Platform Complexity: Lessons from the Music Industry

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Abstract

Platforms provide anchor-points for coordinating varied activities within an ecosystem. Understanding platform complexity and its effects is therefore a vital concern for academia and industry. The complexity defines the range of possible activities on the platform and the related aspects of control. This paper argues that abstract models of platforms used in current research remove some of the most important features underlying the inherent complexity of digital platforms. This insight is illustrated with a small study of platforms and their evolving complexity in the music industry. The exploration highlights salient phenomena that a more comprehensive theory of digital platforms should encompass. We posit that advancing theoretical perspective that better embrace the complexity of digital platforms is needed to fully capture the strategic and technological implications of emerging digital platforms.

1. Introduction

In their comprehensive review of platforms Baldwin and Woodard [1] argue that all platforms, from credit cards and dating bars to Facebook, share several universal features – they comprises *core* modules, which do not change quickly, coupled with *peripheral* modules that support variety. Module reuse through platforms leads to economies of scale thanks to distributing fixed costs across larger number of products, as well as economies of scope through the increased flexibility and learning as the firm satisfies more types of customers. Given this level of abstraction it is not surprising that the term 'platform' has been applied to diverse phenomena (e.g. products, systems, and services) in academic literatures [2].

Within Information Systems (IS) platforms play an increasingly important role, for example in the transformation of legacy systems into flexible platforms for service innovation, or in the distributed development and delivery of smartphone- and tablet applications. These and other industry platforms are transforming media- and computer industries – thus positioning platforms as socio-technical re-configurations shaping anything from high-level industry changes to the individual appropriation of technologies. Furthermore, some inter-module interfaces deployed industry-wide become standards, which shape the dynamics of cooperation and competition [3]. While such changes are at heart of the IS field's concerns platforms have, paradoxically, received limited attention [4, 5]. Academic literature on platforms almost all originates from the fields of new product development, strategy, and network economics where the world of bits is rarely conceived as different from the world of atoms.

In this paper we heed the unique differences in the non-digital and digital platforms by exploring complexities underlying both digital and non-digital platforms. Based on this analysis we challenge the practical and theoretical viability of maintaining a unified platform perspective. We adopt a longitudinal view going back hundreds of years in order to track changes and the drivers associated with both digital and non-digital platforms within the music industry. Our main focus is on the emergence of specific configurations of components in platforms that created radical industry transformations.

We contribute to the discourse on digital platforms by highlighting their underlying complexity and emphasizing that grasping more of this complexity is essential in balancing the need on one hand to render platforms a researchable unit of analysis while on the other hand avoiding over-simplification of the phenomenon. The paper argues that a theory of digital platforms must address issues not relevant in the world of atoms, such as control arrangements for multiple platforms layered upon one another, or platform dynamics when different layers change at different speeds.

The remainder of the paper is organized as follows. Next, we review the platform concept and examine how platform change, -generativity, and -control points reshape industries. We conclude by discussing the necessary elements of a comprehensive theory of digital platforms.

2. Platforms types and characteristics

The term *platform*[1] has a rich history and many uses. *Plat,* meaning flat or level, and *forme*, meaning shape or arrangement of parts – together imply a flat, possibly raised, surface onto which something can be placed. It appeared in the product development literature in the early 1990s. A *platform product* [6] is one that "meets the needs of a core group of customers but [is designed] for easy modification into derivatives through the addition, substitution, or removal of features." The idea of platform product spurred research on *platform investments*, *platform technologies*, and *platform thinking*, as well as the development of advice for managers [1]. More generally platforms can be classified as: (a) internal, (b) supply chain, or (c) industry platforms [7].

(a) Platform products are examples of *internal platforms* used within a firm and which can be defined as "*a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced*" [8]. It relies on modularity and an organizing logic (i.e. product architecture). Much of the literature on product platforms refers to physical products. In computing, a defining example is the modular design of the IBM System/360 family of computers supporting modular upgrade paths. Here the product structure shaped the organizational structure with different groups responsible for different modules [3].

(b) Outside the boundaries of a firm *supply chain platforms* share key characteristics with internal platforms but some modules are designed and produced externally. This corresponds to component outsourcing if the platform owner sets the architecture and assembles the final product. This introduces the additional complexity of coordinating a supply chain. For IBM's System/360, wider dissemination of module interface knowledge created an industry of competing peripherals [3].

(c) The *industry platform*[2] is a loosely organized supply network or ecosystem in which several firms produce components that can be combined to form complete systems. Increased flexibility may imply that end-uses many not be known in advance [7]. The architectures and instructions sets of Intel and ARM processors are examples of physical electronic platforms. Linux, Microsoft's Windows, Apple's iOS and other operating systems are examples of flexible software platforms. The loss of module interface control in the IBM System/360 case transformed a supply chain platform into an industry one [7].

This paper motivates the hypothesis that in particular digital industry platforms must be considered separately from product and supply-chain platforms by the by the potential for distributed and contested control of industry platforms and the flexibility of software based digital platforms.

2.1 Platform Control and Openness

Control in industry platforms is highly distributed, except in cases of natural monopoly. The distribution of control between industry platform participants varies across cases and across time. Typically, key platform assets and the customer relationship are the most important control points [9].

Because their effects on industry level competition industry platforms have been a prominent focus of interest for technology strategy research. Cusumano & Gawer [10] define an *industry platform* as "a foundation technology or service that is essential for a broader, interdependent ecosystem of businesses. The platform requires complementary innovations to be useful and vice versa. An industry platform, therefore, is no longer under the full control of the originator, even though it may contain certain proprietary elements." The platform leader's reliance on innovation from complementors highlights the establishment of an industry level platform as essentially a sociotechnical process of managing the tensions between controlling platform interfaces to extract value and to retain ecological control versus opening the platform for others' innovations and open participation [11]. This has come to the fore [12, 13] in recent years as Apple and Google have taken different approaches to managing these tensions in their mobile operating system platforms (e.g. Apple's iOS and Google's Android) and the associated ecosystems. At the industry level at least technological platforms can be a product of not just a single strategic actor, but one resulting from the cooperative interplay among several such actors.

[1] http://www.oed.com/viewdictionaryentry/Entry/145374

[2] Gawer's classification includes multi-sided markets or through which two or more groups of customers transact. Not all multi-sided markets are platforms in the sense of a stable modular core providing a foundation for a variety of offerings, e.g. credit cards networks (cardholders & merchants). Other multi-sided markets are platforms as they support innovative new products, technologies, or services, such as operating systems (end-users & developers). The multi-sided market category reflects the terminology used in industrial economics building on earlier network economics literature and tends to focus on the pricing mechanisms for coordinating these markets. For our purposes multi-sided platforms in the sense we have been discussing can be thought of as industry platforms.

2.2 Platform Generativity

Platform *generativity*, implies that platforms have the property of remaining incomplete, underspecified and open for further developments through augmentation and recombination [14]. An important condition for generativity is the extent of platform openness. If the platform is not locked down by an owner's control of critical core assets or intellectual property, there is a possibility that it will be adapted with the addition of new modules to a multitude of new and perhaps unimagined uses. This ability of platforms to support multiple uses and become multi-purpose can be defined as, "*a system's capacity to produce unanticipated change through unfiltered contributions from broad and varied audiences"* [14]. However, generativity is not just about opening a platform to other's contributions and expanding its range of use. In this regard, some platforms have more potential than others depending on how they are architected. Zittrain [14], identifies 5 features that influence platform generativity (p71):

1. Leverage – helps in performing some task
2. Adaptability – flexibility to be used in creative ways / ease of being built upon
3. Ease of mastery – easy for broad audiences to adopt and adapt
4. Accessibility – can access tools (including expense and physical access)
5. Transferability – can share results and get an ecosystem of innovation and collaboration going

The personal computer and the Internet combined form a prime example of a flourishing generative digital platform. It has been studied extensively as have mobile OS platforms [12, 15]. Here we take a different tack by probing the evolution of one industry and its transformation by successive platforms.

3. Platforms in the music industry

Music is both an art form and an industry that has endured for millennia. It has driven the adoption of mobile consumer products from the car and transistor radios, to the Walkman and the iPod. However, the ways in which music is created, distributed, and enjoyed has been revolutionized several times by both tangible and intangible technological platforms – most recently by digital music distribution.

In the following we identify key platforms and control points and examine how industry structure and the generativity of platforms changed over time. The case study helps us identify and illustrate some of the features that a theory explaining digital industry platforms should possess.

In the *pre-industrial age* music meant live performances, troubadours, and patronage – the main source of income was performances. In the *industrial age* music was delivered as products such as sheet music and recordings. Writing and publishing music and songs became a viable business when legal rights (i.e. copyrights) were granted to compositions. The sale and licensing of recordings became an additional source of revenue from the late 19th century onwards. Thus there are three main sources of revenue in the music business: live performance, song/music writing, and recordings [16].

In the *digital age* music is digitally distributed by Internet, mobile phone, and other diffuse delivery and reproduction systems. While digital platforms have transformed the music business, other platforms have also shaped it throughout its history – such as a stage allowing performers to be visible and audible to large audiences as the most literal of platforms. Therefore, in order to better understand the effects of digital platforms we first take a quick tour of the most important non-digital music platforms through the pre-industrial and industrial ages of music production. Except where otherwise noted we relied on two main sources [16, 17].

3.1 Music in pre-industrial / industrial ages

The most fundamental platform for music is the set of relationships between different frequencies of sounds perceived as pleasing to the human ear. The diversity of scales and musical traditions that emerged around the world provided the basis for composition, instrument design, musical training, and cultural significance. Limit ourselves here to Western music implies no disrespect other traditions.

Folk music was not traditionally written down but instead passed from musician to musician. The lack of written representations limited the spread and complexity of musical compositions. The evolution of standardized modern musical notation on five line staves (c.a. 1400-1600) provided a platform for the widespread communication of compositions. It also allowed composers to craft and communicate much more complex musical compositions, e.g. symphonies, chorals, and opera. The emergence of printed music in the 15th century, not long after the introduction of movable type, greatly increased the accessibility of scores and lead to standardized versions of compositions.

Standardized notation and printing technology were thus important platforms with generative characteristics that drove major change in commerce around music. Other developments with platform-like characteristics included the standardization of the types of instruments used and pieces composed (e.g. sonata, symphony, and concerto), as well as the development of musical theory that channeled musical tastes. Since printing presses were not available to all they became control points for the creation of media and in some countries were given monopolies – at least partially to exert control over potentially subversive uses. Thus control of printing presses could be used to exert influence on the trajectory of cultural change in music and elsewhere.

Until the 18th century the formal composition and printing of music relied on the patronage of aristocracies and churches. However, by the middle of the century the wider commercialization of music started in Europe with the printing of scores and wider promotion of concerts (e.g. memorial concerts following the death of Mozart). The popularity of the published music to amateur musicians was greatly aided by the industrial production of instruments, particularly pianos. By the late 19th and early 20th century some scores were selling millions of copies. The nature of the production of instruments, musical training, and music publishing cast music in the shape of an industry as we would now understand it and exerted considerable influence on human culture.

The printing of books and music precipitated new legislation around the rights to print written works. In Britain the Licensing of Press Act (1662) initially granted copyrights to publishers, but the Statute of Anne (1710) granted copyrights to authors. The US constitution (1787) included a copyright clause and the Berne Convention (1886) introduced international reciprocal recognition of copyrights [18]. Copyrights became an important legal platform that underpinned music publishing. Music publishers typically made contracts with songwriters and composers to license the use of their compositions and in the 19th century music publishers dominated the music industry. While details vary by country the original copyright arrangements were typically restricted to the printed material. Over time the copyrights were extended such that royalties were due for the performances of the music in theaters, in movies, on radio, and elsewhere. Copyright duration has also been extended many times by successive legislation.

Thus copyrights became an important platform for the industry as it allowed music composition and the distribution of scores to be profitable on a large scale. This provided financial support for composers as well as publishing companies and arguably supported the creation of more creative works. On the downside there are arguments that overly strict interpretations of copyright law and ever lengthening duration of protection impedes further creativity that often builds on what went before [19].

Edison's cylinder phonograph patented in 1878 instigated a new major revenue stream for the music industry: recorded music. This completely changed people's relationships with performances. It was no longer just a fleeting experience never to be repeated to one that could potentially be enjoyed repeatedly.

Several technical innovations appeared in the following decades. The disc phonograph (1889) was cheaper than its cylinder based predecessors and electrical recording (rather than mechanical) introduced in the 1920s greatly enhanced recording quality. Vinyl 33⅓ rpm disks (1948) and the 7 inch 45rpm disk (1949) enabled the album and single formats respectively. Magnetic tape (1948) brought innovation to the recording of music by allowing editing (literally cutting out pieces of tape) and mastering on multi-track recorders. Tape cartridges and cassettes also made recorded music much more portable. The industry started to switch to digital distribution of recordings, albeit still tied to physical media, with the introduction of the CD in 1982. This was a major boon for the industry (Figure 1)

The recording technologies provided platforms for the transformation of the music industry with the purchase of recordings replacing the purchasing of sheet music for many people – much to displeasure of music publishers [20, p113]. Related technologies also transformed related industries like the movies (talkies and multichannel audio) and radio (content, prerecorded shows, fast paced show with jingles and adverts using tape loop cartridges).

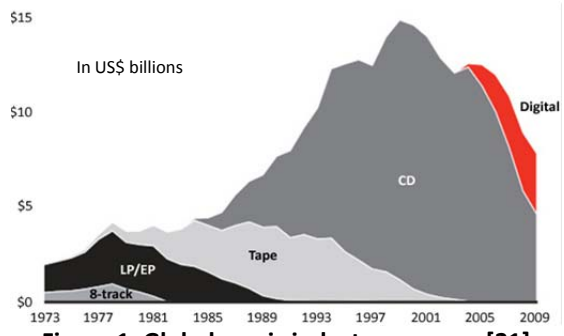

Figure 1. Global music industry revenue [21]

A simplified structure of the recording industry in the twentieth century is presented in Figure 2. Artists could record their own performances, on tapes or CDs, and sell them at their own concerts or in other ways. If a 'record label' signs an artist (or

group of artists) the label typically markets recordings and pays the artist a royalty from the sales. In return the artist agrees to an exclusive deal with the label. Engineers and producers help in the creation of recordings usually in studio settings. Manufacturers make physical copies of the recordings (e.g. on vinyl or CD). Distributors act as wholesalers of physical copies for merchandisers who sell them to the public.

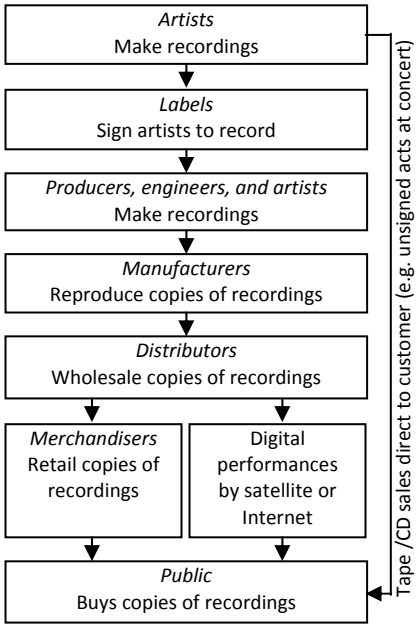

Figure 2. Overview of recording industry [16]

The physical nature of the products in the industrial age allowed copyright owners to control their compositions and recordings by controlling manufacturing and distribution. In most cases the label was the copyright owner as this was a typical stipulation in their contracts with artists. The high barriers to entry in high quality recording, manufacturing, distribution, and promotion gave the recording labels considerable power. They could dictate terms with artists such that the label would make money at sales volumes which still left artists needing a day job. However, it was the hits where the labels made most of their revenue.

In the USA sound recordings were not protected by copyright until 1978. The difficulty of manufacturing and distribution was enough protection until audio cassettes took off in the 1970s. Furthermore, it was not until 1992 that performance rights for recordings were created in USA. Recording performing rights organizations (PRO) collect royalties for the use of the recordings in public places, on TV, in movies and so on. Typical contract terms with artists included signing over performance copyrights to the label. The royalties associated with the song or composition itself (as distinct from the recording) persist. The music publishing segment of the industry has its own PROs to collect royalties on the sale and performances of recordings on behalf of the copyright holders of the song or music.

3.2 Music in the digital age

In 1982 digital music became available on CDs capable of holding ~70 minutes of uncompressed music in ~650 Mbytes. The CD specification was expanded to allow this large digital storage capacity to be used for multimedia content and for general computer storage. In the late-80s/early-90s several algorithms were developed for compressing audio for multimedia CDROMs. In 1993 some were included in standards published by the Motion Picture Experts Group (MPEG) of the International Standards Organization (ISO). The Fraunhofer Institute for Digital Media Technology retained patents for one of the algorithms, MPEG Layer III. It envisaged licensing it for transmitting high quality music using ISDN lines (digital version of traditional phone connections) as well as for use on CDROMs.

By the mid-1990s the Internet was becoming more popular and the Fraunhofer Institute saw the potential for their algorithm to become the standard for audio on the Internet. In 1995 they decided on the "dot m-p-3" file extension that led to the MP3 file format for music. An envisaged business model of charging high prices for using the encoding algorithm was disrupted when a software implementation was fraudulently posted to the Internet. Fraunhofer reduced its prices and the MP3 format became a de facto standard for music on the Internet as both encoding and decoding capabilities became widely available. The key advantage of the MP3 in the context of music was that a typical song required only 3-4 Mbytes of storage in contrast to an order of magnitude more in uncompressed formats. Karlheinz Brandenburg, one of the developers of the MP3 algorithm, said that by 1997 he "got the impression that the avalanche was rolling and no one could stop it anymore" in reference to the use of MP3 files for "unauthorized distribution of music over the Net." The MP3 experience became mobile with the release of the small Diamond Rio player in 1998 [22].

The MP3 file format and the ready availability of encoding and decoding software created a platform for the swapping of music at a larger scale than had been possible by taping LPs or CDs. Music was now inscribed in easily replicable bits rather than in physical artifacts. This was greatly exacerbated once Napster, launched in 1999, allowed strangers across

the world to search for and share music anonymously. The scale and scope of digital sharing removed the constraints imposed by the physicality of tapes, CDs, and LPs and the time-consuming nature of home taping.

While the precise technical details of the audio compression algorithms and protocols used for swapping music files might have turned out differently, MP3 and Napster became important platforms that allowed people to share recordings on a large scale without the permission of copyright holders. Within 18 months Napster had amassed almost 80 million users. However, these were not the only platforms necessary for the transformation. There were multiple layers of technical platforms built upon one another (see Table 1). From physical networks through layers of communication protocols, operating systems, and audio coding schemes, to support the applications which enabled CD ripping, MP3encoding, anonymous file sharing, and playback on computers or portable players.

This complex set of interdependent platforms took decades to evolve to the point where they could be used by a significant proportion of the population in the USA for storing and playing music. There had to be sufficient storage on the computers at relatively low cost to store a non-trivial number of songs, sufficient low-cost bandwidth to make the downloading of even compressed MP3 music files feasible, and low-cost, high-speed, peripherals to rip and burn CDs and to play the music with reasonable fidelity. In the late 1990s the evolution of the computer industry that put these capabilities in place put it on a collision course with the music industry.

Unsurprisingly, unauthorized sharing of MP3 files was opposed by the mainstream recording industry and many established artists – although some artists, particularly less established ones, viewed it as a way of reaching a larger audience or a means of promotion. Napster and other file sharing networks were targeted in the courts by the recording industry and individual artists and by 2001 Napster was closed down. However, there were other sharing mechanisms that persist to this day. The Recording Industry Association of America's (RIAA) attempts to stop the sale of the Diamond Rio MP3 player were not successful either – with the 'space-shifting' made possible with such players viewed in the same light as 'time-shifting' capability of VCRs deemed as 'fair use' by the US Supreme Court in 1981.

While the major labels tried to create a market for legal music downloads their concerns surrounding the replication of songs and attempts at implementing digital rights management (DRM) mechanisms led to delays. Third parties like Liquid Audio and Pressplay found it difficult to get the labels to agree to license their catalogs for download or subscriptions services. None of the labels' own online distribution services (e.g. MusicNet and Duet) were successful.

The first version of Apple's iTunes software (released early 2001) supported ripping and encoding music from CDs, the playback of encoded songs, and the burning of CD with mixes of songs. It could transfer files to MP3 players, including the Rio. Apple's Steve Jobs deplored the poor design of existing mobile music players and ordered the development of Apple's own device. The iPod was launched by the end of 2001 and quickly dominated the market for mobile music players. The iTunes music store was launched in 2003 for legal downloads. So, there was a period when Apple's business model for the iPod almost certainly relied on unauthorized content and therefore was partially built on the illegal sharing platforms. The labels certainly viewed Apple's "Rip, Mix, Burn" campaign as encouraging the theft of music [23].

Table 1. Key 1990s computing platforms that supported large scale distribution of music on-line

Platform / Layer	Examples	Notes
Applic-ations	Web Browser, peer-to-peer clients, CD rippers, MP3encoders & players	Software built around sets of protocols (http, html, SSL) and capabilities of OSs
Encoding Standards	ASCII/Unicode JPG and GIF MP3, WAV, & HTML	Various open and propriety standards for audio, video, and other rich content
Operating Systems	Windows, Mac, DOS, Linux, Unix	Internet protocols in Microsoft OSs from Windows 95 making it widely accessible to home users
Perip-herals	Sound cards, NICs, CD burners, hard disks	Improved performance with each generation
CPU	x86, 68000	Intel x86 architecture for PCs
Internet Protocols	TCP, UDP, IP, BGP DHCP, DNS (and many more)	Provided standardized connectivity across operating system and network types
Comms Links	Ethernet, dial-up, DSL, or cable modems. ATM in backbone	Implemented in physical network components or network interface cards
Physical layer	Copper pairs, coax, radio links, and optical fiber	Many standards for physical cables/connectors and signal formats

Steve Jobs convinced the major labels to license the bulk of their catalogs to the iTunes store partly by implementing strict DRM mechanisms and ensuring that music could only go from the computer to the device and not the other way around. The iTunes music store quickly came to dominate the legal on-line distribution of music, at least in the USA.

However, the digital revenues have not offset the much greater fall in CD sales (Figure 1). In recent years the amount of unauthorized file sharing has reduced and there are over 500 legitimate download/streaming businesses for music distribution around the world. Labels in the US make more than half their revenue from digital sources [24]. Subscription services like Rhapsody and Spotify provide listeners with low or no cost access to vast libraries of music. The links of such streaming services with social networking platforms like Facebook increases the social dimension of listening to music even while alone. Other associated changes include the threatened demise of the album as more buyers chose to 'cherry pick' individual songs. Live performances and merchandising have become more important revenue streams in the music industry. The labels have been able to tap this by new stipulations in their contracts with artists – so called "360 deals."

Apple's expansion of its portable device platform from music only iPods to iPhones, multimedia iPods, Apple TV set-top boxes, and iPads has widened the types of media supported. For Apple content is as much as a means of selling more devices as it is getting into content. The devices, the underlying operating system (iOS) and iTunes form a flexible yet highly controlled platform that integrates access to content from across industries (music, books, TV, movies, maps, social media).

3.3 Analysis of the music industry case

The longitudinal case study revealed a series of music industry platforms that possess varying types and degrees of generativity and that some were important control points. Industry structure, generativity, and the presence of control points were shaped by the tangibility (or intangibility), costs, and flexibility of platforms. The relationships between Zittrain's features of generativity, control points, and the effects on industry structure as new platforms came to the fore are explored next.

Standardized **notation**[3] provided *leverage* for capturing musical ideas and compositions and their *transfer* across time and space. It has proven *adaptable* to many types of music and supported the creation of more complex compositions. *Accessibility* and *transferability* of written compositions improved markedly with the use of printing. While it is not *easy to master* its wide adoption made it more valuable to learn. Notation itself is an intangible platform underpinning the inscription of music onto a physical medium (paper). No *control point* was established around notation but it had a large effect on the creation, performance, and listening experiences.

Printing provided considerable *leverage* for the *transfer* and commercialization of printed scores and song sheets on a mass market scale. Thus extending the ways composers and songwriters could make money. Its use in music was an *adaption* of its primary role for printing text – and thus an early example of cross industry influences. Printing's *ease of use* is a step up compared to manual reproduction. It represented a *point of control* for the dissemination of content and ideas with *access* denied to some by the printer/publishers for economic reasons or the authorities exerting control on them for political reasons. Printing of music relied on, and shaped, the standardization of musical notation.

Publishers emerged as intermediaries who would *transfer* (purchase) **copyrights** from original authors. Copyrights provide a strong platform for controlling the use of creative works and they have been *adapted* to cover an increasing range of creative works and their uses – although doing so took extensive wrangling among various interested parties with governing authorities. However, lobbying by copyright holders has resulted in the on-going expansion of what can be protected as well as the duration of the protection. While in principle registering and protecting copyrights is not *difficult to master* or *access* the need for a means of manufacturing and distributing physical printed material helped publishers attain an important control point on this part of the industry. Thus a more differentiated industry structure emerged that *leveraged* legal rights to creative works.

The layers of platforms for music publishing were accumulating and interconnected with other industries' platforms, i.e. printing/publishing. Music publishing was also shaped by industrialization more broadly including the mass production of instruments and distribution channels for instruments and printed music as well as supporting activities around systematic music education.

A series of innovative technological artifacts were endowed with the *leverage* of **sound recording and playback**. Once the limitations of early versions were overcome they could be *adapted* to a wider range of musical styles and their main purpose was the *transfer* (sale) of recorded music – a major new revenue stream for the industry. Their *ease of mastery* for recording depended on the specifics of the technology. **Cylinders** could be used for home recording but the technologies for creating and duplicating **Bakelite and vinyl disks** were limited to professionals for the most part *(not accessible)* – thus providing a control point similar to the printing

[3] Platforms in **bold** and generative properties in *italics*.

presses for printed music. The economics of recording, manufacturing, distribution, and marketing of recordings meant only commercially promising acts would get a recording contract. The record labels had most of the control in its relationships with artists (unless the artist became a big selling star) and listeners did not have other ways of obtaining recordings (*controlled transferability*). The broadcasting and recording industries shared connections, e.g. radio broadcast of recorded songs was entertainment and promotion for the recordings.

Magnetic tape and later writable **CDs** provided *accessible* recording capabilities that threatened the technological duplication control points which prompted lobbying for greater legal protection.

Thus by the mid-20th century there was a stable industry structure built upon capital investments in manufacturing, interlocking relationships among specialized roles (some enshrined in contracts), along with enforceable copyrights for compositions (and later recordings). The structure proved increasingly profitable toward the end of the century particularly after the CD format launch with its improved durability and recording quality. Although the recordings on CDs were stored digitally this did not in itself lead to industry disruption.

Digital computers and **digital communications** followed their own trajectories in the latter half of the 20th century. That industry had experienced its own accumulation of physical and intangible platforms that very explicitly built upon one another (Table 1). Some, like operating systems, were control points allowing their owners to extract a disproportionate share of the industry's profit. The inherent flexibility of digital technologies is associated with high levels of generativity across all of Zittrain's features. While in principle this always meant that digital systems could be used to encode/decode, store, and transmit digital music it was not practical until the mid-1990s before which consumer computing platforms had no substantive connection to the recording industry.

However, once the storage and processing capabilities of **personal computers** reached a certain level the play back of music became realistic. The *adaption* of the **optical CD format** for general data storage provided physical compatibility that allowed music CDs to be *accessed* on PCs. This along with along with the availability of an effective music compression algorithm (**MP3**) and software implementing it made storing music on PCs *easy to master*. The arrival of **writable data CDs** then made sharing a hundred songs on a CD just as *easy to master,* much quicker, and less tedious, than home taping. Listener to listener *transferring* of music recordings, uncontrolled by the labels, was enabled. The relatively low cost and the *ease of mastery* of PCs and the other technology needed made it widely *accessible*. The weakening of the replication and manufacturing control point (*transferability*) was a major threat to the revenue from recorded music.

At about the same time **World Wide Web** and **email** drove the adoption of **Internet** based networking far beyond the confines of academia and industry. MP3 files were just another sort of computer file and could be replicated across the network to other computers. The *transfer* of music was no longer constrained by inscriptions in physical materials and did not remove the original.

Napster and other **peer-to-peer networks** *leveraged* the interconnectedness of digital networks to make it trivially *easy* to find and download the file (song) desired. With no gatekeepers *access* was also easy and it could be *adapted* to other types of media. The flood of MP3 files spurred the creation of mobile devices and computers configured to play them. The music industry's copyright platform initially did little to dissuade sharing on a massive scale once the limitation of physical replication was removed. A number of legal efforts from the music business has subsequently managed to reduce some music sharing through litigation [20].

Apple's **iPod and iTunes** store was the first effective legal digital music download platform in which the flow of money no longer corresponded tightly to the flow of music inscribed in physical materials. The platform's reduction of *transferability* between users was offset by legality and overall *easy to master/use* experience. Digital merchandising of music all but eliminated the manufacturing (just preparing files and support material) and distribution functions of the industry. Many bricks and mortar retailers of recordings went out of business. Finally, the *adaptability* of **streaming service**s (e.g. Spotify) and **social networks** (e.g. Facebook) introduced a social dimension to lone music listening.

4. Discussion

Platforms build upon one another in both the music and computing industries. When a digital platform's capabilities reach certain inflection points its generative features enable it to make interconnections to the music or other media industry's periphery. While finding stable configurations of new connections takes time it was still very quick on the historical scale of analog platforms tied to physical artifacts. The precise interconnections are path dependent on both happenstance and strategic action.

TV shows, movies, books, and newspapers can all be stored as files and digital content platforms have been *adapted* to support them all. Open or controlled platforms have established disruptive connections with the related but previously separate industries. The inclusion of software applications and platform updates as further modules of content is distinct as they permit evolution of platform capabilities, for purposes of control or enhancement, at rates unimaginable in their analog predecessors. The recasting of industries continues with, for example, the mobile phone industry's relatively simple traditional service offerings with its own control points subsumed in wider digital mobile platforms.

Amazon and Google are active in digital content distribution and in many countries they, along with Apple, own the dominant Internet commerce platforms. This parallels the earlier horizontalization in the computer industry as these multiline Internet firms emerge as potentially universal and dominant platforms for the sale and distribution of content, services, and even physical goods (i.e. both bits and atoms). The generative sparks to cross industry boundaries may need to be stronger than before as incumbents can leverage their institutionalized platforms to move more quickly than an attacker.

Developing platform theories will not only help us better understand industry dynamics. It is also becoming increasingly important as organizations seek to 'platformize' internal IT capabilities that in turn rely on vendor developed platforms, or integrate external platforms, e.g. cloud computing, with internal ones.

Theoretical perspectives are always tradeoffs of generality, accuracy, and simplicity [25]. Many of the perspectives from the product development literature and technology strategy literatures have emphasized generality and simplicity (e.g. Gawer's internal/ supply-chain/industry platform typology). Choosing these trade-offs is very understandable from a pragmatic point of view and the resulting books and papers are the more readable for it. While we have by no means come to an elegant theoretical perspective in this paper we have identified some of the characteristics, complexities, and relationships that theory builders willing to relax the trade-off around simplicity would have to take into account. For example:

Socio-Technical Layering: Platforms do not generally stand apart. Rather social and technical platforms built upon one another with the core of one platform being the periphery of another. The number of active platforms tends to increase with time with some well-established ones becoming infrastructural foundations for new ones.

Intangible: Platforms can be intangible, e.g., digital software based platforms are subject to the economics of digital products including near zero replication costs and potential for rapid large-scale adoption. Intangible platforms can facilitate the communication, storage, or processing of information/content. The number of digital platforms will increase more rapidly than the physical ones. Intangible platforms may or may not be the basis for creating tangible ones but digital platforms will tend to interconnect and enhance physical ones.

New Patterns: New platforms can have radical effects on social structures as they create new standardized patterns of action and new roles or habits for industry participants and users. New platforms can promote the creation of further platforms and interfaces that support further innovation and change. They may break down boundaries between established industries, create whole new industries, or threaten the continued viability of old ones. They can weaken or destroy established control points and foster the establishment of new ones – hence the introduction of new platforms is often contested.

Generativity: Some platforms are inherently more generative than others. Intangible and digital platforms generally tend to possess more generative potential than tangible and analog ones. The pattern of generativity possessed by a platform has a major role in shaping the impacts it will have. Higher levels of generativity tend to increase the number and size of impacts as well as the number of interconnections among platforms.

Performancs & Cost: Performance or cost of a technological platform (or set of platforms) can shape its (or their) potential for impact on an industry. Several platforms must be in place and the performance and cost must cross certain thresholds to realize its potential impact.

Dynamics: Intangible and digital platforms are dynamic and can be changed strategically in response to others' actions. Changes can introduce new affordances that increase generativity or impose new controls that restrict it. Software based intangible platforms can include the capability to change themselves.

Control Points: Control points can be made up of: Tangible platforms with large capital costs; proprietary (technical) platforms; well-established industry practices; superior knowledge about how to leverage platforms; industry practices mandated or protected by law. Control points can be created, captured, or regulated by those with political power. Challenges to control points that can change industry structures/boundaries or create new industries

through: Quantitatively superior technology (e. g. costs); completely new technological affordances; superior ways of arranging industry practices; or by changes in legal arrangements.

It is critical for further platform studies to extend the understanding to include not only the technical elements making up the core technical platform artifacts. Rather, research must fully consider the inherent socio-technical complexity meshing social processes, socio-technical arrangements and the technical artifacts. Characterizing and understanding the tensions between change and control in platforms may well provide the best hope of coming to a unified view of platforms that embraces complexity rather than abstracting it away [5].

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