



Available online at www.sciencedirect.com



Technological Forecasting & Social Change 74 (2007) 1411–1431

**Technological
Forecasting and
Social Change**

Analysing the breakthrough of rock ‘n’ roll (1930–1970) Multi-regime interaction and reconfiguration in the multi-level perspective

Frank W. Geels *

Eindhoven University of Technology, IPO 2.10, PO Box 217, 5600 MB Eindhoven, The Netherlands

Received 17 March 2006; received in revised form 18 July 2006; accepted 26 July 2006

Abstract

The breakthrough of rock ‘n’ roll was part of broader transformations in the American music industry, involving changes in music instruments, music recording technology, audiences, radio programming and music styles. These transformations will be analysed as sociotechnical transition, using the multi-level perspective. One characteristic of the case is interactions between multiple regimes: radio and recording. Another characteristic is the presence of strong cultural components, with rock ‘n’ roll as proxy. These characteristics lead to theoretical adjustments in the multi-level perspective. Further analysis also suggests a particular transition path of reconfiguration, in which multiple niche-innovations cumulatively transform the regime.

© 2006 Elsevier Inc. All rights reserved.

Keywords: Music industry; Rock ‘n’ roll; Transition; Multi-level perspective; Reconfiguration

1. Introduction

This article addresses transitions at the system level in Freeman and Perez’s [1] innovation typology: (a) incremental innovation, (b) radical innovation and product discontinuities, (c) changes in technology system, (d) changes in techno-economic paradigm. Radical innovations and technological discontinuities have been addressed in business studies [2,3] and changes in techno-economic paradigms have been studied in long-wave theories [1,4]. But changes at the system level are under-addressed. These changes

* Tel.: +31 40 247 5414.

E-mail address: f.w.geels@tm.tue.nl.

are complex and sociotechnical [5], involving technological discontinuities and social, political, cultural, infrastructural and economic changes. The analytical challenge is to understand the dynamic interactions between these processes.

Sociotechnical transitions are not only academically interesting, they also have societal relevance, for instance with regard to future transitions to sustainability. Policy makers, planners and scholars show increasing interest in this issue [6–9]. Also TFSC dedicated a special issue to this important topic (July 2005, Vol. 72, No. 6). The promise is that shifts to new systems in transport, energy and agriculture may deliver large jumps in environmental efficiency. The governance of transitions, however, should be based on a good understanding of the underlying dynamics. As the editors of the special issue [10, p. 655] note in the introduction: “transitions are extremely complex processes”. Given the state of knowledge, this article practices ‘appreciative theorising’ [11]. This kind of theory allows for richer understandings than formal models; it appreciates the complexity of the phenomenon at hand and tries to find stylised patterns. So this article does not address the sustainability issue, but aims to better understand the dynamics of transitions. This understanding hopefully assists scholars who analyse future sustainability transitions.

The multi-level perspective on transitions is such an appreciative theory. This perspective argues that existing systems are stabilised by sociotechnical regimes, i.e. shared rules and practices that guide activities in particular directions [9,12–15]. Hence, radical innovations usually emerge outside the regime, in particular market or technological niches. Such radical innovations may diffuse more widely, when several processes link up: (a) external environmental changes, which create pressure on the regime, (b) weakening of the regime, e.g. increasing problems, loss of faith by main actors, (c) stabilisation of the niche-innovation in a dominant design, increasing support from powerful actors, and improving price/performance characteristics. If the radical innovation replaces the existing technology, this is accompanied by broader social, cultural, political and infrastructural changes.

This article aims to further develop the multi-level perspective with a historical case study of a transition that deviates from previous cases. The particular case study is the long-term transformation of the American music industry and the breakthrough of rock ‘n’ roll between 1930 and 1970. One reason to choose this case study is to explore a new aspect: multi-regime interaction. Previous empirical studies looked mainly at transitions which involved transformations in single regimes, e.g. natural gas replacing a coal-based regime [16], steamships replacing the sailing ship regime [17], mechanical elevators replacing manual unloading of ships [18], piped water systems replacing the water supply regime of pumps and wells [15]. An interesting aspect of the new case study is the presence of *two* regimes for the distribution and consumption of music: radio and records. Both regimes involve a range of technical and social elements, e.g. radio sets, phonographs players, jukeboxes, record companies, radio stations, advertising schemes, recording technologies and studios, radio programming, airwave regulations (Fig. 1). The case study makes it possible to explore multi-regime interactions in transitions, enabling new theoretical contributions to the literature.

As indicated in Fig. 1, the case study not only involves distribution and use, but also supply-side aspects, such as the performance of music by bands and singers, the creation of songs by songwriters and music publishers, and the manufacturing of music instruments. This means that the case study entails supply *and* demand side changes.

A second reason to choose the case study is that music is closer to societal end-use functions, with obvious cultural changes. The multi-level perspective has previously been applied to societal functions with strong technical components, e.g. shipping, energy supply, water supply, cargo handling. Transitions in the music industry clearly also involve cultural and demand side aspects. The breakthrough of rock ‘n’ roll is taken as a proxy for these demand side changes. The challenge is to explore the usefulness of the

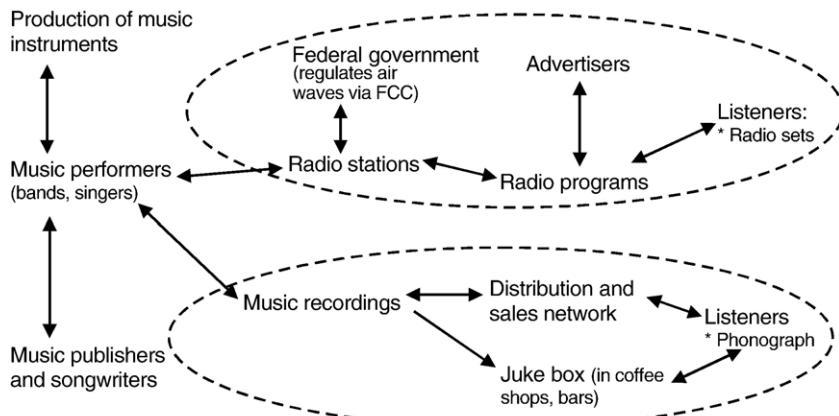


Fig. 1. Two regimes in the production, distribution and consumption of music.

multi-level perspective in such a case, and see if modifications are needed. One common explanation of the emergence of rock 'n' roll highlights creative individuals (e.g. Elvis Presley, Chuck Berry). Another explanation emphasises macro-influences such as the emergence of an affluent teenage market, youth culture and generation conflict. The hypothesis is that the transition can also be analysed as sociotechnical change process. In particular, the idea is that creative artists took advantage of the opportunities that became available to them.

The empirical question in this article is: how did the transition to rock 'n' roll come about? The theoretical questions are: What was the role of multi-regime interaction? Can the multi-level perspective be usefully applied in this case, or are adjustments required?

The structure of the article is as follows. Section 2 briefly describes the multi-level perspective. Section 3 presents the case study about the reconfiguration of the American music industry and the breakthrough of rock 'n' roll (1930–1970). Section 4 draws conclusions, distills patterns and refines the multi-level perspective.

2. Conceptual multi-level perspective on transitions

This section briefly outlines the multi-level perspective on transitions, which has been described more elaborately elsewhere [9,12–15]. The perspective distinguishes three conceptual levels: sociotechnical regime, technological niche, and sociotechnical landscape.

The *sociotechnical regime* forms the meso-level in the multi-level perspective (MLP). This is an extended version of Nelson and Winter's [11] technological regime, which refers to shared cognitive routines (e.g. search heuristics) in an engineering community. These routines guide their R&D activities in similar directions, leading to technological trajectories. Rip and Kemp ([12], p. 340) widened the regime concept with the sociological category of 'rules': "A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures". Geels [5] further distinguished formal, normative and cognitive rules. Examples of formal rules are regulations, standards, laws. Examples of

cognitive rules are belief systems, problem agenda's, guiding principles, search heuristics. Examples of normative rules are role relationships, behavioural norms. These rules do not exist individually, but are linked together in semi-coherent sets of rules, called regimes. Also with regard to social networks, sociotechnical regimes are wider than Nelson and Winter's technological regimes, which refer mainly to engineers. Sociologists of technology showed that scientists, policy makers, users, and special-interest groups also contribute to patterning of technological development [19]. These social groups interact and form networks with mutual dependencies, resulting in the alignment of activities. This inter-group coordination is represented with the concept of sociotechnical regimes. So, sociotechnical regimes incorporate the production, distribution, use and regulation of technology [5].

Transitions are defined as changes from one sociotechnical regime to another. Transitions do not come about easily, because sociotechnical regimes are stabilised in many ways. Established roles, routines, ways of thinking and ways of doing contribute to stabilisation [5,13] as well as legally binding contracts [20]. Favourable institutional arrangements and formal regulations may have been created, and accompanying infrastructures are set up. Other stabilising elements are social relationships, mutual role expectations and the organizational commitments and vested interests of existing organizations [21]. So, for many reasons, existing sociotechnical regimes are characterised by stability and path dependence.

Niches form the micro-level in the MLP, the locus where novelties emerge. These can be small market niches or technological niches, where resources are provided by public subsidies [13,22,23]. Niches act as 'incubation rooms', shielding new technologies from mainstream market selection. Such protection is needed because new technologies initially have low price/performance ratio. Protection comes from small networks of actors who are willing to invest in the development of new technologies.

The *sociotechnical landscape* forms the macro-level, the exogenous environment that is beyond the direct influence of regime and niche actors [12]. The content of the sociotechnical landscape is heterogeneous and includes aspects such as economic growth, broad political coalitions, cultural and normative values.

The key point of the multi-level perspective (MLP) is that system innovations come about through the interplay between processes at different levels. A radical innovation initially emerges in niches, often outside or on the fringe of the existing regime. The network that carries and supports the innovations is small and precarious. There is much uncertainty, and actors search to work out the best design and find out what users want. The innovations do not form a threat to the existing regime, which is stable and reigns supreme. Subsequently, the new innovation is used in small market niches, which provide resources for technical development and specialisation. The new technology begins to stabilise in a dominant design and develops a technical trajectory of its own. The innovation still forms no major threat to the regime, because it is used in specialised market niches. Innovations may remain stuck in these niches for a long time, when they face a mismatch with the existing regime and landscape. The next phase is characterised by wider breakthrough of the innovation and competition with established regime. On the one hand, this breakthrough depends on niche-internal drivers, e.g. price/performance improvements or support from powerful social groups. On the other hand, external landscape developments may create pressure on the regime, leading to tensions. Such tensions may come from technical problems, changing markets, strategic games between firms, policy changes or new cultural values. Transition involves the combination of internal niche-dynamics and wider regime and landscape developments. The replacement of the old regime is accompanied by broader changes on many dimensions (Fig. 2).

In the multi-level perspective there is no simple 'cause' or driver in transitions. For a transition to occur, dynamics at different levels should come together and reinforce each other. System changes are emergent

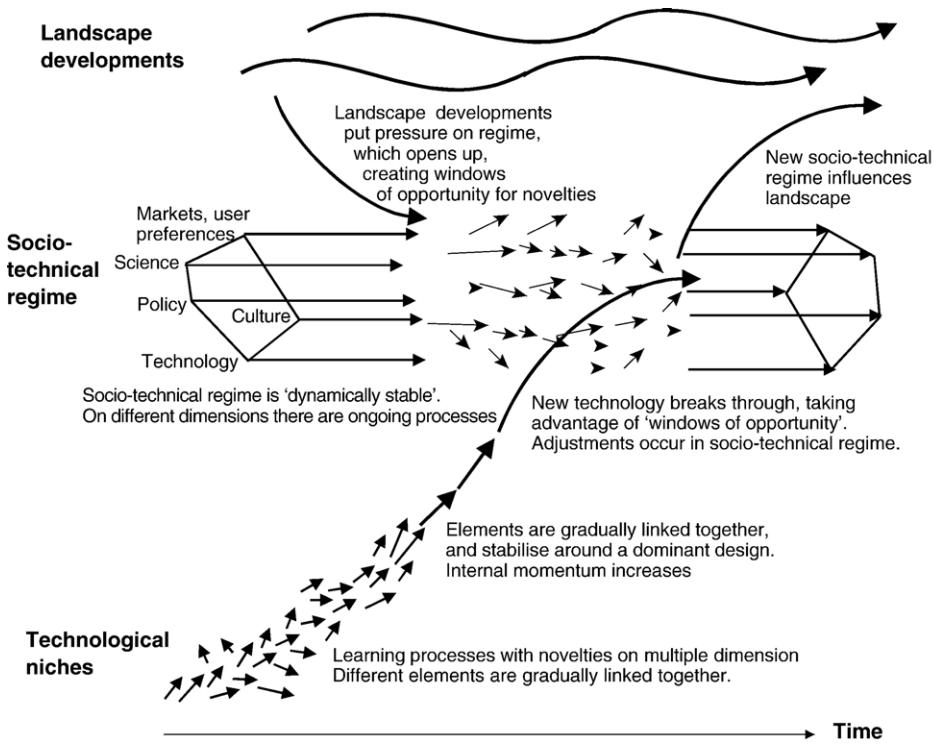


Fig. 2. A dynamic multi-level perspective on system innovations ([17], p. 1263).

outcomes of interactions between social groups with myopic views and differing interests. It should be noted, however, that the representation in Fig. 2, has a bias towards technological substitution, focusing on the emergence of a major innovation that subsequently breaks through and substitutes the existing regime. This pattern has been corroborated with case studies in shipping, energy supply, water supply, and cargo handling. But it remains to be seen if it also holds for the transition in music.

3. The reconfiguration of the American music industry and the breakthrough of rock 'n' roll

The aim is not to find new empirical material, but to test the multi-level perspective for a case study that deviates on certain aspects from previous cases. Hence, data-collection is based on secondary sources from different fields: cultural studies, musicology, business history, history of technology. The case study is stylised and does not aim to include everything. The focus is on the stability of existing radio and record regimes, the interaction between both regimes over time, the influence of external landscape developments, the emergence of novelties and the way they contribute to regime shifts. These novelties not only include technical innovations, but also musical innovations. Rock 'n' roll, for instance, emerged from combinations between country and western and rhythm and blues. Hence, one adjustment of the MLP is to distinguish *music niches* besides technical niches. Music niches refer to protected spaces that shelter and nurture alternative music styles from the dominant mainstream musical genre. The case study is organised in four chronological periods: the 1930s, 1940s, 1950s and 1960s.

3.1. The empires of sound (1930s)

3.1.1. The radio broadcasting regime

Radio broadcasting, with its roots in amateur pioneering, triggered widespread enthusiasm in the 1920s, leading to a radio mania [24]. People were stunned by the ability to hear invisible sound, and radio diffused rapidly in the 1920s (Fig. 3). Radio sets appeared in living rooms all over the country, challenging the phonograph as dominant home entertainment device.¹ In 1933 the average price for a radio receiver was \$35, and one was in 60% of American households. By then, the American family listened about 5 h of radio a day [25, p. 170]. Especially in the evenings families would gather around the radio set, and listen to music or plays.

The simultaneous expansion of broadcasting stations created chaos due to interference of radio waves [27]. The Radio Act of 1927 signalled federal involvement, granting the Federal Radio Commission (FRC) the power to issue licences for the use of airwaves. To limit the number of radio stations, the FRC was strict in the allocation of radio licences, placing heavy emphasis on technical criteria [28]. The shared belief in the emerging radio community was that listeners preferred live music to playing phonograph records, negatively referred to as ‘canned music’ [27]. Most radio stations employed their own orchestras, an expensive option, which created difficulties for small radio stations. Advertising soon established itself as the dominant convention to earn money.

During the Great Depression of the early 1930s, radios continued to diffuse. The rise of national radio networks consolidated the industry and facilitated economies of scale (Fig. 4). In network radio, the ‘mother station’ sent live music and advertising messages to radio stations by telephone lines. The increased reach of audiences led to higher advertising incomes. Network radio also cut costs by removing the need for many radio stations to maintain expensive orchestras. The National Broadcasting Company (NBC) was formed in 1926, the Columbia Broadcasting System (CBS) in 1929 and Mutual Broadcasting Systems (MBS) in 1934. By 1945, almost 95% of all commercial radio stations were affiliated with a national network [27]. Only the smallest stations remained independent.

Advertisers, the main source of income for radio stations, had much influence on the content of radio programming [24]. The common advertising practice was that one firm sponsored an entire radio program. The advertising agencies preferred middle-of-the-road, mainstream popular music that appealed to large audiences. Hence, national radio networks were committed to the status quo and played music that appealed to most listeners: commercial, upbeat, inoffensive and directed to the white middle class mass audience [29]. Radio personnel had little influence on the selection of music and the manner of its presentation. Radio presenters were simply announcers of songs and readers of commercial messages, with no room for individual creativity [30]. On the fringes of the radio regime, some small, independent radio stations survived, operating with different rules and practices. They did not have the same commitment to expensive live music and played more records [31].

3.1.2. The phonograph and recorded music regime

The challenge from radios led to declining record sales in the early 1920s. Between 1925 and 1929 sales picked up again. But the Great Depression was an external landscape development, which almost decimated record sales (Fig. 5). The niche market of the jukebox helped to keep the record industry alive during the Great Depression, accounting for almost 60% of sales in 1938 [31].

¹ In 1929, about 50% of all US households owned a phonograph [25].

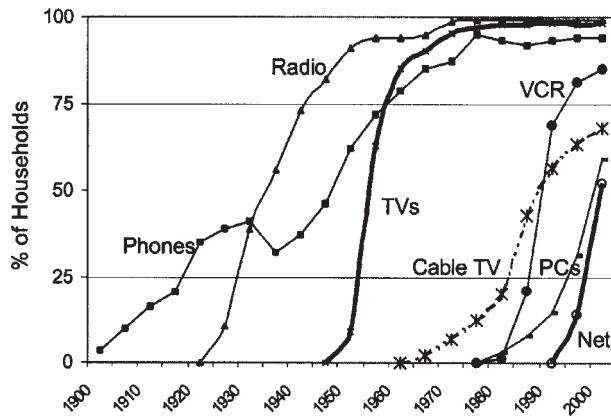


Fig. 3. Information, communication and entertainment technologies in US [26].

The sales decline exacerbated the record companies' economic problems related to the change from acoustic recording to electronic recording (based on vacuum tubes) in the late 1920s. The shift towards electronic recording created problems for small recording companies, because the new technology was expensive and more difficult to operate [33]. Because of the combined problems, most record companies went bankrupt. The shakeout and takeovers led to a consolidation in the record industry. One entertainment empire formed around Warner Bros, the film producer that moved into the music recording business. A second empire formed around RCA/Victor, the result of a merger between Radio Corporation of America (RCA) and Victor Phonograph Company. A third empire formed around Columbia, which had both broadcasting and recording branches. Two of the Big Three recording companies were thus closely associated with radio organizations, resulting in integrated 'Empires of Sound': huge business

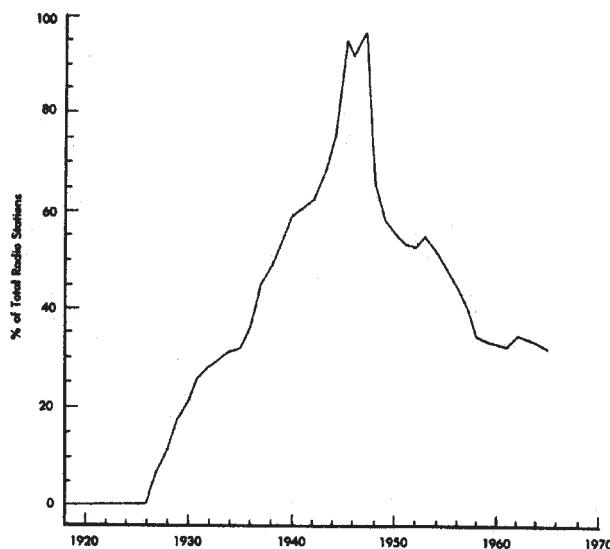


Fig. 4. Growth and decline of affiliated network stations as a percentage of total radio stations ([27], p. 352).

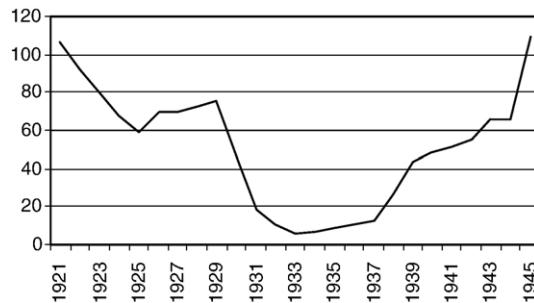


Fig. 5. Value of record sales in US in million \$ (data from [32]).

organizations based on the reproduction and transmission of sound. A fourth record company was Decca, a new firm created in 1934 from combining bankrupt recording companies [25].

Decca pioneered a new marketing strategy, based on the ‘star-system’ and mass production. It was more profitable to sell millions of records from a few popular stars than to sell thousands of records from a wide variety of performers. This strategy was imitated by other firms, leading to the narrowing down of record portfolios. The major record companies increasingly focused on the unmarked, white, mainstream popular music [34]. In the 1920s, recording companies marketed a broad range of music, e.g. classical music, German, Irish and Polish music, as well as ‘race records’ that targeted African Americans and ‘hillbilly music’ that targeted rural whites [34]. But in the 1930s, recorded music styles changed from culturally diverse to mainstream [29].

In sum, both the radio and record regime consolidated into stable oligopolies, with commercial cross-linkages within broader entertainment empires. These regime actors increasingly focused on the white, mainstream mass audience, leading to commercial and inoffensive popular music. Swing was an important product of the ‘Empires of Sound’, accounting for about 85% of record sales in 1939 [25]. Swing was a sanitized and polished form of the Jazz of the late 1920s. Several large dance bands brought swing to national prominence (e.g. Duke Ellington, Count Basie, Benny Goodman). Despite being linked in music empires, the radio and record regime operated as separated divisions that had antagonistic relationships. The national radio networks did not play ‘canned music’ on air, and record companies printed ‘Not Licensed for Radio Broadcast’ on the labels of their records. Record companies also prevented their artists, whom they had under contractual relationship, to perform on radio broadcasts [25]. So both regimes were stable but antagonistically separated.

3.1.3. Niche developments: music and technology

While radio and record regimes focused on the mainstream, alternative kinds of music survived in small market niches. White hillbilly musicians, for instance, played on shows, country fairs, jamboree tours, and live on air with specialised local radio stations [31]. Black musicians had a harder time, suffering from racial discrimination in public life. This cultural dimension was part of the broader landscape. The different musical genres, audiences and performance sites were strictly segregated. Black musicians could hardly play on air, because many radio stations had anti-black policies. Nevertheless, a small number of jazz musicians and blues singers made a living in bars and clubs. Jukebox records also provided some work for black musicians [25].

In the R&D laboratories of big record firms, technical innovations were developed, e.g. stereo sound to improve sound quality and micro-grooves to extend the playing time of records, which was about 7–

8 min in the 1920s. Combined with a new material (vinyl), micro-grooves extended playing time to 30 min [25]. But film producers and businessmen wanted even longer periods of recorded sound. Hence, new methods of sound recording were explored. Manufacturers of dictating machines explored the possibility of storing electric currents, produced by a microphone, as magnetic fields on a metal wire [35]. In the late 1930s several dictating machines with magnetic recording were produced. But the quality of sound reproduction was poor, and the machines were difficult to use. So early efforts to develop magnetic recording failed.

An instrument innovation was the development of electrically amplified guitars. Electric guitars of the early 1920s failed to commercialise, but the rise of big swing bands created new opportunities. In these bands, the use of guitars as solo-instrument depended on increased volume. Pioneers again turned to electrification, adding a pickup to the acoustic guitar. The pickup moved up and down with soundboard vibrations, and signals were fed to an amplifier, resulting in electric–acoustic guitars [36]. An electric Hawaiian guitar sold in some numbers in 1932 [37]. The incumbent guitar manufacturers Gibson produced an Electric Spanish guitar in 1936. Public reactions to the new sound were mixed. But the adoption of acoustic electric guitars by Charlie Christain, a guitar virtuoso in the Benny Goodman band, gave them legitimacy and publicity [38].

3.2. *Changing the rules of the music game (1940s)*

3.2.1. *The phonograph and recorded music regime*

During the Second World War, popular music played an important role in maintaining morale on the war and home fronts. Between 1941 and 1947, record sales rose from about 100 million discs to 325 million [25]. The big record companies shared the perception of a homogeneous national market for popular records. Their marketing strategy put an accent on ‘sameness’, homogeneity and middle-of-the-road music [30]. Popular music was dominated by swing bands and good-looking white young male crooners² (e.g. Rudy Vallee, Frank Sinatra, Bing Crosby). Actors with a vested interest in the music industry worked hard to keep the established music aesthetic viable. This aesthetic accentuated well-crafted, love songs with strong melodies and harmonies [30]. Professional songwriters, employed by music publishers or record companies, had a craftsman orientation to their work. Rather than writing from personal experience or from inspiration, they wrote nice and pleasing songs along established routines [30]. This dominant practice was supported by big record companies, national radio networks, and music publishers.

The record industry remained a stable oligopoly, although two new firms appeared after the war (Capitol and Mercury). As record sales dropped from 325 million in 1947 to around 250 million in 1948, there was concern about the need for a new music formula [25]. But big record companies were bureaucratically and hierarchically organised with functionally differentiated and vertically integrated departments. This organisational form was appropriate to efficiently produce a large number of standard products, but less suited to explore new styles and markets [30].

After the war, record companies commercially introduced innovations that emerged from the R&D laboratories: vinyl microgroove record, and stereophonic sound. Furthermore, Columbia introduced the long-playing record (LP) in 1948, hoping that its 33 rpm, 12 in. disc would become the new industry standard. RCA countered with the introduction of the 45-rpm disc (single). The resulting ‘battle of the

² Crooner music consists of soft, melodious often sentimental songs.

speeds' confused customers who delayed their purchases. After government mediation, the rivals agreed to pool their patents and produce records in both 33 and 45 rpm formats [30].

3.2.2. The radio regime

National radio networks shared the view that music listeners were one homogeneous market. Radio programming was standardised and of high quality within a narrow aesthetic range, playing swing music and crooners. Radio announcers took great pride in being able to read news, advertisements and announcements flawlessly in an even, accent-free 'radio voice' [30]. There was little room for personal touch, spontaneity or creativity.

Pressure on the radio regime came from the federal government, which became more sensitive about monopolies and antitrust issues. The FCC, the successor of the FRC, ordered the break up of the dominant radio network NBC, leading to the creation of the American Broadcasting Corporation (ABC) in 1943 [24]. Furthermore, the FCC became more flexible in issuing radio licenses to stimulate the emergence of independent radio stations [31].

Further pressure came from the emergence of a new technology: television. Radio networks had experimented with television since the 1930s, culminating in the first official TV broadcast in 1939. Halted by the war, television gathered pace in the late 1940s and early 1950s (Fig. 3). The big networks shifted their attention from radio to television, and so did national advertisers. While national radio advertising began to decrease, local radio advertising expanded because of increasing interest from small and local entrepreneurs (Fig. 6). This was accompanied by a shift from program sponsoring, which was too expensive for regional and local advertisers, to 'spot' advertising, i.e. commercial messages from multiple advertisers inserted in a program.

The combined effect of easier licensing and more local advertising was the expansion of local radio stations (Fig. 7). This changed some of the rules of the music game. One change was that local radio stations, which could not afford expensive orchestras, made more use of phonograph records [27]. This

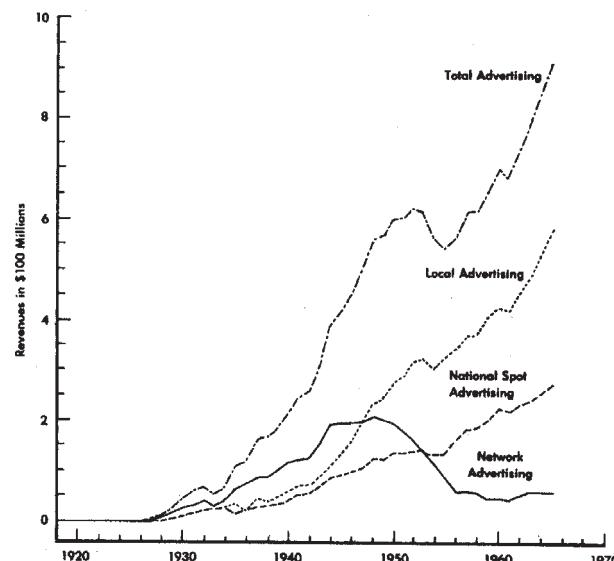


Fig. 6. Growth and diversification in radio advertising ([27], p. 353).

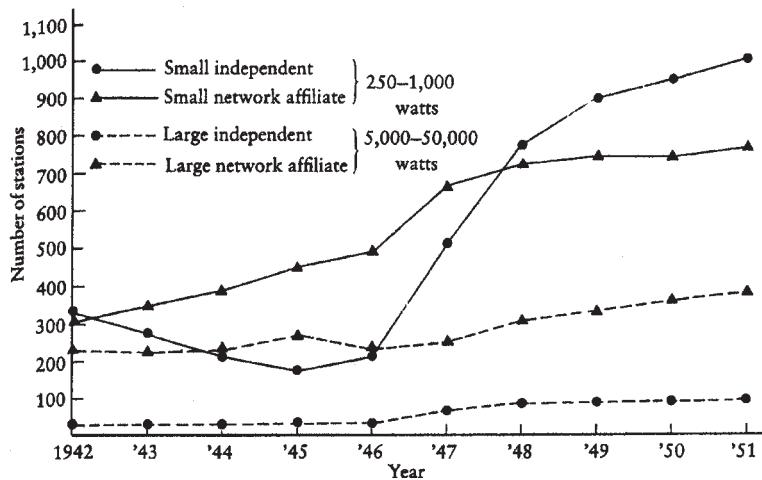


Fig. 7. Growth in AM Radio stations ([31], p. 137).

practice deviated from the established antagonisms between radio and record regimes. Record companies gradually learned that radio airplay of their records increased rather than depressed demand. Hence, the perceived relationship changed from competition to symbiosis [30]. A second change was that local radio stations pioneered the new role of disc jockey (DJ). This radio personality talked about local news and events of interest in an excited yet conversational tone [30]. DJs presented music as if they were one with the audience, sharing the same frame of reference [39]. A third change was that local radio stations played more heterogeneous music styles than the national radio networks, e.g. rhythm and blues, country and western music [29].

3.2.3. Niche developments

During the 1940s, black music and country music remained separated from mainstream popular music, in terms of charts, audiences, performance sites, and sales outlets. Nevertheless, the niches for black and country music grew stronger. Country music grew stronger because the major record companies adopted it in their portfolios, giving it more respectability and momentum. Furthermore, performance sites expanded at the grassroots level, e.g. dedicated country music radio stations and concert halls such as the Grand Ole Opry [31].

Because the major record companies focused on the mainstream, independent record companies appeared to serve audiences with different musical tastes, e.g. Apollo (1943), Modern (1945), Specialty (1945), Chess (1947), Atlantic (1947). These independent labels recorded black musicians, which were frustrated by racists recording policies of the white-oriented labels. Although the jazz, rhythm and blues, Be Bop, and electrified blues records were banned from national network radio, local radio stations were willing to give them airtime. The growing popularity of new music styles was officially recognised in the late 1940s when Billboard created two new charts 'Rhythm and Blues' (R&B) and 'Country and Western' (C&W) [31].

A technological niche development was the revival of magnetic tape recording during World War II. The Naval Research and Development Department sponsored secret war research to develop magnetic recording, as part of breaking German and Japanese codes [25]. In this context, the Minnesota Mining and

Manufacturing Corporation (3M) developed thin tapes coated with ferro-magnetic powder as a recording surface. Developments accelerated through reverse engineering of a captured German Magnetophon. This helped several small firms (Magnetecord company, Ampex) to develop practical magnetic tape recorders. In 1948, Ampex commercially marketed the first professional magnetic tape recorder [35]. Magnetic tape recording made sound recording easier and cheaper. Traditionally music was directly recorded onto discs in one take. This was difficult because when a musician played a wrong note or someone coughed, it would be on record. Magnetic tape recording helped to overcome this problem, because with tape sound engineers could cut away 'clinkers' and replace them with a good piece of sound [40]. The final tape version was then pressed onto records. Because magnetic tape recording was cheaper and easier, it lowered entry barriers and stimulated the emergence of independent record firms [35].

New steps were also made in the development of electric guitars. Efforts to increase the volume of acoustic-electric guitars were hindered by the problem of feedback and distortion, caused by amplified notes that resonated inside the hollow body and were recycled through guitar strings and pickup [37]. Hence, in the early 1940s pioneers explored the option of *closed-body* electric guitars (Les Paul, Leo Fender, Paul Bigsby). This not only changed the body, but also the basic principle of sound production. While electro-acoustic guitars picked up and amplified sound waves, closed-body guitars were based on electromagnetic waves, created by vibrating strings in a magnetic field [36]. Because incumbent guitar manufacturers showed no interest in the new instruments, Bigsby and Fender set up their own firms in 1947 [41]. Electric blues players such as T-Bone Walker and Muddy Waters enhanced the popularity of closed-body electric guitars in the late 1940s. Subsequently, incumbent guitar producers joined the bandwagon (e.g. Les Paul and Gibson teamed up in 1952).

3.3. The breakthrough of rock 'n' roll (1950s)

3.3.1. The radio regime

The 1950s saw further changes in the radio regime. On the demand side, changes occurred in listening practices and the function of the radio within the household. One change was that television rapidly substituted radio as the main family entertainment device (Fig. 3). As a result, radio moved from the central place in the household to the kitchen, children's bedrooms and the garage. Hence radio listening became more private and individualised. Youngsters could listen to radio alone or with friends, free from parental control. This way, teenagers could, for the first time, assert their own musical interests [42]. They listened much to local radio stations, which played black music such as R&B. So, while dance halls and live performances were still racially segregated, radio waves allowed white teenagers to cross racial boundaries and taste new music styles. This change in listening practices was reinforced by the technological development of transistor radios, which were smaller, lighter and portable. After 1954, when the first transistor radio was introduced, it rapidly became an item of mass consumption [43]. Youngsters carried them around as a portable source of music, free from parental control. This linked up with broader cultural landscape developments. The 1950s and 1960s were decades of economic prosperity and an expansion of free time. Fun and entertainment became important cultural values. Teenagers had more money to spend and experienced more freedom in their life outside schools (e.g. cars, dances, parties). Music was an important part of their life.

On the supply side, the shift from national radio networks to local, independent radio continued. One reason was that major networks (CBS, NBC, ABC) shifted their attention to television [30]. Another reason was the growth of local advertising. While in 1947 local stations broadcasted three times as much

music as did the national networks, by 1951 they were producing five times as much [31]. Because local stations played mostly records, radio and records became practically synonymous. Also the function of DJs came into prominence. DJs established close contacts with their audiences, inviting teenagers to the studio and playing records at high school parties. This close ‘user-producer’ interaction enabled audiences to give direct feedback to DJs about new songs. This enabled a DJ to identify potential hits, which he could then make big by playing and replaying them on air. DJs thus helped change the rules of the music hit game [44].

Local radio stations, which existed in great variety, exploited the fragmenting markets of ethnic and youth audiences. The idea of one, homogeneous national market gave way to the idea of many local markets where several radio stations competed [30]. Local radio stations were more sensitive to their audience’s changing needs and played an increasing variety of music styles, alternating white popular music with R&B and C&W [29].

3.3.2. The phonograph and recorded music regime

While changes occurred in the radio regime, the recording industry in the early 1950s was still a stable oligopoly with the majors (Columbia, Decca, RCA/Victor, Capitol, Mercury) controlling 70–75% of the titles on the *Billboard* hit charts [45]. The allocation of new singles for 1952 was about 62% pop, 26% country and western and 12% rhythm and blues [31].³ The genres were separated and had different hit charts, audiences and production companies. Big labels dominated white pop and had ties with country and western. But they were unfamiliar with R&B, which was produced by independent record companies.

The number of independent record companies increased in the early 1950s, stimulated by demand and by magnetic tape recording that lowered the entry barriers to the recording industry [33]. Their records were bought by new audiences and played by independent radio stations that targeted segmented markets. The major record companies, committed to swing and crooner aesthetic, were slow to react to these changes, which they saw as marginal.

The 33-rpm LP-album formed the record industry’s cash cow. These expensive records were the medium for classical music and mainstream popular music (swing, crooners). The 45-rpm single became the medium for radio airplay and jukeboxes [30]. Singles formed the carrier of the hit game and were bought by youngsters. The use of transistors in phonographs enabled downsizing and cost-reduction, bringing them within reach of teenage customers [25]. The downsized phonograph, transistor radio, and 45 rpm single enabled teenagers to listen to music of their own choice and formed the technological base that facilitated the rise of rock ‘n’ roll [44].

Stagnant record sales in the early 1950s led to a shared diagnosis in the music industry that the genre of white popular music was running dry [46]. Many singers and bands began to explore fresh paths, stimulated by DJs and impresarios who suggested that new young audiences were ready and waiting for new music [47]. During this search process, music boundaries became weaker, signalled by more ‘crossovers’ between genres, i.e. songs that first appeared in one chart, and then crossed over to another chart. In the early 1950s there were hundreds of two-way crossovers between C&W and pop (Hank Williams, Patti Page) and between R&B and pop (John Lee Hooker, Joe Turner) [31]. Some of these black R&B songs lay claim to being the first rock ‘n’ roll songs, for instance ‘Rocket 88’ by the Ike Turner band, a number one R&B hit in 1951 [46].

³ Gospel, jazz and folk music were other, smaller genres [31].

DJs at local radio stations galvanised the exciting and creative search process, giving airtime to new records that were not played by big, white radio stations. In the early 1950s, white disc jockeys like Alan Freed and Dewey Philips programmed black R&B records on local radio stations for a racially mixed but predominantly teenage audience. DJs tapped into this market and simultaneously introduced white teenagers to new music styles.

3.3.3. Niche developments: the emergence of rock 'n' roll

The first wave of rock 'n' roll (1955–1959) was carried by artists such as Chuck Berry, Little Richard, Bill Haley, Elvis Presley, Buddy Holly, Fats Domino, the Platters, the Drifters, and Bo Diddley [46]. They crossed boundaries and creatively combined aspects from R&B, C&W and pop. DJ Alan Freed coined the term rock 'n' roll in 1955 to signal a new style that differed from conventional popular music. In mainstream pop music, songs existed within such musical parameters as melody, harmony and formal structure. Pop songs were pleasant, universal and well constructed [42]. Rock 'n' roll, in contrast, placed the emphasis on beat and rhythm rather than on melody. Drums and base guitar formed the driving background section and the electric guitar added power and energy. Rock 'n' roll addressed the senses, something that also came out in the passionate style of singing and the exuberance and eccentricity of performance.

Rock 'n' roll also had a new sound, characterised by electric guitars amplified through loudspeakers [38]. Closed-body electric guitars allowed the boundaries of loudness to be pushed further. It was increasingly recognised that the closed-body electric guitar was a different musical instrument with a different sound and 'voice' than its acoustic parent. Notes had longer sustain and electric currents could be manipulated before they were fed to the amplifier [37].

Although Bill Haley's 'Rock Around the Clock' (1955) signalled rock 'n' roll's arrival, Elvis Presley contributed to its broader popularity by combining C&W and R&B [46]. Because Presley was a white boy who could sing black, he facilitated crossover to the white pop stream. Rock 'n' roll infused the record industry with new vitality, almost tripling the value of record sales between 1955 and 1959 (Fig. 8).

Rock 'n' roll changed the industry structure dramatically, because the songs were produced by independent record companies. The releases of the majors dropped from 70–75% of the *Billboard* charts in 1954 to 36% in 1958 [25, p. 229]. The big labels were initially blind to rock 'n' roll, which they saw as a passing fad.

The first market niche were white teenagers, who could afford to buy 45 rpm singles. Rock 'n' roll's popularity was related to the cultural landscape, in particular the tensions between the oppressive, conservative restoration of American society (e.g. McCarthyism) and the call for pleasure and fun that

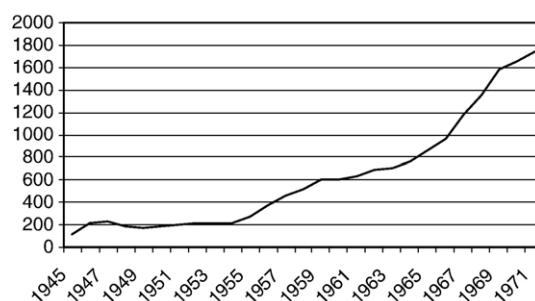


Fig. 8. Value of record sales in US in million \$ (data from [32]).

came from mass media and youth magazines. Social rigidity and conformity in high schools and families was at odds with increased freedom outside schools, e.g. cars, dances, parties [42]. These tensions created fertile ground for rock 'n' roll. On the one hand, rock 'n' roll offered a philosophy of pleasure. Many of the songs were about love, longings, dancing, heartbreak, car rides, etc. On the other hand, rock 'n' roll signalled rebellion to authority from parents, school teachers, church and state [47]. The music was provocative in style, and the performer's black leather jackets and greasy hair formed a deliberate affront to middle-class values [39].

There were vigorous debates in the media about its banality and corrupting influence on the health, school performance, and social development of youngsters. Rock 'n' roll was associated with delinquency, racial mixing, youth rebelliousness, and unbridled sexuality [31]. Established music publishers, big record companies, and radio networks were also opposed to rock 'n' roll, which they saw as a threat to their business and to 'genuine American music'.

Nevertheless, rock 'n' roll was propelled forward through interactions between radio, records, film and television [44]. Elvis Presley's appearance on the Ed Sullivan TV show in 1956 brought him and his music nation-wide popularity. The visual drama of rock 'n' roll performance was an important part of its popularity.

3.4. *Maturation of rock (1960s)*

Between 1959 and 1963 rock 'n' roll lost its spontaneity and vitality [46]. The founding artists had scattered: Elvis was in the army, Buddy Holly was dead, Little Richard had become a preacher, Jerry Lee Lewis was in disgrace and Chuck Berry in jail [31]. Rock 'n' roll imitators flooded the airwaves with music that was a commercial dilution of the original sound. A revitalising development was the increasing alignment between folk music and rock 'n' roll in the early 1960s (Bob Dylan, the Byrds). The politically engaged folk stream infused rock 'n' roll with both enthusiasm and seriousness, leading to a maturing of rock 'n' roll into rock [47]. The so-called British invasion, especially the Beatles' US tour in 1964, followed by the Rolling Stones, sparked off the second wave of rock, boosting record sales (Fig. 8). The Beatles popularised a new sound to the mass audience that was followed by other bands (the Monkees, Beach Boys).

While rock 'n' roll in the 1950s had been mainly for high school teenagers, rock music of the 1960s had a wider appeal [42]. This was related to the coming of age of the post-war baby boom generation and to the emerging youth culture, counter culture(s) and the civil rights movement. Rock songs became linked with politics and social change, thus acquiring significance beyond teenage concerns and puppy love [47]. Consuming rock music was a way of expressing values such as personal autonomy, independence, creativity and vitality [39].

As rock gathered momentum, it spilled over to the more profitable market for album records, where it overtook 'conventional' popular music (Fig. 9). A real transition in music had occurred, signalled also by an increasing acceptance of rock as an art form, discussed in new magazines and journals [31]. Rock music further evolved in the late 1960s and 1970s, by making different musical permutations. Folk rock, surf rock, hard rock, psychedelic rock and a range of other styles were developed by an expanding variety of groups and artists.

A crucial element of rock was the overriding importance the electric guitar, which became the icon of rock music [41]. Guitar sales expanded rapidly, from around 400,000 in 1962 to almost 2.5 million in 1970 [31]. In the 1950s, distortion and feedback from overdriven amplifiers were seen as problems. But in the

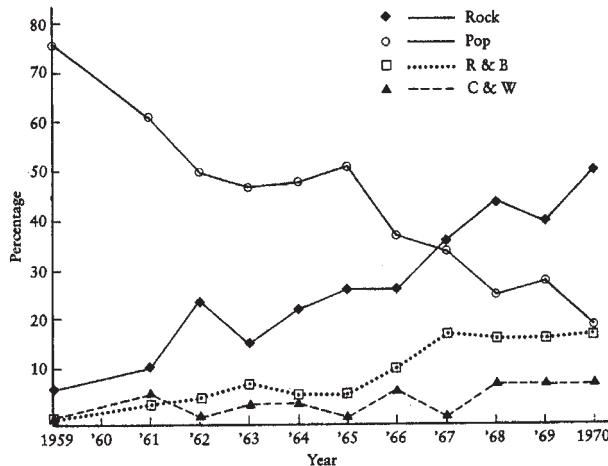


Fig. 9. Shares of the LP market in US ([31], p. 345).

mid-1960s, these problems were reconceptualised as strengths by the Beatles and Jimi Hendrix, who played the 'Star Spangled Banner' with howling feedback and distortion at the Woodstock festival in 1969 [37].

The sound of music also changed because of magnetic tape recording [33]. Once music was recorded it could be edited by cutting, pasting, mixing and manipulating pieces of tape. This gave rise to music engineers, especially when 2- to 4- to 8- and even 16-track recorders appeared in the 1960s. Instruments could be recorded separately and then mixed together with mixing consoles [40]. Further electro-acoustic devices enabled changes in the volume and quality of sound (echo and reverberation devices, equalizers and filters, different forms of tape editing). The new functionalities in magnetic tape recording allowed the creation of new sounds, the layering and shaping of songs. Studio equipment, once considered 'merely machines', turned into an essential musical instrument [48].

The second wave of rock provided opportunities for big record companies to recapture lost market shares. Independent record firms experienced difficulties, because they did not have the financial cloud to offer star salaries, did not have the marketing arms to reach a growing international audience, and did not have the resources to spread over hundreds of artists and albums, only a small percentage of whom ever hit big. Many of the independent labels were bought by the big record companies. The result of the new round of industrial restructuring was that, by 1970, the record industry was again down to a handful of giants that controlled an estimated 70–80% of global recorded music sales [45]. The remaining 20–30% were deliberately left to small independent labels, thus creating a distribution of labour in which small labels formed a breeding ground for new talent and big record companies contracted musicians once they gained popularity.

4. Analysis and conclusions

The empirical research question was: how did the transformation of the music system and the breakthrough of rock 'n' roll come about? Theoretical questions were: What was the role of multi-regime interaction? Can the multi-level perspective be usefully applied in this case, or are adjustments required?

Starting with the first theoretical question, analysis of the case study shows an important pattern in multi-regime interaction: the relationship between radio and recording regimes evolved from

competition to symbiosis. In the 1930s and 1940s both regimes were characterised by stability and antagonistic relations. Stability came from the social networks, which were stable oligopolies in both regimes. A few big firms dominated the market, and had stable linkages to artists and performers. Radio stations had their own orchestras to play live music and record companies had contractual agreements with star performers and songwriters. Stability also came from shared normative rules in both industries (e.g. about music aesthetic, racist values, roles of radio announcers) and shared cognitive beliefs (e.g. perception of homogeneous market, ideas about musical parameters such as melody, harmony and formal structure). And stability came from the demand side, because radio and phonograph were firmly embedded in family structures as central entertainment devices. Relations between both regimes were competitive and antagonistic, with radio stations frowning upon 'canned music' and record companies stating that their records were 'Not Licensed for Radio Broadcast'. In the late 1940s the stability of the radio regime was undermined by changes in the regulations for radio licenses and changes in radio advertising. Also in a cognitive sense the radio regime weakened, because the big networks became more interested in television. The demand side of the radio regime also changed. As television became the central family entertainment device, radio moved to garages and teenage bedrooms, freeing listening practices from parental control. This change was reinforced by a technical innovation, the transistor radio. The changes in licenses, advertising and listening practices provided opportunities for the emergence of a new actor: local radio stations. This new actor developed new practices that made the relationship with the recording regime more symbiotic. Local radio stations could not afford their own orchestras to play live music. Hence, they played records on air. This was initially frowned upon. But record companies gradually learned that they benefited from having their songs played on radio. As a result, relationships between radio and recording regimes evolved from competitive to symbiotic. This is not just an interesting pattern, it was also consequential for the breakthrough of rock 'n' roll.

Turning to the empirical question, it can be concluded that the breakthrough of rock 'n' roll came about in the relatively short period between 1950 and 1956, and was consolidated in the 1960s. Two changes in the radio regime were important: (1) the emergence of local radio stations, (2) the emergence of new demand from white teenagers, with freer listening practices. Both changes began small and were initially overlooked by incumbent actors in the radio and phonograph regimes, who were blinded by shared cognitive beliefs, commitments, and vested interests. Local radio stations introduced new roles such as DJs. These radio personalities wanted to distinguish themselves and played 'alternative' music that was not heard on the big networks. This provided more space for independent record labels and 'alternative' music (black R&B, white country and western) that had existed in the margins during the 1940s. The emergence of new, independent record labels was stimulated by a technical niche-innovation (cheap and easy magnetic tape recording) that lowered entry barriers in the recording business. Airplay of 'alternative' music records stimulated demand by teenagers and allowed further expansion of independent record labels. Macro-developments also influenced this demand. Economic growth gave teenagers buying power, and the repressive cultural climate aroused rebellious sentiments. So in the early 1950s, much was brewing below the surface of the radio and record regimes. Local radio stations, DJs, transistor radios, teenage appetite, independent record labels, magnetic tape recording, new music styles and electric guitars positively reinforced each other, enabling new combinations and experimentation. Most of this occurred out of sight of regime actors (and parents), in cars, with friends, at parties. It provided a stimulating context, in which creative artists such as Elvis Presley and Chuck Berry searched for fresh music by combining aspects from different genres (crossovers).

Because these developments occurred ‘below the surface’, the breakthrough of rock ‘n’ roll in the mid-1950s was a shock to parents and a surprise to regime actors. The breakthrough was an unanticipated, market-driven process with demand being stimulated by external economic, cultural and demographic developments. Because regime actors initially dismissed the new music as fad, they rapidly lost market shares to independent labels. In the late 1960s, however, big record companies converted themselves to the new music style, technology and audience, and were able to regain dominant market positions. So the breakthrough of rock ‘n’ roll was relatively rapid and unexpected. The analysis shows that neither the creativity of individual artists nor external macro-developments are sufficient explanations. The multi-level perspective provides a better explanation, which incorporates both explanations, and adds the importance of regime changes in radio and niche-actors in recording. Creative artists were important, but they took advantage of the opportunities that became available to them.

But this is only part of the story. The second part of the empirical question was: how did the transformation of the music system come about? From a long-term and broader socio-technical perspective, it can be concluded that the breakthrough of rock ‘n’ roll was embedded in a broader change process. Social and technical developments in the 1930s and 1940s helped set the stage for the music revolution of the 1950s. Although radio and recording regimes were relatively stable in the 1930s and 1940s, important niche developments took place ‘below the surface’. Technical niche-innovations (e.g. electric guitars, magnetic tape recording) were pioneered by outside enthusiasts or new entrants (e.g. Fender, Bigsby, Ampex, Magnecord). Their use was initially limited to particular applications: electric guitars were only used by swing bands and in electrified blues, and magnetic tape recording was used for dictating machines and in war-time espionage projects. There were also music niches, such as shows, country fairs, bars and clubs, where ‘hillbilly music’ and ‘race music’ survived. These niche-innovations existed in the margin and did not threaten the regime. Although development trajectories were non-linear and experienced setbacks, they gathered strength in the 1940s. Electric guitars were increasingly accepted; magnetic tape recording appeared on the market and stimulated the emergence of independent record labels; the ‘alternative’ music styles gathered momentum, signalled by the creation of new Billboard charts ‘Rhythm and Blues’ and ‘Country and Western’. These changes formed the context for the music revolution of the 1950s. So, the conclusion is that the breakthrough of rock ‘n’ roll was part of broader transformations in the American music industry, involving changes in music instruments, music recording technology, audiences, radio programming and music styles. This broader analysis suggests that the cultural change of rock ‘n’ roll was linked to previous changes in technology, regulations, firm strategies and market demand.

In response to the second theoretical question, three adjustments are proposed in the MLP, with considerations about wider relevance. The first adjustment is that multi-regime interaction can be an important process in transitions. So far, the MLP has addressed only *single* regime dynamics, both theoretically and in historical case studies. The case study shows a particular pattern: how relationships between *multiple* regimes evolved from competitive to symbiotic. This is an interesting pattern for further research. It may also be relevant for future sustainability transitions. A transition towards fuel cells and hydrogen economy, for instance, may involve interactions between transport and electricity regimes. Multi-regime interaction may also be important for transitions towards biomass [49]: co-combustion of biomass and coal may link waste and electricity regimes; and biofuels may link agricultural and transport regimes.

The second adjustment is to widen the concept of niches. The case study showed the existence of not only technological niches, but also of music niches, which offered protection to alternative music styles in the 1930s and 1940s. This suggests that niches may have general relevance, allowing survival of deviance

from the mainstream. This can be technical novelty, which deviates from technological regimes, or alternative music practice, as in the case study. There are also scholars who talk about policy niches, which create space for trying out radically new policies that deviate from the mainstream policy paradigm [50]. So the widening of the niche concept may be a fruitful avenue.

The third adjustment concerns the type of transition path. The MLP as described in Section 2 emphasises a technological substitution path, focusing on the emergence of *one* major innovation that subsequently breaks through and replaces the existing regime. This pattern does not have a good match with the transformation of the music system, which involved *multiple* niche-innovations, e.g. electric guitar, magnetic tape recording, transistor radio, television. Hence, I propose that the transition in the music system followed a *reconfiguration path*. This transition path does not consist of ‘new replacing old’, but of new being incorporated in the old, leading to new combinations and configurations. New innovations are developed in niches, and subsequently adopted in the regime (or they may replace existing components). When they are adopted in the regime, they may trigger further reconfigurations. For instance, the adoption of television meant that radio changed its place in the household (moving to bedrooms, kitchens, garages), which altered listening practices of teenagers. Likewise, the transistor radio contributed to new listening practices, which facilitated the articulation of new music tastes. The emergence of television also contributed to changes in firm strategies, with big networks shifting their attention from radio to television, thus creating space for local radio. Another example is magnetic tape recording, which stimulated the emergence of independent record labels, which created more opportunities for black musicians. Furthermore, magnetic tape recording completely altered music recording, as more was learned about functionalities and complementary technologies became available. As a result, the recording studio became an instrument itself and music engineers became artists. The case study was full of such intricate causal chains, where new technologies triggered new behaviour, which opened up new markets, which created space for new music styles and new technologies, etc. Such socio-technical ‘leapfrog dynamics’ are important in reconfiguration processes. Over time, they may lead to major system changes that were unforeseen and unintended at the start. So, the conclusion is that the music transition followed a reconfiguration path rather than a technological substitution path. A further hypothesis is that reconfiguration paths may have wider relevance, especially for domains that consist of distributed systems, which function through the interplay of *multiple* technologies (e.g. retailing, agriculture, hospitals). In such distributed systems there is not one ‘core’ technology that can be substituted. Hence, transitions are more likely to involve *multiple* niche-innovations, which replace existing components, gradually altering the system’s configuration.

Elzen and Wieczorek’s [10, p. 655] statement, “transitions are extremely complex processes”, clearly holds for the case study. It has been shown that transitions are complex processes, with many interacting actors and processes. But this concluding section has gone beyond the observation of complexity, deriving stylised patterns with broader theoretical relevance. A particular pattern in multi-regime interaction (from competition to symbiosis) has been identified, and possible applications to future sustainability transitions have been suggested. It has also been shown that the breakthrough of rock ‘n’ roll was rapid, but part of broader sociotechnical transformation dynamics in the entire music system. A general conclusion is that the multi-level perspective is useful for analysing complex transitions. The MLP is also versatile in the sense that its basic concepts can be altered and combined in different ways, leading to different patterns. One such pattern is the reconfiguration pathway, articulated through reflection on the case study. Future sociotechnical case studies of transitions may corroborate this pattern and derive other patterns.

Acknowledgements

I want to thank two anonymous referees, Deborah Tappi, Rob Raven, Geert Verbong, Rene Biasone, Ken Green, Vanesa Castán Broto and Staffan Hultén for their useful comments on previous versions of this paper. I also gratefully acknowledge financial support from the Dutch Knowledge Network on System Innovation (KSI).

References

- [1] C. Freeman, C. Perez, Structural crisis of adjustment, business cycles and investment behaviour, in: G. Dosi, C. Freeman, R. Nelson, G. Silverberg, L. Soete (Eds.), *Technical Change and Economic Theory*, Pinter, London, 1988, pp. 38–66.
- [2] M. Tushman, P. Anderson, Technological discontinuities and organization environments, *Adm. Sci. Q.* 31 (1986) 439–465.
- [3] C. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business School Press, Boston, MA, 1997.
- [4] A. Tylecote, *The Long Wave in the World Economy: the Current Crisis in Historical Perspective*, Routledge, London, 1993.
- [5] F.W. Geels, From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory, *Res. Policy* 33 (6/7) (2004) 897–920.
- [6] P. Weaver, L. Jansen, G. Van Grootveld, E. Van Spiegel, P. Vergragt, *Sustainable Technology Development*, Greenleaf Publishing, Sheffield, 2000.
- [7] J. Rotmans, R. Kemp, M. Van Asselt, More evolution than revolution: transition management in public policy, *Foresight* 3 (1) (2001) 15–31.
- [8] P. Raskin, T. Banuri, G. Gallopin, P. Butman, A. Hammond, R. Kates, R. Swart, *Great transition, The Promise and Lure of the Times Ahead*, Stockholm Environment Institute and Global Scenario Group, Boston, 2002.
- [9] B. Elzen, F.W. Geels, K. Green (Eds.), *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*, Edward Elgar, Cheltenham, 2004.
- [10] B. Elzen, A. Wieczorek, Transitions towards sustainability through system innovation: introduction to the special issue, *Technol. Forecast. Soc. Change* 72 (6) (2005) 651–661.
- [11] R.R. Nelson, S.G. Winter, *An Evolutionary Theory of Economic Change*, Bellknap Press, Cambridge (Mass.), 1982.
- [12] A. Rip, R. Kemp, Technological change, in: S. Rayner, E.L. Malone (Eds.), *Human Choice and Climate Change*, Battelle Press, Columbus, Ohio, 1998, pp. 327–399.
- [13] R. Kemp, J. Schot, R. Hoogma, Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management, *Technol. Anal. Strateg. Manag.* 10 (1998) 175–196.
- [14] F.W. Geels, *Technological Transitions and System Innovations: a Co-Evolutionary and Sociotechnical Analysis*, Edward Elgar, Cheltenham, 2005.
- [15] F.W. Geels, Co-evolution of technology and society: the multi-level perspective and a case study, the transition in water supply and personal hygiene in the Netherlands (1850–1930), *Technol. Soc.* 27 (3) (2005) 363–397.
- [16] A. Correljé, G.P.J. Verbong, The transition from coal to gas: radical change of the Dutch gas system, in: B. Elzen, F.W. Geels, K. Green (Eds.), *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*, Edward Elgar, Cheltenham, 2004, pp. 114–134.
- [17] F.W. Geels, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, *Res. Policy* 31 (8/9) (2002) 1257–1274.
- [18] H. Van Driel, J. Schot, Radical innovation as a multi-level process: introducing floating grain elevators in the Port of Rotterdam, *Technol. Cult.* 46 (1) (2005) 51–76.
- [19] W.E. Bijker, *Of Bicycles, Bakelites and Bulbs: Towards a Theory of Sociotechnical Change*, The MIT Press, Cambridge, MA, 1995.
- [20] W. Walker, Entrapment in large technology systems: institutional commitments and power relations, *Res. Policy* 29 (2000) 833–846.
- [21] G.C. Unruh, Understanding carbon lock-in, *Energy Policy* 28 (2000) 817–830.
- [22] J.W. Schot, The usefulness of evolutionary models for explaining innovation. The case of the Netherlands in the Nineteenth Century, *Hist. Technol.* 14 (1998) 173–200.
- [23] F.W. Geels, R.P.J.M. Raven, Non-linearity and expectations in niche-development trajectories: ups and downs in Dutch biogas development (1973–2003), *Technol. Anal. Strateg. Manag.* 18 (3/4) (2006) 375–392.
- [24] C.H. Sterling, J.M. Kittros, *Stay Tuned: a History of American Broadcasting*, Lawrence Erlbaum, Mahwah, NJ, 2002.
- [25] A. Millard, *America on Record: a History of Recorded Sound*, Cambridge University Press, Cambridge, 1995.
- [26] US Census Bureau, *Statistical Abstract of the US*, 1999.
- [27] H. Leblebici, G.R. Salancik, A. Copay, T. King, Institutional change and the transformation of interorganizational fields: an organizational history of the U.S. Radio Broadcasting Industry, *Adm. Sci. Q.* 36 (1991) 333–363.

- [28] H.R. Slotten, Radio engineers, the Federal Radio Commission, and the social shaping of broadcast technology: creating ‘Radio Paradise’, *Technol. Cult.* 36 (1995) 950–986.
- [29] P.K. Eberly, *Music in the Air: America’s Changing Tastes in Popular Music 1920–1980*, Hastings, New York, 1982.
- [30] R.A. Peterson, Why 1955? Explaining the advent of rock music, *Pop. Music* 9 (1990) 97–116.
- [31] P.H. Ennis, *The Seventh Stream: the Emergence of Rocknroll in American Popular Music*, University Press of New England, Hanover, 1992.
- [32] P. Gronow, The record industry: the growth of a mass medium, *Pop. Music* 3 (1) (1983) 53–75.
- [33] A. Millard, Tape recording and music making, in: H.-J. Braun (Ed.), *Music and Technology in the 20th Century*, Johns Hopkins University Press, Baltimore, 2000, pp. 158–173.
- [34] W.G. Roy, ‘Race Records’ and ‘Hillbilly Music’: institutional origins of racial categories in the American commercial recording industry, *Poetics* 32 (2004) 265–279.
- [35] M.H. Clark, *Mark H., The Magnetic Recording Industry, 1878–1960: An International Study in Business and Technological History*, PhD thesis, University of Delaware, 1992.
- [36] T. Evans, M.A. Evans, *Guitars: Music, History, Construction and Players: from the Renaissance to Rock*, Paddington Press Ltd., New York, 1977.
- [37] R. McSwain, The social reconstruction of a reverse salient in electric guitar technology: noise, the solid body and Jimi Hendrix, in: H.-J. Braun (Ed.), *Music and Technology in the 20th Century*, Johns Hopkins University Press, Baltimore, 2000, pp. 198–210.
- [38] S. Waksman, *Instruments of Desire: the Electric Guitar and the Shaping of Musical Experience*, Harvard University Press, Cambridge, Mass, 1999.
- [39] W. Dolsfma, *Valuing Pop Music: Institutions, VALUES, and Economics*, PhD thesis, Rotterdam University, the Netherlands, 1999.
- [40] S.S. Horning, From polka to punk: growth of an independent recording studio, 1934–1977, in: H.-J. Braun (Ed.), *Music and Technology in the 20th Century*, Johns Hopkins University Press, Baltimore, 2000, pp. 136–147.
- [41] A. A. Millard (Ed.), *The Electric Guitar: a History of an American Icon*, The John Hopkins University Press, Baltimore, 2004.
- [42] P. Wicke, *Rock Music: Culture, Aesthetics and Sociology*, Cambridge University Press, Cambridge, 1990.
- [43] M.B. Schiffer, *The Portable Radio in American Life*, The University of Arizona Press, Tucson/London, 1991.
- [44] S. Jones, *Rock Formation: Music, Technology, and Mass Communication*, Sage, London, 1992.
- [45] D. Spar, *Pirates, Prophets and Pioneers: Business and Politics along the Technological Frontier*, Random House, London, 2001.
- [46] R. Palmer, *The History of Rock and Roll*, Harmony Books, New York, 1995.
- [47] S. Frith, *Sound Effects: Youth, Leisure and the Politics of Rock ‘n’ Roll*, Pantheon, New York, 1981.
- [48] H.J. Braun, Introduction: technology and the production and reproduction of music in the 20th Century, in: H.-J. Braun (Ed.), *Music and Technology in the 20th Century*, Johns Hopkins University Press, Baltimore, 2000, pp. 9–32.
- [49] R.P.J.M. Raven, Co-evolution of waste and electricity regimes: a case study from the Netherlands 1969–2003, *Energy Pol.* (in press).
- [50] P. Ieromonachou, S. Potter, M. Enoch, Adapting strategic niche management for evaluating radical transport policies: the case of the Durham road access charging scheme, *Int. J. Transp. Manage.* 2 (2) (2004) 75–87.

Frank Geels is Assistant Professor at the Department of Technology Management, Eindhoven University of Technology, the Netherlands. Transitions and system innovations are the main topic of his work. He does both theoretical work on this topic as well as historical case-studies to test and refine theory. He also works on translating these insights to policy makers interested in bringing about transitions to sustainability.