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Economic concepts and implications of music subscriptions

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Abstract

The traditional model of music distribution – that of unit sales – is facing increasing competition from a radically different business model: on-demand subscription streaming services. Vast catalogues of music is made available to consumers at the cost of a fixed, monthly fee. On the other hand, composers, artists and record companies are paid through a small payment *per play*. The new business model implies dramatic changes in distribution and consumption of music, and also affects how revenues are distributed among stakeholders.

This exploratory paper points out the main economic differences between the model of unit sales and the on-demand subscription model. It will go into detail on aspects of the music market that are most effected by the new business model, and will point to economic models that can be of use in analysing redistributional effects and effects on social welfare. It will also point to the determinants of redistribution among different stakeholders, and how this may affect the agents' decisions.

Introduction

With a few key strokes, people today have access to large parts of all music that has ever been recorded. Subscription streaming services make all this music available at the cost of a fixed monthly fee, or even for free if one can tolerate advertising in between the music.

On the other hand, composers, artists and record companies are paid through a small payment *per play*. This has redistributed income. Some gain, others lose.

Music subscription services have taken over large fractions of the many music markets in the last few years. The current market leaders *Deezer* and *Spotify* were released in 2007 and 2008 respectively. Other examples are *Rhapsody*, *Rdio* and the recently released *Beats Music* and *Google play*. Such services have been responsible for a new revolution.

Subscription services have entered the fray where download services and illegal file sharing are battling physical sales and each other. Sales of music on physical formats have plummeted for 15 years and illegal sharing appears to have been losing support lately. Both paid downloads and subscription services experience strong growth globally. Subscription services have the strongest growth rate, but downloads still constitute two thirds of digital income globally.(IFPI, 2014)

It is highly unclear how the aggregate revenue streams from recorded music have changed with the introduction of streaming services. Consumers spend a lot of money on the services, but how these revenues are divided among the providers of the services, the record companies and the music artists is not known. Claims in media indicate that certain record companies gain at the expense of music artists. An explanation to the claim is that a lot of the revenues paid from streaming service providers to record companies are not for streams per se, but for access to the company's catalogue in the first place. (Harris, 2012) Shares in Spotify have apparently also been used to pay the major record companies. (Lindvall, 2009)

This paper is mostly concerned with this transition from purchasing music to renting access to music. The technologies of delivery are somewhat overlapping. Subscription services may allow downloading for local storage, but the consumer gains no control of these files, and access is lost if subscription stops. "Digital downloads" can also utilize streaming technology, as several services provide cloud storage of the files the consumer has purchased. Thus one can stream files one owns and one can download files one rents. I will still tend to use the term *downloads* for music that is bought and *streaming* for subscription services, but it is not the technology that is of prime concern here, but the business models. While the modes of distribution are overlapping and rapidly changing, the models of payment are more fundamental and therefore a better variable for categorization of services.

Streaming services are of two different types: subscription services and ad-funded services. The economic viability of the ad-funded model is uncertain at best. Income to rights holders from ad-funded services like YouTube and Spotify are meagre. Spotify appears to view their ad-funded service only as a recruitment ground of potential subscribers. Payment-per-play from ad-funded services is much lower than from subscription services, but in spite of that, the ad-funded section of Spotify appears to be at great loss for the company. (Presencer, 2013) There have also been claims that YouTube is subsidized by google. (Castle, 2014) Even if income from advertisement had been higher,

it is far from certain that this income would scale along with use. For all these reasons, this paper will not consider ad-funded subscriptions a separate business model.

The economic sustainability of the subscription streaming model is also debated. The services are not yet safely established, and it remains to be seen if they are profitable and sustainable. However, I share the investors' obvious belief that this is a matter of time. I believe Spotify are right when they blame high investment costs for not producing a profit. I also believe that the services will scale very well: As more people start using services, these people will to an increasing degree be people that do not listen as much to music as the early adopters. Thus Services can increase payment per play to rights holders, while also increasing their own margins. It is important to note that this scaling is not dependent on individual firm scale, but industry scale. Thus monopoly power does not provide great advantages that I can think of, only the disadvantages.

This paper will provide a clear view on a topic that is fiercely debated among agents of the industry. Incentives to create may be affected by the new technology and the emerging business model of music streaming. This may have consequences for cultural policy.

Part 1.1 and 1.2 of this paper will refer to some literature relevant to the understanding of the economics of subscription streaming services. Part 2 will give an outline of the fundamental economic relations and propose some basic concepts of a model suitable to analyse the shift in business model. Part 3 will discuss some questions and hypotheses of major relevance to the distribution of revenues, and refer to anecdotal evidence to support or reject these hypotheses.

1.1 Relevant literature

The consequences of digitization has been analysed from several directions. There is a considerable literature on the determinants of, and the consequences of, illegal, digital copying. The internet has been credited for improving availability of niche products, which will affect patterns of consumption. Bourreau et. al. (2013) find that record companies that have adapted to digitization release more albums without having higher overall sales (based on data from 2005-2006). This is consistent with the long-tail hypothesis. Handke (2012) analyse the number of new releases in Germany in the period 1984-2006, and find that digitization and the internet have not interfered with the growth trend in releases. This is consistent with a combination of decreasing revenues on the one hand and either decreasing production costs, or that a larger percentage of revenues are directed towards marginal recordings, on the other. Waldfogel (2011) finds that there has not been a reduction in the quality of music released since Napster.

The transition from physical recordings to digital downloads has been studied previously. (Bourreau et al., 2012), (Danaher et al., 2010), (George and Bell, 2008), (Styvén, 2007) The most economically fundamental shift in music distribution due to digitization is arguably *not* the transition from tangible formats to intangible. It is rather the transition from purchasing units to paying for access. From the rights holders' point of view, transition to streaming subscriptions represents a transition from one-off payments to pay-per-play. To cite the *British Recorded Music Industry*:

> *"Overall, the next transition phase for the music industry will not be the move from physical to digital but rather the move from digital ownership (MP3s and other digital files) to digital access (streaming from the cloud)."(BPI, 2013)*

Barr (2013) provides an interesting overview of what the transition to subscription streaming services implies. He identifies three key concepts: the 'basket of rights', 'disruptive innovation' and the 'celestial jukebox'. The first refers to copyright law, the second to technology and the third to business models. These three have to work together in order to provide sustainability in the music industry.

This paper will focus primarily on the change in business model, the introduction of the *celestial jukebox,* and give less attention to both technology and law. Unlike Barr, this paper draws primarily on literature within economics, and the outcome is therefore quite different.

The term of the *celestial jukebox* was popularized by Paul Goldstein in his 1994 book *Copyright's highway : from Gutenberg to the celestial jukebox.* The term refers to an online service that can provide a vast amount of cultural products instantly. He predicted such services to come along in the near future. Many services today have similarities with Goldstein's celestial jukebox. For music services, Spotify, Rhapsody and Deezer are among these. Goldstein's vision was about pay-per-play services and not subscription models, but important aspects of his predictions are still quite accurate. His main concern is the shape of copyright law and enforcement however, which mostly lies outside the scope of this paper.

Eric Harvey (2014) provides a brilliant review of the history of streaming and of recent developments in the delivery of music to consumers. From his account it is obvious that subscription streaming services are no recent revolution, but the logical, until now last step in a long series of technological, legal and economic developments.

1.2 The recent history of streaming

Zhu and MacQuarrie (2003) provide an economic analysis of bundling music into subscription services that at first sight appears to be well fit to understand the dynamics of the current situation in the digital music market. This is, however, not the case. Their model is effectively that of record companies that bundle their products. Their analysis is strongly affected by the subscription services that dominated at the time. *Pressplay* and *MusicNet.*

A distinctive feature of the latest generation of streaming services is that they aim to supply *all* music through their services. No service is quite there yet, but they are getting closer. There are many services that compete for customers while supplying the same material. This in contrast to the last big attempt at such services: the unsuccessful services of *Pressplay* and *MusicNet*, services provided by the major record companies themselves.

Pressplay was established in 2001 as a joint venture between Sony Music Entertainment and Vivendi Universal's Universal Music Group, and distributed the catalogues of these companies. MusicNet was also launched in 2001 and had the backing of EMI Recorded Music, Bertelsmann's BMG Entertainment, AOL Time Warner's Warner Music Group and streaming media company RealNetworks. In the limited market for digital music at the time, these constituted something of a duopoly.[1] Kelly Donohue (2001) writes "*The Big Five are using their copyrights to control an entire*

[1] Contenders soon arrived. From July 2002, Rhapsody supplied access to the material from all five major labels of the time. It should be added that catalogues were very far from complete. The total number of tracks available through Rhapsody was 175 000 in those early days, compared to Spotify's present catalogue of approximately 20 million tracks. EVANGELISTA, B. 2002. *Industry starting to endorse Net music / Listen.com to offer songs from all five major labels* [Online]. San Francisco, California: San Francisco Chronicle. Available:

distribution channel – something that is unheard of in the physical world – and are locking up an entire market in an arguably inefficient, subpar manner." They received harsh criticism and attracted antitrust probes, although they were acquitted. (Pate, 2003) This duopoly did not only compete on services, but was a competition between two agents which each had an effective monopoly on their library. Thus consumers might very well wish to subscribe to both services, as they were two separate goods with relatively low substitutability between them.

The economic dynamics of competition between services providing more or less complete libraries are very different from those of a duopoly where each agent has effective monopoly on large parts of the music library. To properly understand this, one must take into account the *two-sided* nature of the market: the competition among subscription services for licence to distribute music on the one side and the competition for consumers on the other. Market power in one market can affect pricing in the other market. An investigation into the two-sided nature of a market also helps identify what makes monopolization a likely outcome. (Rysman, 2009)

Burkart and McCourt (2004) Analyse the situation as it is somewhat more developed. They study the four most important music subscription providers in the USA at the time: MusicNet, Napster 2.0[2], Rhapsody and eMusic[3]. Their main focus is on the services provided by the record companies themselves: MusicNet[4] and Napster 2.0.

The paper is thought provoking, although maybe overly pessimistic. I will not go into detail, but I would like to emphasize two lessons to be learned: (1) music should still be available in the shape of DRM-free downloads (or CDs) (2) and there should be fair competition between service providers without too close ties to the major record companies or internet service providers.

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http://www.sfgate.com/business/article/Industry-starting-to-endorse-Net-music-2801248.php [Accessed 31.05 2014].

[2] Napster 2.0 was a rebrand of Pressplay. In 2011 Napster merged with Rhapsody.

[3] eMusic was and is a download-to-own subscription service. Since 2011 they have also offered streaming. Up until 2009 eMusic mainly had music from independent labels.

[4] Sony and Universal licenced their music to Musicnet in November 2002, and where thus available in three each of these services. Sony bought a 4% stake in the company in February 2003. Musicnet was only available to AOL subscribers.

Some fundamental economic relations

The fundamental change of business model can be divided into two phenomena. A transition from buying to hiring and a transition from many goods to a single bundled good.

	Buy	Hire
Stand-alone goods	1	2
Bundled goods	3	4

The table above contains four different business models that have all been employed. (1) corresponds to paid downloads or physical records from brick-and-mortar shops.[5] (2) can be understood as three somewhat different things: (a) It could be understood as a single good subscription[6], e.g. a newspaper subscription, (b) It can be a rental good. Rental of CDs is not a common model, but Asai (2011) reports that renting of music CDs has been common in Japan, just like DVD- or car-rental all over the world. (c) In the nontangible world, any pay-per-use service will fit here. Ad-funded streaming services may also be placed in this category, if ads one has to suffer are considered a per-play payment. (3) is not a common business model, but *eMusic* provided a download-to-own subscription service. Boxed sets of CDs (or MP3-downloads) are also bundles of a smaller scale. One may also place the album format here, if singles and single track downloads are considered the stand-alone goods. Finally, (4) represents the streaming subscription model. It resembles the *celestial jukebox.* [7]

Previous papers in economics have compared such models, although not necessarily specifically for the music industry.

1↔2 – Purchase ↔ pay-per-use: This transition has been analysed by, among many others, Balasubramanian et al. (2011). They model how consumers will divide themselves between buying, renting and not consuming information goods under various assumptions of competition.

[5] We ignore that an album is also a bundle of songs, as subscription services offer a very much greater bundle.

[6] It is a matter of definition whether a subscription is an agreement on a stream of unit sales, or paid access to some good/service. The answer to this would likely be connected with the degree of tangibility of the good. See related discussion in Styvén (2007).

[7] Although I will not consider radio here, it is worth noting what Barr (2013) writes about commercial radio and licence funded radio:
*«There are striking similarities between the ad-funded service of Spotify and commercial radio, where advertising revenue is also used to pay rights holders. In the UK there are also the BBC radio stations that are funded by licence fee payers and this could be likened to a subscription service as the listener is paying for the use of music without having to also listen to adverts in between tracks. The fundamental difference between the two services is the interactive nature of streaming.» (*Barr 2013)

3↔4 – Purchasing bundles ↔ pay-per-use of bundles: This situation does not differ substantially from 1↔2.[8] That said bundles that can be purchased are nowhere near as large as the bundles one can rent access to. The pure form of this choice does only exist for smaller bundles.

1↔3 – Stand-alone goods ↔ Bundled goods: Bakos and Brynjolfsson have provided very interesting analyses of bundling of information goods. Their framework is well suited to understand the implications of such bundling. (Bakos and Brynjolfsson, 1999), (Bakos and Brynjolfsson, 2000)

2a↔4: Single good subscription ↔ bundled subscription: Bakos and Brynjolfsson's analyses (1999), (2000) may be at least as relevant here as above, but can be applied both to unit sales and rented access. They show how bundling, given certain assumptions, may maximize supplier profits by both extracting surplus from consumer and by minimizing deadweight loss. Competition strongly favours the supplier that is able to supply the largest bundle.

2c↔4: Pay-per-play ↔ bundled subscription: (Fishburn and Odlyzko, 1999), (Altmann and Chu, 2001)

These are the vertical and horizontal comparisons. What we want to compare is the diagonal 1↔4. A formal model needed for analysing this transition should combine elements from the models employed in the other comparisons. I am aware of no paper that does this formally in a manner that fits with today's reality, but some interesting papers should still be categorized here. (Zhu and MacQuarrie, 2003), (Barr, 2013)

2.1 To buy or to hire?

Rights holders' payment from music consumption has traditionally been subject to a discrete choice of buying/not buying. A subscription makes rights holders get paid according to how much consumers in fact listen to their works, i.e. rights holders are paid according to a model of *pay-per-use.*

Consumers, on the other hand, pay for *access* to music. If you at one point decide not to spend more money on music, you have no music left, whereas with unit sales you would still own music you had bought. The key variable for consumers in the choice between buying and hiring is normally *usage frequency*, although this is slightly different in the case of streaming, as consumers pay according to a model of *pay-per-period*.

If a consumer every month buys recordings while considering a transition to streaming services, the gains from a transition may decrease as the collection grows larger. This collection will be of little use after a transition. But the situation is not symmetrical: a subscriber that ends the subscription will not have access to any music, and will have to build a collection from scratch. The consumer will lose access to all that music he/she had learned to love. To make a correct choice between buying units and renting access one needs to have correct expectations not only of future demand, but also future prices.

While renting music is generally assumed to be a new phenomenon related to internet streaming services, this has also existed for CDs. According to Asai (2011) this model has been widely adopted in Japan since the early eighties.

[8] Bundling may affect elasticities of substitution between the good/service in question and its potential substitutes. Thus it may affect the market power of the retailer/service provider both towards rights holders and consumers. The difference is likely a question of degree, not of qualitative outcome.

This model of payment leads to a permanent lag in revenues to rights holders. With unit sales, they receive their income when the record is sold. With subscriptions, they receive income each time the record is played. Revenues continue to drip in for decades, in many cases long after the composers and performers are dead.

The choice faced by consumers bears similarities to that faced by any person considering purchasing or hiring. It also has similarities with a pay-per-use model of information goods as described by Balasubramanian et. al. (2011), especially the supply side. A key difference is that music subscription is not pay-per-play but pay-per-period independent of use.

2.2 Bundling

In parallel with a transition from purchase to paid access/hiring, streaming services also bundle all recordings in its library into one good. You do not pay for access to a single track or album, but for the entire library.

From the seller's point of view, bundling can be very attractive under certain circumstances. Bundling allows the seller to better predict demand. Predicting a single consumer's valuation of a single good is difficult. But every consumer is likely to value at least parts of the bundle high, especially if the bundle is large. Profit maximization in the absence of marginal costs involves maximizing the product of price and the number of bundles sold. Bakos and Brynjolfsson (2000) show how bundling goods will increase the share of the willingness to pay that can be extracted by the seller.

Product bundling is a common feature of imperfectly competitive markets. This is particularly true for information goods, such as computer software and cable or satellite TV.

Product bundling is most successful, from the seller's point of view, when:

- There are economies of scale in production (marginal cost of production is low),
- there are economies of scope in distribution (marginal cost of bundling is low,
- production set-up costs are high,
- bundling simplifies consumers' decision making and consumption,
- consumers have heterogeneous demands,
- consumers valuation of different goods in the bundle are uncorrelated,
- the number of goods included is high and
- the number of consumers is high.

Considering this bundling, the choice faced by consumers is not that similar to renting housing or consumer durables. A better parallel is the choice between buying a treadmill for home use and paying monthly fees to use all facilities at the gym. The key variable for consumers in the choice between single goods and a bundle is *usage diversity.*

On a side note: Digitization paved the way for *un*bundling of goods that were previously sold bundled in the album format. Download services allow songs to be purchased separately. Altinkemer and Bandyopadhyay (2000) investigate the conditions under which bundling is profitable for the seller.

It may also be worth mentioning that bundling at different levels is common. We have seen several cases of subscriptions bundled with other products like internet access provision, mobile phone

subscriptions and satellite TV subscriptions. Service applications also come pre-installed on some computers and phones.

2.3 Rough outline of a model

I would propose to build a model based on combining elements from Bakos and Brynjolfsson (2000) and Balasubramanian et al. (2011).

One might be tempted to ask: If one uses a model based on bundling, then the comparison of purchasing to renting is just a simple comparison of discounted current and future costs? Well, no. In order to explore the redistribution of revenues among rights holders, one has to decompose consumers' *valuation* into two conceptually distinct features: *how often* one wants to listen and *how strongly* one wants to listen. I.e. a *usage frequency* and a *valuation-per-use.* Some consumers listen a lot, but do not have a lot of money to spend. Others spend a lot, but do not necessarily listen much more than average. In the case of sales, the latter group are responsible for a relatively large share of rights holder's revenues. In the case of subscriptions, both groups of consumers pay the same, but the favourite acts of the frequent users will receive a larger share of revenues through the pay-per-play agreement with the subscription service.

A model can be utilized in several ways, and I would like to hint towards how it can be applied towards different ends.

1) A model comparing static states of only unit sales and only bundled subscriptions will be useful in analysing how the new business model redistributes income between rights holders. Winners and losers can be identified, something that might be an important groundwork with policy implications.

2) Streaming subscriptions may very well have implications for optimal copyright term. In order to analyse this one will need a dynamic model that takes into account the revenues' effect on future releases, and also the age distribution of recordings sold and listened to. But one may prefer to keep the simple setting of *either* unit sales or subscriptions. Such a model can also be used to understand the efficiency of the models and to compare aggregate welfare.

3) A model that allows a *mixed strategy* of both unit sales and bundled subscriptions would be suitable to explore the conditions under which record companies decide to drop unit sales entirely, and only offer their products through the *access* model. These conditions might be more easily fulfilled with collusion than with honest competition. A model with mixed strategies which also considers the two-sided nature of the market might be necessary to understand forces of monopolisation. Results from a model with *mixed strategies* (both bundling and unit sales) will be easier to test empirically than one comparing pure situations of either model.

I have developed a model in line with (1) in order to analyse some of these questions. The model can be found section 2 of this paper. Under the simplified assumptions currently in place, it gives the exact same predictions for both business models. While this was admittedly not planned for, it provides a useful benchmark which will make it very transparent exactly what assumptions future results rest on.

Topics to explore

In the following I would like to briefly present some of the most pressing questions relating to the redistributional effects of the new business model.

3.1 Redistribution for unchanged patterns of listening

The *model of payment* will in itself lead to a redistribution of income, even if one assumes that the *new technology* did not affect the consumers patterns of listening. An empirical investigation might have difficulties factorising the effect of the one from the other, but this is an important division, and one that deserves more attention in the public debate on policy measures.

3.1.1 The spectre of the back catalogue

A lot of the music listen to, I bought in my teens. I paid for the music as much as 20 years ago, and it is now costless for me to replay the music from CDs. If I instead stream this music through a subscription service, then the rights holders will be paid again.

New records released today will to a larger extent *only* be paid per play. In the long term, these recordings may make as much money as they would have made from unit sales, but the revenues are spread across a longer time frame.

Thus old recordings are paid for twice. The second payment is paid for by the introduction of a lag in payments to the performers and rights holders of all new and future releases. This may affect incentives to create. Some agents view Spotify and similar services more as a way to monetize catalogue than to promote new releases. Many rights holders prefer to keep their catalogues off the streaming services, or decide to offer their material through streaming only after a period of sales. Some have raised their concerns that there are now insufficient incentives for them to offer a broad selection of new releases.

Several works make attempts at calculating expected income and incentive effects of copyright length.(Liebowitz (2007), Pollock (2009), Watt (2010) and Akerlof et al. (2002)). None of these have provided the final words of the debate on optimal copyright length, and the subscription model of payment have effectively changed the parameters they have tried to estimate. The degree of redistribution, its consequences for incentives to create and the long-term efficiencies of streaming as opposed to purchasing music, are all important future research questions.

3.1.2 The effect of frequency

Rights holders get paid from subscription services according to how much consumers listen to their works. This implies a permanent redistribution from music that does *not* lend itself easily to repeated listening, to that which does. The losers may be within certain genres or have a fan base that have a

considerable budget available, but limited time. This issue is related to the age composition of the users.

According to British Recorded Music Industry, Artists with a younger fan base dominate the list of most streamed tracks stronger than they do the sales list. (BPI, 2013) Youth generally have less money and more time for music listening than the population in general. Their budget has certainly made an impact also for unit sales, but for subscription, it is their *time budget* that sets the limits of music consumption and directly determines the distribution of revenues to rights holders. Youth as a group are also more likely to listen to present day hit-music repeatedly. This gives rise to a permanent redistribution of income from music that is listened to rarely, but intensely, to that which is listened to frequently.

There is also a transitional effect in that youth are strongly represented among the early adopters of the new technology. Thus revenues from subscription services are distributed more in line with their preferences than those of the public in general. If the subscription model conquers a vastly larger market share than today, then the impact of youth will diminish.

3.1.3 Alternative models of payment

It has been proposed that some issues with the current subscription model may be met by mending the model of payment somewhat. A model that has been mentioned is one where the payment from a given consumer is distributed among rights holders according to this particular consumer's listening. Thus artists streamed by a heavy user will receive less per play than artists streamed by a user that listens less. Maasø (2014) call these two models the *pro rata model* and the *user-centric model*. Using streaming data from the service Wimp for the periods august 2012 and august 2013, he finds that both models give the same share of revenue to the same top 5000 artists collectively. But there is a significant redistribution *within* the group of 5000, with both winners and losers. *Outside* of the top 5000 artists change is considerably stronger, as would be expected when numbers of individual listeners are low and a small number of listeners' occasional streams would make a relative difference.

It has also been discussed that payment to rights holders should be diminishing in the number of plays, thus being played ten thousand times would give less than ten times the payment of a thousand plays. Another option would of course be to replace the subscription model with a *pay-per-play* model. Different business models may be possible within today's copyright laws and distribution technology.

The current model causes a redistribution of revenues and may have less than optimal effects on plurality and, ultimately, welfare. It should be explored, at least theoretically, if other models of payment may lead to a more optimal allocation of revenues.

3.2 New patterns of listening

The new technologies have made more music available to consumers than ever before. This is certain to influence patterns of consumption.

3.2.1 Patterns of listening: Competing with the past

In addition to the effect of the changes in payment models, there is reason to believe that changes in patterns of listening may cause redistribution.

The technology of streaming services has made available a greater variety of music than consumers have previously had access to at any point in history. Current creators must deal with increased competition, not only from new creations, but from cultural heritage. Transaction costs of accessing the past are lowered. History is effectively unearthed.

The reduced costs of making available recordings of marginal popularity may draw a great share of audience from recordings that were previously available, to the benefit of those that were previously not. On the other hand, in the model of music purchase, people have listened to the records already in their collection. New music will in general only make up a fraction of what they listen to. With a streaming subscription a consumer may choose to listen mostly to *new* recordings.

Note that if one does a simple comparison of the age distributions or novelty rates of sales and streams, one would not be able to separate the effect of altered patterns of listening from the effect of the new model of payment. A solution might, as in the previous section, be if one could get access to listening data from both iTunes and subscription services.

3.2.2 Patterns of listening: The long-tail

The principle of the "long-tail" of music sales started with Chris Andersen's text on the *Wire.com* in 2004 (Andersen, 2004) where he argues that the future will hold big business in the tail of the sales distribution, where the items that have not commonly been available in the physical formats can be found. There is a rich empirical literature on the questions of who gains and who loses due to digitization. (Gopal et al., 2006), (Mortimer et al., 2012), (Krueger, 2005), (Connolly and Krueger, 2006) None of these, however, explore the consequences of subscription services. One will certainly expect that consumers will consume a greater variety of music once "everything" is available to them, and with subscription services more music is more readily available than even for legal and illegal downloads. Still there are indications that a lot of us throng around the same superstars.

Andersen's statements concern the shifting effect of digitization specifically, and are thus not contradictory to Sherwin Rosen's identification of a long-term trend towards increased importance of superstars. (Rosen, 1981) A hypothesis derivable from the long-tail theory is that it counteracts the superstar effect, although this is not a mathematical necessity: The losers may be in the middle ground.

Even if each of us listen to a greater variety than before, it is perfectly possible that we, to a larger extent than before, listen to *the same variation.* If most of us have favourite artists that are *not* superstars, and that the superstars are subject to a *lower* willingness to pay, but a *frequent* willingness to pay, then the effect of full availability could be an increased consumption of music by superstars.

A prediction given from such a hypothesis will be that the biggest hits should have a low ratio of plays/listeners. This is testable. Lamere (2009) has calculated a *passion index* that sheds some light on this, and his results do not, on first sight, appear to support the hypothesis. Using data from Echo Nest he finds that the most popular artists generally have a *high* such ratio. But as this is calculated by *artist*

and not by album or track, the result is not entirely conclusive. The top list is dominated by heritage acts with a catalogue of releases that plays are distributed over.

Maasø (2014) finds a similar pattern. They also find that almost all of those with a high passion index will gain from a *user-centric* model of payment. This might imply that those people that listen to the superstars listen to them a lot, but do not listen to a lot of music in general.

Even with data from subscription services, this issue is difficult to get any definitive answer to as we have little knowledge of listening patterns from physical formats. A possible solution might be if one could get access to data on listening from iTunes libraries over time. Such data would measure actual listening in a model of, or similar to, traditional purchases.

Roundup and final thoughts

This paper has made an effort to line up the key concepts and implications of streaming subscription services in an economic language. I thus hope to have helped add to the foundations of future research.

The new business model is a fundamental shift in how rights owners and middle men make money. One cannot rule out that this model will replace unit sales entirely.

Any economic analysis of this transition needs to take into account both the transition from purchase to access, and not least the bundling implied. Depending on research questions posed, the two-sided nature of this market is also of great importance. The fact that streaming services will have to compete both for access to copyrighted material, and for consumers, makes the mechanics quite complicated.

There are important redistributional effects of the new business model, which may in term affect creation and welfare. The economic consequences of the new technology therefore may have important policy implications. A better understanding of the workings of the music market is therefore important.

Section 2 – the model

Economic model of streaming subscriptions

1.1 General assumptions

1) There is no upstream competition: Production is exogenous. All varieties available to all subscription services at fixed, exogenous cost, and all services License all music.
2) Varieties identical between services [perfect substitutes]
3) Services add no value to the product, and demand no mark-up
4) Only one of two business models can exist: unit sales or rented access through subscription services.

1.2 The model

There are *n* varieties[9] available in the market. Consumers demand 0 or 1 unit of each variety, or may choose to pay for time limited access to *all* varieties. Resale is assumed impossible. Valuations for each good are heterogeneous among consumers, and for each consumer *k*, we use v_{ik} to denote a consumers *k*'s valuation of good *i*. The distribution of valuations for individual goods can change as the number of goods changes. We do not utilize a notation for this, as long as we bear in mind that some parameters may change from a model of unit sales to a model of access to a bundle.

We will treat supply of products exogenous. We assume that a supplier of a recording has no a priori knowledge of where on the stochastic distribution of popularity a particular recording will be[10], therefore prize is identical for all recordings. We assume that all recordings are supplied by a monopolist, or that monopoly prizing is possible through collusion.

The distributor, or service provider, takes no share of revenues and there are no taxes. Consumer expenditure is distributed directly among rights holders.

The model is calculated with continuous variables, even consumers and recordings. In the introduction we will use discrete notation, however, to make it a little easier to grasp the main concepts.

[9] In the case of music these can be considered individual tracks or albums. They can also be considered both recordings and releases. The exact content of a «variety» is unimportant

[10] May possibly have knowledge of *c(i)*? But still prizes are the same for all products?

1.3 The variables

θ_{ik}: Consumer *k*'s frequency of use of recording *i.*

ϕ_k: This is a quality of each consumer. It denotes the valuation per play of music, much of which is due to the fact that some people have more money than others, but not more time to consume the music.

d_k: This is another quality of each consumer. It is a *diversity* measure, and it measures the number of recordings consumer *k* listens to. The number of different recordings is the only variable that separates the avid listeners from the less active. This is also the variable we will use to differentiate the superstars from less popular works. The set of d_k works is denoted D_k.

2.1 Valuation of goods

Consumers are characterized by three independent variables: ϕ_k, θ_{ik} and d_k. Consumer *k*'s valuation of recording *i* is equal to the utility per play, ϕ_k multiplied with the frequency of play, θ_{ik}.

$$v_{ik} = \phi_k \times \theta_{ik} \qquad (1)$$

Total valuation of all recordings by all consumers:

$$V = \sum_{k \in \mathrm{K}} \sum_{i \in D_k} v_{ik} \qquad (2)$$

Consumers' decision

Consumers do not have a budget constraint, but will, in the case of unit sales, purchase any good with a valuation $v_{ik} > p_u$. In the case of subscriptions, he will subscribe if $V_k = \sum_{i \in D_k} v_{ik} > p_s$.

Unit sales:

$$u_{ik} = \begin{cases} 1 \; if \; v_{ik} > p_u \\ 0 \; if \; v_{ik} < p_u \end{cases} \qquad (3)$$

Subscriptions:

$$s_k = \begin{cases} 1 \; if \; \sum_{i \in D_k} v_{ik} > p_s \\ 0 \; if \; \sum_{i \in D_k} v_{ik} < p_s \end{cases} \qquad (4)$$

Monopolist profits

Unit sales:

$$\pi_u = p_u \times \sum_{k\in\Omega} \sum_{i\in D_k} u_{ik} \qquad (5)$$

Subscriptions:

$$\pi_s = p_s \times \sum_{k\in\Omega} s_k \qquad (6)$$

Revenues to rights holders:

Unit sales:

$$\pi_{ui} = p_u \times \sum_{k\in\Omega} u_{ik} \qquad (7)$$

Subscriptions:

$$\pi_{si} = p_s \times \sum_{k\in\Omega} s_k \times \frac{\sum_{k\in\Omega} \theta_{ik}}{\sum_{k\in\Omega} \sum_{i\in d_k} \theta_{ik}} \qquad (8)$$

One cannot make a direct comparison between the two business models, as one must assume that the values of certain variables will differ between the two as availability is very different. Specifically d_k and the range of θ_{ik}.

2.2 Valuations decomposed

As stated before, the individual consumer *k*'s valuation of an individual good *i*:

$$v_{ik} = \phi_k \times \theta_{ik} \qquad (1)$$

Consumer *k*'s valuation of the entire bundle:

$$v_k = \sum_{i\in D_k} \phi_k \theta_{ik} \qquad (18)$$

Total valuation of good *i*:

$$v_i = \sum_{k\in\Omega} \phi_k \theta_{ik} \qquad (19)$$

Total valuation of all goods:

$$V = \sum_{k\in\Omega} \sum_{i\in D_k} v_{ik} = \sum_{k\in\Omega} \sum_{i\in D_k} \phi_k \theta_{ik} \qquad (20)$$

3.1 Continuous distributions

We will now turn to a framework of continuous variables, consumers and recordings. This, combined with normalisation of several values to unity, make many statements immediately counter-intuitive. Although the wording may be sloppy at some places, there is actually no such thing as *a consumer* or *a number of recordings.* There is always a large or small *mass* or *set* or *amount* of consumers and recordings. They are not countable.

Maximum utility-per-use $\phi(k)$, maximum frequency of play of a song $\theta(i,k)$ and maximum amount of recordings in the consumption bundle of a single consumer $d(k)$ are all normalized to unity.[11] These three are thus distributed $\sim U[0,1]$.

As $\phi(k)$, $\theta(i,k)$, $d(k)$ and $s(i)$ are uncorrelated, we can state the following:

1. Utility-per-play, $\phi(k)$ is IID uniformly across [0,1]. The density is given by the amount of consumers: Ω.
2. Each of the consumers (Ω in all) listens to a subset D(k) of the *n* existing recordings. d(k) denotes the amount of elements in D_k. $d(k)$is $\sim U[0,1]$. The density is given by the number of consumers: Ω. The subsets D(k) are random but correlated.
3. Frequency of play, $\theta(i,k)$ is $\sim U[0,1]$. The density is given by the total amount of non-zero valuations: $\int_{k=0}^{\Omega} d(k)\ dk$. As $d(k)$ is distributed uniformly with a maximum value of 1, the amount of recordings in the bundle is a linearly decreasing function of *k* from 1 to 0. The area under this graph is equal to $\Omega/2$, which is the density of the distribution of $\theta(i,k)$.
4. The correlation between subsets D(k) is approximated by assuming that a recording *i* is present in $c(i)$ consumption bundles. We have that $\int_{k=0}^{\Omega} d(k)\,dk = \int_{i=0}^{\mathrm{n}} c(i)\ di$ as both of these areas measure the amount of non-zero valuations of recordings by consumers. We have *n* subsets $c(i)$. Thus if we assume $c(i)$ is $\sim U[0,\frac{\Omega}{n}]$ then we get the density $n/\frac{\Omega}{n} = \Omega$. $C(i)$ denotes the set of consumers that listens to recording *i*.
5. We make the rather strong assumption that the utility a given consumer draws from listening to a recording once, does not vary across recordings. Instead, we assume that if a person values a recording more than another he will listen to his favourite more frequently. Thus frequency is assumed to catch all variation in valuation across recordings.

[11] This is done for each of the two business models separately, as these variables may differ between the models.

4.1 Distribution of valuations – unit sales

Next, we need to find the distributions of valuations from the distribution of its factors. As we assume independent and uniformly distributed factors, this is not hard. The joint distribution is

$$f(v(i,k)) = f(\phi(k), \theta(i,k)) = f_{\phi}(\phi) f_{\theta}(\theta) = \frac{\Omega}{2} \qquad (xx)$$

Why? The probability density distributions of both functions are 1 as they are uniformly distributed over [0,1]. Then we multiply with the amount of valuations: $\frac{\Omega}{2}$.

To find the cumulative distribution we must apply the relevant limits of integration and our simple joint distribution:

First, our variables are defined only in the rectangle [0,0], [1,1]. In order not to include values above these limits in the volume calculated, we must divide the volume into two:

For $\phi_k < 1, p_u < \theta_{ik}$ we have the area:

$$Prob(v_{ik} < p_u, p_u < \theta(i,k)) = F(\phi, \theta | p_u < \theta) = \int_{\theta=p_u}^{1} \int_{\phi=0}^{p_u/\theta} 1 \, d\phi \, d\theta$$

$$= \int_{\theta=p_u}^{1} \left(\phi \Big|_{\phi=0}^{\phi=p_u/\theta} \right) d\theta$$

$$= \int_{\theta=p_u}^{1} \frac{p_u}{\theta} \, d\theta$$

$$= p_u \left(\ln(\theta) \Big|_{\theta=p_u}^{\theta=1} \right)$$

$$Prob(v_{ik} < p_u, p_u < \theta_{ik}) = p_u(\ln(1) - \ln(p_u)) = -p_u \ln(p_u)$$

For $p_u > \theta(i,k)$ we have the area:

$$Prob(v(i,k) < p_u, p_u > \theta(i,k)) = F(\phi_k, \theta_{ik} | p_u > \theta_{ik}) = \int_{\theta_{ik}=0}^{p_u} \int_{\phi_k=0}^{1} 1 \, d\phi_k \, d\theta_{ik}$$

$$= \int_{\theta_{ik}=0}^{p_u} 1 \, d\theta_{ik} = p_u$$

Thus the sum of the two is :

$$\boldsymbol{Prob(v_{ik} < p_u) = p_u[1 - \ln(p_u)]}$$

What we are *more* interested in, is the fraction of people[12] with a willingness to pay *above* price:

$$Prob(v_{ik} > p_u) = 1 - p_u[1 - \ln(p_u)]$$

Combined with (3) we have:

$$Prob(u_{ik} = 1) = 1 - p_u[1 - \ln(p_u)]$$

We may then multiply with the density $\frac{\Omega}{2}$ we get the volume of valuations:

$$\boldsymbol{Volume(u_{ik} = 1) = \frac{\Omega}{2}(1 - p_u[1 - \ln(p_u)])}$$

Producer surplus

We can find price by maximising monopolist surplus[13] with respect to price:

$$\max_{p_u} \boldsymbol{\pi_u = \max_{p_u} p_u \times Volume(u_{ik} = 1) = \max_{p_u} p_u \frac{\Omega}{2}(1 - p_u[1 - \ln(p_u)])} \qquad (\boldsymbol{X1})$$

$$\frac{\partial}{\partial p_u} p_u \frac{\Omega}{2}(1 - p_u[1 - \ln(p_u)]) = \frac{\partial}{\partial p_u} \frac{\Omega}{2}\{p_u - {p_u}^2 + {p_u}^2 \ln(p_u)\} = 0$$

$$= \frac{\Omega}{2}\left(1 - 2p_u + 2p_u \ln(p_u) + {p_u}^2 \frac{1}{p_u}\right) = 0$$

$$= \frac{\Omega}{2}(1 - p_u + 2p_u \ln(p_u)) = 0$$

This solves as:

$$\boldsymbol{p_u \approx 0.285} \qquad (\boldsymbol{25})$$

(for any value of Ω .) Inserting into (X1) this gives:

$$\boldsymbol{\pi_u = 0.0509\Omega} \qquad (\boldsymbol{26})$$

$$\boldsymbol{Prob(u_{ik} = 1) = 0.357} \qquad (\boldsymbol{27})$$

Thus, at price 0.285, producers have a profit of 0.051Ω. 36 percent of the non-zero valuations result in purchased units.

Consumer surplus

Consumer surplus' share of total valuation will be equal to the difference between total valuation for all consumers with a valuation at least as high as the price, and monopolist profits:

[12] I guess all the fractions and probabilities here are calculated with to total number of non-zero elements in the omega*n matrix of recording/consumer relations.

[13] "Profits", "surplus" and "revenues" can be used interchangeably, as there are no costs in this model.

We can express consumer surplus as the difference between total valuation for all consumers with valuation above price p_u and *producer profits* π_u.

$$\boldsymbol{CS_u = V_{p_u} - \pi_u = \frac{\Omega}{2} \int_{\phi=p_u}^{1} \int_{\theta=p_u/\phi}^{1} \phi\theta \; d\theta \; d\phi - \pi_u} \qquad (28)$$

We need to calculate V_{p_u}:

$$V_{p_u} = \frac{\Omega}{2} \int_{\phi=p_u}^{1} \int_{\theta=p_u/\phi}^{1} \phi\theta \; d\theta \; d\phi$$

$$= \frac{\Omega}{2} \int_{\phi=p_u}^{1} \frac{1}{2}\phi\theta^2 \; d\phi \Big|_{\theta = p_u/\phi}^{\theta = 1}$$

$$= \frac{\Omega}{2} \int_{\phi=p_u}^{1} \frac{1}{2}\phi - \frac{1}{2\phi}{p_u}^2 \; d\phi$$

$$= \frac{\Omega}{2}\left(\frac{1}{4}\phi^2 - \frac{1}{2}{p_u}^2 \ln(\phi)\right) \Big|_{\phi = p_u}^{\phi = 1}$$

$$= \frac{\Omega}{2}\left(\frac{1}{4} - \frac{1}{4}{p_u}^2 + \frac{{p_u}^2}{2}\ln(p_u)\right)$$

$$\boldsymbol{V_{p_u} = \frac{\Omega}{8}\left(1 - {p_u}^2 + 2{p_u}^2 \ln(p_u)\right)}$$

Inserting $p_u \approx 0.285$

$$\boldsymbol{V_{p_u} = 0.0894\Omega}$$

$$\underline{\boldsymbol{CS_u = V_{p_u} - \pi_u = 0.0894\Omega - 0.0509\Omega = 0.0385\Omega} \qquad (30)}$$

Deadweight loss

Deadweight loss is an inefficiency: it is the consumer valuation of a good that would be sold if goods were priced at marginal cost, but that does not result in a transaction because price is above marginal cost. In our case marginal cost is zero, thus all valuations below price will be deadweight loss.

When calculating deadweight loss we calculate total valuation below the price. We calculate this over the same area that we calculated $Prob(v_{ik} < p_u)$, but instead of integrating the probability function we integrate the value function $\mathrm{v(i,k)}$. Again, we do this in two steps.

I.e. deadweight loss is the area under the demand function where the valuation is below price.

For $p_u < \theta_{ik}$ we have the area:

$$DW_1 = V|\phi_k < 1 \; and \; p_u < \theta = \frac{\Omega}{2}\int_{\theta=p_u}^{1}\int_{\phi=0}^{p_u/\theta} \phi\theta \; d\phi \; d\theta$$

$$= \frac{\Omega}{2}\int_{\theta=p_u}^{1}\left(\frac{1}{2}\phi^2\theta \left| \begin{matrix}\phi = p_u/\theta \\ \phi = 0\end{matrix}\right.\right) d\theta$$

$$= \frac{\Omega}{2}\int_{\theta=p_u}^{1}\frac{1}{2}\frac{{p_u}^2}{\theta} \; d\theta$$

$$= \frac{\Omega}{4}{p_u}^2\ln(\theta)\left| \begin{matrix}\theta = 1 \\ \theta = p_u\end{matrix}\right.$$

$$DW_1 = -\frac{\Omega}{4}{p_u}^2\ln(p_u)$$

For $p_u > \theta(i,k)$ we have the area:

$$DW_2 = V|p_u > \theta = \frac{\Omega}{2}\int_{\theta=0}^{p_u}\int_{\phi=0}^{1} \phi\theta \; d\phi \; d\theta$$

$$= \frac{\Omega}{2}\int_{\theta=0}^{p_u}\left(\frac{1}{2}\phi^2\theta \left| \begin{matrix}\phi = 1 \\ \phi = 0\end{matrix}\right.\right) d\theta$$

$$= \frac{\Omega}{2}\int_{\theta=0}^{p_u}\frac{1}{2}\theta \; d\theta$$

$$= \frac{\Omega}{8}\theta^2\left| \begin{matrix}\theta = p_u \\ \theta = 0\end{matrix}\right.$$

$$DW_2 = \frac{\Omega}{8}{p_u}^2$$

$$\boldsymbol{DW = DW_1 + DW_2 = -\frac{\Omega}{4}{p_u}^2\ln(p_u) + \frac{\Omega}{8}{p_u}^2 = \frac{\Omega}{4}{p_u}^2\left(\frac{1}{2} - \ln(p_u)\right)}$$

Inserting $p_u \approx 0.285$

$$\boldsymbol{DW_u = 0.0356\Omega} \qquad (\mathbf{33})$$

Total valuation of all recordings by all consumers:

$$\boldsymbol{V = \frac{\Omega}{2}\int_{\phi=0}^{1}\int_{\theta=0}^{1} \phi\theta \; d\theta \; d\phi} \qquad (\mathbf{23})$$

$$= \int_{\phi=0}^{1}\frac{1}{2}\phi\theta^2 \, d\phi \left| \begin{matrix}\theta = 1 \\ \theta = 0\end{matrix}\right. = \int_{\phi=0}^{1}\frac{1}{2}\phi \, d\phi = \frac{1}{4}\phi^2\left| \begin{matrix}\phi = 1 \\ \phi = 0\end{matrix}\right.$$

$$\boldsymbol{V = \frac{\Omega}{2}\frac{1}{4} = \frac{1}{8}\Omega} \qquad (\mathbf{35})$$

Of course, one of these can be calculated residually from $V = V_{p_u} + \pi_u + DW_u$. But this way we get the additional control of methods as:

$$DW + CS_u + \pi_u = V$$

$$0.0356\Omega + 0.0385\Omega + 0.0509\Omega = 0.125\Omega$$

4.2 Distribution of surplus – unit sales

The aggregate size of the market, surplus and deadweight loss is dependent on how valuation of each good changes as a greater number of alternatives become available. We do not wish to make assumptions on this, and our comparison between the models will therefore only be between the different stakeholders' *shares* of the total valuation.

Thus, combining (26), (27), (30), (33) and (35), assuming $\Omega = 2$ we can find the numbers expressed as shares of total valuation:

Consumer surplus' share of total valuation from unit sales of all goods:

$$\boldsymbol{\frac{CS_u}{V} = \frac{0.0385\Omega}{\Omega/8} = 0.308 = 30.8\ \%}$$

Producer surplus' share of total valuation from unit sales of all goods:

$$\boldsymbol{\frac{\pi_u}{V} = \frac{0.0509\Omega}{\Omega/8} = 0.401 = 40.7\ \%}$$

Deadweight loss' share of total valuation from unit sales of all goods:

$$\boldsymbol{\frac{DW_u}{V} = \frac{0.0356\Omega}{\Omega/8} = 0.285 = 28.5\ \%}$$

Under these circumstances $Prob(u_{ik} = 1) = 35.7$ % of the non-zero valuations result in sales.

5.1 Distribution of valuations – subscriptions

Next, we turn to subscriptions to calculate the corresponding distribution in order to compare some implications of the different models. The joint distributions of frequency of play and utility-per-play is the same as before. Bear in mind that we allow variables to differ between the models, so normalisation may be different. But as long as we assume the same dependencies between variables, we have the same general shape of the distribution of valuations. Thus our comparisons should be valid.

In the previous section, we were interested in each consumer's valuation of each recording. Now, we are interested in each consumer's valuation of *all recordings* bundled together. This adds a dimension and subtracts a dimension from the previous. We now care about how the total amount of listening is distributed across consumers. We have assumed that each consumer's frequencies of play of recordings are continuously and uniformly distributed from zero to one, but consumers may play a different amount of recordings. Inspired by (18) we include the previously defined variable $d(k)$. As we are not interested in the valuations of the individual recordings, we can replace frequency dimension θ with its average value $\bar{\theta} = 1/2$.

Under the current assumptions there is a strong symmetry between the two business models, relusting in all results below being identical to those above.

$$f(V(k)) = f\big(d(k), \phi(k)\big) = \bar{\theta} f_d(d) f_\phi(\phi) = \Omega\, \bar{\theta} = \frac{\Omega}{2} \qquad (xx)$$

$$\boldsymbol{Prob(V(k) > p_s) = prob(s_k = 1) = \int_{\phi=p_s}^{1} \int_{d(k)=p_s/\phi}^{1} 1\; dd(k)\; d\phi} \qquad (\mathbf{40})$$

$$= \int_{\phi=p_s}^{1} \left(d(k) \Big|_{d(k)=p_s/\phi}^{d(k)=1} \right) d\phi$$

$$= \int_{\phi=p_s}^{1} \left(1 - \frac{p_s}{\phi}\right) d\phi$$

$$= \phi - p_s \ln(\phi) \Big|_{\phi=p_s}^{\phi=1}$$

$$\boldsymbol{prob(V(k) > p_s) = 1 - p_s + p_s \ln(p_s)} \qquad (\mathbf{41})$$

which is the same as for unit sales.

We may then multiply with the density $\frac{\Omega}{2}$ we get the volume of valuations:

$$\boldsymbol{Volume(V(k) > p_s) = \frac{\Omega}{2}(1 - p_s + p_s \ln(p_s))}$$

Producer surplus

We can find price by maximising monopolist surplus with respect to price:

$$\max_{p_s} \pi_s = p_s \times prob(s_k = 1) = p_s \times [1 - p_s + p_s \ln(p_s)] \qquad (43)$$

$$\max_{p_s} \boldsymbol{\pi_s} = \max_{p_s} \boldsymbol{p_s} \times \boldsymbol{Volume(s_k = 1)} = \max_{p_s} \boldsymbol{p_s} \frac{\boldsymbol{\Omega}}{\mathbf{2}} \boldsymbol{(1 - p_s + p_s \ln(p_s))} \qquad (\boldsymbol{X1})$$

$$\frac{\partial}{\partial p_s} \frac{\Omega}{2} (p_s - {p_s}^2 + {p_s}^2 \ln(p_s)) = 0$$

$$= \frac{\Omega}{2}\left(1 - 2p_s + 2p_s \ln(p_s) + {p_s}^2 \frac{1}{p_s}\right) = 0$$

$$= \frac{\Omega}{2}(1 - p_s + 2p_s \ln(p_s)) = 0$$

This solves as:

$$\boldsymbol{p_s \approx 0.285} \qquad (\mathbf{44})$$

This gives a profit:

$$\boldsymbol{\pi_s = 0.0509\Omega}$$

$$\boldsymbol{prob(s_k = 1) = 0.357}$$

Thus, at price 0.285, producers have a profit of 0.051Ω. 36 percent of consumers will subscribe to the service. Bear in mind, this price is not necessarily identical to the price estimated for unit sales, although the number is the same. This is because variables are normalized to unity independently for each model.

Consumer surplus can be calculated as:

$$\boldsymbol{CS_s = V_{p_s} - \pi_s = \Omega\,\overline{\theta} \int_{\phi=p_s}^{1} \int_{d(k)=p_s/\phi}^{1} \phi\theta \; dd(k)\, d\phi - \pi_s} \qquad (\mathbf{45})$$

We need to calculate V_{p_s}:

$$V_{p_s} = \frac{\Omega}{2} \int_{\phi=p_s}^{1} \int_{d(k)=p_s/\phi}^{1} \phi\theta \; dd(k)\, d\phi$$

$$= \frac{\Omega}{2} \int_{\phi=p_s}^{1} \frac{1}{2}\phi \; d(k)^2 \; d\phi \Big|_{d(k)=p_s/\phi}^{d(k)=1}$$

$$= \frac{\Omega}{2} \int_{\phi=p_s}^{1} \frac{1}{2}\phi - \frac{1}{2\phi}{p_s}^2 \, d\phi$$

$$= \frac{\Omega}{2}\left(\frac{1}{4}\phi^2 - \frac{1}{2}{p_s}^2 \ln(\phi)\right)\Big|_{\phi=p_s}^{\phi=1}$$

$$= \frac{\Omega}{2}\left(\frac{1}{4} - \frac{1}{4}{p_s}^2 + \frac{{p_s}^2}{2}\ln(p_s)\right)$$

$$\boldsymbol{V_{p_s} = \frac{\Omega}{8}\left(1 - {p_s}^2 + 2{p_s}^2 \ln(p_s)\right)}$$

Inserting $p_u \approx 0.285$

$$\boldsymbol{V_{p_s} = 0.0894\Omega}$$

$$\boldsymbol{CS_s = V_{p_s} - \pi_s = 0.0894\Omega - 0.0509\Omega = 0.0385\Omega} \qquad (\mathbf{30})$$

Total valuation of all recordings by all consumers:

Total valuation is calculated exactly as for unit sales, and is still:

$$\boldsymbol{V = \frac{\Omega}{8}} \qquad (\mathbf{35})$$

Deadweight loss

We calculate deadweight loss residually:

$$\boldsymbol{DW_s = V - CS_s - \pi_s = 0.125\Omega - 0.0385\Omega - 0.0509\Omega = 0.0356\Omega}$$

5.2 Distribution of surplus – subscriptions

Combining (26), (27), (30), (33) and (35), we can find the numbers expressed as shares of total valuation:

Consumer surplus' share of total valuation in the case of subscriptions:

$$\boldsymbol{\frac{CS_S}{V} = \frac{0.0385\Omega}{\Omega/8} = 0.308 = 30.8\,\%}$$

Producer surplus' share of total valuation in the case of subscriptions:

$$\boldsymbol{\frac{\pi_s}{V} = \frac{0.0509\Omega}{\Omega/8} = 0.401 = 40.7\,\%}$$

Deadweight loss' share of total valuation in the case of subscriptions:

$$\boldsymbol{\frac{DW_s}{V} = \frac{0.0356\Omega}{\Omega/8} = 0.285 = 28.5\,\%}$$

Under these circumstances $Prob(s_k = 1) = 35.7$ % of people will subscribe to the service.

5.3 Distribution of revenues between recordings – unit sales

In our continuous framework we reinterpret (7) as:

$$\boldsymbol{\pi_{ui} = \frac{c(i)}{\int_{i=0}^{n} c(i)}\,\pi_u} \qquad ()$$

The denominator is, as explained in 3.1, $\Omega/2$. Thus:

$$\boldsymbol{\pi_{ui} = \frac{c(i)}{\Omega/2} \times \ 0.0509\Omega = 0.0255\Omega \times c(i)}$$

5.4 Distribution of revenues between recordings – subscriptions

In our continuous framework we reinterpret (8) as:

$$\pi_{si} = \frac{\int_{k=0}^{\Omega} \theta_{ik} \ dk}{\int_{i=0}^{n} \int_{k=0}^{\Omega} \theta_{ik} \ dk \ di} \pi_s \qquad (8b)$$

[DOES THE DENOMINATOR MEAN ANYTHING?]

We can replace the numerator: $\int_{k=0}^{\Omega} \theta_{ik} \ dk = c(i)\bar{\theta}$ The denominator is the total amount of plays. This is the same as the average amount of plays per person per recording ($\bar{\theta}$) times the amount of non-zero valuations. Thus

$$\int_{\theta_{ik}=\theta_{0k}}^{\theta_{nk}} \int_{\theta_{ik}=\theta_{i0}}^{\theta_{i\Omega}} \theta_{ik} \, d\theta_{ik} \, d\theta_{ik} = \bar{\theta} \int_{k=0}^{\Omega} d(k) \ dk = \bar{\theta} \int_{i=0}^{\mathrm{n}} c(i) \ di$$

From the distribution of $d(k)$ we can find $d(k) = 1 - \frac{1}{\Omega}k$.

$$\int_{k=0}^{\Omega} 1 - \frac{1}{\Omega}k \ dk = k - \frac{1}{2\Omega}k^2 \Big|_{k=0}^{k=\Omega}$$

$$= \frac{\Omega}{2}$$

$$\pi_{si} = \frac{c(i)\bar{\theta}}{\bar{\theta}\frac{\Omega}{2}} \pi_{si} = \frac{c(i)}{\Omega/2} \pi_s$$

$$\boldsymbol{\pi_{si} = \frac{c(i)}{\Omega/2} \times \ 0.0509\Omega = 0.0255\Omega \times c(i)}$$

exactly as for unit sales.

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