

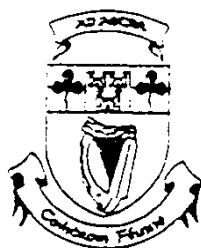
CENTRE FOR ECONOMIC RESEARCH

**Entrepreneurship and Endogenous
Market Structure:
An analysis of Format Innovation
and Vertical Integration
in the Record Industry.**

**Andrew E Burke
University College Dublin**

Working Paper WP93/5

March 1993



UNIVERSITY COLLEGE DUBLIN

Department of Economics

BELFIELD, DUBLIN 4, IRELAND

**Entrepreneurship and Endogenous
Market Structure: An Analysis
of Format Innovation and Vertical
Integration in the Record Industry.**

Andrew E. Burke (1993) ***

*IMRO Newman Scholar,
SIRC and Dept of Economics,
University College Dublin,*

University of Oxford,

and

University of London, Leon Fellow.

Abstract

The paper sets out to examine format innovation in a market with product differentiation where industry firms are divided between hardware and software producers. To this end we examine the Music Recording Industry. The analysis shows that in a market with differentiated products, format innovation biases the industry profit maximising structure towards a higher level of concentration; especially at the vertical level. Thus when an entrepreneur attempts to introduce a format innovation he is capable of altering the constraints under which he is attempting to maximise profits if he is prepared to integrate with other firms in the industry. Thus under these circumstances a certain proportion of industry structure is endogenously determined by the actions of entrepreneurs acting on behalf of firms. If format innovation ceases the market structure will become wholly exogenously determined and tend to move back towards vertical disintegration. In developing these arguments the paper introduces the concept of 'early diffusion costs' which occur in this type of market under format innovation and imply that there is a first mover disadvantage to software firms in adopting a new format innovation. The results are applicable to other industries such as the computer industry and the video industry.

* The author is grateful for financial assistance provided by the Irish Music Rights Organisation, the British Council and the University of London Leon Fellowship.

**The author is grateful for useful comments provided by those attending presentations of this paper at Oxford seminars. In particular he would like to thank Professor Charles Feinstein, Dr James Foreman-Peck and Dr Chris Bliss at Oxford University, Professor Mary MacKinnon of Queen's University and Paul Walsh of Trinity College Dublin. The usual disclaimers apply.



Entrepreneurship and Endogenous Market Structure: An Analysis of Format Innovation and Vertical Integration in the Record Industry.

Introduction

The paper sets out to examine format innovation in a market with product differentiation where industry firms are divided between hardware and software producers. To this end we examine the Music Recording Industry (other industries operating in similar market conditions include the Computer Industry and the Video Industry). Final use of industry output by the consumer involves the utilisation of software on compatible hardware. 'Format' or 'Systems' innovation refers to the introduction of a new style of vertically compatible hardware and software e.g. the Philips' 1992 launch of the Digital Compact Cassette.

The paper aims to model the decisions facing format innovators and in so doing attempts to demonstrate how the profitability of format innovation is positively related to the degree of concentration in the industry; both horizontal and vertical. In other words, in the case of format innovation the demand for entrepreneurship (available profit opportunities) is a positive function of the level of industry concentration. Since the decision of a firm to integrate on a vertical and horizontal level is an endogenous decision of the firm, the paper aims to demonstrate that in the presence of format innovation under product differentiation that market structure is endogenously determined. Further, since the demand for entrepreneurship is the level of unexploited profit opportunities the paper sets out to show how in the same case the entrepreneur can often change the market constraints under which he is attempting to maximise profits. In developing these arguments the paper introduces the concept of 'early diffusion costs' which occur in this type of market under format innovation and imply that there is a first mover disadvantage to software firms adopting a new format innovation.

The paper is structured as follows: Part I provides a brief history of format innovation in the Record industry since 1945, Part II analyses format innovation in the Record Industry and part III generalises the findings by modelling the profit maximising decisions faced by firms selling in a market with differentiated products where new formats are being launched onto the market.

Part I: The Post-War History of Format Innovation in the Record Industry

Prior to W.W.II the Recording Industry was dominated by vertically integrated hardware-software companies who introduced numerous format innovations. Examples include the Victor (later R.C.A.)¹ of the U.S.A. and the Gramophone Company (later E.M.I.) of the U.K. producing gramophone players and discs, Columbia producing a lateral groove disc graphophone and cylinders and Pathe Freres of France producing vertical cut discs and compatible players². By the 1930s the 78 rpm shellac gramophone disc had become the

¹ Recording Industry Association of America [R.I.A.A.] (1985)

² The National Sound Archive [N.S.A.] (1989)

dominant format³.

Post-War innovation opened-up in the U.S. in 1948 when Columbia launched the 33 rpm micro-groove vinylite long-playing record onto the U.S. market⁴. The new disc claimed to be unbreakable which while not completely true was flexible and not prone to snapping like the old shellac discs. More importantly, the disc was vastly superior in sound quality to the popular shellac 78 rpm discs and being cheaper to produce, was selling at a lower price. A year later in 1949 R.C.A. Victor introduced its seven inch 45 rpm micro-groove record to the American market. With a lower playing time to the L.P., R.C.A. marketed packages of seven inch records to form long-playing sets⁵. Decca released Britain's first 33 rpm L.P. in 1950 followed by E.M.I. in 1952⁶. These innovations heralded the launch of a format war which became known as the 'battle of the speeds'. The most widely used speed was the 78 rpm shellac disc using the pin needle as stylus. Vinylite discs had to be played using a much finer diamond needle thus requiring consumers to change their audio hardware to the new format. Realising this fact, both Columbia and R.C.A. produced audio hardware compatible with the stylus and speed requirements of their own particular vinylite record. It was not until the mid 1950s that multi-speed record players appeared. In both the U.S. and Britain, the end of the 1950s saw the 33 rpm disc established as the long-playing format with 45 rpm records restricted to 'single' song release. These trends for the U.K. are portrayed in Figure 3.1 where 'SEPRDN' is 78 production, 'LPPRDN' L.P. production and 'SINPRDN' single production. In the U.K. 1958 marked a sharp downturn in 78 production culminating in the L.P. outproducing the 78 by early 1958 and singles doing the same later in the year.

Given that micro-groove was the established format with hardware available from many different companies, entry into the production of records no longer required the dual production of hardware and software. In light of this constraint relaxation, many record companies entered the market with the aim of only producing software - if the format remained fixed then the risk associated with the 'software-only' strategy was substantially reduced. Therefore, in 1958 it was not surprising that the main international record companies agreed that the 'Blumleincutting method' become the standard format for the entire industry⁷.

The number of record companies continued to grow fed by consumers' heterogeneous music tastes which permitted entry via product differentiation. The 1950s saw a spawning of new speciality record companies in the U.S. catering for diverse music tastes such as blues, jazz, and country and western⁸. The aggregate growth in record purchases which rose from \$189

³ B.P.I. Statistics

⁴ N.S.A. (1989).

⁵ R.I.A.A. (1985).

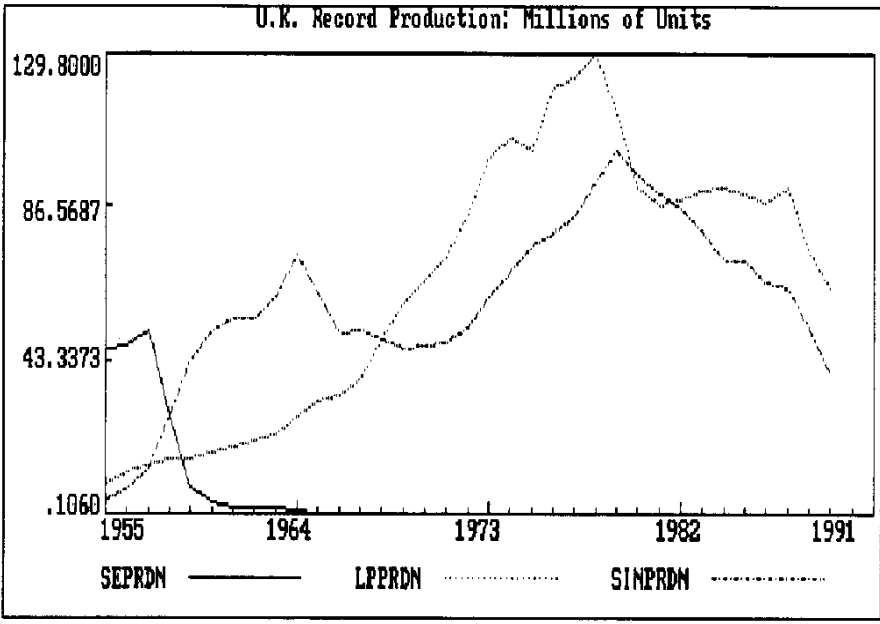
⁶ N.S.A. (1989).

⁷ N.S.A. (1989).

⁸ R.I.A.A. (1985).

million in 1948 to \$511 million ten years later, made these more specialised recordings viable⁹. This growth in the volume and diversity of sales increased further in the 1960s as the teenage population boomed both in numbers and historically high levels of disposable income. In the U.K. these movements occurred later and the wholesale boom in the industry was delayed until the 1960s. However, growth when it came was substantial and by 1968 the L.P. was outselling the single on a unit for unit basis; indicating the purchasing power of the consumer¹⁰.

Figure 3.1



Source: B.P.I.

However, these changes altered the rules of the game in that the decision to adopt a particular format was now dichotomised between two separate groups; hardware manufacturers and record companies. Record companies producing audio software had different priorities to hardware manufacturers. They maximised sales by differentiating their products in sound while following the format used most commonly by hardware manufacturers and other software companies. There was no incentive to introduce a new format since helping hardware companies during the early diffusion stages offered no long-term reward. This point is borne out with the failure of all non-compatible format innovations in the period 1950-1983 with the exception of the tape cassette. Innovations such as Garrard's reel to reel three inch tape in 1961 and Grundig's high speed D.C. cassette in 1963 all failed due to the fact that these hardware manufacturers had no pre-recorded software support from record companies^{11 12}.

⁹ R.I.A.A. (1985).

¹⁰ B.P.I.

¹¹ Bauldie (1991).

The Compact Disc (CD), researched and developed by Philips and Sony, was launched onto the market in 1982. It offered a sound quality that greatly surpassed the existing formats. However, despite this advantage, the question remains as to why record companies without hardware divisions were willing to back this innovation when in the past similar innovations offering superior sound quality were rejected? The main reason for the widespread acceptance of the Compact Disc lay behind the belief in the industry that by dramatically increasing the sound quality of audio software the Compact Disc may be able to increase the demand for albums. So how might the record companies have known this prior to the introduction of the CD so as to explain their ready acceptance of it? We identify three possible signals:

(1). Home-taping had not completely ousted pre-recorded software. On average a ninety minute blank tape costs around 20% of the cost of an LP and given that it has the capacity to tape two LPs, this defines its cost as roughly 10% of an LP. Despite LPs being ten times more expensive, record clubs/libraries did not catch-on on a large scale as consumers were evidently not happy with the inferior quality of home tapes compared to their pre-recorded counterparts. With this background, it seems reasonable to expect that the same consumers would be willing to spend 50% extra for a pre-recorded format that dramatically surpassed the sound quality of existing pre-recorded software in the same manner as home tapes were surpassed by pre-recorded LPs and cassettes.

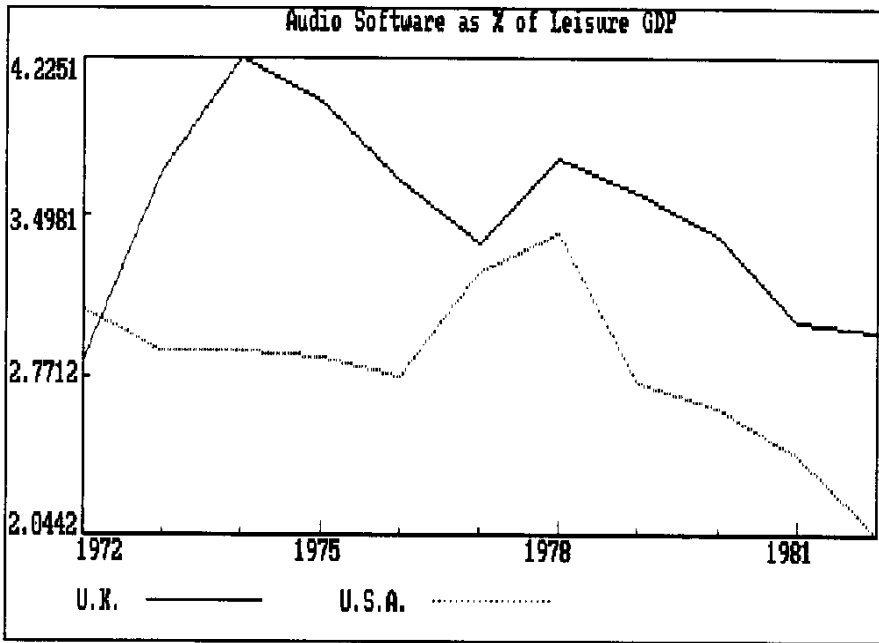
(2). A further indication that consumers would be willing to pay more for higher sound quality could be observed from the hardware market. Hardware manufacturers had introduced many format-compatible innovations that greatly increased the quality of sound reproduction. Some of these innovations were costly and were successfully pushed onto willing consumers in the form of higher prices. By the early 1980s the sales volume of high priced hardware was significant.

(3). There was a growing danger that a product which had not changed much over a thirty five year period had become somewhat inferior as income grew over the same time-span. A test of this view is the trend in the proportion of leisure spending devoted to pre-recorded audio software. We examine this in Figure 3.2. The period of relevance is the run-up to the introduction of the CD. Therefore, we look at the period 1972-1982. For the U.K. and the U.S.A. we see a broad decline in the proportion of leisure spending devoted to audio software

¹² In theoretical economic terms one could argue that the hardware manufacturers could compensate the leading software innovators for helping the diffusion process. In fact, the only two non-compatible innovations that did make some headway in the market, in a manner, did precisely that. These were Philips' 2-track Cassette and R.C.A.'s 8-track Cartridge both launched in 1963. Philips aided the diffusion of the Cassette by not issuing a patent and by producing pre-recorded software from its record division which it had established in 1953. R.C.A. did not allow a free patent but provided pre-recorded software for the Cartridge. Consumers preferred the Cassette for home listening and the Cartridge for car stereos. Originally, the Cartridge was of higher sound quality than the Cassette, but with the innovations of Dolby Noise Reduction in 1969 and 1970 alongside the introduction of Du Pont's 'Chromium Dioxide Tape' in 1968, this imbalance was redressed. The Japanese hardware manufacturers backed the Cassette: the larger potential sales volume for home listening over car listening also aided the hardware companies' strategy to support the Cassette and at the same time encouraged 'software-only' producers to support it resulting in a greater selection of pre-recorded cassette software. In Britain these advantages led to a severe downturn in both cartridge sales and production in 1974 and the eventual withdrawal of the cartridge from the market in 1979.

from 1973 onwards. Thus, the answer seemed to lie in the upgrading of the quality of pre-recorded software which would increase its normality and reduce substitutions into other leisure activities.

Figure 3.3: Substitution of Spending within Leisure
 (Retail audio software sales as a proportion of GDP expenditure devoted to recreational, entertainment, education and cultural services).



Data: Retail audio software sales; IFPI. GDP data from OECD.

Part II: Analysis

The history of systems innovation in the record industry exhibits two periods. The first, which ran roughly from 1877-1950 in the U.S. and 1898-1960 in the U.K., was an era of high concentration in the industry with most hardware manufacturers also being involved in the production of software. Firms maximised profits across both their hardware and software divisions. Therefore, in a format's early diffusion stage firms were willing to pay the price of initial sluggish software sales in order to help their own format get off the ground. This led to a reasonably high level of competition among formats which, through record company sponsorship, were able to be tested in the market by consumers. In the Post-War period the growth in consumers' demand for audio software and the dominance of the micro groove format standardization of production, led to a large increase in 'software-only' manufacturers. These companies had no incentive to suffer diffusion costs in the form of lower software sales

in order to help a new format diffuse unless the long-term gains outweighed the short-term costs. However, the long-term gains depended on whether other software manufacturers also adopted the format (since this determined whether it diffused or not). This interdependence among software manufacturers created a 'catch-22' situation: If a company wanted to capture the gains from a new innovation then it would be tempted to produce pre-recorded audio software in the new format. However, the first few companies to issue software would bear all the diffusion costs associated with the new format. This aspect not only reduces the expected gain to be made from innovating by these firms; but since every firm wants to avoid diffusion costs, it increases the probability that not enough firms will take on the new format and hence the innovation will fail. Therefore, in this type of industry structure, new format-changing innovations will only diffuse if one of two sufficient conditions are fulfilled: either the technology is so attractive from a profit perspective that bearing diffusion costs seems reasonable or, alternatively, that a particular software company readily takes on the diffusion costs when the technology is not overwhelmingly superior from a profit perspective.

Before we focus on both of these aspects let us clarify what we mean by diffusion costs. These arise most pertinently in industries with hardware-software production and product differentiation. Since consumers of differentiated product groups have a preference for variety they will tend to choose a hardware-software format that has a large selection of software products. Therefore, at the early stages of a format's diffusion, sales of individual pre-recorded software would be extremely low. With large fixed costs associated with the production of each disc (i.e. each individual type of software), the profitable sales price of each unit would be well above that payable by consumers, thereby necessitating that the initial innovator incur losses. Thus early diffusion costs are the losses suffered by the software producers who are first to produce software on a new format and who find that there is not enough demand to sell their output at a profitable price. If P_{ed} is the price received by sellers of software during the early stages of diffusion, P_{md} is the price received by software companies during the mature stages of the format's diffusion and X is the total level of output produced by software firms during the time period when the format is still in its early diffusion stage then Total Early Diffusion Costs (TEDC) are defined $TEDC = (P_{ed} - P_{md})X$.

We can observe early diffusion costs directly in the case of the diffusion of the Compact Disc. Record companies negotiated with artists and composers to share some of these costs. The agreement which was lodged with the IFPI applied to over twenty countries in Europe and Latin America. It fixed royalty payments at levels equivalent to LPs and cassettes for a five year period. This led to savings for record companies since the sale price of a CD was 50% more expensive than LPs or cassettes over the period. The Financial Times' Music and Copyright trade journal estimated that this reduction in royalty payments saved record companies \$400 million¹³. With the launch of DCC record companies have again requested artists and composers to share some of the early diffusion costs. Apart from the UK and Ireland, this has been agreed between artists, composers and record companies in EC countries. In Ireland and the UK the Mechanical Copyright Protection Society (MCPS) has been lobbying on behalf of artists to accept a smaller reduction in royalties as that agreed in other EC countries. At the time of writing the issue had gone to the Copyright Tribunal for arbitration.

¹³ Music and Copyright (1992)

Burke (1992) identified the range of format-compatible software and hardware as positive determinants of the demand for vinyl albums. Using DIFLP (which is a four period moving average of the share of the software market accounted for by the vinyl format) as a proxy for the level of the vinyl format diffusion, the regressions showed that an increase in diffusion in previous periods positively stimulated current sales levels: a 1% rise in DIFLP was found to cause a 3.5% and 5% increase in the current level of LP sales for the Kitchen Sink and Real Price Theory Equations respectively.

Table 3.1: International Dates of Launch of the Compact Disc.

Data: Country, Total Expenditure on Audio Software in Millions of U.S. Dollars (.), and total Unit Sales [.]. Source: I.F.P.I.

Year	Country					Average
1982:	Japan (2969.3) [144.65]	Average (2969.3) [144.65]				
1983:	Austria (134.6) [8.2]	Belgium (138.1) [9.3]	France (1084.0) [76.3]	W.Germany (1657.0) [157.2]	Italy (420.4) [45.8]	
	Holland (407.3) [31.0]	Sweden (261.1) [18.4]	Switzerland (208.4) [16.8]	U.K. (1973.4) [160.3]	U.S.A (6254.8) [672.2]	
	Average (1253.9) [119.55]					
1984:	Australia (382.7) [30.2]	Canada (537.2) [51.4]	Denmark (107.9) [8.5]	New Zealand (68.9) [7.5]	Norway (111.2) [8.2]	
	Portugal (70.2) [6.3]	Singapore (31.3) [5.9]	Average (187.06) [16.86]			
1985:	Finland (133.2) [12.2]	Hungary (27.5) [8.14]	Ireland (34.5) [3.1]	Average (65.1) [7.8]		

Therefore, it is clear that demand, in the form of economies of scale, acts as a constraint on

the launch of new formats. In fact, the proliferation of record companies from the 1950s onwards was only possible in light of the fact that the growth in consumers' demand for audio software meant that these large fixed costs could be covered even for specialised tastes. Evidence to support this view can also be seen in the date of launch of the Compact Disc worldwide. This is represented in Table 3.1 where record companies launched the product onto the largest markets first. The C.D. was first launched onto the buoyant Japanese market in 1982¹⁴ and within two years of its inception it had been launched in all of the G7 countries except Canada; where it was introduced a year later in 1984. The average unit sales of audio software was 145 million units for Japan, 120 million units for countries that had the CD in its second year of inception, 17 million units for those who saw it in the third year of its launch and 8 million units for those who encountered it in its fourth year¹⁵.

With early diffusion costs established as significant, the hardware manufacturers who are introducing the new format have a great incentive to bear the diffusion costs themselves so as to ensure that the new format has a fair chance of catching the public's imagination and becoming the new standard format. This is observable in the late 1940s (the early stages of the 'battle of the speeds') when both Columbia and R.C.A. backed their micro-groove formats (33rpm and 45rpm respectively) by issuing compatible pre-recorded software. As it turned out multi-speed record players over-ruled the non-compatibility of the two formats and income differences between the older and younger record buying age groups ensured that both the 45rpm 'single' and 33rpm L.P. could co-exist in the same market. We can also see this strategy pursued by Philips when they introduced the 2-track cassette. They supported the new format by producing pre-recorded software from their software division and encouraged hardware and software producers to adopt the format by not issuing a patent. These moves increased the software companies' perception that the cassette was likely to catch-on and hence encouraged them to produce pre-recorded software. The larger the innovator's share of the software market, the greater his power in ensuring that the innovation diffuses.

The experience of non-compatible format innovations in the Post-War period bears this point out. Firstly, all such innovations by 'hardware-only' companies failed. The only non-compatible format innovations that made any headway whatsoever were those by joint hardware-software companies that supported their own innovation by selling pre-recorded software on its format. These were Philips' 2-track cassette and R.C.A.'s 8-track cartridge. Hardware producers involved in format innovations have evidently noted this fact and recently there has been a wave of hardware companies merging or buying-up audio software manufacturers. Sony who are due to introduce a new (As of February 1993 this has only been released in Japan) non-compatible software format in the form of the 'Mini-Disc' (M.D.) have

¹⁴ Philips and Sony have again respectively chosen to first release DCC and Mini-Disc in the Japanese market (in 1992) before any other national launch.

¹⁵ But what about the objection that if a firm is optimistic with the diffusion prospects of the new format that it could mass produce compatible software and, because of its durable nature, sell it at a later date - only incurring interest charges? Unfortunately, due to fast changing music tastes, audio software is effectively a perishable good: albums sell in waves, once the wave has past a particular album's selling potential declines at a ferocious rate. It is interesting to note that the pioneering software companies who backed the Compact Disc tried to minimise this effect by releasing albums that were less susceptible to sharp changes in music tastes such as The Beatles' 'Sergeant Peppers' and classical music favourites such as Beethoven.

been the most recent overt actor in this regard moving into the software market in 1987 with a 2 billion dollar purchase of C.B.S. Records¹⁶. This was followed by the launch of 'Sony Music Entertainment' in November 1991¹⁷. Matsushita for its part entered the software business with its 6.1 billion dollar acquisition of M.C.A. in December 1990¹⁸. Philips Electric, who having co-operated with Sony to produce the 'Compact Disc' (C.D.) and most recently in 1992 launched the 'Digital Compact Cassette' (D.C.C.), continue to pursue their long standing vertical integration strategy initiated in 1953 by adding R.C.A. in 1986 and both Island Records and A+M Records in 1989 to its repertoire of audio software companies¹⁹.

While these merger moves are large scale as far as software companies are concerned, the actual software activities are relatively small compared to the hardware companies overall operations; thus adding credence to the viability of a strategy involving the internalisation of early diffusion costs. According to 'The Economist' (1991d) annual company reports show music sales (which compose film, audio software, music book publishing, and broadcasting and cable - hence an overestimate of audio software sales) as a percentage of total company sales amounts to 11.1% for Sony, 14.6% for Philips and 7.8% for Matsushita for financial year 1990/91.

Thus these firms, via vertical integration, alter the scenario from a 'catch 22' environment, where non-adoption of an optimal technology format is a likely prospect, to a case where the optimal outcome is likely to be attained. It is important to note that these results are not unique to the record industry but apply to most industries where hardware, using a specific format, requires software to be compatible with this particular format. Therefore, this study would argue that a format-changing innovation by computer hardware companies, which superannuates software in the current format, would be greatly facilitated by vertical integration in the computer industry; especially if the benefits of the new format were not of the order to compensate early software innovators for diffusion costs. Thus, for example, the launch of Amstrad computers, which were not compatible with either Macintosh or I.B.M. formats, required Amstrad to publish compatible software to support their hardware computer.

Often hardware companies try to achieve the same objectives through other means apart from vertical integration. In some cases they attempt to 'negotiate-away' the early diffusion costs by securing the agreement of a large number of software companies to issue compatible software. This strategy has been combined with vertical integration in the case of Philips' Launch of the Digital Compact Cassette. While committing their own software subsidiaries to produce compatible software, Philips have also procured the agreement of E.M.I., Warner, and M.C.A. to do the same. Philips are also making sure that hardware back-up is forthcoming and have undertakings from Matsushita, Sharp and Sanyo to produce compatible hardware²⁰.

¹⁶ Wagstyl (1991).

¹⁷ Financial Times (1991b).

¹⁸ Wagstyl (1991).

¹⁹ I.C.C. Business Ratios (1989).

²⁰ Skapinker (1991).

These 'software-support' agreements are also apparent in the video industry. Graham (1986) in her study of the launch of R.C.A.'s Videodisc observes that the introduction of the hardware required a ready body of pre-recorded software to support the diffusion of the innovation. Thus in 1979, prior to the launch of Videodisc, R.C.A. made programming agreements with Walt Disney Production, I.T.C. Entertainment, rock music promoter Dan Kirshner and several studios. The aim was to produce a broad sweep of programming on Videodisc to support its diffusion. In this regard it is ironic that R.C.A. was prevented from using programmes produced by its television division N.B.C. by the F.C.C. under U.S. monopoly legislation.

However, sometimes financial incentives are necessary to encourage agreement. This could be the case with many of the above examples since these type of deals are generally kept secret. However, we do know that in the forthcoming format battle in the 'interactive video' market between Sony's C.D.-Interactive and Commodore Computers' C.D.T.V., both companies have been giving small film-making firms financial and technical aid in a bid to help them produce multimedia programmes²¹. Philips, who are expected to join this 'dogfight' at a later stage with its own version of the C.D.-Interactive, have made financial contributions to firms such as that to Maxwell Communications to transfer the Berlitz language-teaching books to disc. Most recently in February 1992, Philips have supported C.D.-I with a purchase of a 25% stake in Whittle, the U.S. multi-media company, for \$175 million. The move was described as a "quest to wed electronics *hardware with software* such as music, videos, consumer information and educational programming"²². They have also acquired video retail outlets in Europe and the U.S..

The lesson, therefore, as far as early diffusion costs are concerned as a barrier to a format-changing innovation, is that industry concentration may not be such a bad thing ! Vertical integration between hardware and software companies, by providing the incentive for a company to take on the early diffusion costs, ensures that the innovation is launched onto the market with consumers able to judge it on its own merit rather than on the availability of compatible pre and non-recorded software. Also, it is interesting to note that this tendency towards horizontal integration may facilitate software producers to 'collude', in so far as agreeing to spread early diffusion costs among themselves and thereby breaking the 'innovator pays all' quality of audio software format innovations.

Part III: Economic Modelling

Economic modelling of format and network compatibility was initiated in a monopoly setting by Oren and Smith (1981) and was extended into a competitive oligopoly framework by Katz and Shapiro (1985). This latter paper outlined the industry equilibrium conditions and welfare properties of industry output where all products may not be technologically compatible. Katz and Shapiro assume that consumers' expectations are rational to the extent that in equilibrium

²¹ The Economist (1991a).

²² van de Krol (1992).

the expected level of industry output of a particular format is the actual level produced. Arthur (1989) models the diffusion of format innovations in a dynamic model involving uncertainty and random historic path effects. He argues that depending on random market circumstances and firms' strategic behaviour a finite number of equilibria are possible with no guarantee that the welfare optimal format technology will in fact be the technology that dominates the market. Empirically, this last model seems the most applicable: in the U.K. as of 1993, DCC, Mini-Disc and Compact Disc are the three main formats competing for a stake in a market that can only viably cater for two formats. Industry analysts and business people are in disagreement over which formats will succeed. Consumers, who are also unsure, are wary of purchasing new hardware before it is clear what market share each format will command. In this setting firms' strategic decision-making will play an important role in determining format diffusion outcomes. Thus the aim of this section is to outline a model that explains the forces influencing merger, subsidy and coercive strategy aimed at supporting a particular formats diffusion. Since we are specifically interested in the record industry we will be departing from the above models to the extent that we will assume that firms produce differentiated products. However, this alteration, while producing a unique form of an individual album software demand function, produces general properties that are consistent with the equilibrium conditions established above; except that optimal format outputs would be higher under product differentiation than homogenous products given that the production of an extra output under a given format will be a less than perfect substitute for other outputs within the same format group and hence the negative price effect would be of a smaller magnitude than that under homogenous products. This point will clarify itself once the modelling has been perused. Thus the modelling of this section contributes to the above literature by extending the rigour and depth of analysis in order to pinpoint the strategic merger and subsidy decisions faced by firms as well as demonstrating that the broad conclusions of the above models carry for a monopolistically competitive market.

What we intend modelling here is the decision of a software firm to produce output on a particular format and the level of output that maximises profits on the chosen format. Given this behaviour, we want to examine the scope for hardware firms to affect software companies format and output decisions. Thus, we will be interested in the externalities involved in producing a particular output on a specific format. The analysis will examine three software output spillover effects: (1) spillover effects to other compatible software producers, (2) spillover effects to other non-compatible software producers and (3) spillover effects to hardware producers.

Spillover effects to other compatible software producers

We assume that output in the industry can be taxonomised according to format compatibility 'a...n'. Thus q_a represents the vector of outputs compatible with format 'a'. We assume that each output is compatible with only one format which presently represents the state of the market in the recording industry. The number of elements 'i...z' in each $q_{a..n}$ vector reflects the range of software available on each format e.g. the range of albums available on Compact Disc format. Each element of a particular vector is produced at levels determined by the firm so that q_{ai} is the level of output of the 'i'th element of the 'a'-compatible software output vector. For simplicity of analysis we will only focus on two formats 'a' and 'b'. It is assumed that the market is monopolistically competitive with firms selling differentiated products and

facing downward sloping demand curves for each element of their output vector. In light of the fact that musicians have copyright of their music and that these are sold to individual firms, we assume that each 'i' element is specific to a particular firm and a firm may (and in reality does) produce more than one 'i' element. The Marshallian demand functions are of the form

$$q_{ai} = q_{ai}(P_{ai}, P_{a-i}, P_b, q_{a-i}, q_b, Y, \dots) \quad (3.1)$$

where Y = consumers' disposable income, P_{a-i} = the price of all 'a' compatible software other than 'i' and q_{a-i} = all quantities of 'a' compatible software other than 'i'. Inverting the demand function we get the price function

$$P_{ai} = P_{ai}(P_{a-i}, P_b, q_{ai}, q_{a-i}, q_b, Y, \dots) \quad (3.2)$$

with the derivative qualities (all second derivatives are decreasing in their arguments):

$$\begin{aligned} \frac{\partial P_{ai}}{\partial P_{a-i}} >, =, < 0, \quad \frac{\partial P_{ai}}{\partial P_b} > 0, \quad \frac{\partial P_{ai}}{\partial q_{a-i}} < 0 \\ \frac{\partial P_{ai}}{\partial q_{a-i}} <, > 0, \quad \frac{\partial P_{ai}}{\partial q_b} < 0, \quad \frac{\partial P_{ai}}{\partial Y} > 0 \end{aligned} \quad (3.3)$$

This demand equation is not of the traditional form as it incorporates the consumer's preference for a format that allows her access to a wide selection of compatible products. This factor will be very influential at early stages of diffusion but of less significance when a format has diffused to a level where selection of compatible products is great and taken for granted. We can see this effect with the derivative $P_{ai}'(P_{a-i})$. Looking first at the *substitution effect* of the price change; an increase in the price of other outputs on the same format has two effects. The first is due to the substitutability between q_{ai} and q_{a-i} and the second due to their complementarity. As the price of q_{a-i} increases consumers would tend to substitute out of q_{a-i} and into q_{ai} thereby pushing up the price of q_{ai} , causing the derivative to be positive. However, the complementarity of q_{ai} and q_{a-i} , which stems from the fact that the consumer has the option to substitute between formats, may mean that an increase in the price of outputs in vector q_{a-i} reduces the appeal of format 'a'. This causes substitution into format 'b' thereby reducing the demand for q_{ai} and causing a negative sign on the derivative. So which effect dominates? The answer seems to depend on what stage of diffusion format 'a' is at. If it is at an early stage then much of the demand for q_{ai} will be from consumers considering entry to format 'a' and hence we would expect a strong cross-price elasticity of demand between format 'a' and format 'b'. At more mature levels of 'a's' diffusion individuals are already strongly pre-committed (via hardware purchases and an existing collection of complementary 'a' compatible software) to format 'a' so that cross-price elasticities between formats 'a' and 'b' would be expected to be low. These considerations imply that as far as the price substitution effect is concerned $P_{ai}'(P_{a-i})$ is likely to be negative at early stages of diffusion and positive at more mature levels when flexibility for format switching is weaker.

The *income effect* of price changes is more predictable. A rise in P_{a-i} will reduce the consumer's budget set and hence reduce the demand (assuming normality given the income coefficients in Burke (1992) and hence price of q_{ai} . This effect, however, is likely to get stronger the larger the audio software market share format 'a' commands so that the absolute value of the negative derivative will increase as the format diffuses. Therefore, the *total effect* of the change in P_{a-i} on P_{ai} will definitely be negative at early stages of diffusion and ambiguous at later stages of diffusion depending on whether the income or substitution effect dominates.

Similar considerations are in play in determining the sign of $P_{ai}'(q_{a-i})$. An increase in q_{a-i} implies either a rise in the level of output of the existing range of software available on format 'a', an increase in the range of output available on 'a' or both simultaneously. $P_{ai}'(q_{a-i})$ will tend to be negative in so far as an increase in the range of outputs available on format 'a' will cause a substitution out of q_{ai} and into other 'a' compatible software, thereby causing the price of q_{ai} to drop. However, a rise in the range of 'a' compatible software will make the 'a' format more attractive as an overall hardware-software package and hence substitutions into format 'a' can cause q_{ai} to increase resulting in a positive sign on $P_{ai}'(q_{a-i})$. We would expect this latter factor to be more important to the consumer at earlier stages of diffusion as the marginal benefit from a per unit increase in the range (and hence selection) of 'a' compatible outputs would be expected to decline as the selection on offer increased. Therefore, the net sign on $P_{ai}'(q_{a-i})$ is more likely to be negative at more mature levels of 'a's' diffusion and possibly positive at early stages.

The remaining derivatives are more orthodox in their interpretation. $P_{ai}'(P_b) > 0$ is justified by the fact that products on format 'b' are substitutes for those on 'a'. $P_{ai}'(q_{ai}) < 0$ is trivial. $P_{ai}'(Y) > 0$ simply states our assumption of the normality of audio software. $P_{ai}'(q_b) < 0$ implies that a greater selection of products on the 'b' format is likely to cause substitution out of 'a' and into 'b'. We would expect this effect to decrease as the range of q_b increases so that as q_b increases in the limit; $P_{ai}'(q_b)$ approaches zero.

To analyze firms optimal behaviour we will assume that there exists a firm 'f' who produces a range of audio software compatible with format 'a'. Thus 'f' produces a vector of output $q_{ai,k}$ which is a subset of the industry's total range of output on format 'a', $q_{a..z}$. Firm 'f' optimises its output of each q_{ai} when

$$\frac{\partial \pi_f}{\partial q_{ai}} = \frac{\partial \sum_i^k \pi_{ai}}{\partial q_{ai}} = 0.$$

i.e. $\frac{\partial \pi_{ai}}{\partial q_{ai}} + \dots + \frac{\partial \pi_{ak}}{\partial q_{ai}} = 0.$ (3.4).

Note that this implies that for each $q_{ai,k}$ the optimal position does not necessarily imply that $MR_{ai} = MC_{ai}$. We can see this by differentiating the firms profit function which for each output is defined by (3.5) where $c(q_{ai}, w)$ is the cost function and 'x' and 'w' are the respective vectors of inputs and their prices.

$$\pi_{ai} = P_{ai}(q_{ai}, P_{a-i}, q_{a-i}, P_b, q_b, Y, \dots) \cdot q_{ai}(x) - c(q_{ai}, w) \quad (3.5)$$



$$\frac{\partial \pi_{ai}}{\partial q_{ai}} = \frac{\partial P_{ai}}{\partial q_{ai}} q_{ai} + P_{ai} - \frac{\partial c}{\partial q_{ai}} \quad (3.6)$$

This is the traditional monopolistic competition first order condition where the first two elements represent marginal revenue and the last, marginal costs. If this is the only output the firm produces then it will produce up to the point where marginal revenue equals marginal costs. However, if the firm produces other outputs on format 'a', which we have assumed to be the case for firm 'f', then it will take spillover effects into account. Therefore, it will examine the cross-quantity derivatives on its other output. For output 'k' these are

$$\frac{\partial \pi_{ak}}{\partial q_{ai}} = \frac{\partial P_{ak}}{\partial P_{ai}} \frac{\partial P_{ai}}{\partial q_{ai}} q_{ak} + \frac{\partial P_{ak}}{\partial q_{ai}} q_{ak} \quad (3.7)$$

(+)	(-)	(-)	(+)
(-)	(+)	(-)	(-)

The signs on these derivatives are already explained in the interpretation of equation (3.2). Apart from $P_{ai}'(q_{ai})$ which is always negative, we argued that the signs on the remaining two variables depend on the stage of diffusion of format 'a'. At early stages of diffusion, we argued that $P_{ak}'(P_{ai})$ is almost definitely negative. $P_{ak}'(q_{ai})$ is intuitively most likely to be positive at early diffusion stages. Therefore, at early diffusion stages the increase in supply of products on a specific format will most likely have positive profit spillover effects on other outputs on the same format. Thus we have the plus sign (+) on the first row on the left hand side. When the format has diffused more fully these effects are likely to diminish and even become negative as the sign on $P_{ak}'(P_{ai})$ tends towards a positive value if the substitution effect which is now positive dominates the income effect. Similarly $P_{ak}'(q_{ai})$ is likely to become negative as increased selection of outputs reduces the demand for individual differentiated outputs. Thus as far as more mature diffusion levels are concerned the properties of the derivatives tend to suggest that $\pi_{ak}'(q_{ai})$ becomes negative. Intuitively this is more attractive for stability reasons.

These properties imply that a firm maximising profits across all its outputs does not necessarily produce at the point where an output's *internal* marginal revenue is equal to its marginal costs. Rather the firm will take into account any profit spillover effects from one output to another. Therefore, we get three possible outcomes of profit maximising output (q_{ai}^{**}) for a firm producing an output tied to a particular format compared to the normal textbook case of a firm producing the profit maximising output (q_{ai}^*) where formats are perfectly compatible. For firm 'f' these are

$$(a.1) \quad q_{ai}^{**} > q_{ai}^* \quad \text{if} \quad \sum_j^k \left(\frac{\partial \pi_{a-i}}{\partial q_{ai}} \right) > 0 \quad \text{at} \quad q_{ai}^*$$

$$(a.2) \quad q_{ai}^{**} = q_{ai}^* \quad \text{if} \quad \sum_j^k \left(\frac{\partial \pi_{a-i}}{\partial q_{ai}} \right) = 0 \quad \text{at} \quad q_{ai}^*$$

$$(a.3) \quad q_{ai}^{**} < q_{ai}^* \quad \text{if} \quad \sum_j^k \left(\frac{\partial \pi_{a-i}}{\partial q_{ai}} \right) < 0 \quad \text{at} \quad q_{ai}^*$$

We note that firm 'f' has only $\frac{100}{z}$ percentage share of the 'a' compatible software output market. Therefore, its own profit maximising output strategy is not necessarily the industry's optimal output strategy given that it does not take into consideration the spillover effects on outputs $q_{a1..z}$. Again we get three possible configurations comparing firm optimal output (q_{ai}^{**}) with optimal industry output (q_{ai}^{***}).

$$(b.1) \quad q_{ai}^{***} > q_{ai}^{**} \text{ if } \sum_l^z \left(\frac{\partial \pi_{a-i}}{\partial q_{ai}} \right) > 0 \text{ at } q_{ai}^{**}$$

$$(b.2) \quad q_{ai}^{***} = q_{ai}^{**} \text{ if } \sum_l^z \left(\frac{\partial \pi_{a-i}}{\partial q_{ai}} \right) = 0 \text{ at } q_{ai}^{**}$$

$$(b.3) \quad q_{ai}^{***} < q_{ai}^{**} \text{ if } \sum_l^z \left(\frac{\partial \pi_{a-i}}{\partial q_{ai}} \right) < 0 \text{ at } q_{ai}^{**}$$

Conditions (a.1) and (b.1) where output is below its optimum are more likely to occur at early stages of format diffusion since the profit spillover effects are likely to be positive. Conversely, at more mature levels of diffusion these spillover effects are likely to be negative resulting in outcomes (a.3) and (b.3). Therefore, the important lesson from the above conditions is that *the existence of positive spillover does not necessarily imply that industry output is below its optimum*. The issue is whether these externalities evolve from positive to negative values before the firm has reached q_{ai}^{**} . But note that horizontal integration can move the industry towards its profit maximising output in either case by allowing firms, via mergers, to internalise the spillover effects and move output towards its optimum. The difference, however, is that when merger activity occurs when condition (b.1) is in play the outcome is an increase in output and hence an increase in welfare. However, merger activity in response to condition (b.3) is the traditional kind that government policy aims to mitigate against, namely reducing industry output in order to optimise industry revenue. From a policy perspective, the former should be encouraged and the latter discouraged. However, we do not relish the prospect of attempting to determine which is in fact operative since condition (1.b) might be the state of the market but a merger may imply a discrete change to (b.3) with ambiguous welfare effects.

Spillover effects to non-compatible software producers

We will now examine the impact of an the increase in output in one format on the profitability of other formats. We will continue along the current track of examining the effects of an increase in q_{ai} . We will examine the impact on format 'b'. Summing the effects of a rise in q_{ai} from equation (3.6) and (3.7) and aggregating these to the industry level we note four channels of impact on the profit function (3.8) π_{bi} : q_{ai} , P_{ai} , q_{a-i} , P_{a-i} .

The first two elements of equation (3.9) show the *direct output effect* on q_b of an increase in q_{ai} . $P_{bi}'(q_{ai})$ is negative as an increase in q_{ai} widens the selection of output on format 'a' causing an increase in the demand for 'a' at the expense of 'b'. As 'a' diffuses, the marginal impact of q_{ai} on q_b via this route will decline so that as q_a increases in the limit $P_{bi}'(q_{ai})$ approaches zero. The second element also reduces the profitability of 'b'; here the increase

in q_{ai} pushes the price of q_{bi} down, causing a substitution out of q_{bi} into q_{ai} .

$$\pi_{bi} = P_{bi}(P_{b-i}, P_{ai}, q_{ai}, q_{bi}, q_{b-i}, \dots) - c(q_{bi}, \dots) \quad (3.8)$$

$$\begin{aligned} \frac{\partial \pi_{bi}}{\partial q_{ai}} &= \frac{\partial p_{bi}}{\partial q_{ai}} q_{bi} + \frac{\partial P_{bi}}{\partial p_{ai}} \frac{\partial P_{ai}}{\partial q_{ai}} q_{bi} \\ &\quad (-) \quad (+) \quad (-) \\ &+ \left(\frac{\partial P_{bi}}{\partial q_{a-i}} \frac{\partial q_{a-i}}{\partial P_{a-i}} \right) \left(\frac{\partial P_{a-i}}{\partial P_{ai}} \frac{\partial P_{ai}}{\partial q_{ai}} + \frac{\partial P_{a-i}}{\partial q_{ai}} \right) q_{bi} \\ &\quad (-) \quad (+) \quad (-) \quad (-) \quad (+) \\ &\quad (0) \quad (+) \quad (+) \quad (-) \quad (-) \\ &+ \left(\frac{\partial P_{bi}}{\partial P_{a-i}} \right) \left(\frac{\partial P_{a-i}}{\partial P_{ai}} \frac{\partial P_{ai}}{\partial q_{ai}} + \frac{\partial P_{a-i}}{\partial q_{ai}} \right) q_{bi} \quad (3.9) \\ &\quad (+) \quad (-) \quad (-) \quad (+) \\ &\quad (+) \quad (+) \quad (-) \quad (-) \end{aligned}$$

The third and fourth elements in equation (3.9) represent the 'indirect range effect' (of compatible software) of q_{ai} on π_{bi} through spillover effects on the 'a' compatible output. These effects will vary depending on what stage of diffusion the 'a' format is at. The third element is the equivalent indirect route of q_{ai} to π_{bi} to the first direct element i.e. the effect coming through the quantity q_a (selection of differentiated 'a' compatible products). Thus the third element tells us how q_{ai} by affecting P_{a-i} causes changes in the quantity supplied of q_{a-i} and hence the price of q_{bi} . These effects will be more significant at early stages of 'a's diffusion since $P_{bi}'(q_{a-i})$ is likely to decline in absolute value as q_{a-i} increases; since at these higher levels the selection of output on the 'a' format is already great so that additions will only have a marginal impact on the demand for q_{bi} . Looking first at early diffusion effects in the third element (by removing the bracket) we see firstly that an increase in q_{ai} causes a fall in P_{ai} which pushes up the demand and hence price of P_{a-i} causing an increase in the quantity and range of q_{a-i} supplied, thereby reducing the demand and price of P_{bi} . Secondly, a rise in q_{ai} causes an increase in P_{a-i} directly via the selection effect which increases the supply of q_{a-i} thus reducing the demand and price of q_{bi} . Therefore, the combined spillover effects tell us that at early diffusion stages an increase in q_{ai} reduces the profitability of q_{bi} by enhancing the relative selection of outputs available on format 'a' over 'b'. At more mature levels of 'a's' diffusion these effects are likely to be reversed as the signs on $P_{a-i}'(q_{ai})$ and $P_{a-i}'(P_{ai})$ are likely to change: the former becoming negative and the latter positive. However, these effects are likely to be negligible since when 'a' has effectively matured $P_{bi}'(q_{a-i})$ will be near zero in value.

Turning to the fourth element in equation (3.9) we have the 'indirect spillover price effects' from P_a to q_b . Removing the brackets and focusing first on the early diffusion stage of format 'a' the first multiplicative element shows an increase in q_{ai} reducing p_{ai} which pushes up the price of P_{a-i} making q_b more attractive to consumers thereby pushing up the price of q_{bi} . The second multiplicative term shows q_{ai} causing an increase in P_{a-i} via a selection effect which again causes an increase in P_b . Thus the fourth element of equation (3.9), unlike the previous three, shows a positive impact of q_{ai} on the profitability of q_{bi} .

We now need to assess the net effect of an increase of q_{ai} on π_{bi} at early 'a' diffusion stages. The first three elements show a fall in π_{bi} and intuitively one would expect this not to be offset by the relative price movements since these are driven by an *increase in demand* for q_a . Therefore, we have two propositions:

Proposition 1: If consumers' budget for software (a+b) is fixed, then a profit maximising increase of q_{ai} for its producer must imply a fall in π_{bi} since there has been an overall increase in expenditure on q_a .

Proposition 2: If consumers' budget for software (a+b) increases the effect of an increase of q_{ai} on π_{bi} is ambiguous since although total expenditure on q_a has increased this may be more or less offset by a possible increase in expenditure resulting from changes in the consumers' budget.

The likelihood of a positive net impact of q_{ai} on π_{bi} may seem counter intuitive and, therefore, it is worth clarifying how this might occur. Namely, if an increase in q_{ai} enhances 'a' so much that the demand for 'a' increases substantially then both 'a' and 'b' might benefit. 'a's' total expenditure increases as new consumers enter the market and 'b's' expenditure increases as former 'a' consumers switch to 'b' as the price of q_a is driven up by new consumer entrants. This might have happened in the audio software market where the launch of the Compact Disc is often claimed to have enhanced the size of the audio software market.

At more mature levels of 'a's' diffusion the fourth element of equation (3.9) is likely to become negative so that the net effect of an increase in q_{ai} is a reduction in the profitability of producing q_{bi} . This occurs because $P_{a-i}(P_{ai})$ may become positive and $P_{a-i}(q_{ai})$ becomes negative. Thus again removing the brackets the first multiplicative term tells us that an increase in q_{ai} pushes the price of q_{ai} downwards which causes a substitution out of q_{a-i} into q_{ai} forcing P_{a-i} downwards reducing the demand and price of q_{bi} . The second multiplicative element tells us that the rise in q_{ai} directly pushes the price of q_{a-i} downwards by increasing the selection of q_{a-i} substitutes. The resulting fall in P_{a-i} then pushes the price P_{bi} downwards, reducing the profitability of q_{bi} . Therefore, at mature levels of 'a's' diffusion an increase in q_{ai} almost definitely reduces the profitability of q_{bi} .

Spillover effects to hardware companies

Having modelled the interaction of software output and software profits within and across format 'a' and 'b', we now examine how a hardware company may form a strategy to facilitate the diffusion its own format. We have seen that as a result of the positive profit externalities (associated with software output on a particular format), spilling over to affect the profitability of producing other software on the same format that the profitability of producing software on a format at an early stage of diffusion is likely to be relatively low. In fact, the profits are likely to be negative for very early adopters of a new format. These are the early diffusion costs we referred to in the analysis of the record industry. They show that there is a degree of inertia in the choice of software format as a move to a new format will only be undertaken if each software firm knows other firms are making the same move (so that profit levels will be high as a result of the positive profit spillover effects portrayed in

equations (3.7) and (3.9)). Reluctance on the part of software companies to be 'first adopters' of a potentially superior format technology may mean that the format never reaches the market. Thus in this sense there is an element of 'prisoner's dilemma' in firms' decision making - we will return to this aspect later.

In the knowledge of the manner in which spillover effects augment software companies' format choice, it may be optimal from the hardware company's perspective to 'back' its own format through cash subsidies to, or vertical integration of, software companies in order to incite production of compatible software. As we saw in equations (3.6), (3.7) and (3.9) any increase in output on a particular format at early diffusion stages will enhance the profitability of producing software on the format and reduce the profitability of competing formats. Thus via this channel the hardware company can induce more firms to adopt their format and hence increase the probability of its successful diffusion.

To see how much the hardware company can afford to subsidise output per unit of compatible software, we must examine its profit function π_h . We take hardware company 'h' producing 'a' compatible hardware q_{ha} at price P_{ha} and licensing the production of 'a' compatible software $q_{sa} = q_a$ at price P_{sa} . c_h and c_s are the respective cost functions for q_{ha} and q_{sa} and $R+D$ are research and development costs associated with the development of the 'a' format.

$$\pi_h = P_{ha}(q_{ha}, \dots)q_{ha} + P_{sa}(q_{sa}, \dots)q_{sa} - c_h(q_{ha}, \dots) - c_s(q_{sa}, \dots) - (R+D) \quad (3.10)$$

$$\frac{\partial \pi_h}{\partial q_{ai}} = \frac{\partial P_{ha}}{\partial q_{ha}} \frac{\partial q_{ha}}{\partial q_{ai}} q_{ha} + \frac{\partial P_{sa}}{\partial q_{sa}} \frac{\partial q_{sa}}{\partial q_{ai}} q_{sa} - \frac{\partial c_h}{\partial q_{ha}} \frac{\partial q_{ha}}{\partial q_{ai}} - \frac{\partial c_s}{\partial q_{sa}} \frac{\partial q_{sa}}{\partial q_{ai}} \quad (3.11)$$

$$\text{where } \frac{\partial q_{sa}}{\partial q_{ai}} = 1.$$

We immediately see from the first derivative that $R+D$ expenditure does not affect the hardware company's reservation subsidy level payable for a per unit output increase in 'a' compatible software. This is the standard sunk cost argument in favour of vertical integration common in industrial economics. Its implication here is that if the hardware company is forced to pay (by software companies) its reservation subsidy it will end up only covering variable costs and hence make a loss. Thus, in cases where the hardware company is facing strong format competition, so that software companies are only marginally interested in its format, it could easily be forced to subsidise software companies close to its reservation subsidy price, thereby increasing the likelihood of negative profits. Therefore, in these cases it may be optimal for the hardware company to vertically integrate into software production to avoid exploitation by independent software companies.

This squares up very well with the merger pattern actually observed. When the Compact Disc format was launched it had weak format competitors and, therefore, there was little 'hardware to software' subsidies or vertical integration. Conversely, with the announcement of launch dates for many formats in the early 1990s competition became intense thus leading to significant 'hardware to software' subsidies and vertical integration.

However, there is another benefit to hardware companies from vertical integration. If a hardware company buys up a software company and produces compatible output, then if it subsidises another software company's output, it will itself receive some of the positive profit spillover effects of that same subsidy. Therefore, if our hardware company 'h' owned a software subsidiary producing output $q_{a...p}$ then the rate of increase in profit ' π ' it would receive from a per unit increase in 'a' compatible software output q_{ai} would be

$$\frac{\partial \Pi}{\partial q_{ai}} = \frac{\partial \pi_h}{\partial q_{ai}} + \sum_m^p \frac{\partial \pi_a}{\partial q_{ai}} \quad (3.12).$$

where the first element of (3.12) is equation (3.10) and the second element is the same effect as that represented in equation (3.7) except examined over the range $q_{a...p}$. Thus it is possible that Philips' expansion into the software market in 1953 may have been part of a more subtle strategy than one first imagined. But of paramount importance, is the fact that if a hardware company expects to be involved in a format war, then it will be in a stronger position to fight such a battle, if it is vertically integrated - because the level of subsidy it can offer software companies increases since equation (3.12) is greater than equation (3.10) i.e. its reservation subsidy rises. We should note here that a software company that has pre-committed itself to a particular format (by say accepting an output subsidy from a hardware company) could itself capture some of the positive spillover effects by taking over another software company; especially one which is already pre-committed to the same format.

We finally close this section by representing the model in game theoretic form in order to draw attention to some of the dynamics of the 'hardware-software' bargaining process. We assume that the game is being played by a hardware company promoting a new 'format-changing' technology, 'a', and 'software-only' companies acting independently. The hardware company (h) has two moves (Ah) embrace 'a's' diffusion costs or (Rh) reject them. The software companies' moves are either to adopt a's format in their software (A) or reject it (R). We assume that the hardware company moves first and then, in the knowledge of this move, the software companies move simultaneously - ignorant of each others move.

The payoffs are presented in Table 3.3 in the form (software, hardware). Examining the hardware firm's payoffs first: if 'a' diffuses successfully the hardware company receives a payoff of 8 if it initially embraced the early diffusion costs or 10 if it passed these onto the software companies. If, alternatively, the new technology fails to catch-on the hardware firm minimises losses by having rejected diffusion costs with a payoff of -2 than if having embodied them with a payoff of -4. Therefore, the hardware firm has a dominant strategy not to adopt early diffusion costs. The expected payoffs for the software companies are estimated in the same manner as that described in equations (3.1) to (3.4).. Thus the expected gain from adopting 'a' is enhanced by both the hardware company and notably the expected number of other software firms who support 'a' by supplying a broad, plentiful range of compatible pre-recorded software.

We present two possible payoff matrices, 1 and 2, both of which have the same payoffs for the hardware company but differ for the software companies. Matrix 1 represents the case of the decision to adopt a highly attractive format such as the Compact Disc. Its promising features incites software firms to adopt it but also leads them to believe that it is very likely

to diffuse. This ensures that the software firms dominant strategy is to adopt the new format since they maximise gains regardless of who bears the early diffusion costs. Thus, it makes sense for both software and hardware companies to pursue their dominant strategies: format adoption is the outcome the hardware company wants and since this is the software companies' dominant strategy, the hardware firm is free to collect its maximum payoff of 10 so that (4, 10) is the Nash equilibrium.

Table 3.3: Format Diffusion Game

	<u>Matrix 1.</u>		<u>Matrix 2.</u>	
	Ah	Rh	Ah	Rh
A:	(6,8)	(4,10)	(6,8)	(4,10)
R:	(2,-4)	(2,-2)	(5,-4)	(5,-2)

Matrix 2 represents the case where the technology is of marginal benefit to the software companies and where the issue of who bears the diffusion costs plays a significant role in determining the Nash equilibrium. Here the software companies do not have a dominant strategy. If the hardware company refuses to bear the early diffusion costs then the format will fail. Therefore, in light of these payoffs the hardware company's optimal strategy is to adopt the early diffusion costs, thereby ensuring that the software companies optimise by adopting 'a' and safeguarding its successful diffusion.

The question immediately arises as to why hardware companies, such as Grundig with its D.C. Cassette (which failed to diffuse in the 1960s), who in retrospect were playing in Matrix 2 did not adopt the early diffusion costs? The answer must be that companies like Grundig thought software companies were facing payoffs characteristic not of matrix 2, but of matrix 1, where they had a dominant strategy to adopt the new format. With this perspective, the hardware company would not think it necessary to 'pick-up' the diffusion 'tab'. Thus in a nutshell players were not playing the same game ! Further, hardware companies were not afforded the benefit of learning this through repeated game experiments because either a new competing technology had arrived in the interim, such as Philips's Compact Cassette in Grundig's case, and/or the financial losses involved in playing the first few rounds of the game forced them to withdraw.

The second question is why might hardware and software companies view software companies' payoffs differently ? Asymmetrical information seems a likely candidate; the hardware company has a greater knowledge of the technology and its viability for hardware; while software companies are in a better perspective to assess its viability in the software market. Asymmetric information may also show up in that hardware companies do not have full knowledge of the production and marketing priorities of the software firms, thus causing a degree of uncertainty as to what the software companies' real payoffs should be. Clearly, Sony's launch of D.A.T. did not have the objectives of software companies in mind given pre-

recorded D.A.T. software had no real prospect of being produced profitably. Given the scale of capital investment involved in the development and launch of a new format innovation it would make sense for hardware companies to put resources into estimating software company payoffs more accurately. If this is the case, then part of the moves for vertical integration between hardware and software companies may be motivated by a desire on behalf of the hardware companies to assess the software companies' payoffs more accurately. In plain words a move for synergy: the software company feeds back information to the hardware company on the type of format innovations that are needed and will work. The fact that Sony's entry into the software market, with the takeover of C.B.S. Records, came only one year after the failed launch of Digital Audio Tape may be no coincidence !

Given that there is scope for error in defining which matrix the game is being played on, it might make sense for hardware companies to try to affect the value of the unknown (to the hardware company) probabilities of the level of adoption by other software companies which the software companies are using in its strategy decision. For instance, if the hardware company can get other software companies to signal that they will adopt the format, then the probability of it successful diffusion undoubtedly increase. Such is obviously the motivation of agreements made between Philips and Warner, E.M.I. and M.C.A. in the run up to the launch of D.C.C. The same could also apply to the agreements made by R.C.A. in support of VideoDisc, Sony in support of C.D.-I. and Commodore in support of C.D.T.V.

For the same reason we can also see that industry concentration of software companies at the horizontal level may reduce the risk associated with the probabilities of format success or failure. Such integration facilitates software companies to assess the merits of a new format technology in a more risk-free environment, thereby enhancing the payoffs for risk averse firms. In this sense horizontal integration, by increasing the likelihood of the game taking the form of matrix 1, may promote format innovation.

It is worth pointing out that the confusion over which game is being played rapidly dissipates when more than one similar quality technology hits the market simultaneously. In these cases Matrix 2 is the most likely scenario as software companies payoffs from adopting a new format decline and the hardware companies are forced to embrace early diffusion costs. Such was the case with R.C.A. and Columbia in the 'battle of the speeds', Philips and R.C.A. with the 'Cassette versus Cartridge' tape war, Sony and Philips with D.C.C. versus the M.D., and Commodore and Sony with C.D.T.V. against the C.D.-I.

Conclusion

By analyzing the history of format innovation in the Record Industry and through modelling the payoffs to firms in an industry with differentiated products in the presence of format innovation, we have argued that hardware-software integration facilitates the launch of new formats by hardware companies through:

- (1) Reducing the possibility of exploitation by software companies who bid for high subsidies in the knowledge the 'R+D' investment undertaken by hardware companies, in the development of new formats, is a sunk cost. Essentially, software subsidiaries of hardware innovators will support their parent company's format.

(2) Allowing the hardware company to capture some of the positive profit spillover effects of other software firms adopting its format. Ultimately, it increases the level of subsidy the hardware company can offer to independent software companies.

(3) It gives the hardware company a better knowledge of the payoffs facing software companies and thus puts the hardware company in a more informed position to choose the optimal level of software subsidy.

We argued that horizontal integration may also facilitate format innovation by:

(1) Allowing firms to capture some of the positive profit spillover effects of output increase on a particular format in its early diffusion stages.

(2) Facilitating industry agreement on the optimal format technology so that uncertainty and hence risk involved in the adoption of a new format is reduced.

So in general we conclude that at early diffusion stages, vertical integration promotes format innovation and horizontal integration 'might' do so. Once the format has diffused, the benefits from vertical integration are greatly reduced from a company perspective and in the absence of further systems innovations the market structure will tend to move back towards vertical disintegration as the exogenous (relatively low minimum efficient scale in software production) factors dominate.²³

The analysis showed that in a market with differentiated products, format innovation biases the industry profit maximising structure towards a higher level of concentration; especially at the vertical level. Thus when an entrepreneur attempts to introduce a format innovation he is capable of altering the constraints under which he is attempting to maximise profits if he is prepared to integrate with other firms in the industry. Thus under these circumstances a certain proportion of industry structure is endogenously determined by the actions of entrepreneurs acting on behalf of firms.

²³ We note that economic welfare is maximised by letting consumers rather than firms decide the merits of different consumer goods. This can only occur when there is a high degree of competition among consumer products. Economic theory assumes that the best way to ensure this outcome is to have a high degree of competition among the firms producing these goods. However, we have seen that in the case of format innovations that market concentration on a vertical level promotes format competition and that less concentrated vertical structure severely hinders superior formats' diffusion. Horizontal integration among software companies may also help format innovation diffusion if high concentration facilitates agreement to share early diffusion costs. Thus as far as format innovation is concerned in terms of diffusion at early stages, the rule is reversed, in that a monopolistic rather than competitive market structure leads to a greater level of format competition among consumer goods.

References

Arthur, W.B. (1989): 'Competing Technologies, Increasing Returns and Lock-in by Historical Events'. The Economic Journal, Vol 99, March 1989, pp 116-131.

Bauldie, J. (1991): 'It'sssss All Over For Tape hissssss.' 'Q': The Modern Guide to Music and More, No. 63, December 1991.

Burke, A.E. (1992): 'The Demand for Vinylite Record Albums: Times Series Estimation of a Product Group in the Presence of Product Differentiation Innovation'. University College Dublin Dept of Economics Working Paper and UCD Services Industries Research Centre Discussion Paper.

Financial Times (1991): 'Nikkei down again on arbitrage unwinding'. Financial Times, November 23/24, p 21, 1991.

I.C.C. Business Ratios (1989): 'Business Ratio Report: An Industry Sector Analysis. The Record Industry'. I.C.C. Business Ratios, Hampton, 1989.

International Federation of Phonographic Industries (1990): 'World Record Sales 1969-1990: A Statistical History of the World Recording Industry'. Edited by Michele Hung and Esteban Garcia Morencos, I.F.P.I., London, 1990.

Katz, M.L. and Shapiro, C. (1985): 'Network Externalities, Competition, and Compatibility'. American Economic Review, Vol 75, No 3, 1985.

Oren, S.S. and Smith, S.A. (1981): 'Critical Mass and Tariff Structure in Electronic Communications Markets'. Bell Journal of Economics, Autumn 1981, 12, 467-71.

Record Industry Association of America (1985): 'Inside the Recording Industry: An Introduction to America's Music Business'. R.I.A.A. Inc, Washington D.C., 1988.

Skapinker, M. (1991): 'Cassette tape world sales decline.' Financial Times: World Trade News, October 3, 1991.

The British Phonograph Industry (1991): 'B.P.I. Year Book 1991: A Statistical Description of The British Record Industry'. The B.P.I., 1991.

The Economist (1991): 'Lights, Music...Action?'. The Economist, August 3rd, 1991.

The National Sound Archive (1989): 'Developments in Recorded Sound: A Catalogue of Oral History Interviews'. The British Library Board, 1989.

van de Krol, R. (1992): 'Philips to buy 25% stake in Whittle for \$175m'. Financial Times, p 23, February 6, 1992.

Wagstyl, S. (1991): 'Japan seeks its fortune in Tinsel Town.' The Financial Times: Companies and Markets, October 8, 1991.