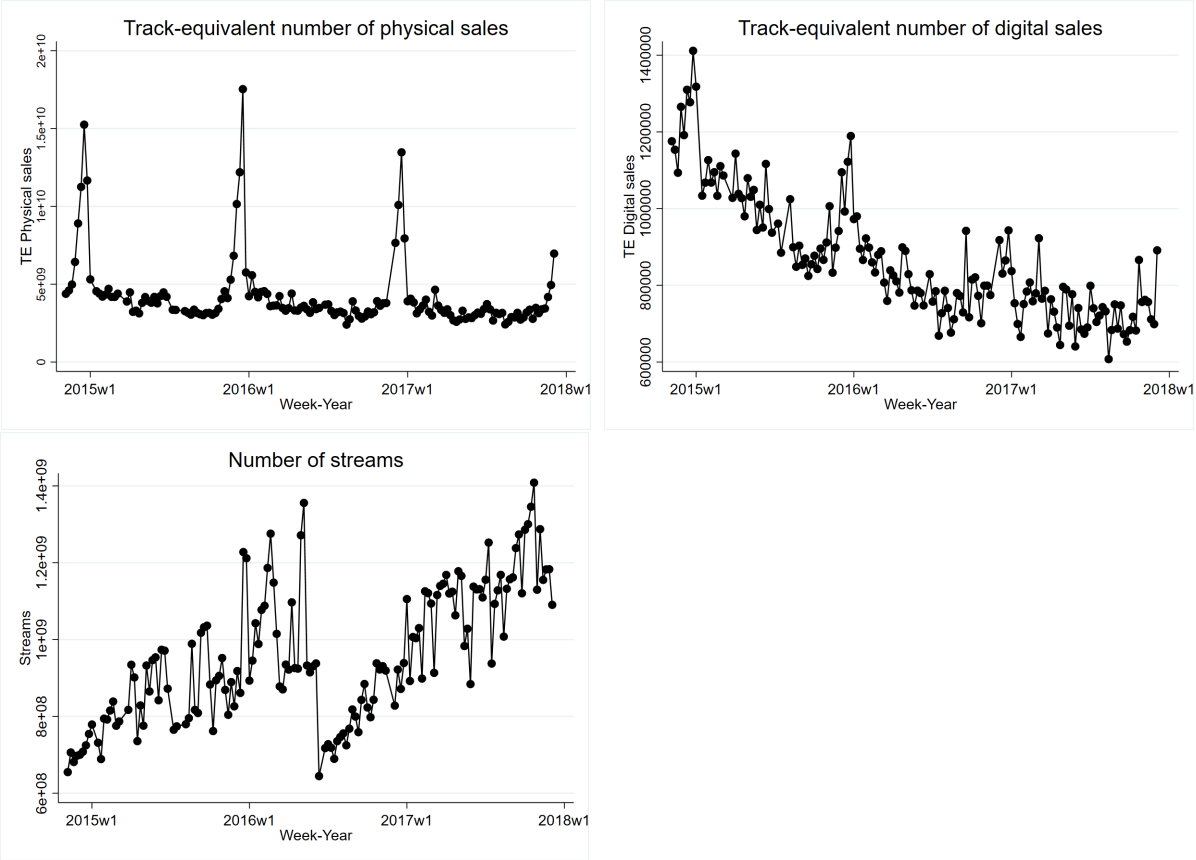



Figure A.2: Market share of recorded music in France in Volume (Data source: GFK)



## Volumes and prices

Figure A.3: Total number of units sold and streamed over time




Note: The decline in the number of streams observed in the middle of the year 2016 is caused by a change in the dataset construction rule by GFK.

Figure A.4: Histogram of prices

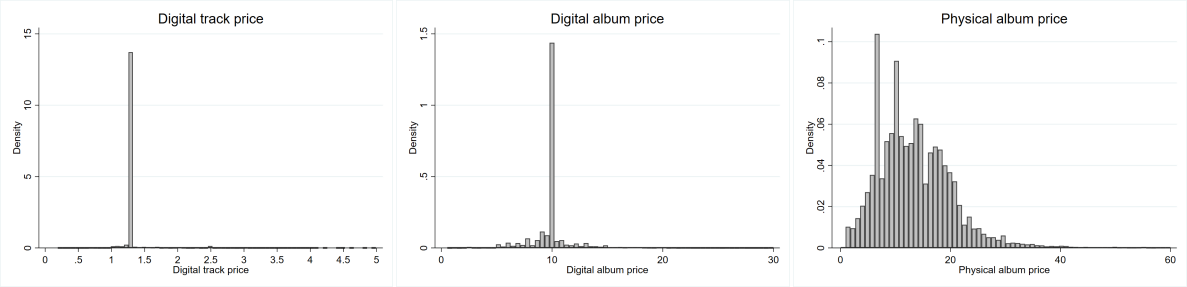


Figure A.5: Evolution of average price over time

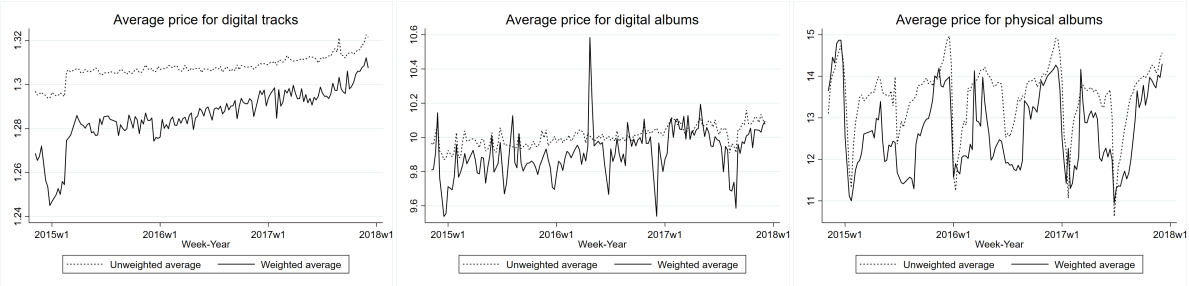



Figure A.6: Histogram of price variations (in %)

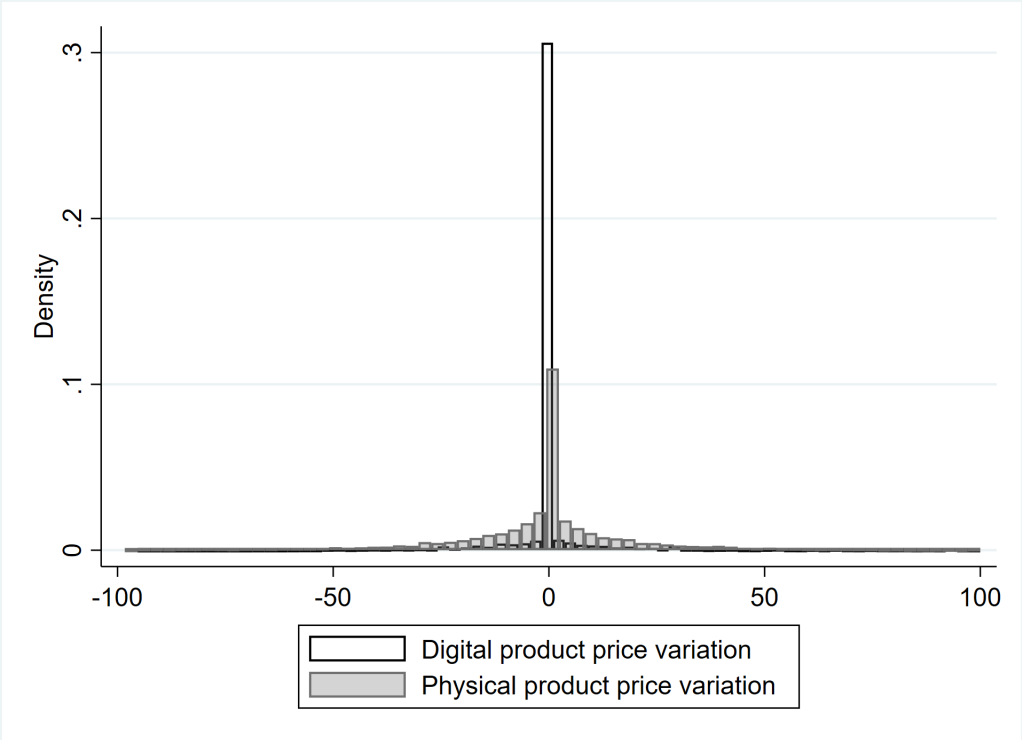
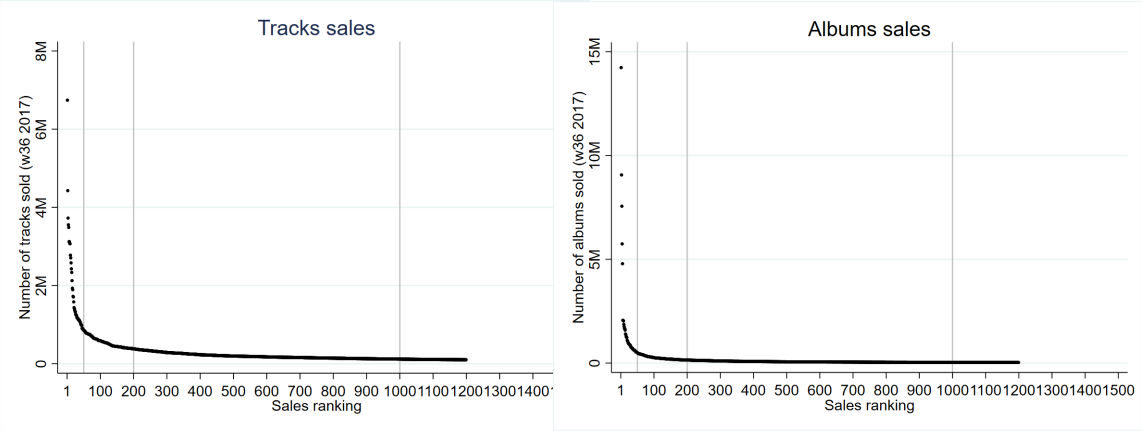


Table A.1: Statistics on price variation

| Variable | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|
| | | At the product-week level | | | |
| Change in the digital price occurred (0 or 1) | 0.2 | 0.4 | 0 | 1 | 20,225,846 |
| Magnitude of the digital price variation (%) | 0.37 | 10.11 | -95.39 | 100 | 20,225,846 |
| Magnitude of digital price variation $\geq$10% | 0.05 | 0.22 | 0 | 1 | 20,225,846 |
| Magnitude of digital price variation $\geq$20% | 0.03 | 0.17 | 0 | 1 | 20,225,846 |
| | | | | | |
| Change in the physical price occurred (0 or 1) | 0.95 | 0.23 | 0 | 1 | 6,094,793 |
| Magnitude of the physical price variation (%) | -0.83 | 24.2 | -98.3 | 100 | 6,094,793 |
| Magnitude of physical price variation $\geq$10% | 0.19 | 0.39 | 0 | 1 | 6,094,793 |
| Magnitude of physical price variation $\geq$20% | 0.12 | 0.32 | 0 | 1 | 6,094,793 |
| | | | | | |
| | | At the product level | | | |
| Share of periods where the digital price varied (%) | 5.02 | 14.64 | 0 | 100 | 3,848,012 |
| Average digital price variation observed (%) | 0.38 | 6.64 | -93.38 | 100 | 1,841,533 |
| | | | | | |
| Share of periods where the physical price varied (%) | 52.48 | 38.1 | 0 | 100 | 445,419 |
| Average physical price variation observed (%) | -4.7 | 20.07 | -98.18 | 100 | 308,789 |

## Tops and genres

Figure A.7: Distribution of sales and streams




Computed for Week 36 in 2017. We use the total of track-equivalent units sold or streamed for each product type (tracks or albums)

Table A.2: Concentration of sales and streams

| | Share of units sold and streamed |
|---|---|
| **Tracks** | |
| Top 50 products | 11.52 |
| Top 200 products | 21.65 |
| Top 1000 products | 41.31 |
| Top 2000 products | 67.86 |
| **Albums** | |
| Top 50 products | 30.00 |
| Top 200 products | 42.96 |
| Top 1000 products | 60.30 |
| Top 2000 products | 79.72 |

Computed for Week 36 in 2017. We use the total of track-equivalent units sold or streamed on all channels.

Table A.3: Share by main genres

| | Freq. | Percent |
|---|---|---|
| Pop | 7,075,213 | 24.76 |
| Rock | 2,190,273 | 7.66 |
| Urban music | 2,059,606 | 7.21 |
| Variety | 2,043,720 | 7.15 |
| Electro and Dance | 2,024,860 | 7.09 |
| Classical music | 2,002,636 | 7.01 |
| Other genres | 11,181,645 | 39 |
| | 28,577,953 | 100 |

We use the total of track-equivalent units sold or streamed on all channels.

# Appendix B: Additional estimation results

Table B.1: Product-level estimation results for physical albums sales (by sample size)

| *Dep. Var* | **Physical albums sales** | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | All | Top 5000 | Top 1000 | Top 200 | Top 50 |
| Digital albums sales | -18561.21*** | -22954.06** | -19841.4* | -18325.01** | 6419.6 |
| | (4788.77) | (7164.457) | (5785.65) | (10894.32) | (6940.111) |
| Week-Year FEs | Yes | Yes | Yes | Yes | Yes |
| Albums FEs | Yes | Yes | Yes | Yes | Yes |
| First stage regressions | | | | | |
| *Dep var* | Digital albums sales | | | | |
| Digital album price | -0.076*** | -0.246*** | -0.749*** | -2.176** | -4.917 |
| | (0.010) | (0.048) | (0.163) | (0.646) | (2.944) |
| Physical album price | 0.002 | 0.019 | 0.046 | -2.530 | -8.689 |
| | (0.004) | (0.039) | (0.200) | (1.444) | (4.613) |
| Observations | 2,154,035 | 364,446 | 87,575 | 20,545 | 5,367 |
| Unique albums | 60,697 | 13,871 | 5,809 | 2,356 | 939 |

Standard errors, clustered at the album-level, in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B.2: Product-level estimation results for physical albums sales (by genre)

| *Dep. Var* | **Physical album sales** | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | Pop | Urban Music | Electro | Rock | Variety | Classical |
| Digital albums sales | -28071.56** | -15495.75 | -41375.62 | -3057.504 | -16190.36 | -619.32 |
| | (8824.20) | (13593.27) | (52518.19) | (5054.51) | (13470.72) | (2829.92) |
| Week-Year FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| Album FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| First stage regressions | | | | | | |
| *Dep var* | Digital albums sales | | | | | |
| Digital album price | -0.110*** | -0.196 | -0.032 | -0.061*** | -0.103*** | -0.034*** |
| | (0.016) | (0.161) | (0.032) | (0.022) | (0.005) | |
| Physical album price | 0.007 | 0.023 | 0.000 | 0.007 | 0.004 | -0.003 |
| | (0.004) | (0.045) | (0.009) | (0.004) | (0.002) | |
| Observations | 444,866 | 157,372 | 95,567 | 419,172 | 307,774 | 102,260 |
| Unique albums | 10,804 | 3,440 | 3,253 | 11,824 | 6,888 | 3,135 |

Standard errors, clustered at the album-level, in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B.3: Artist-level estimation results for physical track-equivalent sales (by sample size)

| *Dep. Var* | **Physical track-equivalent sales** | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | All | Top 5000 | Top 1000 | Top 200 | Top 50 |
| Digital track-equivalent sales | -3888.97* | -14946.64 | -13347.96 | -10823.55 | -9148.57 |
| | (1670.29) | (9709.75) | (16999.71) | (22127.01) | (15640.55) |
| Streams (thousands) | 14135.64*** | 24550.26** | 22069.08 | 10367.96 | 10121.47 |
| | (3909.26) | (8598.32) | (12709.61) | (6520.67) | (9639.82) |
| Week-Year FEs | Yes | Yes | Yes | Yes | Yes |
| Albums FEs | Yes | Yes | Yes | Yes | Yes |
| First stage regressions | | | | | |
| *Dep. var.* | | | Digital sales | | |
| Average price of digital units | -14.43*** | -2.82 | 55.50 | -103.10 | -934.56 |
| | (1.43) | (7.43) | (76.86) | (452.40) | (1431.92) |
| Average price of physical units | 3.82*** | 17.30*** | 68.39*** | 83.75 | 236.16 |
| | (0.74) | (3.41) | (16.09) | (59.18) | (181.96) |
| *Dep var* | | | Streams | | |
| Average price of digital units | 4.42** | 23.77** | 248.06** | 1248.61** | 1438.75 |
| | (1.38) | (7.25) | (77.10) | (485.89) | (1223.41) |
| Average price of physical units | 3.40*** | 17.61*** | 81.41*** | 258.07** | 460.21* |
| | (0.69) | (3.38) | (16.26) | (75.09) | (232.80) |
| Observations | 941,021 | 381,249 | 107,219 | 25,312 | 6,963 |
| Unique artists | 34,164 | 9,887 | 2,900 | 1,006 | 410 |

Standard errors, clustered at the artist-level, in parentheses.
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

Table B.4: Artist-level estimation results for physical track-equivalent sales (by genre)

| *Dep. Var* | **Physical track-equivalent sales** | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | Pop | Urban Music | Electro | Rock | Variety | Classical |
| Digital sales | -23046.2 | 1281.54 | -16167.99 | -7921.90* | -8288.069* | 439.95 |
| | (14791.19) | (2701.44) | (51969.5) | (3420.92) | (3948.37) | (4982.82) |
| Streams (in thousands) | 51262.27** | 4763.30* | 3783.63 | -6731.58 | 52242.49** | 133316.3 |
| | (18798.86) | (2027.53) | (18593.06) | (16355.12) | (16983.41) | ( 341726.8) |
| Week-Year FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| Album FEs | Yes | Yes | Yes | Yes | Yes | Yes |
| First stage regressions | | | | | | |
| *Dep var* | | | Digital track-equi sales | | | |
| Average price of digital units | -2.58 | -13.93 | -4.32 | -18.06*** | -20.59*** | -10.85*** |
| | (8.27) | (20.42) | (0.79) | (2.20) | (3.71) | (0.84) |
| Average price of physical units | 10.44* | 7.76** | 0.46 | 2.68 | 14.31*** | 0.72** |
| | (3.67) | (3.62) | (0.91) | (1.40) | (4.10) | (0.36) |
| *Dep var* | | | Streams | | | |
| Average price of digital units | 11.98** | 50.40 | 5.56* | 2.47* | 0.67 | 0.19 |
| | (4.03) | (28.60) | (2.49) | (1.12) | (1.83) | (0.15) |
| Average price of physical units | 6.73* | 10.43 | 1.38** | 1.620* | 8.32** | -0.07 |
| | (2.85) | (5.72) | (0.52) | (0.59) | (3.00) | (0.14) |
| Observations | 140,508 | 77,648 | 50,018 | 140,505 | 100,570 | 89,768 |
| Unique artists | 4,004 | 1,981 | 2,171 | 4,608 | 3,037 | 4,271 |

Standard errors, clustered at the artist-level, in parentheses.
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

Table B.5: Market-level estimation results for track-equivalent sales

| *Dep. Var* | **Physical track-equivalent sales** | |
|---|---|---|
| | (1) | (2) |
| | OLS | 2SLS |
| Digital track-equivalent sales | 1439.23 | 2904.15 |
| | (1375.19) | (7847.49) |
| Streams | 1002.30 | -19,200 |
| | (757.11) | (17,290.17) |
| Month FEs | 0.000 | 0.000 |
| | (.) | (.) |
| Year FEs | 0.000 | 0.000 |
| | (.) | (.) |
| First stage regressions | | |
| *Dep Var* | | Digital sales |
| Average price of digital track | | -1,958,367* |
| | | (973,729) |
| Average price of digital album | | 30,196.12 |
| | | (47,273.2) |
| Average price of physical album | | 20,078.16 |
| | | (13,988.8) |
| 4G antennas | | 721,340.9*** |
| | | (171,297.1) |
| *Dep Var* | | Streams |
| Average price of digital track | | 641,730.8 |
| | | (1,929,882) |
| Average price of digital album | | -68,308.54 |
| | | (93,693.1) |
| Average price of physical album | | -22,818.6 |
| | | (27,725.2) |
| 4G antennas | | 121,907 |
| | | (339,502.2) |
| Observations | 152 | 152 |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table B.6: Market-level estimation results for track-equivalent sales (alt. price instruments)

| *Dep var* | **Physical track-equivalent sales** | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | 2SLS | 2SLS | 2SLS |
| Digital track-equivalent sales | 2904.2 | 18.7 | 829.7 |
| | (7847.5) | (4903.7) | (3578.9) |
| Streams (thousands) | -1.92e+04 | -9252.6* | -456.6 |
| | (17290.2) | (4387.8) | (2982.9) |
| Month FEs | Yes | Yes | Yes |
| Year FEs | Yes | Yes | Yes |
| Instruments | Weighted price av. | Weighted price av. (fixed basket) | Unweighted price av. |
| First stage regressions | | | |
| *Dep var* | | Digital track-equivalent sales | |
| Average price of digital track | -1,958,367* | -558,104.8 | 1,673,408 |
| | (973,729.3) | (511,261) | (2,418,748) |
| Average price of digital album | 30,196.12 | -61,521.45 | -230,144.7 |
| | (47,273.22) | (35,487.34) | (143,068.1) |
| Average price of physical album | 20,078.16 | 16,641.65 | 13,801.94 |
| | (13,988.85 ) | (15,856.69) | (12,226.74) |
| 4G antennas | 721,340.9*** | 667,928.7** | 764,357.5*** |
| | (171,297.1) | (206,087) | (168,625.7) |
| *Dep var* | | Streams (thousands) | |
| Average price of digital track | 641730.8 | 1989044* | 1.26e+07** |
| | (1,929,882) | (984,557.3) | (4,621,058) |
| Average price of digital album | -68,308.54 | -54,877.5 | -433,574.6 |
| | (93,693.1) | (68,339.5) | (273,334) |
| Average price of physical album | -22,818.6 | -59,448.02 | 17,076.86 |
| | (27,725.18) | (30,535.9) | (23,359.4) |
| 4G antennas | 121,907 | 756,701 | 90,785.62 |
| | (339,502.2) | (396,870.7) | (322,162.2) |
| Observations | 152 | 152 | 152 |

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$