Aalborg University

MASTER THESIS

Between the Winner's Curse and the Blessings of Vintage

Exploring technological change made by users of discontinued home video games hardware

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ABSTRACT

In this thesis we analyse the relation between use and technological change, exploring a limitation in the Product Life Cycle model. Influenced by the finite potential for technological improvements depicted by the s-curve, that model closes the question of technological limits at an early stage, leaving the analysis of what happens with products after they reach the maturity stage out of its' scope.

To address that shortcoming, we recognise that in some occasions those limits are transcended, drawing on two perspectives. First, users acting as agents of technological change, reinterpret "old" technologies, and find new ways of using them for purposes that were not thought of when they were originally designed. Second, technologies do not merely fade away, but continue to be improved and to shape the technological landscape long after their supposed obsolescence, often against newer rivals.

To explore those phenomena, we analysed the home video games industry, whose network-based, standard-driven character leaves many hardware users in the position of "angry orphans", without any support from both hardware and software manufacturers. They seem affected by the "winner's curse", having overpaid for a product that was discontinued, lost a large share of its value, and apparently became a piece of obsolete technology.

However, some of those users find the "blessings" emerging from the emotional side of video gaming linked with the retrogaming phenomenon, and from the online communities of orphans that appreciate the technical challenge of modifying discontinued (vintage) home video games hardware.

We conducted an empirical study of such users (modders) and communities, comprising qualitative and quantitative research activities combined through the technique of "crystallisation".

The results show that technological limits are indeed transcended, and that technological change seems a complex process, done through small incremental steps, on an individual learning by doing basis, within a context of information sharing, and constructive support within the communities. This context motivates the modders, concurring to the improvement of their skills, the quality of their projects, and reputation building. Nonetheless, the scope of those technological changes, although relevant from a technical point of view, does not reach the economic relevance of an innovation: the outcomes remain confined to an individual sphere, skipping the logic of the market, and they do not feedback into the innovation processes of companies.

Our findings confirm thus that "old" technologies continue to exist and to be improved long after they reach the maturity and declining stages and their supposed technological limits, and that the users are responsible by the extension of the period in which they are in use and their physical limits.

In face of this evidence, we suggest that the Product Life Cycle literature should allow leeway to recognise that in some cases there is a subsequent phase to the maturity stage, in which products and technologies are still in use, and furthermore being improved, but no longer available on the market.

We also suggest that further research should compare cases of other discontinued technologies, where users act as agents of technological change and others where this does not happen. Such comparative study would capture how general the pattern of technological changes made to discontinued products is, and render a deeper understanding of different dimensions of analysis and characteristics of such products and users.

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To me, this document represents far more than its contents: it marks the achievement of an objective I set some years ago, and the turning of a new page in my life. I want to express here my gratitude to the people that during these two years contributed directly and indirectly, and in different ways to that.

The original idea for the thesis came several months ago while reading an article about the QWERTY keyboard in an in-flight magazine during a trip back to home. A couple of months later, I had the opportunity to spend the 9^{th} semester at the Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE) at Lund University, where I would like to thank in particular Emelie Stenborg for her warm welcome and assistance, and Gustav Holmberg, from the Research Policy Institute, for his helped with useful advice on the outline of the research.

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I am in debt to my friends in Faro, Lisbon, Brussels, Lund, and the ones I made here in Aalborg, especially the fellow MIKE students, for their resilience and kindness that made this and other journeys more lively and pleasant.

Lastly, but most importantly, I am ever grateful to my parents, Maria and Manuel, for their unconditional support, patience and generosity during these years.

Aalborg, June 2010

Man is far too clever to be able to survive without wisdom.

E. F. Schumacher

in *Small is Beautiful – a study of economics as if people mattered*

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LIST OF ABBREVIATIONS

AES – Neo Geo Advanced Entertainment System

AM – Amplitude Modulation

APP – Application

BASIC – Beginner's All-purpose Symbolic Instruction Code

BIT – Binary Digit

CD – Compact Disc

CPU – Central Processing Unit

CRT – Cathode Ray Tube

DC – Sega Dreamcast

DJ – Disc Jockey

DVD – Digital Versatile Disc/Digital Video Disc

DYI – Do It Yourself

ESA – Entertainment Software Association

FM – Frequency Modulation

GB – Gigabyte

GC – Nintendo Game Cube

GD – Sega Gigadisc

GPU – Graphics Processing Unit

GSM – Global System for Mobile Communications

IM – Interactive Multiplayer

JVC – Victor Company of Japan

KB – Kilobyte

LAN – Local Area Network

LCD – Liquid Crystal Display

MB – Megabyte

MHz – Megahertz

MPEG – Moving Picture Experts Group (standard)

NEC – Nippon Electric Company

NES – Nintendo Entertainment System

N64 – Nintendo 64

PC – Personal Computer

PDA – Personal Digital Assistant

PLC – Product Life Cycle

PS – PlayStation

PSP – PlayStation Portable

RAM – Random Access Memory

RCA – Radio Corporation of America

RF – Radio Frequency

ROM – Read-Only Memory

R&D – Research and Development

SCOT – Social Construction of Technology

SMS – Sega Master System

SNES – Super Nintendo Entertainment System

SS – Sega Saturn

STS – Science and Technology Studies

TV – Television

UK – United Kingdom

US – United States of America

USB – Universal Serial Bus

VCS – Atari Video Computer System

VES – Fairchild Video Entertainment System

VHS – Video Home System

INTRODUCTION

This thesis was motivated by three related observations. First, in spite of the appearance of all sorts of new and revolutionary state-of-the-art products, some people keep on using the "old" things they intend to replace, although all other things being equal, new and more sophisticated products usually provide additional advantages.

That means some people prefer to dirty their fingers and read the newspaper from two days ago, although they might have free access to real time news on the Internet. That means some people prefer using paper and fountain pens that need constant refill to write their memoires, when they could use a computer and a word processor to make text editing easier. For what concerns this thesis, that means some people prefer to play video games in their old video game consoles rather than use the latest models that provide better graphic quality.

Second, those new achievements demonstrate the capacity of the human mind to realise surprising inventions that fulfil the most varied needs. This means we created ways of being better informed at all times. This means we can instantly share information with someone who lives in the other side of the world. For what concerns this thesis, this means we found ways of enjoying endless hours of entertainment.

Lastly, our creative capacity is such that we even come up with ways of using old things that were not envisaged by their original creators, and most surprisingly, often these new uses cannot be done with the new things.

That means some people use two-day-read newspapers to shelter from a sudden downpour, something to which the ethereal Internet would not be of great assistance. That means some people make paper airplanes from their memoir-writing scrap paper, when a computer flying by itself means bad news. For what concerns this thesis, that means some people prefer the limited possibilities of making 8-bit music based on the old video games soundtracks, to the wider opportunities offered by digital music processing.

In a nutshell, the motivation for this thesis lies in the fact that use and consumption are not simple actions. They are first and foremost human actions, and as such complex, and emotional, carrying many dimensions. In this thesis we explore some of those dimensions.

BACKGROUND

The literature on Product Life Cycles describes the stages of evolution and properties of markets in terms of the number of firms, rate and type of innovations, market shares and profits in the process of introduction of a new product. The patterns and behaviours it predicts have been found in different products and industries (e.g., Gort and Klepper (1982) and Klepper (1997)), yet the model presents several shortcomings.

This thesis contributes to the understanding of one of them: the fact that the model closes the question of technological limits at an early stage, leaving the analysis of what happens with the products after they reach the maturity or declining stages, out of its' scope. The reason might be that the S-curve of technology predicts a finite potential for technological improvements: the performance characteristics of a technology (or product) become increasingly harder to improve as time progresses. However, evidence suggests that in some occasions technologies transcend those limits (e.g., Utterback (1994, pp. 145-66)), in line with the idea that they continue to be improved, postponing the time when they are "clearly outmoded" (Rosenberg, 1972).

Moreover, it is often the case when that extension is carried out by the users of those products, who take on the role of agents of technological change (Kline and Pinch, 1996), reflecting that technological change is influenced by both the intrinsic characteristics of technologies (e.g., Dosi (1982) and Sahal (1985)), and social dynamics (e.g., Tushman and Rosenkopf (1992), Henderson (1995) and Pinch and Bijker (1984)).

It is thus not a surprising that many technologies thought of as "old" remain in use for longer than the accounts based on the mental picture of the S-curve would allow. That is actually a recurrent feature of the technological landscape (Lindqvist, 1994), where many technologies only become truly significant much later than the initial invention and innovation stages conveyed in that picture (Edgerton, 2007).

Are there then limits to technological development? This thesis is based on the two central ideas mentioned above to explore answers within this broader background: the connection between technological change and use.

AN AGENDA BASED ON THE IMPORTANCE OF TECHNOLOGICAL CHANGE AND USE

Innovation can be defined as the introduction of new products and services on the market, the use of new organizational models and ways of addressing the market, or the implementation of new forms of producing and delivering products and services. In abstract terms, Innovation caters two dimensions: the generation of something new, and its' commercial exploitation, regardless of the processes through which this is achieved (Rothwell, 1994).

The success and importance of an innovation is linked to the second dimension, which encompasses the wider effects on the society deriving from the introduction of something new in the market, and the measure to which it becomes relevant from an economic point of view. The first dimension has thus a narrower scope, encompassing the development of something that might become socially relevant, should it achieve that economic significance. This thesis is concerned with this narrower dimension, in particular with its' technical significance.

To address the shortcoming of the Product Life Cycle model mentioned above, we explore the relevance of technical (or technological) change made to products after they have reached the maturity and declining stages. Products that have been discontinued, and are no longer on the market, nor supported by the manufacturers, and are regarded as obsolete in most cases.

Put it another way, we focus on cases of technological change, understood as an advance in knowledge embodied in new designs for existing products or entirely new products (Mansfield, 1968, pp. 3-4), which skip the logic of the market, and that therefore do not fulfil the second dimension of innovation, at least not in the short term.

What is more, we place the user (or consumer), defined as someone who has used a product at least once in his or her life, as the agent of the technological change, and therefore use is seen as a precondition to carry out such technical changes on discontinued technologies.

This question becomes a more complex and interesting problem in the context of a network industry such as the home video games.

THE HOME VIDEO GAMES INDUSTRY

In network industries, manufacturers' main goal is to rapidly achieve a large installed base for a product, because the existence of network effects – positive and negative externalities – makes the 'strong get stronger and the weak get weaker' (Shapiro and Varian, 1999b, p. 175). Hence, firms' strategies are designed to create consumer switching costs, so the latter find it difficult to move to a new product or standard (Klemperer, 1987), and to win the standards wars in which they engage to impose a standard in a market (Shapiro and Varian, 1999a).

The combination of network effects, switching costs and standards wars means that when a new standard (product) prevails, many users of the previous one(s) are left out of the new dominant network. These "angry orphans" (David, [1987] 2005) find that a substantial part of the value they get from the technologies they use is lost (e.g., lack of support from the suppliers). This is what happens in the home video games industry.

Since the emergence of the first dominant design in 1976, hardware manufacturers have a *de facto* standards war about every five years (Gallagher and Seung Ho, 2002). Moreover, firms' strategies aim at increasing consumers' switching costs, which is combined with short hardware life cycles progressing through successive waves of innovation (e.g., Altinkemer and Shen, 2008, Clements and Ohashi, 2005). As a result, many "orphans" are left behind as home video games' technology and industry advance.

Angry orphans are affected by what became known as the "winner's curse" (Thaler, 1988). With incomplete information about the future value of the investment in a video game console, i.e., without knowing if a model will remain the industry standard, the consumer buys it anyway. With the industry dynamics outlined above in place, that standard is eventually replaced, and the hardware loses a significant part of its value, because direct and indirect network effects decrease or completely fade away. The user is deemed to be "cursed" because she/he realises that she/he has overpaid for the product, and is now apparently "stuck" with a piece of useless technology.

But the story does not end here. As mentioned above, users sometimes act as agents of technological change. In particular they have been recognised as playing an important role in technological change both at the initial stages of product development (von Hippel, 1988, Lundvall, 1985), and in exploring new possibilities and purposes for the use of products long after they cease to be commercialised, and that were not thought of when they were first conceived (Lindsay, 2003, Kline and Pinch, 1996). This is what happens with some of the home video games industry orphans.

Video gaming is an emotional experience (Järvinen, 2009, Perron, 2005). It stays with users for long, justifying the increasing popularity of the retrogaming phenomenon today (Rehak, 2008). Moreover, the use of objects that became symbols of the past, such as vintage video game consoles, carries in some cases an aura of prestige, and is connected with a certain type of subculture and way of living (Lindqvist, 1994, p. 284).

This suggests that gamers look back to video games with nostalgia, and do not necessarily feel "angry" about being orphaned because they own old consoles that are technologically obsolete. Even with no support activities from the hardware manufacturers or game developers, these orphans are often "blessed" because they find themselves part of that vintage subculture adamant of the music and graphic design of older games.

In particular, some of those orphans that act as of agents of technological change gather in online communities, developing a specific subculture of appreciators of modifications of obsolete home video games hardware. The activities and behaviours of the users that gather in these communities and conduct hardware modifications are the object of the empirical part of this thesis.

RESEARCH QUESTION

The research question arises in the confluence of the research background, the agenda we set based on it, and the industry we propose to study. We identified a limitation in the literature that opens up a research avenue to be explored, and limited the boundaries of the research to technological change conducted by users of discontinued technologies. We then concluded that the orphans of the home video games industry are a case study for the exploration of that avenue, within the boundaries of the agenda. We will therefore look for answers to the following research question:

What are the characteristics of technological changes made by users of discontinued home video game consoles?

Throughout the thesis we will also answer to a set of subsidiary questions. What is the context and motivations for those changes? What are the new uses they are put to, if any? What influences do they have on the innovation processes of firms? What is the importance of the home video games industry's dynamics in the process?

RELEVANCE AND CONTRIBUTION

Why is it then relevant, and what contributions accrue from studying old technologies and what sorts of things its' current users do with and to them? After all, studying things that lost their momentum long ago and have been apparently forgotten does not seem the province of Innovation studies, nor to bring insights to the field, at first.

The consumption of old products is not a new phenomenon if we consider, for instance that antiques stores and auctions exist for many years now. It is rather the result and part of the complexity and multidimensional character of consumption mentioned at the outset of this introduction: different people have varied needs and wants. In this case, whereas a clear majority of people might be interested in "what is new", there are also those who prefer "what is not so new". So this latter dimension, the one we are interested in, cannot be considered to be "common" either, and yet this fascination with the old (retro, or vintage), has transformed itself into a mainstream and economically relevant phenomenon today (e.g., in fashion and music).

We are not interested in the qualities of old home video games *per se*, though. We are interested in studying the new things people do with them. We describe a particular sort of user-producer interaction, between users and old technology. This is a specific phenomenon, found in subcultures and skipping the logic of the market, at least for the moment, but because of the trend mentioned above, that sort of relation might be happening in other areas, and so firms have something to learn and gain from being aware of these activities, understand their nature, and integrate them in their innovation processes.

In sum, we focus on something which is a not a widespread phenomenon: the study of this revival of the old embodied in a subculture of users conducting technical changes on vintage home video game consoles. However, that becomes relevant because it can be the inception of an innovation later on, with significance from an economic point of view, thus providing insights for the field of Innovation.

1. METHODOLOGY

Stephen Hawking writes in his popular science bestseller *A Brief History of Time*, that a good theory 'accurately describe[s] a large class of observations on the basis of a model that contains only a few arbitrary elements' and defines 'predictions about the results of future observations' (Hawking, [1988] 2008, p. 11). This is to some extent the ambition of this thesis, to contribute with a valid model of analysis for the home video games industry that can be used in other industries with the broader purpose of understanding technological change conducted by users.

In this Chapter we present and discuss the set of methodological issues we defined beforehand to inform the thesis, and achieve the aforementioned goal. They are a contribution to the internal consistence of the thesis, and to understand the scope and validity of its conclusions. First, we present our interpretative framework, and then discuss the data collection process and the limitations of the study we conducted. The operative paradigm of the thesis is presented in the final section.

1.1. INTERPRETATIVE FRAMEWORK

In this section we present the philosophical orientation of our interpretation of the world (ontological approach), and the grounds on which we based our relation with the surrounding reality and the claims made about it (epistemological approach). We then discuss the choice of methodological approach resulting from those two approaches, that is, the processes we used to acquire knowledge about the reality we proposed to study. Finally we describe the stance we kept towards research.

1.1.1. Ontological and Epistemological Approaches

In our view, the world is fundamentally complex by nature, an evolving set of interconnected elements and events that cannot be completely understood or explained. Hence, although we had the ambition mentioned above, we maintained a realistic and self-critical attitude towards our work, and the scope it could achieve. We strived for substantial analyses and explanations of the research problem, yet conscious that this could only be a limited contribution to knowledge, given the complex nature of the surrounding reality.

Taking that into account, we followed a philosophical orientation within the post-positivist paradigm, which claims that reality can only be imperfectly apprehended, contrary to the traditional positivistic paradigm that claims a fully apprehensible reality (Guba and Lincoln, 2005).

Consequently, we kept an objectivistic approach, in what concerns the basis on which we can claim the validity of our knowledge about the world. This reflects that on the one hand reality exists independently of our consciousness, but on the other, that it can be interpreted through sensory perception relying on experimental or quasi-experimental surveys, and rigorously defined qualitative methodologies, as prescribed by our ontological perspective (Denzin and Lincoln, 2005, p. 24). Those procedures are discussed next.

1.1.2. Methodological Approach

To insure the validity of the conclusions of the empirical study, we defined a methodological approach based on a mix of qualitative and quantitative procedures, combined through the technique of "crystallisation" (Richardson and St. Pierre, 2005, Janesick, 2000).

We used Grounded Theory in the qualitative part of the study. This approach it is especially indicated in cases such as ours, where new knowledge was sought in an area where very few or no previous data was available (Goulding, 2002, Strauss and Corbin, 2008). Furthermore, this also allowed us to be in closer contact with the reality, experiences and perspectives of the home video games industry's orphans, and through the analysis of the meanings of their words, thoughts and opinions about their activities, we were able to put forward new insights about the technological change they were responsible for.

To give consistence and objectivity to the qualitative analysis, and broaden the scope of its findings, the study also included a quantitative online survey, focusing mostly on dimensions related to the context and motivations of that technological change.

The data collected through both approaches were combined into a coherent whole as their analysis progressed and crystallised during the process of writing, and therefore writing was also used as a method of inquiry, i.e., to uncover more knowledge about the topic (Richardson and St. Pierre, 2005).

1.1.3. Stance towards Research

An objectivist approach towards reality implies that the researcher's own values and beliefs should be kept aside throughout the research. However, in the realm of social sciences, when qualitative research is at stake, it is argued that the researcher can benefit from drawing on past experiences, because this will help him/her to develop sensitivity towards the focus of research and be aligned with it, and the events and happenings found in the data (Strauss and Corbin, 2008, p. 32).

We followed this idea, drawing on past experiences as video game players to approach and understand the research area and be more sensitive and apprehend better the issues that came up during the process of data collection and analysis (e.g., regarding the jargon and technicalities).

To a certain extent, it was useful to "walk in the shoes" of the video games users we analysed, but this stance could have hampered the desired objectivity, both in the processes of data collection and analysis. Notwithstanding, we strived to maintain our own perceptions, values, and past experiences aside as much as possible in the reflexive debate between them and the data and during the interpretation of the findings. Furthermore, we established a set of criteria to clarify how to collect the data, and what data could be included, as described in the next section.

1.2. Data Collection

The empirical data was collected from databases and websites that constitute "virtual" communities of users that perform modifications (technical changes) to discontinued home video games hardware, a specific case of hardware hacking, and where they publish their projects:

- Retrothing.com. Website dedicated to vintage gadgets and technologies, where readers comment and discuss them.
- Instructables.com. Collaborative community where members upload and download instructions of how to make different sorts of DIY projects, and interact with each other through discussions in the forums.
- Engadget.com. Web magazine covering mostly new, but also vintage gadgets and consumer electronics.

- Hackaday.com. Website dedicated to the publication of a variety of types of technology hacks, where users and readers get the chance to comment and discuss them.
- Benheck.com. Website of a recognised consoles modifier, where users share their projects and interact with each other through a forum.

Those databases and websites were then scanned on the basis of pre-established criteria, to insure that only real cases of technological change, made by "angry orphans" and contributing to the extension of the life cycle of the console in cause were selected. The cases had to:

- Involve technological change, defined as an advance in knowledge embodied in new designs of home video games hardware.
- Use hardware that had been discontinued at the time of the modification.
- Use at least one piece of original hardware, although other items might have been used or added in the modification process.
- Be made by a former or current user of video games, regardless of the platform.
- Be finalised and proven to be operating.

The application of these criteria resulted in a sample comprising 70 cases, made by 59 different users (or "modders"), since some of them were responsible by more than one case (see Appendix B). The qualitative data resulting from this research track consisted of the documents concerning each case, including technical descriptions, photos, and comments of the modders and others in reaction to the projects.

Since those documents focused essentially on the technicalities and uses of the modifications, although some cases also referred to the context and motivations, the analysis of that data alone would result in a narrow scope of the findings, mainly centred on the technical aspects. Therefore, we then conducted an online survey to consolidate some of the aspects that were related, but not clear from that analysis.

After identifying the users responsible by each case, we contacted 50 of them directly, either by e-mail or through messages in the forums and websites, asking for the participation in the survey. The participants were therefore chosen on the basis of having been responsible by at least one case of technological change.

The questionnaire was created using Google Docs Form, and all the questions made compulsory, except for the personal details of the respondents (age, sex and location) (see Appendix C). It was made available online through April 2010, and a total of 20 valid answers were received, representing a response rate of 40%, and corresponding to 24 cases (22% of the sample). The outcome of this survey was a quantitative data set on the context and motivations of the modifications (e.g., video gaming habits, motivations, constraints to the technical changes and the demographics of modders).

1.3. Limitations and Validity

The nature of the data collection and search processes could be somehow limitative for the scope and validity of the findings from the empirical study. We based those processes on the fact that the research subjects were found in the communities mentioned above, and furthermore, a similar procedure had been used before to collect data about users of video games with fruitful results (see Pearce, 2008). Nonetheless, taking into account that there might be users that do not share their projects online, the study could therefore be circumscribed to a very specific phenomenon, and not be representative of all types of users.

Adding to that, we were unable to determine the appropriate sample characteristics (e.g., size and demographics), since no data was found on the universe of users of discontinued video game consoles (angry orphans), nor on the percentage of them that make technical changes to that hardware. Our primary concern was then to find a sample that would portray the phenomena, which was not based on a solid statistical reasoning, but obeyed certain selection criteria.

In any case, given our ontological orientation we can claim that the findings that spur from the data, are valid at least within the scope of the study. Yet, considering our epistemological orientation, and the restrictions mentioned above, we are conscious that they are a provisional expression about the nature of the portion of the world we studied. These are in fact principles that also underlie the process of crystallisation we used to reach those findings:

> Crystallisation provides us with a deepened, complex, thoroughly partial, understanding of the topic. Paradoxically, we know more and doubt what we know. Ingeniously, we know there is always more to know (Richardson and St. Pierre, 2005, p. 934).

The empirical study should thus be seen as a thorough exploration of the characteristics and context of the technological change in which home video games' angry orphans engage and produce. The conclusions made might be narrow in scope, since we do not know to what extent our sample is representative of the universe, but even if that was not the case, given our philosophical orientation, we would maintain that this is an exploration of technological change and not a full description of the whole reality, and the results should be seen within this character.

1.4. Operative Paradigm

The thesis was structured into three parts. The structure was designed to bridge the point from when users of home video game consoles become "orphaned" until the period when they act as agents of technological change on the "old" surviving vintage hardware no longer on the market. Each part fulfils a specific purpose, and we followed different methods and resorted to different sorts of data and information in each one. This section presents the strategies and practices we employed throughout the thesis, as we moved further away from the theoretical paradigms into the empirical world, in the process of answering the research question.

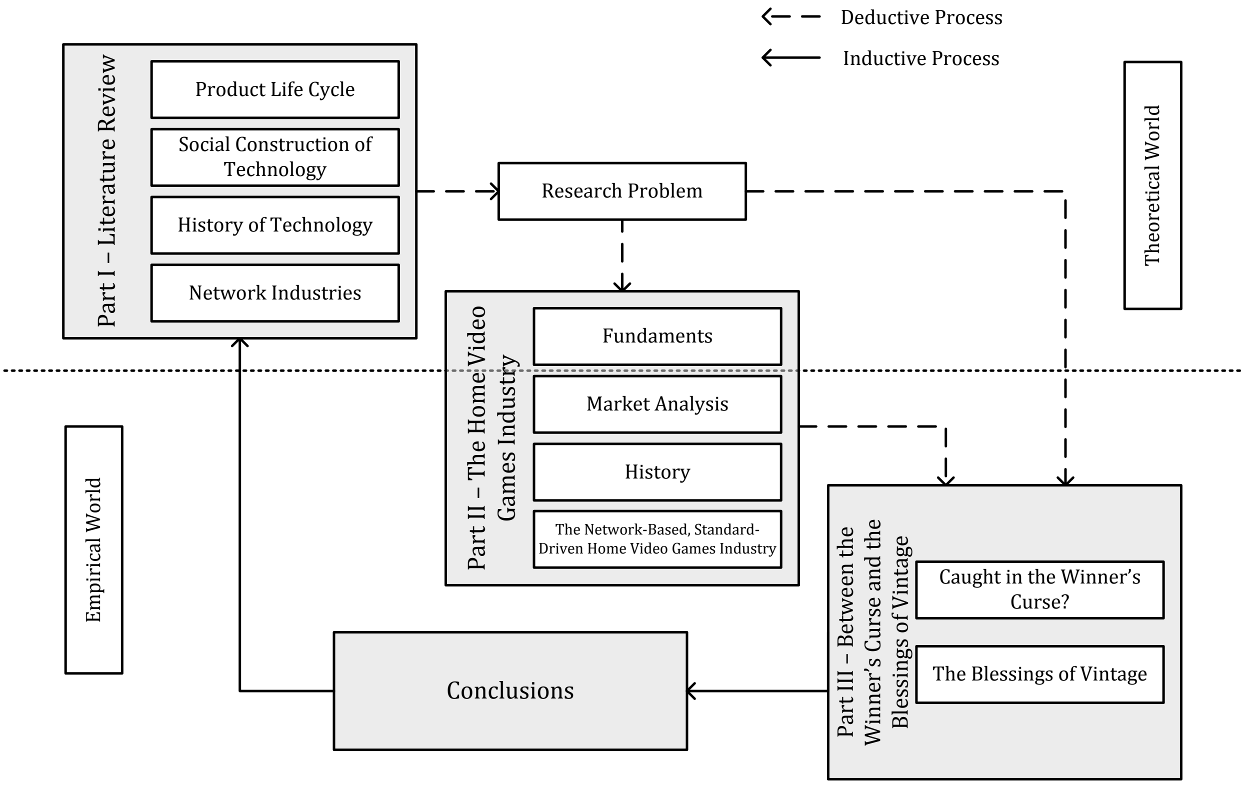
Part I – Literature Review – conceptualises the research problem and presents the possibilities envisaged in the theory to find answers to the research question. This was done through the review of relevant literature in academic journals and books within the areas of Management, Economics, Innovation, Science and Technology Studies and History of Technology.

Part II – The Home Video Games Industry – approaches the research object, outlining the fundamental characteristics and history of the home video games industry, and how its dynamics and the technology impact the users of home video games and the creation of "angry orphans". This was done through a background research based on data and information collected from specialised academic journals, books and online resources.

Part III – Between the Winner's Curse and the Blessings of Vintage – describes the context surrounding the "orphans" of the home video games industry, and discusses the findings from the empirical study we conducted.

The first two parts close the theoretical overview of the thesis. The second part also functions as a connection between the theoretical and the empirical worlds, and the third part is the result of our investigations about the empirical world. Hence, we used the deductive method, looking at the theory to find the origins of the research problem and support our reasoning about it, and from there we took an inductive perspective looking at the facts in the case studies that could contribute to the theory and the research problem. Figure 1.1 sums-up this process.

Figure 1.1 – Research design



Source: own elaboration.

The thesis proceeds as follows. In **Part I** we overview the relevant literature related to the Product Life Cycle, Science and Technology Studies, History of Technology, and Network Industries. In **Part II**, we focus on the home video games industry's fundaments, market data, history, and explain its network-based, standard-driven character. In **Part III**, we assess the context of the angry orphans of the home video games industry, and report the results of the empirical study. Finally, we present the **Conclusions** reflecting on the main issues that resulted from the analyses and discussions in the thesis, and some hints for further research.

Part I Literature Review

Dogan and Pahre (1989) claim that the increasing fragmentation of social sciences promotes the cross-fertilisation and hybridisation of disciplines, and is a fruitful way to produce new insights with the knowledge from individual subjects. That notion is complemented by Gardner (2009, pp. 45-76) who recognises that the production of new knowledge is linked with the development of a *Synthesizing Mind*, the idea that the ability to survey a range of different sources and disciplines, and moreover the capacity to integrate them into a coherent whole, is crucial for those aiming at developing new knowledge.[1]

In praise to the virtues of combining different areas of knowledge, we integrate four theoretical perspectives that inform the theoretical paradigm within which this thesis operates: Product Life Cycle, Science and Technology Studies, History of Technology and Network Industries. These paradigms serve three purposes.

First, they frame the research problem. Kuhn ([1962] 1974) defined scientific paradigms as 'universally recognised scientific achievements that for a time provide model problems and solutions to a community of practitioners' (p. viii), which later become the genesis of a number of new problems (p. 10). Taking into account this perspective, in **Chapter 2** we probe into the limitations of the Product Life Cycle paradigm to identify our research problem.

Second, they are promising alternatives to find answers for the problems and limitations in the Product Life Cycle paradigm. Karl Popper, quoted by Hawking ([1988] 2008, pp. 19-20) refers that a paradigm is not a rule that can be followed mechanically, but a resource that should be used. With this in mind, in **Chapters 3** and **4** we rely on contributions and developments from the Science and Technology Studies and the History of Technology.

Third, considering that the thesis focuses on the network-based home video games industry, we frame the understanding of this type of industries at a more abstract level in **Chapter 5**.

The reader may be surprised by the eclecticism of the contributions included. However, the unity of the theoretical approaches is made clearer towards the end of this part. At this point, we stress that according to the agenda defined in the introductory section, the common perspective through which we discuss these theoretical contributions are the implications that can be drawn to technological change, users, or both.

[1] The Synthesising Mind is part of a "cultivation of the five minds" – the Disciplined, Synthesizing, Creating, Respectful and Ethical minds – that Gardner (2009) puts forward as a metaphor for the ways one should behave to thrive academically and professionally.

2. Product Life Cycle

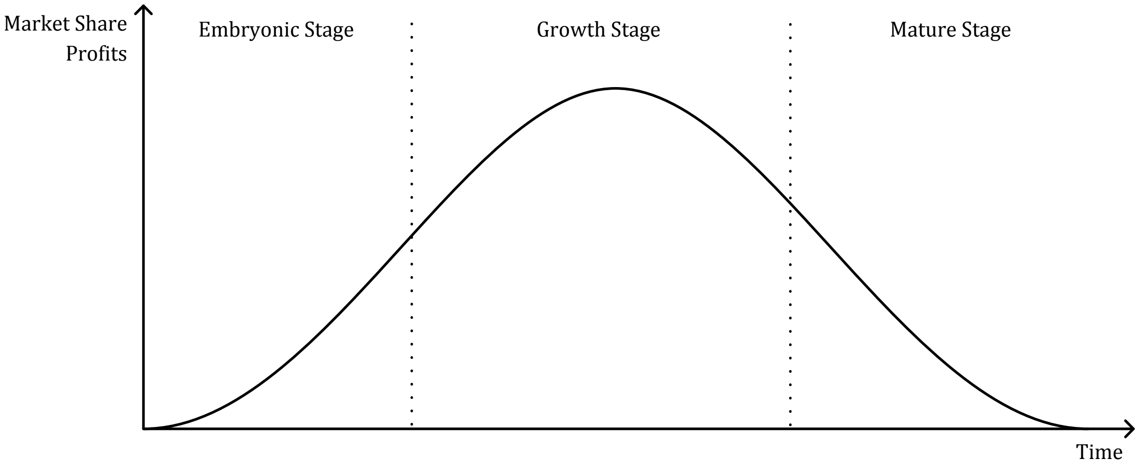
In abstract terms, a life cycle refers to the different stages of development of an organism, from birth to death. The concept can be used metaphorically to describe the evolution of something, and in business, the metaphor is concretised in the Product Life Cycle (PLC) model.

This Chapter explores the evolution of that model. First, we discuss the original model and subsequent refinements made to it. We then present two complements that stem from the limitations in the original model and are crucial to this thesis – the question of technological limits and the importance of the social dynamics of technological change.

2.1. The Model

The PLC model was originally developed in the marketing literature as a tool to understand how firms could exploit the perceived evolution patterns of new industries to their advantage, both within the domestic market (e.g., Levitt, 1965, Dean, 1976), or internationally (e.g., Vernon, 1966) within three stages: exploratory or embryonic, intermediate or growth, and mature (see Figure 2.1).

Figure 2.1 – Product life cycle



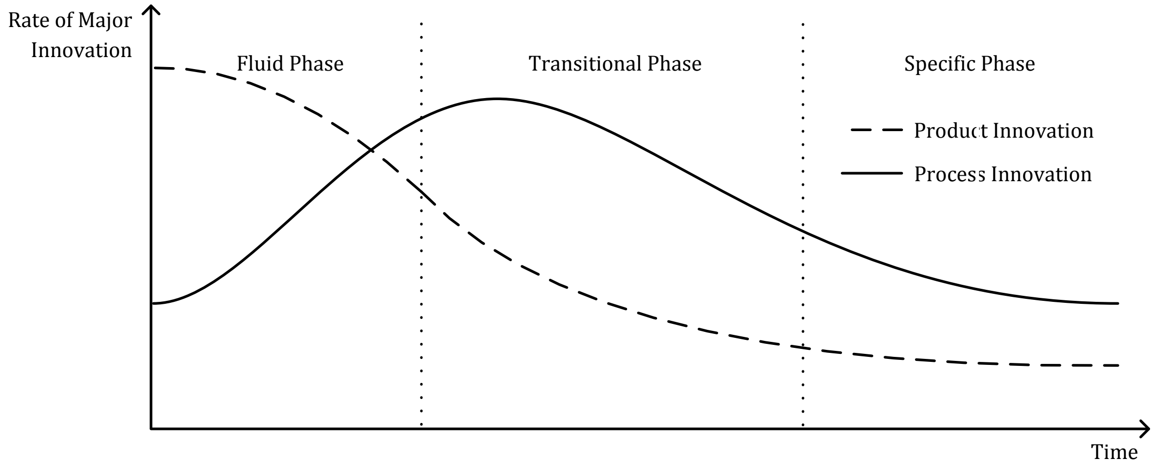
Source: own elaboration, based on Levitt (1965).

Later on, Utterback and Abernathy (1975, 1978) incorporated a stage model of the evolution of industrial innovation along the PLC – a fundamental insight that depicts the interplay between the dominance of product and process innovation at different moments (see Figure 2.2, next page). With this addition, the PLC could now describe the properties of markets (industries) in terms of number of firms (entry and exit patterns), rate and type of innovations (new or improved products), and market shares and profits during a period of time.

In the first, exploratory or "fluid" stage (Abernathy and Utterback, 1978), a new product is introduced on the market, though there may not be a proven demand for it, because market needs are often not clear at this point yet.[2] Since not all technical aspects (including those of production) have been optimised and finalised, there is a high degree of technological uncertainty. Therefore, sales tend to grow slowly, but they eventually take-off, and as demand accelerates, profits increase, and more companies are attracted to the market.

[2] Hence the importance of *lead users* for the early understanding of future consumer's needs (von Hippel, 1986), a subject we return to in Section 3.2.

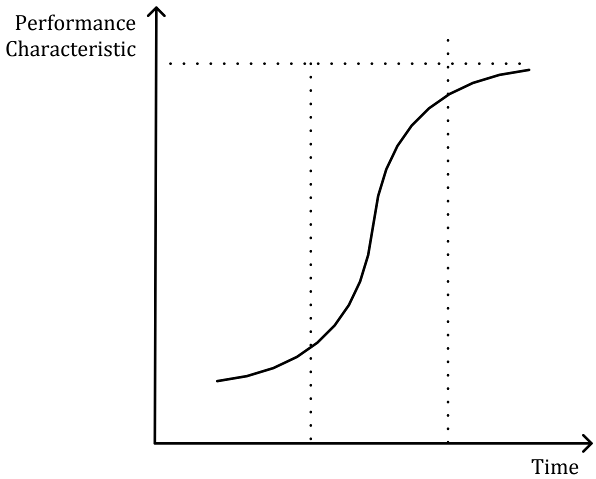
Figure 2.2 – Rate of product and process innovation



Source: Utterback (1994, pp. 82-83).

Product innovation is intense as firms try to explore the new technology in diverse ways. The technology branches off in multiple directions, yet within certain boundaries. At this point the notion of technological trajectory is important, emphasising the physical constraints to the level of experimentation a technology can undergo and the direction this can take (Dosi, 1982). This is usually depicted as an S-shaped curve, a complementary analytical tool to the PLC, describing the trajectory of a single technology (see Figure 2.3).

Figure 2.3 – Technology s-curve



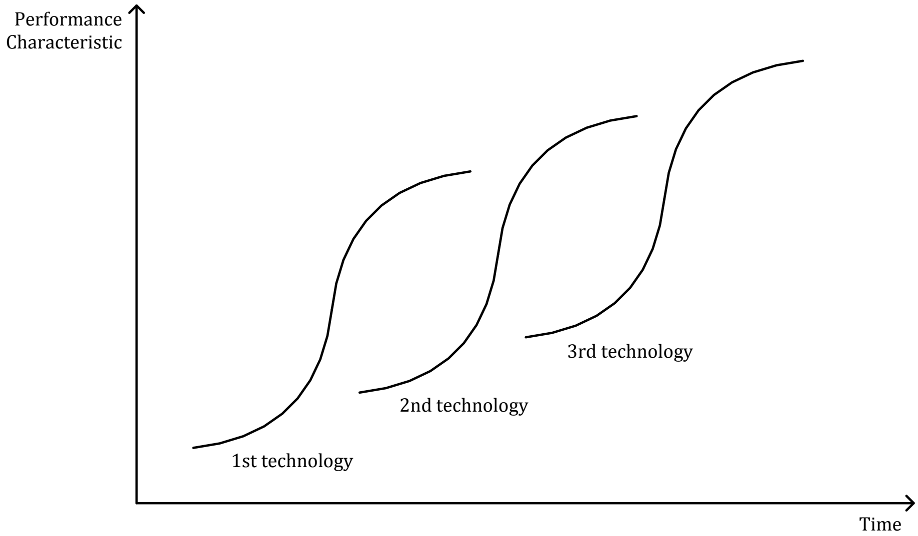
Source: own elaboration.

At the growth or "transitional" stage (Abernathy and Utterback, 1978), the basic characteristics of the product are more defined, and as such the design stabilises. Market needs become more explicit and the technological uncertainty diminishes with the crystallisation of the trajectory. Companies tend towards it, and a dominant design emerges, the architecture that 'wins the allegiance of the marketplace, the one that competitors and innovators must adhere to if they hope to command significant market following' (Utterback, 1994, p. 24).

Since product characteristics are clearly defined now, the production process can be standardised, so firms benefit from increasing returns from adoption. Hence, process innovations become relatively more important than product innovations, which at this point occur only incrementally within the dominant design. Competition is now based on price, causing firm entry to slow down and eventually a shakeout, as less efficient firms become unable to compete within the narrower trajectory.

At some point, the industry reaches the mature or "specific" stage (Abernathy and Utterback, 1978). Market shares stabilise, output growth slows and demand decreases. Over time, the possibilities of the current technology are exhausted and new entrants introduce substitute products, usually technologically superior. This technological discontinuity, initiates a new competitive cycle (see Figure 2.4).

Figure 2.4 – Evolution of established and disruptive technologies



Source: adapted from Christensen (1992).

The competences of incumbent firms may also be undermined, since new entrants often shift the technological base on which the industry competes (Tushman and Anderson, 1986, Anderson and Tushman, 1990), through the introduction of a disruptive technology (Bower and Christensen, 1995). Consequently, when the paradigm changes, incumbents have to 'start (almost) from the beginning in the problem-solving activity' (Dosi, 1982).

Such cycles can last months, years or decades, or have no determined ending. They involve at least one firm and in theory there are no upper limits to the numbers of firms that can be engaged in the process. The model can be applied to different levels of technological complexity, yet the drivers of technological progress, bases of design dominance, and social, political and organisational dynamics vary accordingly (Tushman and Rosenkopf, 1992).

One can say that this is a rather arbitrary and at the same time stylised approach to analyse the market. On the one hand, there are not clear definitions of the boundaries of the stages and the criteria for each one; on the other all industries seem "obliged" to follow the same evolution and there is limited role for learning. In straight terms:

> initially the market grows rapidly, many firms enter, and product innovation is fundamental, and then as the industry evolves output growth slows, entry declines, the number of producers undergoes a shakeout, product innovation becomes less significant, and process innovation rises (Klepper, 1997).

Notwithstanding, the PLC is a recurrent pattern in a wide range of industries and products, as revealed by several empirical studies. Gort and Klepper (1982) systematically examine the history of several products, confirming that configuration. Relying on a rather historical and descriptive analysis of the typewriting industry in the US, Utterback (1994, pp. 1-21) accounts for several of the aspects described above: the process of dominant design crystallisation, firm entry and exit patterns, and the existence of intertwined "innovation waves", triggered by the introduction of disruptive technologies (e.g., the PC in that case). Klepper (1997) describes similar findings in the US automobile industry. Furthermore, such patterns also occur in the home video games industry, as we shall see in detail later (e.g., Clements and Ohashi, 2005, Altinkemer and Shen, 2008).

There is thus sufficient evidence demonstrating the PLC's significance to explain the industry's dynamics described above:

> The initial question addressed was whether this depiction [of industries proceeding through distinct cycles or stages as they age] captures the way a number of industries evolve. The answer, which can now be related, is a qualified yes (Klepper, 1997).

From the perspective of this thesis, however, the model presents an additional shortcoming: it closes the problem of the technological limits at an early stage. This might be related with the fact that the model primarily aims at describing the period from the introduction of a product until its withdrawal from the market. Nonetheless, what occurs with products and technologies after they reach the maturity stage is left out of the scope, and furthermore the length of time the product may remain in use after withdrawal is disregarded.

After all, people did not stop using their cars because commercial air travel became widely diffused, nor because a new model is introduced on the market. Hence, one must reflect on whether there are limits to the evolution of a technology, particularly because they are sometimes being used long after the period described by the PLC. The notion of technological limit is therefore explored in the next section, as an attempt to understand how the scope of the PLC can be extended.

2.2. Challenging Technological Limits

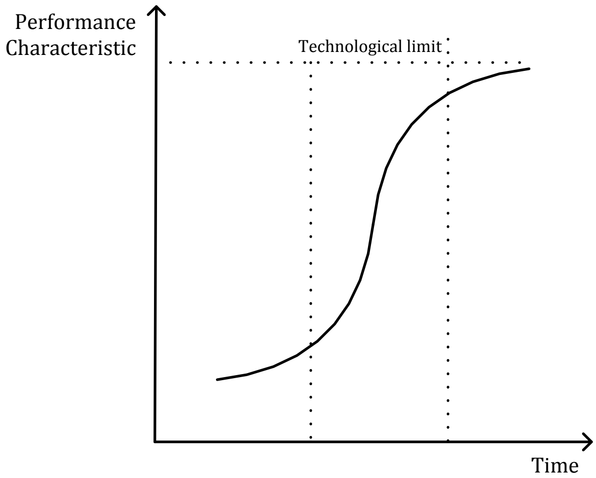
As mentioned in the previous Section, the S-curve plots the progress of a technology trajectory through time. Christensen (1997, p. 39) describes this progress in simple terms:

> [...] in the early stages of a technology, the rate of progress in performance will be relatively slow. As the technology becomes better understood, controlled, and diffused, the rate of technological improvement will accelerate. But in its mature stages, the technology will asymptotically approach a natural or physical limit such that ever greater periods of time or inputs of engineering effort will be required to achieve improvements.

That implicitly means that in the early stages of development, a technology operates below its potential. Over time, performance improves, first through small steps, eventually accelerating in result of users' and designers' accumulated experience (learning), so it is difficult to foresee at that initial stage what the full potential of a technology is going to be. In any case, technological improvement does not occur indefinitely, it has a limited potential, given for instance constraints in the amount of available knowledge, engineering and financial effort, competition with other technologies, and the physical characteristics of the technology.

Hence, improvements in the characteristics become increasingly harder to achieve, as a technology approaches its limit (see Figure 2.5).

Figure 2.5 – Technological limit



Source: own elaboration.

These patterns have been found in a range of technologies, as diverse as microprocessors, computer hard drives, fertilisers, light bulbs, and jet engines (Asthana, 1995). Nonetheless, empirical evidence also demonstrates that in some circumstances technologies can be pushed further to transcend the limits, confirming the idea that "old" technologies continue to be improved, postponing the time when they become "clearly outmoded" (Rosenberg, 1972).

Utterback (1994, pp. 145-166) describes the improvements caused by successive discontinuities in the ice and refrigeration industry in the US. Initially, ice harvesters were forced to refine the production, storage, and distribution system in response to the threat from the cheaper plant-made ice. Then the efficiency of ice boxes was further improved when competition came from home electric refrigerators.

Christensen (1992) suggests that one of the reasons why incumbents in the disk drive industry were able to outcompete established firms, was the fact that they were more capable of taking both the existing technologies, and the ones resulting from the need to push the conventional limits of physical laws to the market, which led to dramatic and unexpected improvements in the performance of individual components.

Particularly interesting is Henderson's (1995) analysis of the photolithographic alignment technology. The author shows that the limits of a technology are influenced not only by the structure of the dominant design, and the approximation to the limits of materials imposed by the laws of physics. They also depend on the evolution of key complementary technologies, and more importantly, on the needs and preferences of the users.

The cases mentioned above suggest that the PLC model depicts only a part of the cycle, because technologies (products) can, under certain circumstances (e.g., due to external competition), exceed their technological limits, therefore postponing the otherwise "inevitable" maturity and declining stage. Furthermore, technology limits are not determined only by the intrinsic characteristics of the technology.

Adner (2004) criticises this mainstream approach to technology life cycles, because it leads to misleading interpretations of the factors influencing the dynamics of technological evolution, given the emphasis on the production side and on the innovations firms introduce, neglecting users' evaluation and actions. Therefore, he argues that:

> a better understanding of technology evolution [...] requires a better understanding of the interactions between technology and the demand environment in which it is deployed (Adner, 2004, pp. 39-40).

Reviewing empirical evidence, Tushman and Rosenkopf (1992, pp. 311-12) found support for the view that the dominance of particular technological designs cannot be accounted on the basis of technological factors only, calling for a broader scope of the analysis of technological change, focusing on the social dynamics that influence it:

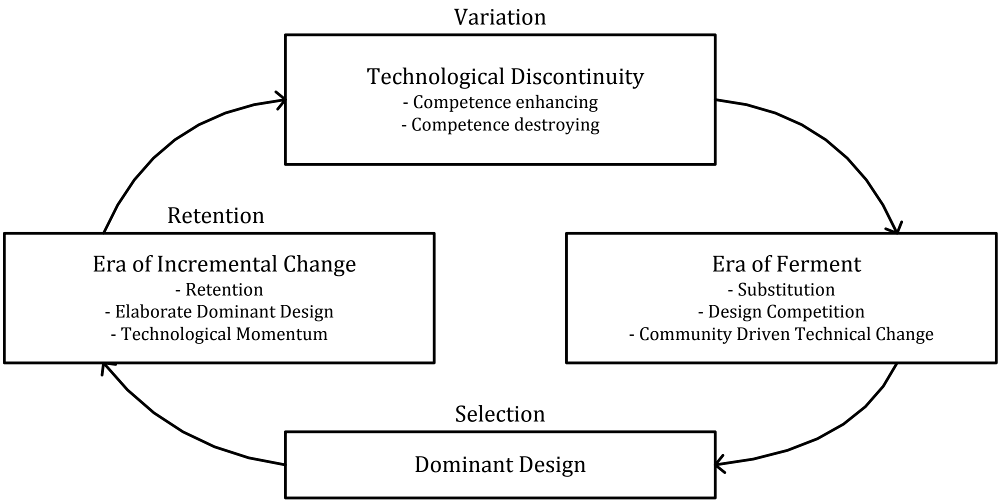
> Rather than reviewing technology as an autonomous force or as driven by an elite set of organizations, we argue that technologies evolve through the combination of random events, the direct action of organizations shaping industry standards, and the invisible hand of multiple competing organizations in a technological community. [...] This approach to technological change suggests that technological evolution is driven by a combination of technical, economic, social, political, and organizational processes.

In the next section we take this perspective and look at the social dynamics of technological change, which also contribute to the extension of the technological life cycle, i.e., to extend the PLC, as we shall see later in Chapter 3.

2.3. Social Influences on Technological Change

Tushman and Rosenkopf (1992) developed a four-stage cyclical model of technological change, based on evolutionary mechanisms (variation, selection and retention), widening the scope of the sources of technological change (see Figure 2.6).

Figure 2.6 – Technology cycle



Source: Tushman and Rosenkopf (1992).

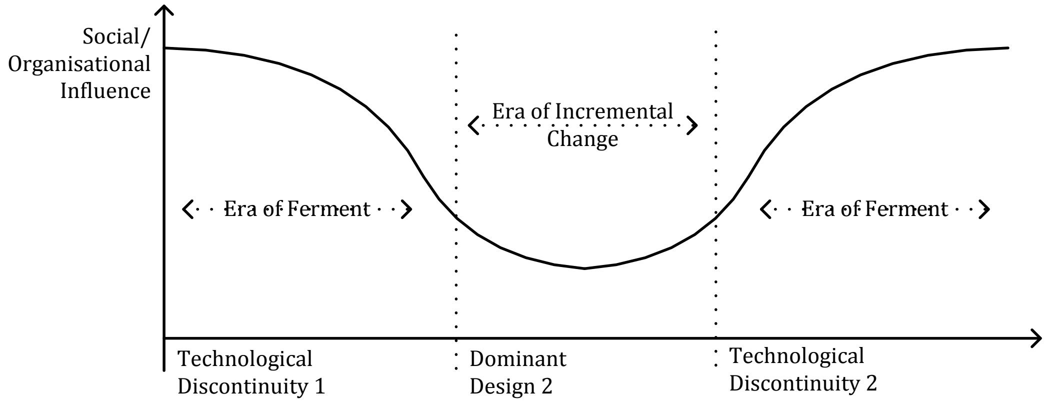
In this broader model of technological evolution, variation is ignited by a technological discontinuity, leading to an "era of ferment" – corresponding to the exploratory or embryonic stage – where several technologies compete within the community that promotes technological change (users and firms, individually or in groups). Eventually a dominant design emerges, shaped by the socio-political processes that select a technology from the technical/economic options available, and retention takes place in a process of 'compromise and accommodation between suppliers, vendors, customers and governments' (Tushman and Rosenkopf, 1992, p. 322). This corresponds to the growth stage of the PLC.

An "era of incremental change" follows, and 'critical problems are defined, legitimate procedures are established, and community norms and values emerge from the interaction between interdependent actors' (Tushman and Rosenkopf, 1992, p. 323). Here there is thus an interaction between several types of actors and not just companies in the definition of the dominant design.

Market matures, and the aforementioned processes remain retained in the community, which continues adamant of the existing paradigm. This inertia is broken through another stage technological discontinuity, although the impetus comes usually from outside the established community, which is otherwise conservative to change. Eventually another period of variation follows, and the cycle repeats itself.

In this model, industries' dynamics are thus similar to those of the conventional PLC framework, and to some extent, one can even point out the same problems as in the previous model. However, on this occasion organisational dynamics are complemented with socio-political factors, which vary according to the stage the industry finds itself in (see Figure 2.7), allowing for a better understanding of the influences on technological development.

Figure 2.7 – Social and organisational influences along the technology cycle

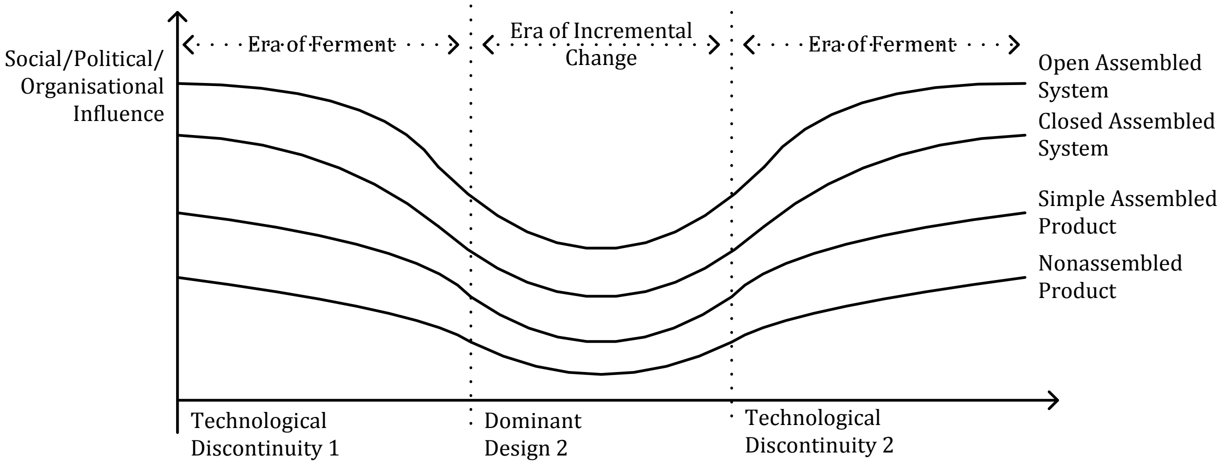


Source: Tushman and Rosenkopf (1992).

Another important aspect of this model is that the prominence of nontechnical determinants of technological change also varies with the level of technological complexity (see Figure 2.8, next page):

> The more complex the product, the more subsystems, the greater the number of internal and external interfaces, the greater the technical and contextual uncertainty. The greater these uncertainties, the greater the intrusion of socio-political dynamics in the technology's evolution (Tushman and Rosenkopf, 1992, p. 340).

Figure 2.8 – Social, political, and organisational influences along the technology cycle, according to the complexity of technology.



Source: Tushman and Rosenkopf (1992).

Home video game consoles can be thought of as closed assembled systems because they are made up of 'a set of component subsystems or simple products [e.g., microprocessor, motherboard] that are linked together through linkage and interface technologies [e.g., software]' that interact with each other (Tushman and Rosenkopf, 1992, p. 331). Assuming such a classification, their technological evolution is thus prone to be highly influenced by social, political, and organisational factors.

We have seen that there is evidence supporting the patterns depicted by the PLC model, yet sometimes technologies remain in use long after that, challenging the technological limits predicted by the S-curve, and the "tragic fate" of being condemned to disappear at some point.

In face of this, we are arguing that the importance of the established PLC model should be acknowledged, but that one must look further and depart from it to be able to describe an existing reality that is not fully embraced at the moment. To do this, we look elsewhere for contributions that are discussed in the next two Chapters.

First, following Henderson's (1995) suspicions that '"normal" technical evolution may be quite "socially constructed", in the next Chapter we discuss contributions from the field of Science and Technology Studies that have proven useful to study the way the social domain shapes the evolution of technology, and in particular the roles users play in it.

After that, we look at the ways principles from the History of Technology can be convenient to explore the entire life cycle of a technology, beyond the traditional PLC picture

3. Social Construction of Technology

Science and Technology Studies (STS) draw on a variety of perspectives (e.g., sociology, history, philosophy, anthropology) to study the active *social* processes and outcomes of science and technology (Sismondo, 2010, p. 11). We are interested here in the technological "half" of STS, i.e., its contributions to the analysis of technology. We begin by presenting the Social Construction of Technology (SCOT) framework. After that we analyse the importance of users as agents of technological change within this approach. In the final Section we discuss the technological shaping of technology. Along the way, some links with contributions from the field of Innovation are made as well.

3.1. The SCOT Framework

The foundations of the SCOT perspective were laid by Trevor Pinch and Wiebe Bijker in the 1980s, referring to the way in which relevant social groups involved with a technology (institutions, organizations and groups of individuals) construct their interpretations of that technology according to the different meanings they attribute it as a group (Pinch and Bijker, 1984).

Those different interpretations and meanings evolve with time, a phenomenon Pinch and Bijker call *interpretative flexibility*, until a predominant use and context for the technology emerge for the group. In fact, Rosenberg (1972) notes that 'most inventions are relatively crude and inefficient at the date when they are first recognized as constituting a new invention… [and] …it seems to be extraordinarily difficult to visualize and to anticipate the uses to which an invention will be put'. Therefore, the acknowledgment that the meanings attributed to a technology change and evolve, is the recognition that 'no technology – and in fact no object – has only one potential use' (Sismondo, 2010, p. 98).

This can be exemplified focusing on two relevant groups from the home video games industry, the children that play video games, and their parents; and on the object of interpretation, usually the video games console. For the first group, that artefact might be used mainly for entertainment. For the second group, it may be seen as a complement to education and teaching. These two groups have thus different (flexible) interpretations of what the console means for them and the way of using it.[3]

These different interpretations are thus utilised to explain and understand why and how a technology evolved the way it did, with reference to the influences from the relevant social groups that interact with it.[4] However, that is not an open-ended process. Based on the development of the bicycle in the nineteenth century, Pinch and Bijker (1984) specified two closure mechanisms through which interpretative flexibility is curtailed, as technology stabilises towards a dominant design, its problems are addressed and a predominant meaning and use emerge. First, *rhetorical closure*, through which relevant social groups have the *perception* that the problems are solved. Second, *closure by redefinition* of the key problem 'to which the artefact should have the meaning of a solution' (Pinch and Bijker, 1984).

[3] Video consoles' interpretative flexibility can look quite limited at first, in line with the suggestion that 'designed objects are becoming increasingly specific, increasingly closed: they can be used or not, rather than used for a variety of purposes' (Mackay and Gillespie, 1992). Yet, as shall be seen in Chapter 11, that this is actually not the case.
[4] According to Pinch and Bijker (1984), the analysis of the consensus about the stabilisation of meanings and uses of a technology is only partial in some cases, because it may be impossible to analyse all the relevant groups involved.

A recurrent problem in the home video games industry is the content rating of software (games). Exposure to violent or otherwise inappropriate content is perceived as a problem by parents with regards to their children (Cragg et al., 2007, pp. 86-97). An example of rhetorical closure is the ratings that accompany the games, so that parents *perceive* this is a problem that they can at least monitor.[5] An example of the second closure mechanism can be seen in the problem of physical inactivity in video games, which are perceived as defective to a healthy lifestyle. Attempting to *redefine* the problem, manufacturers are now releasing games where players engage in physical activity (e.g., sports and dancing), and advertise this as an advantage, so the artefact has also a meaning of solution to that problem.

Hence, in the SCOT analysis there is a broader perspective of the factors influencing the success of a technology. Technological change is not just driven by producers. It is also largely dependent on the strength and size of the group that embraces and promotes it. The approach was nevertheless criticised on several aspects.

One of the problems was the lack of reference to the structure and power of social relationships within which the development of technology takes place (Russell, 1986). According to Russell, this should be done by including users' relations not only with technology, but also with the economic, political, ideological and historical constraints that also influence the interpretations and the options available to them in the relation to the technology (e.g., in being a developer, adopter, operator, or consumer).

The two other points of criticism towards the SCOT approach have special relevance to this thesis, and are closely related with those discussed in connection with the PLC framework (see Sections 2.2 and 2.3, respectively). First, the initial formulation of the SCOT focused exclusively on the design stages of technologies, closing the question of users' interpretations at an early stage, and devoting little attention to the ways they actively appropriate and modify stable technologies (Mackay and Gillespie, 1992). Second, by putting so much emphasis on the influence the social has over the technological, 'the valid aspect of technological determinism: the influence of technology upon social relations' is neglected (MacKenzie and Wajcman, 1999, p. 23).

In the next two sections we analyse how the SCOT approach addresses those two problems: on the one hand, the need to broaden the scope of the limits of a technology, on the other the interplay of different influences on technological development.

3.2. Users as Agents of Technological Change

Users are not merely passive consumers of technologies, something anticipated in Section 2.2 in connection with their importance in the expansion of technological limits. Mackay and Gillespie (1992) refer to this, on the grounds that

> People are not merely malleable subjects who submit to the dictates of a technology: in their consumption they are not the passive dupes suggested by crude theorists of ideology, but active, creative and expressive – albeit socially situated – subjects. People may reject technologies, redefine their functional purpose, customize or even invest idiosyncratic symbolic meanings in them. Indeed they may redefine a technology in a way that defies its original, designed and intended purpose.

[5] Ratings are usually published by non-profit organisations such the Entertainment Software Rating Board (see www.esrb.org).

The authors go further and describe a number of occasions where the 'double life' of technologies driven by the actions of users can be seen:

> [...] home personal computer use has ended up being largely for non-utilitarian purposes; early cassette recorders were intended to be used for playing pre-recorded tapes, but were generally used for recording from records; scratch music involves moving a record deck backwards and forwards at discos; video is used to make films as well as to watch them at home, and even within the home, use goes beyond the designers' intentions in that video is used predominantly to 'time shift' television [...] (Mackay and Gillespie, 1992).

Those are examples of the several roles users play not only in the consumption, but also on the modification, domestication, design, reconfiguration and resistance to and of technologies, bringing to bear on them purposes other than those originally intended by the technology's designers and marketers (Oudshoorn and Pinch, 2003).

That broader view of users' freewill was not taken into account in the original formulation of the SCOT, and later on, Kline and Pinch (1996) addressed the question, extending the scope of users' activities within the approach. They analysed the adoption of the car in the rural United States in the first half of the twentieth century. By then, the car was a technology with rather stabilised meanings and uses in urban communities. Notwithstanding, the authors found that in rural areas users were still introducing a series of modifications to adapt the car to the needs of rural life. People customised the machines to do things like grind the grain, plough the fields, or carry the produce to town, which could not be done had they not reinterpreted the technology.

Users were thus dubbed "agents of technological change", and the scope of the SCOT approach extended, to incorporate the roles they play in the development of stabilised technologies. This extension accommodates an idea not fully explored in the original formulation of the approach: new problems, and by consequence interpretative flexibility, can emerge at all times from new, emerging, relevant social groups. This is an important point that allows the extension of interpretative flexibility to the use stage of a stabilised technology, and not only at the initial design stages, an idea close to the notion of challenging technological limits (see Section 2.2).

Similar findings are reported in a study about the users of the TRS-80 computer, although the purpose was to uncover the different representations users assume after a technology is discontinued (Lindsay, 2003). Released in the late 1970s, the TRS-80 was still being kept alive by its existing users almost 25 years after it was discontinued by Radio Shack in 1984. Much beyond its expected obsolescence, and with all kinds of support withdrawn by the manufacturer, users took on the roles of designers, producers, marketers, and technicians – agents of technological change – not only 'further developing the technology, but [...] also defining their identities and constructing new ideas of what it means to be a user of the TRS-80' (Lindsay, 2003, p. 29).

The conceptualisation of users as agents of technology change can thus be linked to the works of von Hippel (1988), Rosenberg (1982) and Lundvall (1985) within the realm of Innovation studies. Von Hippel's main point is that from a functionally distributed perspective of the sources of Innovation, the phenomenon of users contributing to the innovation process – acting as agents of technological change – is rather frequent (von Hippel, 1988). In many instances the largest share of the innovation process is carried out by the user, who 'recognizes the need, solves the problem through an invention, builds a prototype, and proves the prototype's value in use'; the commercial application and diffusion are then carried out by the manufacturer (von Hippel, 1988, p. 25).

Rosenberg (1982, pp. 120-140) discusses the importance of the feedback from the experience of use into the design and way of operating products – learning by using. The feedback from that learning takes place through small and gradual changes that eventually add up leading to changes in design, and productivity, and where 'the participation of the user in the process of making technological improvements is one of the critical features' (Rosenberg, 1982, p. 135).

These ideas seem to have been synthesised in the user-producer interaction discussion (Lundvall, 1985), and their core can also be found on the extension of the SCOT framework (Kline and Pinch, 1996), because many of the particular adaptations, improvements and extensions made by the rural automobile users were taken up by car and parts manufacturers and transformed into new products (e.g., new vehicles such as trucks and vans) or introduced in existing ones (e.g., adapting kits for horse power usage).[6]

The perspective that users act as agents of technological change as described in the extension of the SCOT approach is central for this thesis, because it recognises the several ways in which users contribute to the development of "old" technologies, that is, how they attribute new meanings to a technology that has long reached a phase of closure. Furthermore, just as in the TRS-80 case, such contributions often come from groups of enthusiasts and hobbyists:

> One of the remarkable characteristics of technological improvement over the past century or so has been the role played by enthusiasts and hobbyists. The irony of this is that it has typically been in technological realms of great complexity that such individuals have had their greatest influence. E.g., automobile, wireless telegraphy transformed into "radio", and the personal computer (Friedel, 2007, p. 513-514).

Therefore, by using the perspective of users as agents of technological change one can demonstrate that technologies live much after the "normal" life cycle, challenging technological limits, as hypothesised in Section 2.2, and contribute to address the limitations of the PLC model discussed in Section 2.1, while incorporating the social dimension in the discussion of the influences on technological evolution highlighted in Section 2.3.

3.3. Technological Shaping of Technology

Another point of criticism towards the SCOT approach, is that it disregards the influence of technology on society, a notion rooted in the idea that technology is *also* influenced by itself and therefore, that technological change might also follow an autonomous logic, and impact the society "from the outside", as we have seen before.

Dosi's (1982) contribution is also important here, because the author asserts that technological paradigms embody "strong prescriptions" that serve as boundaries of technological trajectories that progress within it through the cumulative retention of technological advances. Along these lines, Sahal (1985) argues that innovation processes are constrained by the limitations of the relation between the functional performance of a technology and its size and structure and that therefore evolve upon 'bit-by-bit modification of an essentially invariant pattern of design'

[6] This reverts again to von Hippel's work, and the importance of *lead users*, early adopters of a new technology that becomes widely diffused (von Hippel, 1986). In the case of Kline and Pinch's study, the rural users, made substantial innovations that were a valuable source of data for firms to anticipate future product development needs.

As noted by Dosi (1982):

> [...] technological paradigms have a powerful exclusion effect: the efforts and the technological imagination of engineers and of the organizations they are in are focussed in rather precise directions while they are, so to speak, "blind" with respect to other technological possibilities.

Hence, technical change stems from the need to overcome the limitations of existing technology in a non-haphazard fashion, i.e., within the technological trajectory: technological evolution is path-dependent; it influences itself, what MacKenzie and Wajcman (1999, pp. 9-11) call the "technological shaping of technology".

That is an argument that might be at the root of the notion of technological determinism, a concept criticised, and at the origins of the SCOT and other affiliated approaches (Williams and Edge, 1996). The central idea of technological determinism is that 'material forces, and especially the properties of available technologies, determine social events… [and that therefore] …technological changes force social adaptations, and consequently constrain the trajectories of history' (Sismondo, 2010, p. 96).

The concept involves two parts: technological developments occur independently of social, economic, and political forces, and technological change causes or determines social change (Wyatt, 2007, p. 168). In a nutshell, since technology enables human action, 'people act in the context of available technology, and therefore people's relations among themselves can only be understood in the context of technology' (Sismondo, 2010, p. 9).

Nonetheless, as seen before, the social realm influences technology decisively, which means that a balanced stance should be kept when discussing the nature of technological evolution:

> it is mistaken to think of technology and society as separate spheres influencing each other: technology and society are mutually constitutive (MacKenzie and Wajcman, 1999, p. 23).

This is a balance we strive for in this thesis. While Part II is deliberately influenced by the idea of technological determinism, in particular the effects of the home video games technology have on its users, Part III goes along the argument that "old" technology is shaped by the social sphere, in particular by its users, acting as agents of technological change.

In the next section we search for perspectives from the History of Technology, which also contribute to understand the importance of "old" technologies and its users.

4. History of Technology

So far we have made references to "old", "obsolete" and "discontinued" video game consoles and other technologies. These adjectives incorporate a common notion, the notion that technologies do not just appear in a vacuum, but are preceded by a history.

In this Chapter we start by discussing the need to depart from the traditional notion of history of technology. Afterwards, we discuss how the analysis of technology in use contributes to a better understanding of the whole life of a technology, by emphasising the importance of the latter stages of its existence, as in the case of the SCOT.

4.1. From an S-curve-based Analysis...

Lindqvist (1994) argues that historians usually approach technology in a rather narrow perspective, because they are mainly concerned with technological growth, in particular the initial periods of rapid growth, instead of considering the ensemble of existing technologies at any given time, what he calls the "technological landscape". This view is shared by Edgerton (2007, pp. xiv-xv):

> Innovation-centric history focuses on the early history of some technologies which become important later. The history of invention and innovation needs to focus on all inventions and innovations at a particular time, independently of their later success or failure. It needs to look too to invention and innovation in all technologies, not just those favoured by being well known and assumed to be the most significant.

In the same line, Rosenberg (1982, p. 19) notes that historians of technology, and economists alike, seem to be "fascinated" with things that change rapidly, rather than with things that simply exist and remain:

> [...] many historians, even economic historians, have focused their attention overwhelmingly upon one aspect of the question of technical progress: "Who did it first?". [...] Such questions are, indeed, important to the history of invention. Much less attention, however, if any at all, has been accorded in the productive process. Indeed, the diffusion process has often been assumed out of existence. This has been done by identifying the economic impact of an invention with the first date of its demonstrated technological feasibility or – what is hardly the same thing – the securing of a patent.

Consequently, a wealth of landscape has been left "undiscovered" by historical accounts of technology. In particular the relatively more permanent technological structures which seem less interesting *a priori*, or fundamental questions about their mature and declining stages of existence such as routine maintenance and dismantling. That 'could form a fruitful point of contact between the history of technology and other disciplines, e.g. economics' (Lindqvist, 1994, p. 272), as is the case of Edgerton's portrayal of the unexpected connections between maintenance and mass production, large-scale industries, and innovation in the automobile and aviation industries, and the longevity of war technologies such as bombers, expanded due to the maintenance of those old technological systems (Edgerton, 2007, Chp. 4).

Those accounts are examples of the richness stemming from the broader analysis of the technological landscape, and the connections that can be made with other fields, but unfortunately, they seem to be isolated islands. The vast numbers of archipelagos of typical histories of technology provide only the initial half of the whole story, because in parallel to the discussion in Sections 2.1 and 2.2, so do histories of technology concentrate on the initial phases of the S-curve.

That mental image describes essentially the performance characteristics of technologies and tends to exaggerate the importance of the initial growth stage in historical studies of technology. Therefore historians of technology are made awry of the fact that technologies do not merely fade away, they also struggle for survival, often against superior rivals, and show their historical importance at later stages (Lindqvist, 1994, p. 275-277).

The history of video games follows along the lines just described. Two of the more recognised and comprehensive accounts trace the history of the industry back to the first inventions and successes, describing the fast development of consoles (hardware) and games (software) in terms of their contemporaneity, yet they fail to consider what happens with pre-existing technologies within that contemporaneity (Wolf, 2008c, Kent, 2001).

Therefore, a different perspective is necessary to cover the totality of a technology's existence. Noting this, Kline and Pinch (1996) had already extended the scope of the history of technology in their work, shifting 'the field's traditional focus from the "producers" of technology (e.g., inventors, engineers, and manufacturers) to the "users" of technology (e.g., laborers, factory owners, homeworkers, and consumers)' with positive results for the understanding of the shaping of technology. Following that lead, we discuss next the approach to the history technology in use, which is particularly suitable to encompass the whole technological landscape:

> by thinking about the history of technology-in-use a radically different picture of technology, and indeed of inventions and innovations, becomes possible. [...] It will give us a history which does not fit the usual schemes of modernity (Edgerton, 2007, p. xi).

4.2. ...TO A HISTORY OF TECHNOLOGY IN USE

Lindqvist (1994, p. 276) states that 'the human-made world, the environment in which we form and experience our social relations, is almost completely shaped by "old age" technologies that have reached a state of maturity or decline', reflecting that technologies remain in use after their supposed obsolescence:

> We still have buses, trains, radio, television and the cinema, and consume ever-increasing quantities of paper, cement steel. The production of books continues to increase. Even the key novel technology of the late twentieth century, the electronic computer, has been around for many decades. The post-modern world has forty-year-old nuclear power stations as well as fifty-year-old bombers. It has more than a dash of technological retro about it too: it has new ocean-going passenger ships, organic food and classical music played on "authentic" instruments. (Edgerton, 2007, pp. xi-xii).

A survey conducted by the Swedish Society of Graduate Engineers in 1980 quoted by Lindqvist (1994, p. 277), concluded that the majority of its members (72%) were engaged in the maintenance and supervision of existing technologies and technical systems, a smaller group (10%) were engaged in training other people to maintain the current technological world, and only 18% were developing new technologies. This suggested that about 80% of the technologies in modern industrialised nations were "old aged" and in a stage of maturity or decline, and that only 20% were in the stage of infancy or early growth.

That tendency can be observed in transportation technologies. The privately owned steel-and-petroleum "system of automobility" remained largely unchanged since it began in the late nineteenth century, and although there are some signs that it might change (e.g., new fuel systems, new materials, new ownership schemes), they are not sufficiently strong to transform a system that survives enshrined in a physical, political, and social infrastructure (Urry, 2004). The importance of the horse, to the extent it can be considered a transportation technology, increased during World War II when the German army deployed many of the more than 3 million horses it possessed in battlefield operations; or in Cuba when in the 1990s, in the aftermath of the Soviet bloc collapse, the government established an animal traction programme to recover the agricultural sector from the shortage of Soviet and East European agricultural machinery supplies (Edgerton, 2007, pp. 35-36).

Those examples show that technologies remain in use for long and sometimes unexpected periods, contrasting with the importance given to the initial stages of technology. Therefore, Edgerton (1999) argues for historical accounts of technology based on use rather than merely on the innovation phase. Furthermore, most inventions only acquire true economic importance many years after they are invented and widely diffused (Rosenberg, 1982, pp. 55-80), and as seen before, not necessarily for the purposes that they were thought of in the first place (Edgerton, 2007, Chp. 1, Oudshoorn and Pinch, 2003).

However, a practical and difficult problem to tackle arises from that sort of analysis, because 'few if any significant technologies could be measured in a single human working lifetime' (Lindqvist, 1994, p. 274), as illustrated by the case of steam power:

> [...] held to be characteristic of the industrial revolution was not only absolutely but relatively more important in 1900 than in 1800. Even in Britain, the lead country of the industrial revolution, it continued to grow in absolute importance after that. Britain consumed more coal in the 1950s than in the 1850s. The world consumed more coal in 2000 than in the 1950 or 1900 (Edgerton, 2007, pp. xi-xii).

Nonetheless, approaching the history of technology from the perspective of use means devoting attention to a broader set of aspects, 'from the new to the old, the big to the small, the spectacular to the mundane, the masculine to the feminine, the rich to the poor' (Edgerton, 2007, p. xiv). This is exactly what we strive for in this thesis: analyse a technology because it is being used, regardless of whether it is thought of as old or new. Although we will refer to the conventional idea of "old" and "new" technologies, this is to be regarded as indicating the chronological order by which they were introduced, and not as a measure of modernity or superiority, because as we have seen in this chapter, all technologies should be treated equally.

Hence, by looking at "obsolete" home video game consoles that are still in use, we are focusing on a recurrent feature of the technological landscape, the fact that technologies continue to exist and be used long after their useful and foreseeable life-span has been outlived, and users often play an important role in that.

The importance of technology in use should not be confused with the idea that users are seen as agents of technological change (see Section 3.2), although they are complementary to some extent. While the first is a general perspective of analysis on the use of technologies through time, the latter points to the importance of users acting technically over the technologies they interact with, and this of course also happens through time.

In fact, users are an important nexus of any industry, particularly of network-based industries, whose characteristics are explored in the next Chapter.

5. Network Industries

From the ensemble of issues network-based industries involve, we focus on the ones that constitute the backbone for analysing the several technological generations of home video games, according to Gallagher and Seung Ho (2002).[7] We start by introducing the concept of network effect, and focus then on the characteristics of consumer switching costs. We then proceed with an analysis of the role, formation and dynamics of standards, dominant designs and architectures. Finally, we discuss the problem of the "angry orphans".

5.1. Network Effects

A good exhibits network effects (also known as network externalities or demand-side economies of scale) when its value and demand are determined by how many others consume the same good, and not seldom by the composition of this network of users (Varian et al., 2004, p. 33). This perspective complements the traditional theory of demand, where consumption is only related to the intrinsic characteristics of a product.

The literature distinguishes between *direct* network effects and *indirect* network effects (Farrell and Saloner, 1985, Katz and Shapiro, 1985). The first arise because consumers directly benefit from the interconnection to a larger network of users. The latter emerge because the existence of a large network of users means that a variety of supporting products and services will be available in principle, indirectly benefiting the consumer (e.g., spare components, complements, technical assistance).[8] Examples of goods that exhibit such effects include telephones, fax machines, computers, music players (regardless of the format), and home video game consoles.

Hence, the decisions of some consumers affect the utility others get from a product, so network industries display reinforcing effects – positive (or negative) externalities – that make the 'strong get stronger and the weak get weaker' (Shapiro and Varian, 1999b, p. 175). This points to the notion of path dependency: that the future of a product, and consequently of a network, is substantially influenced – positively or negatively – by the dynamics and decisions that occur previously and during its adoption (Liebowitz and Margolis, 1995, Arthur, 1989).

In the home video games industry, the existence of network effects is evidenced in the fact that the value of a video game console for a user depends on the number of other users that possess the same model, because in principle more games will be made available. This implies that on the one hand users tend to prefer platforms that offer more games, while software (games) developers favour platforms with more users (Evans et al., 2006, p. 138-139). When deciding to buy a console or to develop a game for a particular platform, consumers and developers are not only choosing a product, they are first and foremost choosing a network, although they may not be aware of that.

Networks can have a sponsor who creates and manages them, in the case of home video games, the hardware (consoles) manufacturers. The main challenge for sponsors is to build a network with a sufficient critical mass, or installed base of users, that can generate important network externalities and thrive from that basis. An effective way to achieve this is it to create consumer switching costs (Klemperer, 1995, Farrell and Shapiro, 1988).

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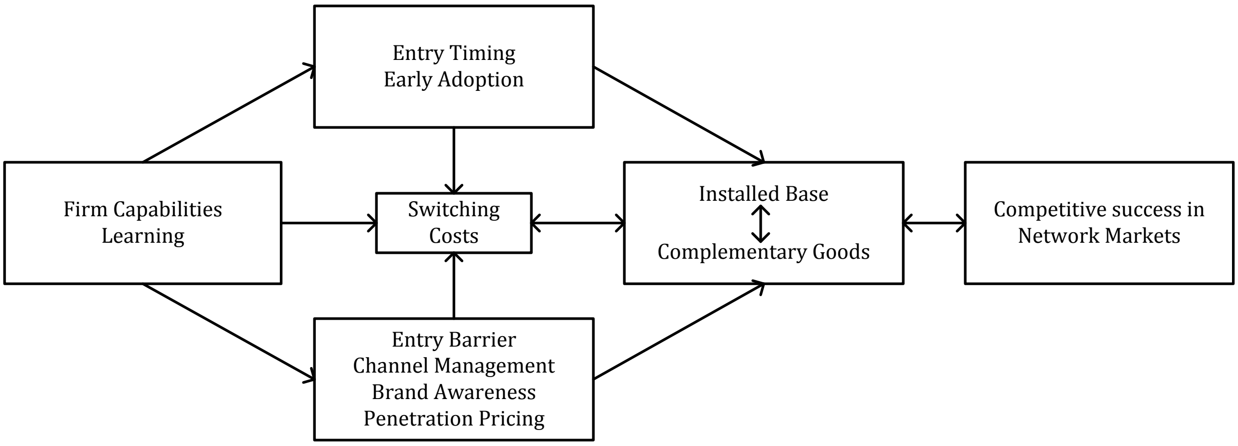
[7] We are specifically in the realm of network industries that do not rely on the pre-existence of an infrastructure, contrary to what happens for instance with the railway or the telephone, although the implications are to a large extent similar (Hanseth, 2001).

[8] Varian et al. (2004, p. 33) explain indirect network effects rather intuitively: 'I don't directly care whether or not you have a DVD player – that doesn't affect the value of my DVD player. However, the more people that have DVDs, the mode DVD-readable content will be provided, which I do care about. So, indirectly, your DVD player purchase tends to enhance the value of my player.'

5.2. SWITCHING COSTS

Switching Costs, the ones consumers incur if they switch to an incompatible but functionally identical technology, are a critical success factor for firms' competitive success in network industries (see Figure 5.1). These costs are relationship-specific investments, which may include the physical investment in the product itself, the development of an informal relationship with a supplier or loyalty to a brand, the time spent on learning how to use a technology, and particularly important for home video games users, the acquisition of complementary goods (e.g., software).

Figure 5.1 – Framework for firms' competitive success in network industries



Source: Gallagher and Seung Ho (2002).

The existence of switching costs means that brands and products that are undifferentiated for consumers *ex ante*, become heterogeneous after the purchase, giving suppliers a certain degree of monopoly power over the market segment, dependent on consumers' investment (Klemperer, 1987). Hence, the importance of promoting early product adoption to generate positive feedbacks. Switching costs work as an entry barrier. They help expanding incumbents' installed base and the possibility of introducing complementary goods, so if a firm succeeds in building them, the market "tips" to its side, in the self-reinforcing cycle mentioned in the previous section.

In many cases the combination of switching costs and network effects leads to the lock-in in a solution that is widely adopted, yet not technically the best nor the most efficient from an economic point of view. When such lock-in occurs, collective switching costs make it difficult for users to coordinate the switch to another technology. Well-known examples include the QWERTY keyboard, whose performance is deemed inferior to the alternative Dvorak Simplified Keyboard (David, 1985); the triumph of VHS and JVC's strategy over Sony's Betamax, deemed to have better image quality than its surviving rival (Liebowitz and Margolis, 1995); and the resistance of AM radio users to switch to the superior FM band immediately after World War II (Besen, 1992).

The focus on results such as those might render a biased perspective that users inevitably end up making the worse choices, and more astonishingly choices that are to some degree voluntary, which is not always the case. Furthermore, the existence of standards can contribute to tone down that situation.

5.3. Standards, Dominant Designs and Architectures

The European Commission (2008, p. 3) defines standardisation process as:

> A voluntary cooperation among industry, consumers, public authorities and other interested parties for the development of technical specifications based on consensus.

This definition stands for formal (or *de jure*) standards, issued from 'political ("committee") deliberations or administrative procedures which may be influenced by market processes' (David and Greenstein, 1990). However, it is also the case when standards are defined informally, informal (or *de facto*) standards. These can be sponsored by one or more entities (usually firms) holding a 'direct or proprietary interest', or on the contrary unsponsored when the sets of specifications have 'no identified originator holding a proprietary interest, nor any subsequent sponsoring agency', but nevertheless exist in a well-documented form (David and Greenstein, 1990).

The latter type, also known as dominant design (see Section 2.1) is of particular interest because it is the usual standard-setting process in the home video games industry. We will sometimes (abusively) refer to it as an "architecture", a term with a broader scope, encompassing the way in which the components of a product are linked together. Hence, an architecture carries the same meaning for technical purposes, but it might not necessarily be adopted as the dominant design (Henderson and Clark, 1990). Put it another way, all dominant designs have their architecture, but not all architectures become a dominant design.

5.4. Standards Wars

The agreements and alliances mentioned above are not always reached, and often 'incompatible technologies battle it out in the market in a high-stakes, winner-take-all battle' for standard domination (Shapiro and Varian, 1999b, p. 261). Besen and Farrell (1994) reviewed the economic literature on standards formation when two firms try to champion their own *de facto* standard, engaging in what is commonly known as a *standards war* (Shapiro and Varian, 1999a). Based on that work, Varian et al. (2004, pp. 38-41) describe the forms such competitive standard-setting processes may take:

- Standards War. Both firms wish to make its standard incompatible, and therefore engage in a "battle of the sexes" until one is adopted, something that usually happens in the home video games industry.
- Standards Negotiation. Compatibility is so overwhelmingly important, that each player prefers a standard to no standard, but since both disagree on what it should be, they must negotiate.
- Standards Leader. A firm achieves a large installed base with its proprietary standard, and a competitor follows that lead and interconnects with it.

To win a standards war, firms use two sets of tactics: pre-emption to build an early lead and generate positive feedback; and expectations management to influence consumer decisions and establish credibility (Shapiro and Varian, 1999b, pp. 273-276). Within these two groups several strategies can be discerned, some more important than others in the home video games industry, as shall be seen later. These strategies remain valid in cases where two or more firms compete, as is the case with home video games industry, where contrary to the recurrent "one-shot" standards war, several technologies evolve simultaneously and in general one *de facto* standard dominates for a period of time, until a superior one enters in the contention for market lead (Clements and Ohashi, 2005).

Within the first group of tactics early product introduction is the most obvious way to build the early lead.[9] This can be done by releasing a product to the market 'as soon as is "good" rather than wait until it is at its "best"', but such strategy can backfire, especially in software which is frequently released with a number of "bugs", deceiving customers' expectations (Swann, 2009, p. 98).

Two related strategies are the promotion of the new product to pioneers who are keen on trying the latest technologies and the sponsoring of large, visible, or influential users to whom the product is made available almost for free.

The second group of tactics includes product preannouncements, often made by producers that are relatively late to the market, and aiming at persuading users to hold-up from buying rivals' products. Preannouncements can also involve promises of backwards compatibility or gateways to other products from the new entrants, i.e., the promise that the new models will be compatible with the software of older ones, in an attempt to make the first more appealing to consumers, by reducing switching costs.

Price commitments are another form of convincing prospective buyers that they will get the benefits from joining a particular network at lower prices over the long term. Finally, attracting noticeable suppliers through the licensing of the production of a variety complements (add-ons) that interlock with a product, can mount indirect network effects, and therefore influence consumer decisions.

There are large rewards to be gained by the producers with the use of those tactics, because:

> In these circumstances, victory need not go to the better or cheaper product: an inferior product may be able to defeat a superior one if it is widely expected to do so (Besen and Farrell, 1994).

Nonetheless, David ([1987] 2005) points out three problems accruing from standards wars and the phenomena of network externalities and increasing returns:

- Narrow Policy Window. Effective public policy interventions aimed at shaping the expectations about future adoptions by other users can only be implemented at moderate costs within a narrow timeframe.
- Blind Giants Quandary. Public agencies are likely to have the greatest power to influence the future trajectories of network industries when they have the least information on which to base the socially optimal choice.
- Angry Orphans. Consumers that are the victims of the "competitive gale" of standards, because they made sunk investments in technologies whose maintenance and further elaboration are going to be discontinued.

This last group of users is the one relevant for this thesis. In the next section we discuss the problems they face.

[9] Firms can also opt to be a fast second, and learn with the errors of early entrants, which can be a wise decision. However switching costs work in favour of incumbents, so fast seconds need to act swiftly, avoiding switching costs reaching a level at which consumers are no longer willing to do the switch (Shapiro and Varian, 1999b, p. 184).

5.5. Angry Orphans and the Winner's Curse

The so called "angry orphans", are the unfortunate users that were left outside of the new prevailing network standard because they could or did not switch to another standard or network on time. They are *angry* because they made an investment in a technology whose maintenance and further elaboration was or will soon be discontinued, so they are or will became *orphaned* of support from the manufacturer of that technology.

Besen and Farrell (1994) refer that consumers who are part of what turns out to be a losing network 'must either switch, which may be costly, or else content themselves with smaller network externalities than those who associate with the winner.' That is precisely what happens with angry orphans, which are thus affected by what became known as the "winner's curse" (Thaler, 1988).

Capen et al. (1971) noted that in the competitive bidding environment of the petroleum industry 'normal good business sense utterly failed to give people the return they expected.' Firms bidding for the right to drill in a particular parcel of land, and not knowing beforehand the information competitors possessed about the tract that lied beneath it, tended to overestimate the value of the bid, so as to insure that they would win that right. Due to the competitive nature of the bidding process, firms failed to judge the return of a particular tract, overestimating it up to a factor of 4 to the second highest bidder. They were therefore "cursed": despite having won the bid, this often exceeded the real value they could obtain from a tract.

The analogy with the angry orphans is evident. They had incomplete information about the future value of the investment in a *de facto* standard (embodied, for example in a video games console), i.e., they could not foresee if a specific model would be widely adopted and become or remain the industry standard.[10] Yet for some reason they bought the product, when it would have been better to wait until the standard was settled for good, so they could maximise the investment.

With the industry dynamics described in Sections 5.2 and 5.3 in place, the standard is eventually replaced and the hardware loses a significant share of its value, because direct and indirect network effects, some of the reasons why the product was acquired in the first place, decrease or are completely lost. Consumers are thus "cursed" because they realise that they have overpaid for the product.

Despite this, it should be made clear that angry orphans and the winner's curse do not constitute problems in themselves, as we shall see later on, and they do not occur exclusively in network industries. They can happen regardless of the type of technology in question, because products eventually end up by losing the support from manufacturers (e.g., because of warranty voidance), and a significant part of their initial value for a variety of reasons (e.g., normal wear and tear, financial devaluation, substitution by other products, malfunctioning).

However, we resort to these concepts, first to clearly identify the period when technologies are discontinued, and also because in network industries these problems are aggravated by the fact that products also lose the network effects in addition to the other factors that may be normally involved in such situation.

[10] Thaler's (1988) overview of experimental evidence of the 'winner's curse', concluded that the key ingredient of this problem is 'the existence of a cognitive illusion, a mental task that induces a substantial majority of subjects to make a systematic error.'

PART II THE HOME VIDEO GAMES INDUSTRY

Video games are an important component of entertainment in the twenty-first century, and they contribute to reconfigure the notions of time and space in popular culture. Players convert themselves into 'actor[s] in [a] small-scale electronic theater', and so video games become a relevant part of people's lives and a ubiquitous phenomenon among some groups (Betts, 2004, p. 90-1).

In this part we characterise the home video games industry, drawing on some of the theoretical perspectives discussed in Part I. We start by describing the industry's fundaments in **Chapter 6**, i.e., the core concepts used in the remaining of this work (e.g., concerning the technology, the relations between the actors, and links with complementary industries). We then proceed with a brief presentation and analysis of the market (market shares and profitability, geographical scope, and demographics) in **Chapter 7**. These two sections are meant to be an outlook of the industry, and so being, specificities such as the geography and maturity of the markets for instance, remain outside of their scope.

Chapter 8, probes deeper into the understanding of the historical evolution of the industry, through a continuum from inventive activity to commercial feasibility (innovation) and subsequent diffusion, as proposed by Rosenberg (1972). We saw in Chapter 4, that an account of the technological landscape includes not only emergent technologies, but also the ones that did not succeed or that might be considered obsolete but are still in use. Within that perspective, we made some restrictions to the description of the technological landscape included in that historical account.

We focus essentially on hardware, on the interactions between manufacturers and on the relative success achieved by the different models, excluding clones or otherwise "compatible" systems and handheld consoles. The first because they for the most cases localised phenomena, and because normally several clones exist for one original model, making the task of including them all here impossible. Handheld systems constituted a breakthrough in the way games are enjoyed, but their configuration has basically remained unchanged, and the fact that there has been one dominant manufacturer, makes them less interesting from the point of view of analysing the evolution of the technology and the rivalry between companies. Finally, we include only models that were released in more than one country, taking the US market as a reference of the industry trends and the timeline of release and discontinuity of the hardware.[11]

As mentioned before, in this Part we deliberately follow the technologically deterministic perspective seen in Section 3.3, because the aim is to understand how the evolution of the technology and the characteristics of the industry concur to the creation of angry orphans. In **Chapter 9** we analyse in more detail how technology influences the society in the home video games industry.

[11] Manufacturers usually release different technical variations of the consoles in different regions at different times, which made it impossible in certain cases, especially the earlier ones, to determine the exact date (month and year) of release and discontinuity.

6. FUNDAMENTS

There are different modes of video game exhibition, comprising the use different hardware, including mainframe games, coin-operated arcade video games, home video game systems, handheld portable games, and home computer (PC) games (Wolf, 2008b). Our interest resides in home video game systems only, bearing in mind that the connections between the different types of hardware are crucial in some cases.[12]

Home Video Games

We adopted a working definition of video game system throughout the thesis, based in Wolf (2008d):

> A dedicated electronic system that connects to or incorporates a visual interface (e.g. a TV), with the only purpose of gameplaying through the interaction of the software (game titles) and the hardware (comprising the video game console and its controllers).

A terminological clarification must be made regarding that definition, though. Early hardware manufacturers controlled the development and production of both hardware and software, a trend that changed in the late 1970s, when some companies started developing and producing hardware and software independently. This transition is the reason why the term *system* is used to describe the first generation home video games hardware, conveying the message of a complete and immutable hardware and software set; and the term *platform* is adopted from the second generation onwards to convey the message of a business catering two or more distinct groups establishing complementary relations, where hardware and software coexist in a separate, but complementary ways. The term *console* is used indistinguishably.

Home video games can be console-, cartridge-, or laserdisc-based (Wolf, 2008b). Console-based (dedicated) *systems* are ready to go when turned on because the games are hardwired into the console. By contrast, in cartridge- and laserdisc-based *platforms* games are stored externally, the first in cartridges that are plugged into the console, the latter in CD-ROMs, DVD-ROMs or other form of laserdisc data support which are read digitally.

Regardless of the type, the performance of a console is determined by three main factors:

- Instruction word length (measured in bits) of either the CPU or the GPU. The maximum complexity of a single command sent to the processor.

- Clock speed (measured in MHz). The number of instructions that can be processed per second.

- Amount of RAM (measured in MB). The capacity of temporary storage of information while a game is played.

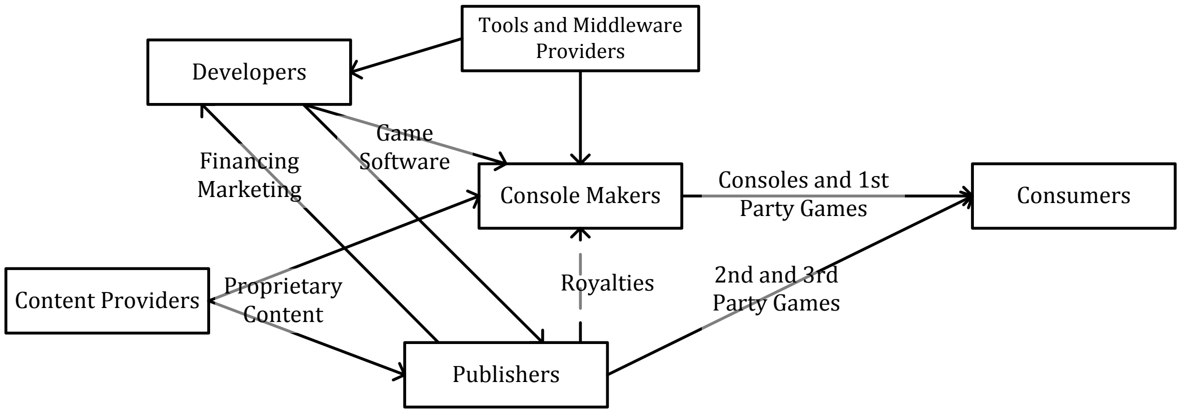
Industry Ecosystem

The home video games industry can thus be defined as the set of groups involved in the development, production, marketing, distribution, and consumption of home video game hardware and software. Since its' beginnings in the 1970s, the industry evolved from what Evans et al. (2006, pp. 257-58) call a one-sided business into a multisided business, a network industry, with its own ecosystem (see Figure 6.1, next page).

[12] Games are often "ported", i.e., rewritten into different languages, for different platforms (industry segments), as software developers attempt to expand the market for the games they create.

The consumers are the final link of a network that has its nexus and is maintained together through the hardware – hence the term "platform". In that sense, console makers (i.e., network sponsors) are at the centre of the ecosystem, because they are responsible for the design, production and marketing of the hardware. They also usually keep some software development in-house, as to insure that enough games are readily available to help start the adoption process and inform the bandwagon of the future installed base.[13]

Figure 6.1 – Home video games industry ecosystem



Source: Evans et al. (2006, p. 147).

Manufacturers frequently utilise the strategy of "giving away the razors to sell the blades", meaning that the hardware is sold near its marginal cost. The primary source of revenue are thus the licensing fees (royalties) game developers or publishing houses pay for every unit of a game they independently produce and sell to the consumers. In sum, hardware manufacturers are responsible by the platform through which all the other groups connect, and so being, they can also be called platform providers.

Developers are the companies that write the software for the different platforms (and not only home video games).[14] The first games required few lines of programming code, compared to the millions of lines required now, so teams of skilled engineers and programmers are currently needed to cope with the complexity of video games (Postigo, 2003). To simplify the task, game developers and hardware manufacturers rely on programming languages, development tools, software libraries, and middleware from platform suppliers or other third party companies, which significantly reduce development time and programming costs. Games and hardware can also be produced on the basis of information, educational or entertainment content developed by content providers.

Referring to the SCOT framework, those are then the relevant social groups that shape home video games technology (both hardware and software). However, the reach of the influence and construction of meaning of these technologies could be extended to other groups such as governments (e.g., through regulatory agencies that supervise hardware's radiation emissions) or non-governmental bodies (e.g., those responsible by rating the content of games).

[13] Clements and Ohashi (2005) found that in the period 1994-2002 the software share from platform providers themselves started at an average of 27,7% in the year after a console was released, declining to 21,5% in the following year, rising again to 26,6% on the sixth year in the market, the point from where the share declined again.

[14] Game developers carefully choose the platforms they develop games for (Venkatraman and Chi-Hyon, 2004). They are less likely to launch games for platforms which are already crowded with other developers and titles, and so they prefer platforms which are newly released. They seek platforms that have a more dominant market position and where the possibility of lock-in with platform providers is lower.

7. MARKET ANALYSIS

Video gaming has established itself as a dominant form of leisure and entertainment, education, social interaction, competing with television and movies both in scope and economic value. In 2001, total revenues of the industry reached $9.4 billion, overtaking the $8.4 billion box-office revenues in the movie industry (Clements and Ohashi, 2005).

In this Chapter we present the relevant market data of the video games industry. Given that companies usually specialise in the production of either hardware or software, the section splits between the two, focusing on firms' market share, turnover and geography. In the final section we look at the demographics of video games users.

7.1. HARDWARE

Although there were many players in the first years of the industry (see Chapter 8), currently three companies dominate the global market of home video game consoles – Nintendo, the largest player accounting for more than half of the global sales of consoles, Sony and Microsoft (see Table 7.1).[15]

Table 7.1 – Video game consoles global sales share by manufacturer 2008 (%, by volume)

Company	Share (%)
Nintendo Co., Ltd.	59,2
Sony Corporation	31,9
Microsoft Corporation	8,9
Total	**100,0**

Source: Datamonitor (2009a, p. 11).

Although the main players are Japanese companies, the home video games industry has a global scope, and the two main geographical markets for hardware are the Americas and Europe, representing 85% of the market revenue in 2008 (see Table 7.2).

Table 7.2 – Video game consoles global sales share by geographical area 2008 (%, by value)

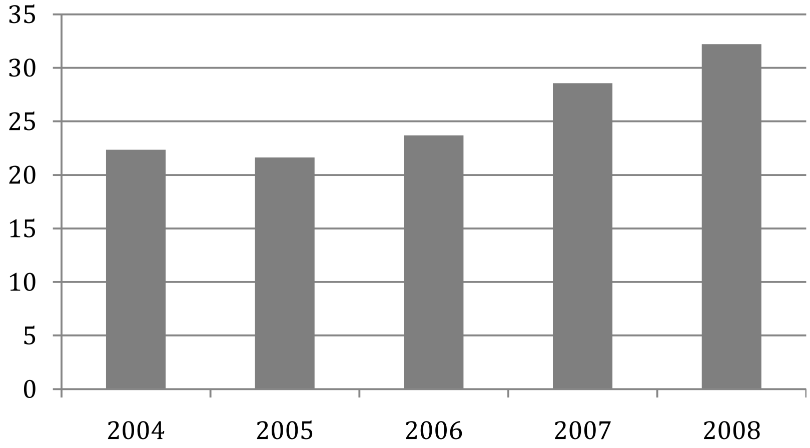
Area	Share (%)
Americas	42,9
Europe	42,1
Asia-Pacific	15,0
Total	**100,0**

Source: Datamonitor (2009a, p. 10).

Console sales more than doubled in the period 1994-2001, from 6 to 13.1 million units (Clements and Ohashi, 2005). The global games sales of consoles of the three market players generated total revenues of $23.2 billion in 2008, with an annual growth rate of 21,2% over the period 2004-2008 (see Figure 7.1, next page).

[15] Comprising Americas (Argentina, Brazil, Canada, Chile, Colombia, Mexico, Venezuela, and the US), Asia-Pacific (Australia, China, Japan, India, Singapore, South Korea and Taiwan) and Europe (Belgium, the Czech Republic, Denmark, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Romania, Russia, Spain, Sweden, the Ukraine and the UK).

Figure 7.1 – Global video game consoles market value 2004-2008 (in $US billion)



Source: Datamonitor (2009a, p. 9)

7.2. SOFTWARE

Four players dominate the market for home entertainment and educational software, with the biggest, Electronic Arts, accounting for 11,3% of the market share. It is interesting to note that in contrast with the hardware, the software market is highly fragmented, with smaller firms, usually creative start-ups, representing more than 70% of the market share (see Table 7.3).

Table 7.3 – Home entertainment software global sales share 2008 (%, by value)

Company	Share (%)
Electronic Arts	11,3
Konami	8,9
Take-Two Interactive Software, Inc	4,8
Sega Sammy Holdings	4,2
Other	70,8
Total	**100,0**

Source: Datamonitor (2009b, p. 12)

Electronic Arts and Take-Two are American companies, whereas Konami and Sega are Japanese. Sega was formerly a leader in hardware, and yet remains one of the main players in the software market.

Console software is far more representative than PC entertainment software, accounting for 79,2% of the home entertainment software, and indicating a preference for console-based gaming (see Table 7.4).

Table 7.4 – Global home entertainment segmentation by software type 2008 (%, by value)

Software Type	Share (%)
Console Software	79,2
PC Entertainment Software	20,8
Total	**100,0**

Source: Datamonitor (2009b, p. 10).

The Americas and Europe are also the most important software markets, accounting for about 70% of its' value (see Table 7.5, next page). This shows to some extent the complementarity between hardware and software.

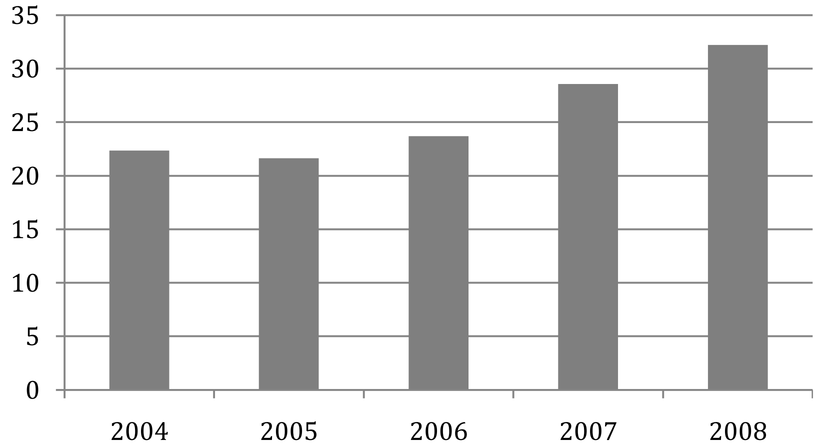
Table 7.5 – Home entertainment software global sales share by geographical area 2008 (%, by value)

Area	Share (%)
Americas	36,6
Europe	33,6
Asia-Pacific	16,3
Rest of the World	13,5
Total	**100,0**

Source: Datamonitor (2009b. p. 11).

Overall, entertainment software generated revenues of $32.3 billion in 2008, growing at an annual rate of 9,7% in the period 2004-2008 (see Figure 7.2). Although growing at a slower rate, software produces more profits than hardware, which might be the reason why hardware manufacturers charge royalties to game developers: to appropriate the profits generated on the software market, which would not exist without the platform networks they sponsor.

Figure 7.2 – Global home entertainment software market value 2004-2008 (in $US billion)



Source: Datamonitor (2009b, p. 9).

7.3. Demographics

The Entertainment Software Association (ESA), reports that 68% of American households play video games (ESA, 2009a, p. 2), showing the pervasiveness of a phenomenon, which does not reach all age groups equally, in every corner of the world, though.

Contrary to the common perception that video games are played mostly by teenagers, in the US the average age of players is 35 years old, and they have been playing computer or video games for 12 years on average, while only 25% of the players are less than 18 years old (ESA, 2009a, p. 3-4). These statistics are similar in Great Britain, where 59% of the population between 6-65 years of age are gamers (Pratchett, 2005, p. 5).

Countering the recurrent idea that video gaming is a predominantly male activity, in the US 40% of the gamers are female, whereas in Great Britain the number reaches 45% (Pratchett, 2005, p. 5, ESA, 2009a, p. 3).

Those facts go against some preconceived ideas about the gamers. Yet they are not surprising taking into account that video games have been "grabbing their hearts" since the 1970s, as shall be seen in the next Chapter.

8. HISTORY

This Chapter draws an historical account of home video games focusing on the technological evolution of the industry. This will necessarily be one of the "possible histories", not only because of the reasons mentioned in the introduction to this Part, but also because

> The history of video games is dense and multifaceted, as it coincides with other areas such as film, television, the Internet, and other interactive media; storage technologies such as diskettes, laserdiscs, CD-ROMs, DVDs, and computer technology in general; various transmedia entertainment franchises, popular fads, and of course, merchandising (Wolf, 2008c, p. xv).

As such, we analyse the releases of home video games consoles, highlighting the main characteristics of the models and the innovations some introduced in the market, while assessing the commercial success of some and the failure of others. When justified references are made to other dimensions of analysis such as market data (e.g. market shares). As seen in Chapter 6, the home video games industry is not a closed system, so references to relations with complementary industries and technologies (e.g. PCs and Internet), and interactions between the industry's players and with players in other segments are also part of this account.

The evolution of the industry is presented according to the generations of technological changes in home video game consoles and complementary products. Each generation usually comprises a new set of competitors, architectures, and market leaders that introduce hardware that is technologically superior, out-competing the leaders of the previous generation, and meaning that not all consoles in each generation are of the same type. This evolution is summarised in Appendix A.

First Generation – The PONG Years

It is commonly accepted that the home video games industry started in 1966 when Ralph Baer, a television engineer in the pursuit for more practical and interactive uses for the TV other than passive watching, proposed to build a device that could act as a normal transmitter, delivering signals to the TV, and one with which users could respond and send signals back to (Kent, 2001, pp. 21-26, Herman, 2008a, p. 53). A prototype dubbed the 'Brown Box' was finalised by 1968 at Sanders Associates – a defence contractor, Baer's employer.

The company made several demonstrations to TV manufacturers trying to find a licensee for the system, and after a failed licensing agreement with RCA in 1970, the product was licensed with exclusivity to Magnavox in 1971. After some modifications, the production started in January 1972 in the United States and the console would be released in September that year under the name of *Odyssey* (Evans et al., 2006, p. 118).

With this, Magnavox became the first company to market a home version of PONG, an electronic version of tennis that was booming in the arcades in the 1970s. The *Odyssey* was the first of the many "PONG-type" systems released thereafter. It was quite a primitive system, made of discrete components (e.g., resistors and capacitors) (Winter, 2008, p. 50). It had no electronic chip, no software, no microprocessor, and it did not produce sound or colour graphics. It basically displayed pre set games where the two players were represented by squares. Users had the possibility of buying extra program chips to play different games with the help of plastic overlays on the TV screen to simulate the scenario, or a shooting gallery pack featuring a rifle.

In the US, the system was sold through Magnavox TV dealerships only, although it was also exported to several countries, including the UK, Egypt, and France. Because of that, the *Odyssey* achieved limited success, but other factors contributed to its demise, the main being its high price and poor marketing. Advertising incorrectly suggested that the system would only work if connected to a Magnavox television, retracting the consumers, who thought they would need to buy another TV just to be able to play with the *Odyssey*.

Another problem came with the introduction of the *Home PONG Game* by Atari in 1975. Noting that the *Odyssey* was losing throttle, Nolan Bushnell, Atari's founder, thought a home version of PONG would be a "good idea" (Herman, 2008a, p. 54). Building on the success of PONG in the arcades, the company was a designer, manufacturer of arcade games, but with the release of *Home PONG*, it became the first to manufacture both arcade and consumer products (Kent, 2001, pp. 49-80). The system had a single chip, and addressed the main shortcomings of the *Odyssey*, producing both on-screen scoring and a characteristic sound when the paddle touched the ball. Later on, Atari released a line of more advanced systems, such as the *Super PONG* in 1976 that could play more games based on the ball and paddle principle.

Atari tried to sell the product on its own at first, but only when it made a distribution agreement with Sears, which sold the system under its *Tele-Games* label, would the home PONG became a sales success (Kent, 2001, pp. 80-2; 94). Sears sold $40 million of home PONG games in the first year. This might have been the reason why 'dozens of other companies decided to jump on the video ping-pong bandwagon by releasing their own versions of the game' (Herman, 2008a, p. 55).[16] Only a few other companies found their path amidst that bandwagon, releasing more than one type of console and the making technology advance, however.

In 1975, Magnavox released two new systems. The *Odyssey 100*, using four Texas Instruments chips, played only two simple games and had neither on-screen scoring nor colour. The *Odyssey 200* was basically the same as the 100, but with two more chips which played an additional game, and had an archaic form of on-screen scoring. The most noticeable innovation of the 200 was that for the first time in the history of home video games, there was the possibility of four players competing at the same time.

More innovations would follow in 1976, a turning point in the industry. General Instruments introduced a revolutionary chip that could have several games built into it. Coleco, a toy manufacturing company, was the first customer, and the result was the *Telstar*, a system that contained three games with on-screen scoring and went on to sell 1 million units (ESA, 2009b).

The move was followed by Magnavox with the release of the *Odyssey 300*, which played the same three games as the 200, but players only needed to contend with one knob instead of three. This feature was abandoned in the new *Odyssey 400*, which was basically the 200, but with an additional chip for on-screen scoring. The *Odyssey 500* was the same as the 400 externally, and it played the same games, but the graphics was its greatest breakthrough. It could display colour images, contrary to the black and white of the previous Magnavox models, and instead of white squared paddles representing the players, it pictured human characters for the first time in the history of home video games.

[16] Evans et al. (2006, p. 120) estimate that by 1977 there were around 75 PONG clones, most of them using the same five-dollar chip developed by General Instruments.

1976 marked the end of the first generation of home video games. The main legacy of this generation was not the invention of video games, which had been around since the early 1960s (Kent, 2001, pp. 16-21). Nor was it the invention of the arcades, which had been around since the 1930s (Kent, 2001, pp. 2-14). It was rather the opening-up of the home video games market that did not exist before, based on the 'outgrowth of the first successful coin-operated video game, PONG' (Gallagher and Seung Ho, 2002). The idea of bringing the commercial success of the arcades into people's houses was visionary, and developed a bandwagon of home users, building on the existence video arcades users.

As pointed out in Chapter 6, this was by then a single-sided business, and not a truly network-based industry, because manufacturers sold complete systems with one or more built-in games. Since consumers could not buy or add new games, network effects did not exist at this point yet. That was one of the main problems of the first consoles: people got tired of playing the few available games quite rapidly after some rounds of tennis or hockey. Video games were invented to provide entertainment; the problem was that the PONG generation did not demonstrate the capacity to do it on a continuously improved way, in part because the technology was very limited.[17] The use of the revolutionary cartridge-based system solved the problem of a limited number of games, inaugurating the second generation of programmable home video game consoles.

Second Generation – The first programmable video consoles and the market downturn

A new generation started with a breakthrough by Fairchild Camera and Instrument, one of the pioneers in the development of the transistor. Jerry Lawson, an engineer with Fairchild realised that the main differences between the existing consoles were in the chips that carried the games, and took the initiative to solve the problem of the first systems (Herman, 2008a, p. 56). If some consumers bought a new model, they would more easily buy just the chips housed in cartridges at a lower price than a complete new system. The result was the Fairchild *Video Entertainment System* (or VES, later renamed *Channel F*), the first programmable home video game system with plug-in cartridges containing ROM and microprocessor code instead of dedicated circuits. This completely overshadowed Magnavox's latest improvements.

The *Channel F* embodied the architecture which became the dominant design, consisting of a central console with removable cartridges, connected to the TV. It included other innovative features that were copied by later systems – it had more advanced controllers, players could adjust the speed and the length of the game and for the first time the "pause" function was included in a console. Nonetheless, Fairchild had trouble maintaining its initial technological lead, because it did not advertise the system properly and consumers did not find the games the company made available particularly interesting (Herman, 2008a, p. 56). Furthermore, Atari came as a challenger once more, releasing the *Video Computer System* (VCS), and preventing the *Channel F* from being as successful as it could have been otherwise.

In the meanwhile RCA entered the home video game market, with the *Studio II*. While cartridge-based, the system could only play black and white graphics and instead of controllers, it had two sets of numeric keyboards to control the games. The *Studio II* was technologically far behind its competitors, waning rather quickly.

[17] Due to its high cost at that time, there was no significant use of microprocessors, nor did companies invested in software development.

Replicating what happened with the *Home PONG*, in 1977 Atari launched two translations of arcade coin-operated games: a new type of ball and paddle system, the *Video Pinball*, based on the arcades game *Breakout*, followed by the release of *Stunt Cycle*, a motocross game.

Designed and marketed to compete with the *Channel F*, Atari released yet another system in 1977, the VCS, later renamed *Atari 2600*. The console was designed to be situated on or near a television and so the characteristic casing with a wood-grain plastic front made it look 'more like a piece of furniture or a stereo component than like some piece of esoteric hobbyist electronics' typical of the 1970s (Montfort, 2006). The 2600 could play multiple games, becoming a sales hit coupled with the release of killer apps like *Breakout*, *Missile Command* and *Combat*, the cartridge originally bundled with the VCS. In 1979 Atari licensed a home version of *Space Invaders*, an arcade game credited with starting the video game craze in the US (Gallagher and Seung Ho, 2002, Kent, 2001, p. 190).[18] The 2600 remained in the market until 1991, and eight variations, including a redesigned version known as the *Atari 2600 Jr.* in 1986, were produced over its 14-year run, the longer to this day (Herman, 2008c, p. 117).

The 2600 inaugurated the era of third-party game development, and software licensing greatly contributed to its success, but in this chapter Atari found great difficulties later on. The licensing "movement" was initiated by Activision, a company put together by former Atari programmers (Herman, 2008d, p. 65). Resented they were not entitled to royalties from their creations, which earned Atari millions of dollars, they started releasing quality titles for the 2600 independently.[19] This threatened Atari's profits, because its business model built on selling hardware at the lowest possible price and making profits from software sales, a strategy that would be replicated many times by other manufacturers. Understanding this loss of control, Atari unsuccessfully sued Activision (Kent, 2001, pp.193-94). As a result, other companies started independently releasing games for the 2600, and Atari could not prevent the flood of poor quality titles, which would eventually damage the company's reputation.[20]

Coleco released another dedicated console, the *Telstar Combat* that played four variations of a tank battle. This was an attempt to depart from the PONG-clone path. However, the company released a series of PONG-like Telstar variations such as the *Alpha*, the *Colormatic*, the *Colortron*, the *Deluxe*, the *Marksman*, and the *Galaxy*. These were unfortunate moves, because 1977 is known as the year when dedicated consoles' collapsed, due to the success of the *Channel F*, and especially of the *Atari 2600*.

Magnavox would also stay in the electronic ping-pong path for a while releasing three more systems, which were the most advanced PONG systems of the 1970s. The *Odyssey 2000*, which was as the 300 with an additional game, and the *Odyssey 3000*, identical to the 2000 but with a restyled casing. The *Odyssey 4000* was Magnavox's final dedicated system. It had eight new built-in games and detachable joystick controllers similar to the ones featured in the 3000.

[18] It is estimated that *Space Invaders* sold one million copies in the first 18 months, contributing in part to Atari selling more than 15 million 2600 consoles between 1979 and 1982 (Evans et al., 2006, p 121).
[19] The games developed by Alan Miller, Larry Kaplan, Bob Whitehead and David Crane, the co-founders of Activision, accounted for half of Atari's games sales (Grahame, 2007). The story of Robert Fulop, a programmer at Atari, illustrates the lack of credit they were given by the company. In 1981 Fulop received a certificate for a free turkey as a Christmas bonus, despite having developed *Missile Command*, a killer app that sold 2.5 million copies, more than any other game up until then (Bohus, 2007).
[20] One such game was *Custer's Revenge* released by the Swedish company Caballero under the name Mystique (Kent, 2001, p. 226-27). The game involved helping the main character escaping the battlefield by dodging arrows, and once safely away he would find and rape an Indian woman tied to a stake.

Coleco would release yet another system in 1977, the *Telstar Arcade*, which played games other than PONG-style. The most interesting feature was its' triangular-shaped case which allowed the user to play several games using the controls on each side – the usual knobs for PONG-like games, a revolver for shooting games, and steering wheel and gear shift for driving games.

Early in 1978, the video game developer Bally made its' only appearance in the hardware market with the release of the *Bally Professional Arcade*. The system was developed by Midway, Bally's video game division created in 1975, in the aftermath of the arcade revolution started by PONG. The system featured a Z80 processor (originally used in the arcades), three built-in games, a calculator with numeric keypad and up to four controllers, combining a joystick and paddle. In 1982, Bally withdrew the system and sold the rights to Astrovision Inc., who reintroduce it as the *Bally Computer System* (because it included a BASIC cartridge). Both the company and the system were later renamed *Astrocade*.

Magnavox made a move into cartridge-based systems with release of its second major system, the *Odyssey*^{2}, designed to compete with Atari and Coleco. Unlike any other system at that time the *Odyssey*^{2} included a full alphanumeric flat membrane keyboard that could be used for game selection, educational games, programming, and entering the player's name for hi-scores, for instance. The keyboard was its' major innovation, together with the standard joystick design of the 1970s and early 1980s. The *Odyssey*^{2} did not perform so well in graphics compared to its main competitors, the *Atari 2600* and the *Bally Astrocade*. It was a contained commercial success.

Coleco released another Telstar console, the *Gemini*. This system was completely different from any other Telstar system until then. It looked like a normal PONG, but it offered shooting and pinball games. The case had a flipper button on each side for simulating a real pinball and a rifle was available for the shooting games.

In 1979, Zircon International bought the rights to the *Channel F* and released the *Channel F System II*, a scaled-down model of the original *Channel F*, with a different design, and the sound output through the TV speakers. This system was also licensed in several countries in Europe and sold under other names in Sweden, the UK, Germany, Italy and Belgium. With other strong competitors in the market such as the *Atari 2600*, and later the *Intellivision*, the new *Channel F* did not succeed either.

In 1980 Mattel Toy Company, released the *Intellivision* (from Intelligent Television). It was not the first platform designed to challenge the *Atari 2600*, but it was the first to pose a serious threat to its' dominance.[21] It was the first 16-bit video game console, and the first to feature a controller with a sixteen-direction pad. Mattel used Atari's original strategy of selling rebranded versions, including the *Radio Shack TandyVision*, the *GTE-Sylvania Intellivision*, and the *Sears Super Video Arcade*. Activision and Imagic, third party developers for Atari began releasing games for the *Intellivision*, and so did Atari and Coleco, rivals in the hardware segment.

In June 1982 General Consumer Electric (later bought by Milton Bradley) released the *Vectrex*. This unique 8-bit console utilised vector graphics instead of the usual raster graphics. Another interesting feature was the bridging of the gap between tabletop electronics and video game consoles by including its own CRT monitor, over which plastic overlays were used to provide some illusion of colour (Kent, 2001, p. 230).

[21] In 1980 Atari had an 80% share of the gaming market (Evans et al., 2006, p. 121).

The *Arcadia 2001* released at that time by the consumer electronics company Emerson was another not so successful platform, because it came out at nearly the same time as the *Atari 5200* and the *ColecoVision*, and Atari had exclusive rights to many games, which made it difficult for Emerson to get popular games. Nonetheless, the console was licensed worldwide, and over thirty clones exist, which are two measures that contradict the modest sales success it achieved.

Atari released the *Atari 5200 SuperSystem*, the follow-up of the highly successful 2600, later that year. The internal hardware was based on Atari's existing 400/800 computers, although software was not directly compatible with these. The 5200 was powerful than Mattel's *Intellivision* and equivalent to the *ColecoVision*, released at roughly the same time. Among some of the innovations introduced were a controversial automatic RF switch box that also supplied power to the unit, but was incompatible with many televisions, and the possibility of four players playing at the same time using analog joysticks. The *Atari 5200* was not as successful as the 2600 for two main reasons. It only allowed backward compatibility with the 2600 when an adapter was later released in 1983, so it could not profit from its' predecessor's large installed base. The second problem was that Atari kept the focus on the 2600 – at the time its' "cash cow" – and faced increasing competition from the *ColecoVision*.

Coleco had been accomplished releasing mainly dedicated PONG consoles. Nonetheless, the success attracted many competitors producing PONG clones, and when more advanced systems with interchangeable cartridges were introduced, Coleco decided it needed to keep up with the times and the technologies. The *ColecoVision* was superior to the competitors, because it provided arcade quality graphics and gameplay. However Coleco had no presence in the arcades, forcing the company to license games from third party developers, and putting it in a weaker position than Atari with this regard. *Donkey Kong* was one of the most successful games at that time, and Coleco managed to license it exclusively for six months from a Japanese playing card, toy and video games company called Nintendo. The game was included as the official pack-in cartridge of the *ColecoVision* and in 1983 its games outsold Atari's (Kent, 2001, p. 208-210, Schilling, 2003).

Several expansion modules were developed for the *ColecoVision*. The Expansion Module #1 is noteworthy, because it made the *ColecoVision* compatible with the industry-leading *Atari 2600*. This allowed ColecoVision's users to access the largest software library for any console available at that time, and with this the company offset the advantage the 2600 had in consumers' minds. Atari attempted legal action for patent infringement, which was not sustained, because the module was made from standard parts.[22]

Mattel later released a downsized version of the *IntelliVision*, the *IntelliVision II*. The main reason for this was the need to cut costs, so circuits were redesigned, and the components that were prone to fail in the previous model – the power supply and hand-controllers – were made replaceable. One major problem with this new model was the fact that in an attempt to lock out competitors, the *IntelliVision II* did not play successful Coleco games such as *Donkey Kong*, *Mouse Trap*, and *Carnival*. Furthermore there were technical problems even with original Mattel games, which conditioned even more the console's success.

[22] In fact, the complete *Atari 2600* could be made from standard parts, so Coleco released a stand-alone clone named *Gemini* – not to be confused with the *Telstar Gemini*. The system only differed in the case design and type of controllers.

By the end of 1983, the video game industry suffered a downturn. There were too many models available, and the industry leader, the *Atari 2600*, oversaturated the market with games, particularly those released by third-party companies (Herman, 2008a, p. 58).[23] These smaller companies, many of them start-ups, were selling low quality titles at discount prices in an attempt to avoid bankruptcy. The situation pressured top-tier manufacturers whose games cost as four times more because of higher development costs. As a result, the video game market crashed and by 1984 most third-party developers did go bankrupt despite the struggle.[24] Mattel and Magnavox abandoned the market, Coleco stopped manufacturing the *CollecoVision*, and went on to focus on the development of its *Adam* home computer, a move which nearly led the company into bankruptcy (Kent, 2001, p. 252-255).

The accompanying meltdown in the computer industry was of great concern, because most of the video game manufacturers were also involved in it. Even Atari, the industry leader, was struggling with losses in 1983 (Gallagher and Seung Ho, 2002).[25] The company decided to abandon the video game business, where it had interests in all of its segments – home, arcade and computer– to focus primarily on the home computer business, with only limited success (Herman, 2008d).

Overall, the second generation of video games was a period of introduction to a new architecture of consoles based on cartridges, which would remain as the dominant design for several years. Another characteristic of this generation was the rise of big players dominating a significant share of the market and distributing products at a world-wide scale, as was the case with Atari.

One can say that the cartridge system was designed primarily to meet the demand for games other than PONG-type. But in reality this architecture has a twofold logic built into it. On the one hand, consumers need not to upgrade the entire system, since only the software enclosed in the cartridge is changed. This provides them with more variety of games at lower prices. On the other hand, as games are separated from the consoles, so it is easier for manufacturers to licence the development and manufacturing of games to third-party companies. This means that a significant share of the responsibility of attracting more users to a platform depends on the licensees' ability to come up with applications that please vast numbers of users, in other words, the responsibility of creating indirect network effects and expanding the installed base.

The third feature of this generation was the increasing market complexity. As Evans et al. (2006, p. 120) put it, 'the foundations for the two-sided business model that dominates the video game industry today were laid in the late 1970s'. The foundations of a fully fledged network industry model emerged when the new dominant design based on cartridges lead to the emergence of specialised hardware and software manufacturers. Both types of companies started then to be concerned with the creation of network effects and widening their installed bases so the interaction between the two sides became ever more prone to end-up in conflicts.

[23] An example of this was the production of 12 million Pac-Man cartridges in 1982, although Atari estimated that less than 10 million users owned a 2600 (Kent, 2001, p. 236).
[24] It is estimated that there were more than 130 significant software firms in 1982, with only half a dozen making it through the crash (Evans et al., 2006. p 124).
[25] In 1983 Atari lost $356 million, impacting Warner Communications', which bought Atari in 1976, share price by 50% over 10 months (Evans et al., 2006, p. 124). Warner sold Atari in the following year (Kent, 2001, p. 240).

Was it more important to produce a technologically superior platform? Or was the capacity to be the first to licence a smash hit game from a developer that defined a platform's success? Furthermore, should hardware manufacturers raise the prices of the consoles, or should they charge licensees less for each game – or the other way around? Either way, this ultimately benefited users because companies struggled to be at the edge of the technology with consoles that had the most popular titles.

Acknowledging these opportunities, Nintendo introduced a console that was not only technologically superior to its predecessors, but that was first and foremost backed by a well-designed business model, that allowed the company to strategically compete and thrive in the increasingly complex home video game market. In 1985, the *Nintendo Entertainment System* (NES), released originally in Japan in 1983 under the name *Nintendo Famicom* (from "family computer"), inaugurated the third generation of home video games.

Third Generation – The second 8-bit wave rescuing the industry

The downturn of the US video game industry was still ongoing when Nintendo introduced the NES. Retailers were not yet willing to market a new platform, fearing the crash was a sign that video games were not more than a fad. Despite the initial hardware and programming instabilities, the *Famicom* had been a success in Japan and eventually NES took home video games to another level both in technological terms, and along a large library of games. Sales took off, and the NES helped reviving the American video game industry, although the hardware was sold at an operating loss.

Yet more impressive than NES' technological supremacy over past and new rivals, were the clear "rules of the game" Nintendo designed to avoid a critical shortcoming in the strategy of other manufacturers, including Atari: they had not been able control the quality of its complementary products, i.e., the quality of licensed games, and maximise the returns from the platform (Gallagher and Seung Ho, 2002, Evans et al., 2006, p. 125, Arsenault, 2008, pp. 110-11). A series of measures was put in place, and draconian as the rules imposed by Nintendo may seem, licensees enjoyed the terms because the industry was recovering and the NES was one of the few outlets for games at the time.[26]

NES' cartridges contained a "lock out" chip to prevent illegal production of compatible cartridges. Licensing of game development was limited to a small number of companies, and the manufacturing of the cartridges and a substantial part of software development were kept in-house. Licensees were only allowed to make the games available for other competing systems two years after the game was released by Nintendo. This gave the company a lead time over its rivals, and increased consumer lock-in through the release of several hit games before its rivals. Finally, licensees were themselves responsible for selling the games, and were limited to develop only five games per year. This reduced Nintendo's marketing risk and ensured that only the best titles were available.

The strategy worked perfectly and the NES became the most popular 8-bit gaming platform, with the market share reaching 90% in the US in 1987. Nonetheless, under the scrutiny of the US Federal Trade Commission, Nintendo was forced to drop the exclusivity clause in licensing agreements, stop setting retail prices of the games and allow developers to manufacture the cartridges themselves (Evans et al., 2006, p. 126).

[26] By 1989 NES games were selling at a rate of 50 million cartridges per year (Evans et al., 2006, p. 126).

Nintendo claims to have sold over 60 million units worldwide, and support to the NES was only withdrawn officially in 1994 (Arsenault, 2008, p. 110). Coupled with popular titles such as *Super Mario Bros*, the pack-in game, or *Donkey Kong*, the NES overturned the video industry game crash, with such success that other companies followed its lead.

In June 1986 Sega and Atari released the *Sega Master System* (SMS)[27] and the *Atari 7800* respectively, but neither was able to achieve NES' sales figures. The 7800 was fully backward compatible with the *2600's* impressive game library, but the graphics were of course inferior to NES'. Both Sega and Atari struggled with the fact that the best games were exclusive to Nintendo. Sega had a further problem with accessing the distribution network, and Atari had been sold to Jack Tramiel the founder of Commodore who intended Atari to make computers to compete against his former company (Herman, 2008c, pp. 117-18). Unable to compete with Nintendo, Atari sued its rival for monopolistic practices in 1988, while Coleco filed for Chapter 11 (Schilling, 2003).

In general, the third generation of home video consoles is characterised by three main features. First, the cartridge architecture was definitively established as the dominant design. The cartridge-based architecture remains a permanent feature of the home video games industry until today, especially in handheld systems, which still house the software in the traditional plastic casing.

Second, the geographical dominance of the market shifted. Whereas before the crash the industry was centred in North America, the second generation saw the rise of Japanese manufacturers, which would begin to dominate the market from then on.

Third, consoles started to be categorised according to the speed and amount of information they could process, represented by the number of "bits". Starting from 1989, the number would double with each generation.

Fourth Generation – The rise of the 16-bits and the introduction of the CD

Although it was technically the second 16-bit system, after the *Intellivision*, NEC's *TurboGrafx-16* is credited as the console that truly initiated the 16-bit era. In 1989 the electronics giant NEC released an American version of the PC Engine which had been marketed in Japan from 1987 to compete with the *Famicom*, with better sound and graphics quality. The most innovative feature of the *TurboGrafx-16* was the addition of an optional CD player (the *Super CD-ROM*) that made it the first system to read data from CDs. Later in 1992, NEC released the *TurboDuo* that combined the *TurboGrafx-16* and the CD-ROM drive into a single platform.

Shortly after, Sega released the *Genesis* (SG, also known as *Mega Drive*). The console was deemed to be faster than rivals such as the NES and even the *Super Nintendo Entertainment System* released later. Furthermore Sega also offered an array of peripherals, such as the *Sega CD* and a converter to allow backward compatibility with SMS' games. Based on aggressive marketing campaigns, the release of sports-based titles, and the popular "Sonic the Hedgehog" mascot emphasising the speed of the platform, the *Genesis* became a sales success, especially in Europe and North America (Gallagher and Seung Ho, 2002).

[27] A Japanese version had been released earlier in 1983.

A redesigned version, the *Genesis 2*, and an add-on, the *Sega 32X* which could turn the *Genesis* into a 32-bit console were released in 1994. Sega released yet another 8-bit system, the *Master System II* in 1990, a downsized version of the original SMS, which did not appeal to consumers' interest.

SNK, a Japanese arcades video game company released the *Neo Geo Advanced Entertainment System* (AES) in 1990 in the US, following a successful introduction in Japan in 1989. The AES was a home version of the popular Neo Geo MVS arcade, and in fact the cartridges were interchangeable between the two versions, so users could play exactly the same hits from the arcades. The major weakness of the system was its' high price, because technically it was superior to both the *TurboGrafx-16* and the *Genesis*. The AES attracted hardcore gamers but it was no competition for the *Genesis*. That would be provided by Nintendo.

The NES was now eight years old, and it was no longer competitive in the 16-bit era. Acknowledging this Nintendo released the *Super Nintendo Entertainment System* (SNES), which put the company back in the race again. A leaner version – the SNES II – was released in 1997 in North America and Japan only. However, during the 1991 Christmas season Nintendo lost the top-selling position to Sega, which controlled 55% of the 16-bit market share (Herman, 2008c, p. 120).

The fourth generation was marked by three milestones. First, the polarisation of the home video game market between two major rivals with well-developed market strategies, a war in which 'the legacy of Nintendo's strength coupled with Sega's successful innovation resulted in a draw' (Gallagher and Seung Ho, 2002). Second, as Nintendo removed the prohibition of licensees making their games available for other platforms at the same time, this generation also marks the start of simultaneous releases of third-party games for several consoles. Third, and the seed of the 32-bit generation, the introduction of the CD technology into video games led by NEC and Sega.

Fifth Generation – The 32-bit era and the establishment of the CD-ROM

3DO, a start-up company initiated the fifth generation with the introduction of the *Interactive Multiplayer* (IM). In addition to technological leadership, the company took an innovative approach to the market. 3DO pushed Nintendo's market strategy one step forward, and instead of producing the consoles, it licensed the hardware technology to third-party manufacturing companies as well (e.g., Matsushita, Goldstar, and Sanyo) in return for royalties (Evans et al., 2006, p. 115).

Furthermore, 3DO gathered a network of licensees for software development, charging about one fifth of the royalties that were industry practice.[28] 3DO aimed at creating the CD-based video game and entertainment standard, but failed to do so for two reasons. The units were sold at as much as the triple the price of the main competitors, the SNES and the *Genesis*, and the game library was mostly based on ports from other systems, so the IM was competing on turf that had already been explored by others.

At roughly the same time, Atari took yet another unsuccessful run at the home consoles market, which would actually be the last, with the release of the *Jaguar*. The system suffered from several problems, among them a limited game library and a cumbersome controller with more than 15 buttons. A CD-ROM add-on was released later in 1995 with disappointing sales.

[28] By July 1994, 3DO had signed 750 agreements with developers, although many them would not result in games (Schilling, 2003).

Fearing 3DO's dominance, both SNK and Sega tried to revive models from the previous generation adapting them to the emerging CD-ROM technology. While SNK released the *Neo Geo CD*, which had essentially the same hardware as the AES but a CD drive instead of the cartridge slot, Sega released the *CDX* (also known as *Multi-Mega*), which combined the *Genesis* and the *Sega CD*.

In May 1995, Sega released its' first 32-bit, CD-ROM-based console, the *Saturn* (SS). Third-party developers found it difficult to program the games because the console ran on eight processors and two CPUs instead of one. This impeded the fast development of a large library of games, but still the platform became fairly popular in Japan, although it failed to gain a similar market share in North America and Europe against the new competitors that would follow – the *Sony PlayStation* and the *Nintendo 64*.

The consumer electronics giant Sony entered the video game industry in late 1995 with the *PlayStation* (also known as PS1).[29] This platform embodied the second dominant design established in the industry, after the cartridge-based architecture (Gallagher and Seung Ho, 2002). It followed the likes of the IM and the *Saturn* using CDs as the media support for games, but went beyond, offering optional memory cards, for players to save their games in progress, a distinctive advantage, that became a permanent feature in most platforms ever since. Coupled with a strong marketing campaign and a vast library with action games, the PS1 became the most successful platform of this generation.[30]

Despite the CD-ROM technology being consolidated at that point, Nintendo released the *Nintendo 64* (N64) in 1996, a model which did not conform completely to the newly-established dominant design. It utilised memory cards, but software was still stored in cartridges, on the grounds that this would please gamers because access time to games was quicker than that of optical media (Evans et al., 2006, p. 130). It was the last major system to use cartridges, but even so it managed to compete well in terms of sales against the CD-based platforms (Herman, 2008b, p. 165).

The fifth generation was thus marked by the rise of a new dominant design based on the CD-ROM technology and memory cards, but as Therrien (2008, p. 121) notes, 'when it became the most common video game distribution format in the mid-1990s, the compact disc was already a standard in the music industry'. Despite its relatively recent introduction in the video game industry, the CD-ROM technology brought two main advantages. First, production costs were substantially lower, benefiting both manufacturers and consumers, since lower production costs for manufacturers mean cheaper games for consumers. Second, CD-ROMs had a larger storage capacity (up to 700 MB), while SNES's cartridges were limited to 6 MB, for instance, which expanded developers' range and quality of the games put forward (e.g., in terms of graphic quality, and longer and more complex game plots), and provided more entertainment for gamers.

[29] The company had already been approached by Nintendo with a proposal to manufacture the latter's CD-ROM drive for the SNES, a deal that did not materialise, as Sony went on to develop its own console (Evans et al., 2006, p. 129).
[30] Sony sold more than 81 million PlayStations worldwide by 2000, while Nintendo 29 million N64s, and Sega only 17 million Saturns by 1998 when it was discontinued (Evans et al., 2006, p.131).

Moreover, this generation saw the definitive settlement of a few large competitors in the market – two survivors from previous generations (Nintendo and Sega) and an incumbent (Sony). It is also interesting to note that, contrary to the third generation when Nintendo enjoyed first mover advantages, this was not a decisive factor in the fifth. By contrast, challengers prevailed this time. Sega over Nintendo, and Sony over 3DO and Sega. With different strategies, though. Sega put emphasis on the provision of complementary products, especially games based on the popular "Sonic the Hedgehog" character (Gallagher and Seung Ho, 2002). Sony relied on the expansion of the installed base by lowering the prices of the PS1 that cost up to a third less than a *Saturn*, and on the fast development of large game library, providing third-party developers with more development tools and software libraries than its rivals (Evans et al., 2006, p. 130).

This was also the generation of consoles that allowed home video games to catch up with the popularity reached by the arcades (Wolf, 2008a, p. 140). Until then, the latter were usually ahead in technological terms, making its games more popular. However, three technological advancements of this generation contributed to the decline of the arcades: the leap into three-dimensional computation (3D graphics), the availability of more specialised controllers for the games, and increasingly powerful consoles. One such model was the 128-bit *Sega Dreamcast*, which initiated the sixth generation.

Sixth Generation – The 128-bit era and rise of online gaming

Sega took the lead in this generation with the *Dreamcast* (DC). It had more processing power, and largely conformed to the dominant design. However it was the first console to include a built-in modem and support for online gaming and web browsing.[31] Sega went even further, and used a proprietary format for the discs called *Gigadisc* (GD) which was not compatible with other systems; notwithstanding the *Dreamcast* could play standard audio CDs (Herman, 2008b, p. 166).

Dreamcasts sold well initially, but sales stagnated after Sony announced the release of the *PlayStation 2* (PS2), which led many casual gamers to hold-up before committing to a new platform. The PS2 was released in October 2000, offering two significant advantages over incumbent models. It was backward compatible with existing *PlayStation* games and it could play consumer DVDs, a format introduced in late 1995. Furthermore, it cost less than most standalone DVD players at the time, making it an appealing item for movie buffs too. Instead of discontinuing the original *PlayStation*, Sony released a redesigned version of the console, almost the size of a portable CD player, at an affordable price – the *PlayStation One* (PSOne). The PSOne outsold all competitors, including the PS2 (Herman, 2008b, p. 167). A slim line version of the PS2 was released in 2004.

In November 2001 two new platforms were released, the Nintendo *GameCube* (GC), and the Microsoft *Xbox*. Microsoft had been involved in the development of the *Dreamcast* and aspired of releasing its own console.[32] This marked the return of an American manufacturer to the home video games industry almost a decade after Atari abandoned the market.

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[31] Earlier attempts at online gaming for home platforms date back to 1988 when Nintendo sold a modem for the *Famicom* that allowed users to play games, read the news, and use stock trading and banking services (Evans et al., 2006, p. 150).
[32] The *Dreamcast* actually used a version of Microsoft's Windows CE operating system as a development environment (Evans et al., 2006, p. 133).

The *Xbox* was based on technology from the personal computer industry (DirectX, a collection of Windows software services especially designed to help PC game developers cope with hardware diversity), also played DVDs, but most importantly it had a high-speed Ethernet adapter, and it was the first system to feature an 8 GB hard drive (Evans et al., 2006, pp. 133-34). Nintendo released the GC, which could be used for LAN gaming, but used a proprietary storage, so it could not play DVDs.

One year later Microsoft introduced the *Xbox Live*, a subscription service allowing players to compete over the Internet. Realising the importance of online gaming, Sony introduced an optional network adaptor, and a 40 GB hard drive that could be used to download extra content. What is more, gamers did not have to pay to play online with the PS2. Nintendo joined the movement releasing optional online adapters in the end of 2002, but with little success.

Overall, the sixth generation was marked by new technological improvements that led to the emergence of the third dominant design represented in the characteristics of the Xbox. The most important being the definitive establishment of online gaming through home consoles, the possibility of using the consoles as DVD players, and finally the capacity of storing data in hard drives.

Another landmark of this generation was Sega's resolution to abandon the hardware market. With fierce competition, especially from the PS2 which largely outsold all the other rivals, *Dreamcast's* sales lagged behind. On January 31, 2001, the company officially announced that it would stay in the video game industry as a software developer for multiple third-party platforms only, abandoning hardware manufacturing in March 2001 when the production of the Dreamcast stopped.

The latest and current generation draws on the developments from previous generations. The dominant design is still valid, although some experimentation with new architectures mainly in what regards the controllers might result in a new dominant design in a near future. Since this generation is still ongoing, we will attain to general considerations about the platforms and reflections regarding further developments.

Seventh Generation – Battling for the Present and Beyond

In general, it is interesting to note that all the platforms currently available – *Microsoft Xbox 360*, *Sony PlayStation 3* and *Nintendo Wii* – allow internet connectivity and have a myriad of complementary online resources (not only for online gaming, but also music and video stores and software updates services), allow data storage (hard drives), play other formats (e.g., MPEG) and use wireless controllers.

The most interesting and innovative system is probably the *Wii*, because it defies the traditional notion that playing video games is synonymous of sitting on the sofa pushing buttons. Nintendo has been releasing a series of *Wii Sports* games which allow players to simulate sports practice (e.g., tennis or baseball) using wireless controllers that act as a racket or a baseball bat.[33] Another version of this sort of sports games followed, the *Wii Fitness*, where gamers and non-gamers work out in front of the TV, following the instructions on the screen.[34]

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[33] A similar type of sports game called *XaviXPORT* had been introduced for the first time in 2003 by the Japanese company SSD Company Limited (Herman, 2008b, p. 169).

[34] The so-called "exergaming" phenomenon, the combination of on-screen action with physical exercise, is trespassing video games and changing the shape of "normal" gyms, which adopted video game consoles as part of the fitness equipment (----, 2007).

In the same line of games that require physical activity, Sony released *Guitar Hero* for the *PlayStation 2*, a game where players use a mock up guitar to simulate that they are actually playing the instrument. Other versions followed, and are available for other platforms: *Band Hero* (where other instruments are available) and *DJ Hero* (where gamers simulate the actions of a DJ).

The current generation seems to be a turning point in the very philosophy of video games as it stood thus far. Whereas home video games entertainment was deemed a more passive and cerebral activity, it is now moving towards including both a physical and social dimension to the entertainment provided. This is a particularly interesting subject if analysed from the perspective of the relation with arcade and PC games.

The arcades created the market for video games in general, and it its success originated home versions of several hit titles, which contributed to the development of the home video games segment. Later on in the 1990s, as technology improved, home video games (both for consoles and PCs) became more popular, and the arcades eventually succumbed the competition. However, it is interesting to note that the arcades had always been ahead on the social and physical dimensions of video games, at least until this generation of home consoles.

With the increased competition from home video games in the 1990s, the old-style arcades declined, and had to redefine themselves as game or amusement centres, video game lounges, or even cybercafés, where players could have a meal and socialise besides the usual gaming activity (Wolf, 2008a). Furthermore, some games offered in the arcades simulated the physical performance of sports (e.g., cockpits for racing games, and skis for skiing games), which enhanced the gamers' experience, and could not be replicated at the time by home consoles. Yet, the current generation of home video games is challenging the arcades again, now in the social dimension:

> Most people play console games in the living room, often with friends or family competing against each other. By contrast, PC games are more solitary experiences: users sit alone in front of a computer and play either against the machine or against other players in remote locations (Evans et al., 2006, p 150).

This means that the social and physical dimensions of the gaming experience are becoming particularly popular in home video games. Acknowledging this, console manufacturers began experimenting with new solutions to enhance players' entertainment as referred above, which might be an indication that a new dominant design may emerge in a near future.

Having closed the historical circle, we proceed to the analysis and understanding of the dynamics of this network-based, standard-driven industry in the next Chapter.

9. The Network-based, Standard-driven Home Video Games Industry

Due to the existence of network effects in the home video games industry, a console has intrinsically no value if no software can be purchased or rented to be used in it. Software and hardware are complementary, as seen in Chapter 6, and becomes clear in its history, and is confirmed by several empirical studies (e.g., Gallagher and Seung Ho, 2002, Schilling, 2003, Clements and Ohashi, 2005).

In addition to the technical performance, the two other cornerstones for the success of a platform are the ability to appeal to consumers' demand and expand the installed base (accounting for the direct network effects) and the availability of software (accounting for the indirect network effects). To achieve this, console makers establish *de facto* standards, that on the one hand lower the transaction costs of the producers in the ecosystem (see Figure 6.1), and on the other increase buyers' switching costs. Positive feedback effects that promote the industry's sustainability are created, but also stimulate the competition between firms, and generate negative effects for users.

In this Chapter we elaborate on the aspects of the network-based and standard-driven character of the home video games industry which are crucial to understand the context surrounding the emergence of angry orphans: the characteristics of the technology life cycle, the development of architectures and dominant designs, the disregard of backward compatibility, and strategies that increase consumer lock-in.

Technology Life Cycle

The technological evolution of home video games is characterised by a succession of intertwined waves of technological innovation, where new entrants have often outcompeted established players. The seventh wave is ongoing, and the common denominator to all of them is the fact that each new console attempts to improve the previous technology, an example of what Friedel's (2007) "culture of improvement":

> While some new entrants were more successful (Coleco, Sega, and Sony) than others (Mattel, NEC, and 3DO), they all were able to enter with a technologically superior platform (Gallagher and Seung Ho, 2002).

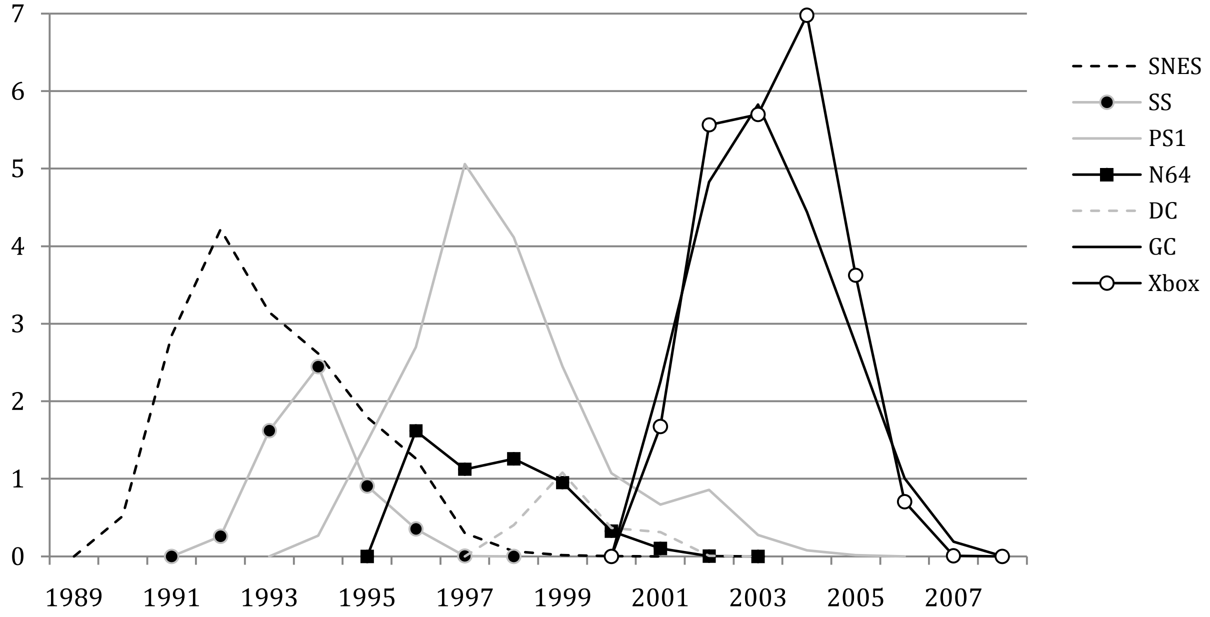
This behaviour is described by Schilling (2003) as a technological leapfrogging pattern, and occurs both within the different models of a company (e.g., Magnavox's *Odyssey* or Sony's *PlayStation* series), and in the technological battles between companies (e.g., Sega's introduction of the *Dreamcast*, a platform more powerful that any of its competitors at the time).

The constant search for improvement leaves a multitude of incompatible systems on the market, and stimulates intense inter- and intra- generational rivalry due to the short product life cycle of the hardware (Clements and Ohashi, 2005), that follows the patterns described in Section 2.1 (see Figure 9.1, next page). In Figure 9.1 it can be seen that usually several incompatible models coexist at the same time.

That technological rivalry pattern is recurrent, but it does not explain the success of a platform alone. In addition to technological leadership, new entrants often try to duplicate non product advantages of incumbents. These were the cases of Coleco when it bundled the arcade hit *Donkey Kong* with the *Collecovision*, or Sega using its character franchise "Sonic the Hedgehog" to compete with Nintendo's "Mario Brothers", for instance.

Furthermore, the most successful systems are usually the ones coupled with hit games. It was the case with the *Atari 2600* and the NES. Both platforms remained in the market long after competitors came up with technologically superior consoles, mostly because they had build impressive game libraries with hit titles, creating large installed bases of users. This reveals the fundamental aspect of the network-based home video games industry: hardware and software have a symbiotic relationship; neither can perform without the other, and the direct and indirect effects that arise from this symbiosis are the incentive that draws users to or repels them from a platform.

Figure 9.1 – Product life cycle for selected consoles 1989-2008 (sales volume in millions in America, Europe, Japan and Australia)



Source: own elaboration based on monthly data from VGChartz, retrieved online 26 April 2010 at www.vgchartz.com.

Architectures and Dominant Designs

The first and second generations of home video games exemplify the high technological experimentation the industry underwent initially, something that eventually eased in latter generations, as the technological trajectories became more explicit. This is demonstrated by the fact that while it took 20 years to establish the second dominant design, the third dominant design was established only 6 years after that (see Appendix A).

Several architectures appeared during the PONG era, crossing the first two generations, even after the dominant design emerged, embodied in the characteristics of the *Channel F.* Two examples are particularly interesting, because their architecture departed from any other model in the market at the time. The *Video Pinball* and the *Stunt Cycle*, both by Atari, were "strange animals", with an architecture that hybridised the influences of the arcades and the dominant notion of dedicated console of the PONG era: both models were based on ported hits from the arcades and the configuration of the controllers and the console mimicked the arcades, but they could only play one game. That sort of experimentation soothed in latter generations.

However, the processes of establishment of the three dominant designs that appeared in the industry so far – revealed in the characteristics of the *Channel F*, the PS1, and more recently the *Xbox* – underwent the evolution patterns described in Utterback (1994, pp. 79-102). For instance, the fluid phase preceding the establishment of the second dominant design involved the departure from the trajectory defined around the dominant design based on the cartridges, and technological tinkering based on attempts such as the Neo Geo CD or the Sega CDX to introduce the CD, which resulted in a new dominant design, and a new trajectory based on that data support.

Backward Compatibility

Backward compatibility has not been an important feature, contrary to what one would expect in this sort of industry and happens for instance with personal computers. This means that often software (games) of previous consoles cannot be played in newer or competing models, something which occurred especially in the earlier generations. As a result, companies fight a "full-blown standards war" to impose their latest models every five years, approximately the length of a generation (Gallagher and Seung Ho, 2002).

There are two reasons why backward compatibility may not be an important feature. On the one hand, it does not necessarily contribute to the success of a platform. Although the *Atari 5200* was compatible with the vast game library of its highly successful predecessor *Atari 2600*, this did not prevent it from achieving limited sales success. On the other hand, a console can be successful even if not compatible with its predecessors. Nintendo made the SNES deliberately incompatible with NES' outsanding game library, but even without that leverage, the SNES became one of the most successful platforms of the fourth generation.

Nevertheless, the *Playstation* series shows that backward compatibility can be advantageous. Its success can be attributed to the extensive game library and installed base of users from previous generations of the *Playstation* "family" that constitute the leverage for the new platform. This may be one of the reasons why in later generations intra-platform backwards compatibility is a recurrent feature, but inter-platform compatibility remains inexistent.

Consumer Lock-in

As mentioned in Chapter 5, in network industries, manufacturers seek the smallest initial advantage that caters positive feedbacks and confers larger advantages in the future. In the case of home video games industry that advantage usually lies on the entrants' side. They achieve the initial lead also through aggressive pricing strategies that rapidly build a large installed base, and allows them to appropriate the most benefits from a platform thereafter.

By lowering hardware prices, platform providers increase the confidence that the consumer will want to buy games in the future. Noting this, Nintendo sold its NES consoles at a minimum profit, while the lion's share of revenues came from the royalties charged to game developers, who had to order a minimum 10.000 game cartridges that were produced exclusively by Nintendo.

Because consumers face uncertainty regarding the quality of a platform and the gaming experience they enjoy from the games available thereof, manufacturers change hardware's pricing policies throughout its life cycle to reduce the possibility of hold-up. Clements and Ohashi (2005) found that between 1994 and 2002, market growth was stimulated by aggressive pricing from platform providers. In the first three years in the market, the average price cut of a console was about 28,4% per year, whereas the price drop for older consoles was only 7,5%, but the prices continued to drop even in the period when console sales were in decline.[35]

While a low hardware price is necessary to start the adoption process of a console, software availability and variety are necessary for it to continue. Clements and Ohashi (2005) also suggest that once a platform provider establishes an installed base, it encourages software entry because software variety signals a strong commitment that there will be continuous maintenance of the platform in the market, which in turn attracts more users.

The characteristics of the technology life cycle, the development of architectures and dominant designs, the disregard of backward compatibility, and consumer lock-in are factors play in favour of platform providers, but are contrary consumers' interests.

Because the life cycle of a console is relatively short, and there is intense rivalry between companies to establish a *de facto* standard, there is frequent console turnover (Clements and Ohashi, 2005). This competition between *de facto* standards and architectures reveals the standard-driven nature of the industry, and means that consumers are prone to be captive of a platform and can be induced to pay more than they should for the software, given the pricing strategies described above.

Together with limited backward compatibility between manufacturers in the past, gamers have a sort of Trojan horse in their living rooms that contributes to increase their lock-in in a specific model.

Frequent console turnover combined with the competition between *de facto* standards and high switching the costs leave many of the users of older platforms in the position of angry orphans, that is, without any support from the manufacturers. This demonstrates the (negative) effects of technological development and the industry dynamics have on the social sphere (see Section 2.3).

In the next Part, we analyse closer the actions of this group, in our exploration of technological change made by the users of discontinued home video games hardware.

[35] It is current practice that when the sales of a platform decline, manufacturers decrease both the prices and the technological complexity of the consoles (Bohus, 2006). By introducing downsized versions of successful platforms, which require lower R&D investments, manufacturers create another way to capture the market of gamers that are reluctant to move to the next generation, and still expand the installed base.

PART III BETWEEN THE WINNER'S CURSE AND THE BLESSINGS OF VINTAGE

In Section 3.3 we concluded that a balanced view should be kept on the mutual effects technology and society exert over each other. Whereas Part II was centred on the consequences of the evolution of the technology and the dynamics of the home video games industry, for the consumers, in this Part we turn the attention to the influences of the social sphere over the technology, in particular drawing on the perspective that users act as the agents of technological change (see Sections 2.3 and 3.2).

We start by contextualising and debating the existence of angry orphans in the video games industry in **Chapter 10**. Based on this, in **Chapter 11** we report the findings from the empirical study we conducted that involved the collection of qualitative data on cases of technological change in discontinued home video game consoles and an online questionnaire to the orphans involved in those activities.

Therefore, we are also in a sense closing the process of analysis of the life of angry orphans. We have seen how these users become orphaned (see Chapter 9), and in this part we confirm that that condition needs not to have a negative connotation (something hinted in Section 5.5).

In this part we are also contributing to the analysis of an "extended" PLC of some of the consoles. We have seen how they appeared in the market and competed against other rivals (often technologically superior), and eventually lost their relevance in terms of sales (see Chapter 8). But as mentioned in Chapter 4, technologies do not just simply disappear, as the picture provided by the PLC and the S-curve would anticipate, and in this Part we also confirm that.

10. CAUGHT IN THE WINNER'S CURSE?

The history and dynamics of the home video games industry reflect a constant improvement of the technologies through several intertwined waves (generations) of technological innovation. Since the mid-1970s, when the first dominant design emerged, platform providers have been introducing new consoles approximately every five years. They are designed to satisfy the needs of users who seek more entertainment, and benefit from technological developments both within (e.g., the cartridge system) or outside the industry (e.g., the use of the CD as data support, adopted from the music industry).

Yet while consumers benefit from more entertainment, made possible by the increased capabilities of the hardware, this does not come without its costs. Frequent console turnover, and the successive innovation wave behaviour, combined with the emergence of *de facto* standards, leaves many users outside the new prevailing network standard. In addition, manufacturers' strategies concur to increase consumers' switching costs, making it more difficult for the latter to constantly change hardware.

Because of that, many users become orphaned and affected by the winner's curse in the transition to a new innovation wave. A substantial part of the value of the video games consoles is lost, in terms of direct and indirect network effects (e.g., the support from the manufacturers ceases to be available). Thus, consumers get apparently "stuck" with a piece of obsolete technology. However, for some of them another "life" lies beyond the winner's curse.

In this Chapter we describe two fundamental aspects of this other life, the first emerging from the emotional side of video gaming, and the second linked to the online communities of orphans.

10.1. AN EMOTIONAL EXPERIENCE

Video gaming is described as an emotional experience (Järvinen, 2009, Perron, 2005). While this emotive side develops during the action of gameplaying, it is likely to stay with users for a longer period because:

> Even when one plays an old video game, like an old Atari cartridge from the 1970s, there is a sense in which the events depicted in the game are occurring for the player in the present (Wolf, 2006).

This emotional experience adds up to the fact that people have been playing video games for more than a decade on average (see Section 7.3), and so the reasons why the retrogaming movement that 'revisits the history and evolution of classic or "old school" video and computer games, appreciating the innovations of the past' (Rehak, 2008) is increasingly popular today are found. Furthermore, in some occasions the use of objects that became symbols of the past, such as vintage video game consoles, carries an aura of prestige, and is connected to a certain type of subculture and way of living:

> There is, in general, no social prestige in employing a technology that has reached a stage of maturity or decline. However there is often high social status in employing either a technology that is in its initial stage of growth or – paradoxically – a technology which has already declined and been by and large abandoned. It is, for example, prestigious to write either on a portable word-processor or with a fountain pen. A ball pen, le dernier cri in the 50s, lends little glamour to its present owner. [...] To flaunt a nylon shirt was the dream of us all during the initial growth stage of the synthetic fibre industry, but today it is a symbol of the nerd (Lindqvist, 1994, p. 284).

This suggests that gamers look back to the past of video games with nostalgia. Hence, when this sort of emotional side of use develops, consumers do not necessarily feel "angry" about being orphaned and owning old video game consoles that have been discontinued and become technologically obsolete. Even if they are left with no support from the platform manufacturers or game developers, they often find themselves part of a vintage subculture adamant of the music and graphic design of older games that keeps the "old and orphaned" consoles alive and bustling.

Commenting on the "love for what others consider obsolete", Milecki (2008) asserts that:

> When treated properly, retro things don't age like people do. A good record can always make you want to dance or sing along. A good game will always be fun. We have respect for our "aged" hardware. We love to find where our favorite old things shine.

10.2. Online Communities

With the growth and establishment of online gaming, backed by the pervasiveness of the Internet, there is a proliferation of websites, groups and forums dedicated to video games and platforms. While some have a commercial purpose, many are set up in a spontaneous and collaborative manner by video game fans, and used for different purposes (e.g., fan-based game production (Postigo, 2007), or exchange of information regarding technical aspects and gameplay).

Users of vintage video game consoles have also established their own online communities of enthusiasts and hobbyists that keep the old machines and software alive, also as part of the emotional side of video games depicted above. If not the original ones, through newer replacements such as the so called emulators that 'replicate the experience of playing a game from an older system' (Wolf, 2008c, p. 312). These communities of vintage consoles users also function as a virtual support network for its members, who discuss for instance technical problems and tackle them with the help from others, in the same line of the TRS-80 computer users studied by Lindsay (2003). This is another reason why these users do not necessarily feel "angry" because the systems they own were orphaned.

The orphans of the home video games industry acting as agents of technological change, also gather online, a subculture of appreciators of modifications of obsolete (vintage) home video games hardware that is part of the ones mentioned above. These users reopen the interpretative flexibility of the hardware, and contribute to the extension of its life cycle after it has been discontinued by the manufacturers. They finding new creative ways of improving the hardware and using it for purposes that were not thought of originally,

In the next Chapter we evidence the results of the two "blessings" arising from the vintage video game consoles, reporting the findings from the empirical study we conducted on those users and communities, in our exploration of technological change made by users of discontinued technologies.

11. The Blessings of Vintage

Resorting to the SCOT framework, we can say that home video game consoles are relatively stabilised technologies, whose predominant meanings and contexts of use have been clearly defined. However, the empirical study we conducted departed from this idea, which nevertheless remains largely valid. We analysed how and why home video games' angry orphans, develop from that stable ground, and became agents of technological change reinterpreting the use of discontinued video game consoles.

They are generally called "hackers", a term imported from computing but not limited to computers that designates someone who acts on hardware or software to expand their capacities, give them new features or make them do something they were not intended originally, either by building, rebuilding, modifying and creating them.

Our concern was hardware hacking, in particular the modifications (technological changes), an activity known as "modding". In this case it was conducted by the (not so angry) orphans of the home video games industry, to whom we will also refer as "modders', and whose modifications are called "mods".

The modified hardware is usually accompanied by a more or less detailed technical description of the process. The publishing of such tutorials and how-to guides is a current practice by the modders, and aims not only at sharing information with peers, but also at encouraging other hobbyists to contribute and learn the techniques.

The results of the empirical study reported in this Chapter are based on 70 of those descriptions (see Appendix B), collected according to the criteria and the process outlined in Section 1.2, from the online communities of modders. On the basis of those cases, we also conducted an online survey with the users. Hence, the study comprised qualitative and quantitative research activities that were then combined through the technique of "crystallisation", as the writing process unfolded (see Section 1.1.2).

First, we describe the characteristics of technological change made to discontinued video game consoles. After that we refer to the particularities of the communities of modders, i.e., the context of technological change. In the last section we discuss the relation between use and technological change.

11.1. Characteristics of Technological Change

Since the data collected from the websites and databases was mostly technical, the coding process (Strauss and Corbin, 2008, pp. 159-60) resulted in a typology comprising five categories along which technological change was analysed (see Table 12.1, next page):

- Object. The part(s) of the hardware being modified.
- Process. The process(es) used in the modification.
- Outcome. The type of final product of the modification process.
- Interaction Set-Up. The hardware set-up resulting from the modification.
- Purpose. The use of the outcome.

In this section, we explore these categories, and some of the most significant relations between them. The analysis should be seen from the perspective of the discontinued hardware used in each modification, regardless of the use of other type(s) of components.

Table 12.1 – Categories of technological change made to discontinued home video game consoles

Category	Characteristics	
Object	Console	
	Controller	
	Data Support	
Process	Substitution	
	Addition	
	Removal	
Outcome	Within Original Hardware	
	New Piece of Hardware	
Interaction Set-Up	New	Link to other technologies
		Function independently
	Same	Same console
		Older console
		Newer console
Purpose	New Use	
	Same Use	

Source: own elaboration, based on Appendix B.

Object

We considered that any part of the hardware, including the console, the controllers, and also the games' physical data support (e.g., cartridges) could be the object of modification. The console and the controllers were the preferred parts to conduct modifications (see Table 12.2). That might have to do with the fact that they offer more possibilities to act upon. They are more complex, and incorporate for instance more circuitry, whereas the physical data support, cartridges in all the cases, basically consist of a microchip installed on a small circuit board inside a plastic casing, as noted by a modder of a NES cartridge (case 50):

> You'll notice that a NES cartridge contains plenty of empty space in which to store your nostalgia.

Table 12.2 – Object of technological change made to discontinued home video games hardware

Object			Nr. of Cases	%
Console	Controller	Data Support		
+	+	+	0	0%
+	+	-	5	7%
+	-	+	0	0%
-	+	+	0	0%
+	-	-	28	40%
-	+	-	26	37%
-	-	+	11	16%
		Total	**70**	**100%**

Note: + yes; - no.

Source: own elaboration, based on Appendix B.

The majority of cases involved the modification of only one of the hardware parts, and the remaining two parts (always the console and controller), but never the three parts at the same time, nor were cases found involving the modification of the data support in combination with one of the other parts.

Process

The modifications were made using three types of processes (see Table 12.3):

- Substitution of at least one component of the original hardware by another, performing the same function (used in 51% of the cases);
- Addition of at least one new component to the original hardware, performing the same or another function (used in 84% of the cases);
- Removal of at least one component from the original hardware (used in 91% of the cases).

Table 12.3 – Processes of technological change made to home video games hardware

Process			Nr. of Cases	%
Substitution	**Addition**	**Removal**		
+	+	+	28	40%
+	+	-	0	0%
+	-	+	8	11%
-	+	+	26	37%
+	-	-	0	0%
-	+	-	5	7%
-	-	+	3	4%
		Total	**70**	**100%**

Note: + yes; - no.

Source: own elaboration, based on Appendix B.

Only a minority of the modifications was achieved by using just one of the processes, and the substitution of components never occurs in isolation, because by definition, the component that is replaced has to be taken off, so at least removal has to precede that step, which naturally occurred in all such cases. Furthermore, component removal almost never occurred in isolation. To keep these closed assembled systems (see Section 2.3) working, when something is taken out, another needs to be added (in 37% of the cases), substituted (in 11% of the cases), or both (in 40% of the cases).

Hence, two or three processes were usually necessary to conduct a modification, which together with the preference for modifying the more complex parts of the hardware mentioned above, leads to the conclusion that these technical changes involved some degree of complexity, as expressed by the words of reassurance and encouragement from a modder (case 8):

> Don't be afraid of mid-80's technology, it is pretty simple.

This apparent complexity would lead to the assumption that modders' individual skills play an important role in the modification process, which does not seems to be the case. Modifications seemed to be done through small incremental steps, involving learning by doing. In fact, the survey showed that the education background was not deemed to be a strong contribution to the success of a modification, and 75% of the respondents referred that individual learning (by doing) is very helpful to the success of a modification (see Figure D.6, Appendix D). The words from one of the modders sum-up these aspects (case 46):

> Most of the time, I made the steps up as I went and worked on trial and error.

A complementary observation is that contrary to what we were expecting, playing video games for many years (getting to know a technology by using) does not seem to be a decisive factor in the success of modifications either (see Figure D.6, Appendix D).

These are thus processes that seem to encompass a large amount of tinkering, where modders advance through small incremental steps, learning by doing, most of the times without establishing any of rules prior to the modification (see Figure D.7, Appendix D), something manifested in the comment of a respondent, that the only rule he sets beforehand is to "use whatever I have on hand already".

Outcome

This category can be interpreted as the "location" of the physical outcome of the modification (see Table 12.4). In most cases, the outcome remained within the boundaries of the original hardware (e.g., a SNES cartridge transformed into a USB hub (case 31)), but modifications did also result in the production of a new piece of hardware (e.g., the "Super Genintari", a console made from parts of 4 different systems (case 62), or the "Super Nintoaster", a SNES put inside the casing of a toaster (case 57)).

Table 12.4 – Outcomes of technological change made to discontinued home video games hardware

Outcome	Nr. of Cases	%
Within Original Hardware	54	77%
New Piece of Hardware	16	23%
Total	**70**	**100%**

Source: own elaboration, based on Appendix B.

The fact that less cases resulted in a new piece of hardware, is an indication that modders try to preserve the "looks" of the original hardware, at least to some extent, pointing to the influence of the emotional attachment to video games and their appreciation as symbols of the past (see Chapter 10), expressed in the words of a modder that used the casing of a NES to build a lunchbox (case 28):

> What I ended up with was a lunchbox that gets all kinds of funny looks.

One of the respondents to the survey mentioned that the vintage aspect of the mod is actually an important factor he takes into account before doing a modification:

> Nothing negative should be visible from the outside (e.g., ventilations, etc). When looking at the mod in question it should look just like it did back in the old days.

Interaction Set-Up

In Chapter 6, we defined home video game as one that incorporates, in very few occasions (see Chapter 8), or needs to interact with a visual interface, and whose hardware components interact with each other and with the software. This means that the system usually interacts with another technology, and so do the technologies it incorporates interact with each other, something we called the "interaction set-up".

Our findings point to the fact that the modifications aimed at changing the original interaction set-up (see Table 12.5, next page), and contrary to what happens with the process, these goals seemed to be well defined beforehand. 75% of the respondents mentioned that "to fulfil a special need" is an important or very important motivation to conduct a modification (see Figure D.5, Appendix D).

Modders seem to know what they want to achieve with the technological changes, although as seen before, they do not know best to do that, as expressed in a comment to a modification (case 5):

> My head hurts just thinking through all the glitchy possibilities.

Table 12.5 – Interaction set-up results of technological change made to discontinued home video games hardware

Interaction Set-Up		Nr. of Cases	% of category	% total
New	Link to other technologies	25	53%	36%
	Function Independently	22	47%	31%
Same	Same console	18	78%	26%
	Older console	2	9%	3%
	Newer console	3	13%	4%
	Total	**70**	-	**100%**

Source: own elaboration, based on Appendix B.

The new set up can ,on the one hand, link the old hardware to a technology it did not before the modification (e.g., a NES cartridge transformed into the casing for an external hard drive (case 15)). Commenting on a case of such "hybridisation" that turned a NES controller into an iPod remote (case 45), one of the users says:

> Old school meets new school. Love it.

On the other hand, the outcome can function as an independent system without any connection to an external technology whatsoever (e.g., various cases of hardware transformed into handheld systems ("portabilisations")) (see cases 11, 35, for instance).

The original interaction set-up is also maintained, although this is less frequent and done not necessarily with the same console, as it would be expected. Although these are residual phenomena, the interaction set-up may also involve older consoles (e.g., a Sega Master System controller that was modified to work with an Atari 7800 (case 32)), and more surprising, newer consoles (e.g. a SNES controller for the PSP (case 51)).

Whereas the second type can be explained by the emotional attachment to the older hardware, the first is mostly related to the need of improving the performance of the older hardware, as referred in the comment of a modder that transformed a PS controller so it could be used with a Vectrex (case 40):

> I found the PSX controller to be much easier and more comfortable to use than the original controller, allowing far more rapid firing. I easily got to the end of MineStorm the first time I tried it out.

It is interesting to note that when the interaction set-up was maintained, this happened mostly within the original hardware (see Table 12.6, next page), indicating that modders do look for the improvement of the technology. For example, it can be cumbersome to load games in the NES (case 29):

> Ah, the Nintendo Entertainment System. Brings me back a lot of good memories: Super Mario Bros., Double Dragon, Megaman. It also brings back not-so-great memories. The agony of changing cartridges, blowing until you're dizzy and still getting nothing but a flashing screen when you start the console. When you finally got the cartridge to run, it could freak out at any time from the smallest dust particle in the connectors.

However in one of the cases, another modder addressed the problem, modifying a NES so that the cartridge just needed to be plugged through the top (case 70).

Table 12.6 – Relation between the interaction set-up and the outcomes of technological change made to discontinued home video games hardware

Interaction Set-Up		Outcome: Within Original Hardware – Nr. of Cases	Outcome: Within Original Hardware – %	Outcome: New piece of hardware – Nr. of Cases	Outcome: New piece of hardware – %
New	With Other Technologies	25	69%	24	69%
	Function Independently	11	31%	11	31%
Same	Same console	13	72%	5	100%
	Older console	2	11%	0	0%
	Newer console	3	17%	0	0%

Source: own elaboration, based on Appendix B.

These results point to the fact that modders like to keep playing vintage video games. They act on the discontinued consoles to maintain the original interaction set-up, i.e., to be able to play. This was evidenced in the survey, where 60% of the respondents claimed to be currently playing the consoles they modified before (see Figure D.4, Appendix D), and manifested in the words of a user that modified a TurboGrafx-16 (case 37):

> The TurboGrafx is a great system, it deserves to be remembered and played!

Nonetheless, the fact that the original interaction set-up can also be changed, indicates that these orphans also look for other purposes to the hardware, as discussed below.

Purpose

Modifications either maintained the original use of the discontinued hardware, or on the contrary, reopened its interpretative flexibility, making it do something to which it was not originally intended (see Table 12.7).

Table 12.7 – Purposes of technological change made to discontinued home video games hardware

Purpose	Nr. of Cases	%
New Use	33	47%
Same Use	37	53%
Total	**70**	**100%**

Source: own elaboration, based on Appendix B.

Modders are thus not necessarily reinterpreting the use of the hardware when they modify it, although the results of the questionnaire point to the fact that finding other uses for the hardware was an important or very important motivation to carry on modifications to 65% of the respondents (see Figure D.5, Appendix D). New uses, for instance a NES advantage controller used as a guitar pedal (case 24), or a NES controller used as an iPod remote (case 45) account for 47% of the cases. This is also another indication that these orphans continue to be fond of the vintage video games looks, as mentioned before.

This category defines the redefinition or not of the meaning of the discontinued video game consoles, that is, if and how are modders reinterpreting its uses, and what are the effects they exert over it. We analysed its' relation with the other categories (see Table 12.8, next page), and three relevant ideas stem from these relations.

Table 12.8 – Relation between the purpose and the remaining categories of technological change made to discontinued home video games hardware

Categories of Technological Change			Purpose: New Use Nr. of Cases	New Use %	Purpose: Same Use Nr. of Cases	Same Use %
Object	Console		7	21%	26	70%
	Controller		15	45%	16	43%
	Data Support		11	33%	0	0%
Process	Substitution		4	6%	32	34%
	Addition		30	46%	29	31%
	Removal		31	48%	34	36%
Outcome	Within original hardware		32	97%	22	59%
	New piece of hardware		1	3%	15	41%
Interaction Set-Up	New	Link to other technologies	22	67%	3	8%
		Function independently	10	30%	12	32%
	Same	Same console	1	3%	17	46%
		Older console	-	0%	2	5%
		Newer console	-	0%	3	8%

Source: own elaboration, based on Appendix B

First, consoles represented the majority of modification cases that resulted in the same use, reinforcing the idea that modifications aimed at improving the performance of the discontinued hardware, something summed-up in the words of an acknowledged NES modder (case 68):

> Ah the NES! It's old but still great. And with a few mods and tweaks, it can get even better.

Furthermore, the controller and the cartridges were used more often to new uses, showing again that these orphans like to keep playing with the original consoles. A commenter to a NES controller modification (case 16) refers that he has and old NES "sitting in a drawer and can't get rid of it", but now he knows "what to do with the controllers".

Second, removal and addition of components were the main processes involved in new uses, and in most cases within the original hardware. As mentioned before, this indicates modders wish to maintain the old looks of the hardware, although part of them seems to like old things, yet not necessarily only video games, although they seem to have some sort of attachment to them.

Third, users appeared to be creating hardware customised their own needs. A significant number of cases of same uses resulted in a new piece of hardware that functions independently, e.g., the "portabilisation" phenomenon mentioned above, which seems to configure a particular community within those that perform modifications.

11.2. Characteristics of the Communities

Our "submersion" in the realm of the modders led us to an understanding of the community context within which the technological changes analysed in the previous section take place. In this section we outline the characteristics of those online communities.

The Orphans

The respondents of the survey were 27 years old on average, and only 10% were women (see Figures D.10 and D.9, Appendix D, respectively). This was somehow unexpected, given the contrast with the numbers in Section 7.3. Yet an explanation for this difference could be that we were not able to define a sample that was representative of the universe of modders, as mentioned in Section 1.3, which might have biased the results.

Despite this, the numbers indicate that on the one hand modding seems to be a recent phenomenon, where younger people look at the old video games as icons of the popular culture of the past, in line with the idea mentioned above that modders try to preserve the looks of the original hardware.

On the other hand, these results are also an indication that older people might prefer to keep playing vintage video games in their original condition and not "destroy" them by doing such modifications, in line with the idea that modders also aim at improving the technology to keep playing the original games, mentioned above. This feeling of "preservation" is actually quite common, and can be grasped in the comment to a modification that involved the removal of all the components of a NES, whose shell was then used to house a DVD player (case 59):

> I would do the same thing, except my now-21-year-old NES still works, and I have no intentions of breaking it.

The majority of respondents was located in North America (see Figure D.11, Appendix D), indicating that while these are "virtual" communities, they have strong geographical rooting. This is not surprising, taking into account the size of video games markets, in this case the fact that the United States is the largest (see Sections 7.1. and 7.2), where the industry also started (see Chapter 8), and therefore where it is expected that more orphans exist.

Rules

Communities function on the base of some rules, most of them tacitly recognised by the modders and the other participants in the discussions in the forums and websites. In general, acknowledgement is always given to modders that have done the same or similar modifications before. Furthermore, before engaging in a project, modders usually search for the existence of similar projects to the ones they have in mind. As seen above, they define the goals of the modification beforehand, and in this way they can assess the originality of an idea.

Only positive comments are allowed, and this is one of the few written rules of the forums. For instance, one of the modders was compared to an artist (case 6):

> A sculptor can look at a piece of raw marble and see the sculpture within. A painter sees limitless possibilities in a blank canvas. Then there are those modern craftsmen who see the massive bulk of a classic NES game as a work of art waiting to happen.

The exchange of constructive comments helps improving each others' projects, so negative comments are not accepted, as expressed in the response from a member of a community to an unpleasant comment (case 17):

> I can see YOU aren't a hardcore nerd, or you would see that taking two obsolete electronic devices and sticking them back together is cool.

Individual process, shared outcome

Modding seems to be an utterly individual activity, although its results are disseminated within the community. Only one of the cases in our sample was conducted by two persons, and in a particular context, since it was made for academic purposes (case 49). All the others were the providence of a single individual.

Furthermore, only 15% of the respondents to the survey referred that the influence of others was helpful or very helpful in the modification process, and 60% mentioned that the cooperation with other people doing modifications is only somehow helpful, or not helpful at all (see Figure D.6, Appendix D). This aspect was already implicit in the importance of "learning by yourself" mentioned above.

However, the individual character of the process is not motivated by the competition among modders, as mentioned by 55% of the respondents (see Figure D.5, Appendix D). The ideas and the projects are shared within the communities, and modders are keen on showing their achievements, as stated by one of the respondents that he wants to "share the experience" when he mods something that has not been made.

This willingness to share is a manifestation that reputation plays an important role. Recognition from peers is somehow important or important for 75% of the respondents (see Figure D.5, Appendix D), and often the projects are published in more than one site, contributing to the tacit recognition of some modders as "gurus" that gather following and become hubs of the community.

Entertainment with no commercial purpose

Modding is an activity run mostly as a hobby with non-commercial character. It is an important phenomenon from the perspective of its technical relevance, but it is also the mere result of individual attempts to act over technology, with no further ambition of reaching the economic relevance of innovations. On the one hand, 70% of the respondents of the survey mentioned that making additional income is not one of the motivations, and on the other, 85% referred that being entertained for some hours is an important or very important motivation (see Figure D.5, Appendix D).

In few occasions, though, the modifications are made by request from others, and when that is not the case, they are sometimes sold afterwards (e.g., through e-Bay), but not before the modder has used them for some time. Nonetheless, the effects of technological change do not expand beyond this individual and non-market logic. It is a phenomenon with relevance to define the "life" of these communities, but with no economic impact. We did not find any cases where the technological changes feedback into the economy, in the sort of processes described by von Hippel (1988) and Rosenberg (1982, pp. 120-140).

However, there are some examples of platform manufacturers that build on the retrogaming phenomenon, to release new versions of vintage software and hardware. This is a small-scale phenomenon, but in any case a sign that manufacturers regard the markets for vintage products as not "dead" yet, indicating that in the future, some of these modding projects could inspire the introduction of new products on the market.

Two paradoxes

These communities carry two paradoxical aspects. First, although they seem to provide alternative support networks for their members, the latter do not feel "angry" about the fact that their hardware was orphaned and therefore several of the actors of the original ecosystem (see Chapter 6) are not available to them anymore. Second, although orphans come together in thematic communities, they unite fundamentally due to the technical aspects of modding, and not necessarily because of a shared appreciation for vintage video games.

75% of the respondents referred that internet resources (e.g. tutorials, forums or communities) are deemed to be helpful or very helpful in the modification process (see Figure D.6, Appendix D). Nonetheless, 75% of the respondents also claim that overcoming the lack of technical support from the manufacturer in not an important motivation to conduct the modifications (see Figure D.5, Appendix D). These are yet two more indications that modders do not feel "angry".

Orphans enjoy modding in general. 80% of the respondents claimed that they modify other types of products, new or old, as diverse as telephones, clocks, turntables, amplifiers, vintage woodworking machines, toys (see Figure D.8, Appendix D). This indicates that technological changes made to vintage video games hardware is a part of a larger community that is involved in modding in general, an idea reinforced by some comments made by the respondents of the survey, that referred they modify "anything worth a try to fix or make better" or "anything to make it more interesting". One of them referred that he mods "for a living".

The driver for the modifications in not necessarily the emotional attachment to vintage/retro objects (see Figure D.5, Appendix D). Modding seems to be an activity motivated by the appreciation of doing technological changes to objects in general.

11.3. USE AND TECHNOLOGICAL CHANGE

What was discussed in the previous sections brings us to three central ideas regarding the connection between technological change and use. First, old video game consoles are still in use, even after they are no longer on the market or are thought of as being obsolete. Second, users act as agents of technological change on that hardware. Third, and in consequence of the previous, users extend the life of the vintage video games hardware, by challenging its technological limits.

These ideas can be considered obvious to some extent, since we implicitly hypothesised them as the focus of our research, and therefore the problem was narrowed from the beginning, influencing the direction of the research. They are nonetheless central in this work, and we discussed them with more detail below.

Discontinued, but still in use

The mere fact that we were able to find a sample of cases of technological change is enough to prove that discontinued video game consoles are still in use, in line with the idea that technologies do not just disappear completely (see Chapter 4).

Beyond the narrow scope of our focus, there are certainly other instances where discontinued video game consoles are still used for their original purpose, and in their original condition. In fact, as seen above, a share of the cases we found aims at improving the performance of the old consoles, while maintaining the same use.

The quantification of those phenomena remains an open question. We can nevertheless say in this regard that most of the cases we found, involved modifications to the NES and to the Atari 2600, both sales hits, discontinued more than fifteen years ago.

Users as Agents of Technological Change

All the respondents to the questionnaire claimed to have played video games (regardless of the format) at least once in their lives (see Figure D.1, Appendix D). Since the questionnaire was sent to people who had been responsible by at least a case of technological change, this confirms that users are the agents of technological change, i.e., the use of video games seems to be a precondition for its modification later on, although the appreciation for modding in general also plays a role in this activity.

A modder that transformed a ColecoVision into a portable system (case 12), made a remark showing that there is still place to improve old video game consoles, and users see themselves as an important factor in this process of improvement:

> I hated the original ColecoVision controller. The original "stunted stick" was too small for your hands (like an Atari) but too big for your thumbs (like a Nintendo) Perhaps it was designed by Hobbits - who knows? So here's my big chance to change the world.

However, that does not necessarily mean the use of the same models. From the 90% of the respondents that claimed to have played home video game consoles before they started modifying them, 22% used to play the models they came to modify later on, and 72% both the models they modify and models other than the ones they modify (see Figure D.3, Appendix D). This result can be interpreted as another expression of the emotional side of video games and the popularity of retrogaming, confirmed by the fact that emotional attachment to video games was deemed to be an important or very important motivation to start a modification for 75% of the respondents (see Figure D.5, Appendix D).

Challenging Technological Limits

In consequence of the previous, users are thus responsible by the technical change that is at the basis of the extension of the life cycle of video games hardware after it is discontinued, something we anticipated in Sections 2.2. and 3.2. These orphans are therefore challenging the technological limits of the hardware, although they do it in an unconscious way.

60% of the respondents felt motivated to conduct modifications by the thrill of the technical challenge, but challenging the limits of the hardware and improving its performance do not constitute strong motivations (see Figure D.5, Appendix D), although these are two clear conclusions from the analysis of the characteristics of the technological change.

CONCLUSIONS

Throughout the thesis we overviewed the period from when the users of home video game consoles become "orphaned", until the point when they act as agents of technological change on the "old" surviving vintage hardware no longer on the market. By bridging those two points, we have answered the questions set at the beginning of the thesis, and hopefully contributed to a deeper understanding of the phenomenon we studied.

The first and more general question was if *there are limits to technological development*. A conclusion that stems from this work is that in some occasions technological limits are in fact transcended, something we anticipated in the literature review. Still this was not the primary focus of our work, so no great reasoning or justification for that conclusion can be put forward, but the fact is that it derives from the cases we studied. Users of discontinued video game consoles thought of as obsolete, took on the role of agents of technological change and acted on the technology in different ways and with several purposes.

This brings us to the main intent of this thesis: *to explore the characteristics of technological change made by users of discontinued home video game consoles*. Technological change tends to be somewhat complex, and done through small incremental steps, on an individual learning by doing basis. By acting on the technology in such manner, orphans have two main purposes: to improve the hardware so they are able to play the same games they did before, or reopen the hardware's interpretative flexibility and use it in new contexts and ways.

In fact, we can take the interpretative flexibility argument one step further and claim that regardless the use of the modification being the same or not, just by doing these technical changes, orphans are in any event reopening the interpretation of the hardware. We explored what can be considered an additional form of entertainment provided by home video games: their modification. Being modified is something for which consoles are not designed originally, and in that sense, by modifying them hobbyists are always reopening its' interpretative flexibility, and redefining its' use, in the same manner as the rural users of the car in Kline and Pinch (1996).

Those hobbyists come together in online communities in a spontaneous way, although influenced at an early stage by the *industry's dynamics*, when they become orphaned. Short product life cycles, combined with intense rivalry between *de facto* standards lead to high console turnover. Limited inter- and intra-platform backward compatibility, combined with manufacturers' strategies aimed at increasing consumer switching costs contribute to consumer lock-in. Many users are thus left in the position of "angry orphans", because some elements of the industry's ecosystem cease to be available henceforth, e.g., support from hardware and software manufacturers.

However, later on, some of those users gather in online communities, developing a sort of alternative network where they find support, and renewed value in the outcome of their modifications. These orphans of the home video games industry are thus comfortable with the old. They do not necessarily feel "angry" or captive of the "winners' curse" by the fact that they are still using "old" or "obsolete" hardware.

The exploration of those communities of modders rendered a characterisation of the *motivations and context* of the technological change. The process is an individual activity, yet there is a constructive context of information sharing, and support from the community. This context motivates the modders, contributing to the continuous improvement of their skills, the quality of their projects, and to build reputation within the community.

The emotional attachment to video games, in particular their appreciation as symbols of the past is another important driver of the modifications, yet many orphans engage in technological changes to vintage home video game consoles because they usually do them, regardless of the type of product. Thus, these users enjoy being part of this subculture, on the one hand because of the blessings of the emotional side of vintage video games, and on the other because they appreciate the technical challenge of modifying things.

However, the outcome of those technological changes does not feedback into the *innovation processes of companies*. Their scope is relevant from a technical point view, but confined to an individual sphere that skips the logic of the market for the moment, something we anticipated in the introduction. This sort of technological tinkering conducted by hobbyists has proven essential in the development of the electric guitar, for instance (Waksman, 2004), however in the home video games industry, although there are some companies reviving past hardware and software, linked to the popularity of the retrogaming phenomenon, they do not incorporate the results of the activities we studied in their processes yet.

In general, our findings confirm that on the one hand, "old" technologies continue to exist and to be improved long after they reached their supposed technological limits, and on the other that users are responsible by the extension of both the period in which they are in use and their physical limits. In face of this evidence, the product life cycle literature should at least allow some leeway to recognise that in some cases there is a subsequent phase to the maturity stage, in which products and technologies are still in use, and furthermore being improved, but no longer available on the market.

We believe this thesis and its findings demonstrate the importance of studying technology in use, and are a valid contribution to the understanding of this reality, and the relation between use and technological change, within the exploratory character, and the limitations mentioned before. However, a dissertation is by definition something prone to constant evolution and improvement, and so being some aspects were left outside its scope. For those reasons, the reflexive debate about the outcome of our work, and the possibilities for further research that are opened on its basis resulted in three ideas for improvement: the deepening of the analysis of the industry's context and the diffusion process, the exploration of the analysis from the perspective of the leaning economy, and the broadening of the scope of the study, to include other industries or products.

The analysis could have benefited from a deeper understanding of the industry's context, although this was somewhat covered in the historical account. Nevertheless, in this regard, a rather subtle but decisive detail is for instance that without the prior diffusion and generalised use of the TV, especially in the households of America, the evolution of the home video games industry would not have been possible. The complementarity between video game consoles and the TV is implicit in the possibility of players enjoying video games at home, and that certainly influenced the particularities of use and the characteristics of users, and might have been an important factor influencing the technological change.

This points, on the one hand, to the need for a deeper understanding of the industry's context and its impacts on the users (e.g., political factors, and income levels), and on the other, for a refined analysis of the diffusion process of the technologies and how its nature affected the results of the study (e.g., its contribution to the creation of orphans).

In our analysis we might seem to be advocating for a "culture of the old", relegating a cornerstone for economic progress in the learning economy: the need to renew competences, and rapidly learn new things, while forgetting old knowledge that gets in the way of learning new ways (Lundvall and Archibugi, 2001).

That was not the case. What we implicitly mean with our analysis is that the orphans that conduct technological changes on vintage home video games might not be forgetting everything, but even so, they actually leave their options open to develop new knowledge. Although those technological changes do not achieve the economic relevance of an innovation, they certainly represent some level of technical originality, and a contribution to the advancement of technological progress, the nuance being that the new knowledge is created based on "old" things that are thought of as obsolete.

Hence, it would have been interesting to explore the study from the perspective of the learning economy, probing into the analysis of the relation between "old" things that linger on for a long time and the extent to which users of such orphaned technologies create new knowledge based on them when conduction technological changes. Within this sort of reasoning, Postigo (2007) shows that fan-based add-ons for games can reach an important scope regarding both the knowledge that is needed to create them and the new knowledge resulting from them, and achieve considerable economic significance.

Finally, the scope of thesis could be broadened, so the same sort of analysis would be used as a template to explore other industries or products. This was an ambition mentioned at the outset of this work, that we believe it is feasible, and can produce a wealth of results to the understanding of use in connection with technological change.

Therefore, it would be interesting in the follow-up of this work to conduct a comparative study of discontinued products and technologies including cases similar to the one we analysed, where users take on the role of agents of technological change, and simultaneously look at other cases, that are equally discontinued, but whose users do not technically act on them. "Angry orphans" and the "winner's curse" occur in other types of industries and products, as we mentioned. So what happened, for instance, to the users of typewriters, cars, washing machines, PDAs, VHS recorders that are no longer on the market, but that are surely still being used?

Such study would capture the extent to which technological changes to discontinued products is a general pattern or not, and render a deeper understanding of different dimensions of analysis and characteristics of such products and users (e.g., the specificities of the products that make them more prone to be modified, or the patterns of technological tinkering according to the different types of users and products).

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APPENDIX

APPENDIX A – DATES OF RELEASE AND DISCONTINUITY, AND TECHNICAL SPECIFICATIONS FOR SELECTED CONSOLES

Generation	Console	Manufacturer	Time-Span		Media	Operating Performance		
			Release Date (US)	Discontinued	Media	CPU Speed (MHz)	CPU Bits (Width)	RAM
1st (1972-1976)	Odyssey	Magnavox	1972	Mid-1975	-	n/a	-	-
	PONG	Atari	Jan. 1975	1977	-	n/a	-	-
	Telstar	Coleco	Jun. 1976	n/a	-	n/a	-	-
2nd (1976-1984)	VES (Channel F)DD	Fairchild	Aug. 1976	1978	Cartridge	2	8	64 KB
	Studio II	RCA	Jan. 1977	1979	Cartridge	1.78	8	4 KB
	2600 (VCS)	Atari	Oct. 1977	Jan. 1991	Cartridge	1.19	8	128 b
	Astrocade	Bally	Feb. 1978	1984	Cartridge	3.58	8	4-64 KB
	Odyssey2	Magnavox	1978	1983	Cartridge	1.78	8	64 b
	Intellivision	Mattel	Dec. 1979	1984	Cartridge	0.5	16	7 KB
	Arcadia 2001	Emerson	Mar. 1982	1983	Cartridge	3.58	8	1 KB
	ColecoVision	Coleco	Sep. 1982	1984	Cartridge	3.58	8	8 KB
	Vectrex	Milton Bradley	Nov. 1982	1984	Cartridge	1.5	8	512 b
	5200	Atari	1982	1984	Cartridge	1.79	8	16 KB
3rd (1985-1991)	NES	Nintendo	Oct. 1985	1993	Cartridge	1.79	8	8 KB
	Master System	Sega	Jun. 1986	1990	Cartridge	3.6	8	128 KB
	7800	Atari	Jun. 1986	Jan. 1992	Cartridge	1.79	8	4 KB
4th (1989-1997)	TurboGrafx-16	NEC	Aug. 1989	1995	Cartridge	3.6	16	8 KB
	Sega Genesis	Sega	Aug. 1989	1997	Cartridge	7.61	16	64 KB
	Neo Geo AES	SNK	1990	1997	Cartridge	12,5	16	64 KB
	Super NES	Nintendo	Sep. 1991	1997	Cartridge	3.58	16	128 KB
	NEC TurboDuo	NEC	Oct. 1992	1995	Cartridge CD-ROM	7.16	8	64 KB
5th (1993-2001)	IM	3DO	Oct. 1993	1996	CD-ROM	12.5	32	3 MB
	Jaguar	Atari	Nov. 1993	1996	Cartridge	26.6	64	16 MB
	Neo Geo CD	SNK	1994	n/a	CD	14	16	64 KB
	Saturn	Sega	May 1995	1998	CD-ROM	2x28	32	2 MB
	PlayStationDD	Sony	Sep. 1995	2000	CD-ROM	33.9	32	2 MB
	Nintendo 64	Nintendo	Oct. 1996	2001	Cartridge	93.75	64	4 MB
6th (1999-present)	Dreamcast	Sega	Sep. 1999	Mar. 2001	GD	200	128/64	16 MB
	PlayStation 2	Sony	Oct. 2000	-	DVD	300	128	32 MB
	GameCube	Nintendo	Nov. 2001	Nov. 2007	GC Disc	485	128	40 MB
	XboxDD	Microsoft	Nov. 2001	Mar. 2009	DVD	733	128	64 MB
7th (2005-present)	Xbox 360	Microsoft	Nov. 2005	-	CD/DVD	3.2 GHz	-	512 MB
	PlayStation 3	Sony	Nov. 2006	-	CD /DVD	3.2 GHz	-	513 MB
	Wii	Nintendo	Nov. 2006	-	Wii Disc GC Disc	729	-	88MB

Note: DD – Dominant Design; n/a – not available; - Not Applicable.

Source: data compiled from Kent (2001). Gallagher and Seung Ho (2002), Schilling (2003), Clements and Ohashi (2005), Evans et al. (2006), Wolf (2008c), and All Game at www.allgame.com, Classic Gaming at www.classicgaming.gamespy.com, Old Computers Museum at www.old-computers.com, Retro Gaming Consoles at www.retrogamingconsoles.com, Retrothing at www.retrothing.com, What Console at www.whatconsole.co.uk, Tieto Kone Museo at www.tietokonemuseo.net, The Video Game Museum at www.vgmuseum.com.

APPENDIX B – CASE STUDIES

Cases		Console(s)				Modification Categories															
						Object			Process			Outcome		Interaction Set-Up					Purpose		
														New		Same					
Nr.	Description					Console	Controller	Data Support	Substitution	Addition	Removal	Within Original Hardware	New Piece of Hardware	Link to Other Technologies	Function Independently	Same console	Older console	Newer console	New Use	Same Use	Description
1	Atari 2600 Joystick TV Remote Control	A 2600					x			x	x	x		x					x		Remote Control
2	Atari 2600 Game Wallet	A 2600						x			x	x			x				x		Wallet
3	Bankzilla	A 2600	A 7800			x			x	x	x	x				x				x	Video Games
4	Atari 2600 Cartridge Wallet	A 2600						x			x	x			x				x		Wallet
5	Circuit Bent Nintendo Famicoms	FAM				x				x		x		x					x		Make Music and Video
6	NES in a Cartridge	NES						x		x	x	x		x					x		Video Games
7	Portable NES	NES						x	x	x	x	x			x				x		Portable Video Games
8	NES Remote for Apple	NES					x			x	x	x		x					x		Remote Control
9	Atari 2600 Portable	A 2600	PSOne			x	x		x	x	x		x		x					x	Portable Video Games
10	Atari 5200 Cartridge iPod Dock	A 5200						x		x	x	x		x					x		iPod Dock
11	Portable SNES	SNES				x	x		x	x	x		x		x					x	Portable Video Games
12	Portable Colecovision	CV				x	x		x	x	x		x		x					x	Portable Video Games
13	Portable Gamecube	GC	PSOne			x	x		x	x	x		x		x					x	Portable Video Games
14	NES AdPad	NES					x		x	x	x	x				x				x	Controller
15	NES Cartridge External Hard Drive	NES						x		x	x	x		x					x		External Drive Casing
16	NES Controller Cellphone	NES					x			x	x	x		x					x		Mobile Phone
17	NES Cartridge PDA	NES						x		x	x	x		x					x		PDA
18	NES Controller Wallet	NES					x			x	x	x			x				x		Wallet

Note: A 2600 - Atari 2600; A 5200 - Atari 5200; A 7800 - Atari 7800; CV - Colecovision; FAM - Nintendo Famicom; GC - Nintendo GameCube; NES - Nintendo Entertainment System.

Continued on the next page.

Source: own elaboration.

(Cont.)

Cases		Console(s)				Modification Categories															
						Object			Process			Outcome		Interaction Set-Up					Purpose		
														New		Same					
Nr.	Description					Console	Controller	Data Support	Substitution	Addition	Removal	Within Original Hardware	New Piece of Hardware	Link to Other Technologies	Function Independently	Same console	Older console	Newer console	New Use	Same Use	Description
19	NES USB Controller	NES					x		x	x	x	x		x						x	Controller
20	NES Controller with LEDs	NES					x			x		x				x				x	Controller
21	Atari 2600 Joystick with LEDs	A 2600					x			x		x				x				x	Controller
22	NES Cartridge Powered Speakers	NES						x		x	x	x		x					x		Speakers
23	Nestune	NES	FAM			x			x	x	x	x		x					x		Make Music and Video
24	NES Advantage Guitar Pedal	NES					x			x	x	x		x					x		Guitar Pedal
25	Bent NES	NES				x				x		x		x					x		Video Synthesiser
26	NES Controller Bike Flasher	NES					x			x	x	x			x				x		Bike Flasher
27	NES Cartridge Clock	NES					x			x	x	x			x				x		Clock
28	NES Lunchbox	NES				x					x	x			x				x		Lunchbox
29	NES PC	NES				x			x	x	x	x		x					x		PC
30	NES Controller PC Card Reader	NES					x			x	x	x			x				x		PC Card Reader
31	SNES Cartridge USB Hub	SNES						x		x	x	x		x					x		USB Hub
32	Sega Master System controller to Atari 7800	SMS	A 7800				x		x		x	x					x			x	Controller
33	NES USB Controller With Games	NES					x			x	x	x		x						x	Video Games
34	GameCube with LCD	GC				x				x		x			x					x	Video Games
35	DreamCast Portable	DC	PSOne			x			x	x	x		x		x					x	Portable Video Games
36	Geosis	AES	SG			x			x		x	x				x				x	Video Games

Note: AES - Neo Geo AES; A 2600 - Atari 2600; A 7800 - Atari 7800; DC - Sega DreamCast; FAM - Nintendo Famicom; GC - Nintendo GameCube; NES - Nintendo Entertainment System; PSOne - PlayStation One; SNES - Nintendo Super Entertainment System; SMS - Sega Master System; TG – Turbografx.

Continued on the next page.

Source: own elaboration.

(Cont.)

Cases		Console(s)				Modification Categories															
						Object			Process			Outcome		Interaction Set-Up					Purpose		
														New		Same					
Nr.	Description					Console	Controller	Data Support	Substitution	Addition	Removal	Within Original Hardware	New Piece of Hardware	Link to Other Technologies	Function Independently	Same console	Older console	Newer console	New Use	Same Use	Description
37	TurboGrafx Portable	TG	PSOne			x			x	x	x		x		x					x	Portable Video Games
38	Atari 2600 Jukebox	A 2600				x			x	x	x	x				x				x	Video Games
39	NES Controller Business Card Holder w/ Sound	NES					x			x	x	x			x				x		Business Card Holder
40	Vectrex PSX Controller	PS1					x		x		x	x					x			x	Controller
41	PSOne Portable	PSOne				x			x	x	x		x		x					x	Portable Video Games
42	Dreamcast Tablet	DC				x			x	x	x		x		x					x	Portable Video Games
43	NES Controller for Nintendo DS	NES	DS				x		x		x	x						x		x	Controller
44	NES64	NES	N64			x			x		x	x				x				x	Video Games
45	NES Controller iPod Remote	NES					x			x	x	x		x					x		Remote Control
46	Wiintendo	NES	Wii			x			x		x	x				x				x	Video Games
47	NES Controller 4 Port USB Hub	NES					x			x	x	x		x					x		USB Hub
48	NES Controller MP3 Player	NES					x			x	x	x		x					x		MP3 Player
49	PS1 Massage Kit	PS1					x		x	x	x		x			x			x		Massage Kit
50	HarmoNESica	NES						x		x	x	x			x				x		Harmonica
51	SNES Controller for PSP	NES	PSP				x		x		x	x						x		x	Controller
52	Nintoaster	NES				x			x	x	x		x			x				x	Video Games
53	NES Controller 4 Port USB Hub	NES					x			x	x	x		x					x		USB Hub
54	SNES Portable V1	SNES	PSOne			x			x	x	x		x		x					x	Portable Video Games

Note: DC - Sega DreamCast; DS - Nintendo DS; NES - Nintendo Entertainment System; N64 - Nintendo 64; PSOne - PlayStation One; PS1 - PlayStation 1; PSP - PlayStation Portable; SNES - Nintendo Super Entertainment System; Wii - Nintendo Wii.

Continued on the next page.

Source: own elaboration.

(Cont.)

Cases		Console(s)				Modification Categories															
						Object			Process			Outcome		Interaction Set-Up					Purpose		
														New		Same					
Nr.	Description					Console	Controller	Data Support	Substitution	Addition	Removal	Within Original Hardware	New Piece of Hardware	Link to Other Technologies	Function Independently	Same console	Older console	Newer console	New Use	Same Use	Description
55	NESp3	NES					x			x	x	x		x					x		MP3 Player
56	Nestation	NES				x			x	x	x	x				x				x	Video Games
57	Super Nintoaster	NES				x			x	x	x		x			x				x	Video Games
58	Nintendo Super Nii	NES				x			x	x	x	x				x				x	Video Games
59	NES DVD Player	NES				x				x	x	x		x					x		DVD Player
60	LED Coffee Table	A 2600					x		x		x	x		x						x	Coffee Table
61	Wireless NES and SNES controllers for Wii	NES	SNES				x		x	x	x	x						x		x	Controller
62	Super Genintari	A 2600	NES	SG	SNES	x			x	x	x		x			x				x	Video Games
63	Dedicated NES Arcade Emulator	NES				x			x	x	x	x				x				x	Video Games
64	NESpV1	NES	PSOne			x			x	x	x		x		x					x	Portable Video Games
65	NESVD	NES				x				x	x	x		x					x		DVD Player
66	SNES Portable	SNES				x	x		x	x	x		x		x					x	Portable Video Games
67	NES Zelda Edition	NES				x				x	x	x				x				x	Video Games
68	Modified NES	NES				x			x	x	x	x				x				x	Video Games
69	NES Cartridge Hard Drive Enclosure	NES						x		x	x	x		x					x		External Drive Casing
70	Top-loading NES	NES				x			x	x	x		x			x				x	Video Games

Note: A 2600 - Atari 2600; NES - Nintendo Entertainment System; PSOne - PlayStation One; SG - Sega Genesis; SNES - Nintendo Super Entertainment System.

Source: own elaboration.

APPENDIX C – QUESTIONNAIRE

Home Video Game Consoles Survey

The data collected in this survey are strictly confidential and will be used for academic purposes only, in the context of a Master thesis at Aalborg University, Denmark.

*Required Answers

1. Uses

This section characterises your past and current video game habits.

1.1. Have you ever played video games in your life? *

- O Yes
- O No

1.2 In which platform(s) do you currently play or have played video games? *

Please check all items.

	In the past	Currently	Never
Home Video Game Consoles	O	O	O
PC	O	O	O
Handhelds (e.g., Game Boy)	O	O	O
Arcades	O	O	O
Other	O	O	O

1.3.1 Did you play games in home video game consoles before you started modifying them? *

- O Yes. Only the model(s) I modify.
- O Yes. Model(s) other than the one(s) I modify.
- O Yes. Both the above.
- O No.

Please specify which model(s) ____________________

1.3.2 Do you currently play games in home video game consoles? *

- O Yes. Only the model(s) I modify.
- O Yes. Models other than the one(s) I modify.
- O Yes. Both the above.
- O No.

Please specify which model(s) ____________________

2. Modifications

This section aims at understanding the motivations, context and uses of hardware modification.

2.1 Rate the importance of the items below as a motivation for conducting modifications in home video game hardware. *
Please check all items.

	Not important at all	Somehow important	Important	Very important
Fulfil a special need	O	O	O	O
Find other use(s) for the hardware	O	O	O	O
Be entertained for some hours	O	O	O	O
Make an additional income	O	O	O	O
The thrill of the technical challenge	O	O	O	O
Improve the performance of the hardware	O	O	O	O
Challenge the limits of the hardware	O	O	O	O
Overcome the lack of technical support from the manufacturer	O	O	O	O
Retro things are trendy and/or fashionable	O	O	O	O
Emotional attachment to video games	O	O	O	O
Be recognised by other people doing modifications	O	O	O	O
Competition with other people doing modifications	O	O	O	O

2.2. Rate the contribution of the items below to the success of the modification(s) in home video games hardware. *
Please check all items.

	Not helpful at all	Somehow helpful	Helpful	Very helpful
Education background	O	O	O	O
Influence of others (e.g., family, friends or acquaintances)	O	O	O	O
Internet resources (e.g., tutorials, forums or communities	O	O	O	O
Learning by yourself	O	O	O	O
Playing games for many years	O	O	O	O
Cooperation with other people doing modifications	O	O	O	O

2.3 Do you specify any rules prior to a modification? *
Please check at least one item. If you check "Other", please specify which.

- ☐ No
- ☐ Limited Timing
- ☐ Technical constraints
- ☐ Limited budget
- ☐ Other: ____________________

2.4 Do you modify or have modified other types of products? *

- O Yes. Old things.
- O Yes. New things.
- O Yes. Both old and new things.
- O No.

If you answered "Yes", please specify which type(s). ____________________

3. Personal Details

This section characterises you.

Age

Sex

- O Male
- O Female

Location

- O Europe
- O North America
- O South America
- O Africa
- O Asia
- O Australia
- O Other:

Thank you very much for your cooperation!!

If you have further comments or contributions regarding the issues covered in the survey, or that should have been included otherwise, please do not hesitate to contact me.

APPENDIX D – RESULTS OF THE SURVEY

Figure D.1 – Question 1.1 "Have you ever played video games in your life?"

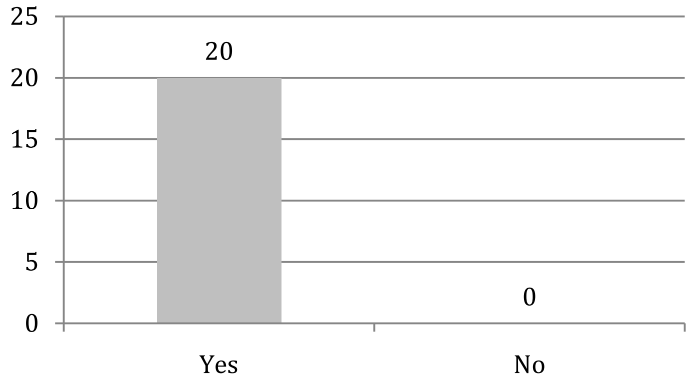

Figure D.2. – Question 1.2 "In which platform(s) do you currently play or have played video games?"

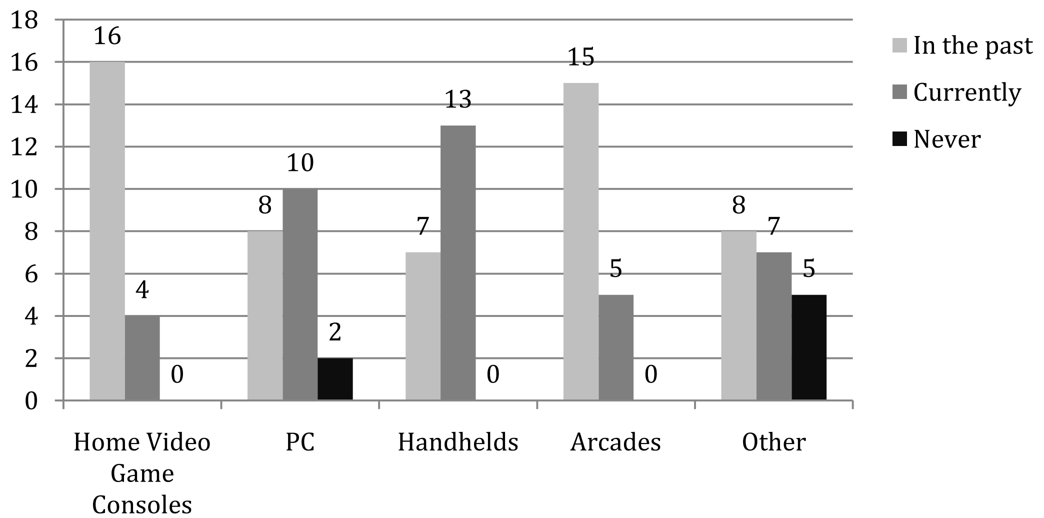

Figure D.3 – Question 1.3.1 "Did you play games in home video game consoles before you started modifying them?"

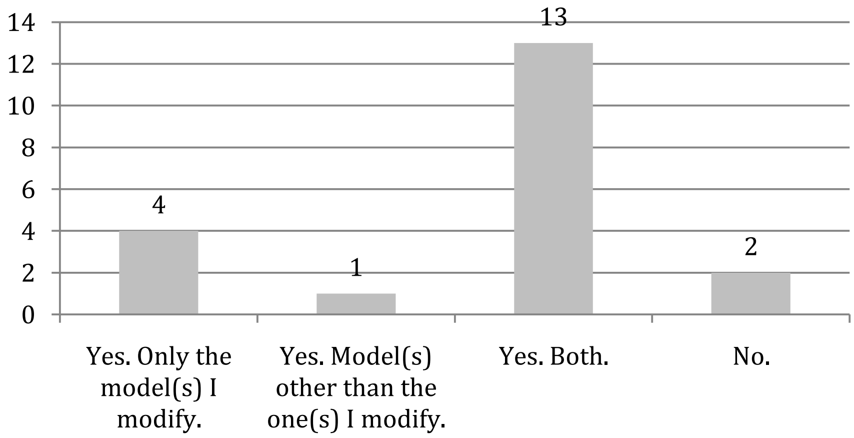

Figure D.4 - Question1.3.2 "Do you currently play games in home video game consoles?"

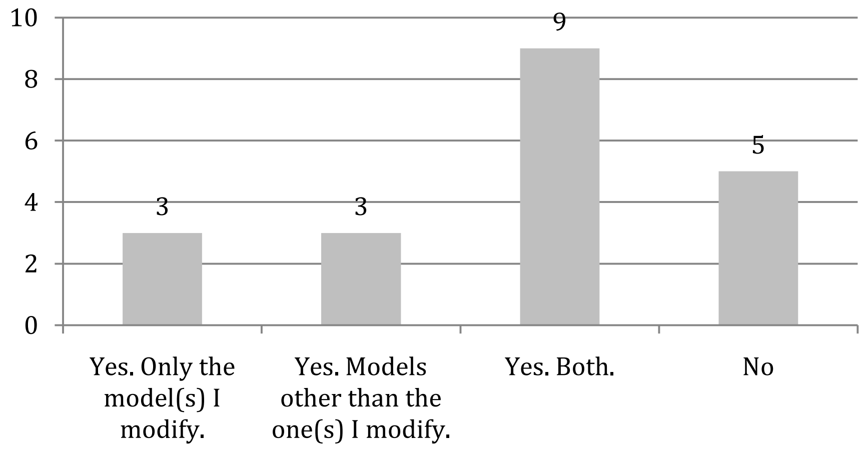

Figure D.5 – Question 2.1 "Rate the importance of the items below as a motivation for conducting modifications in home video game hardware."

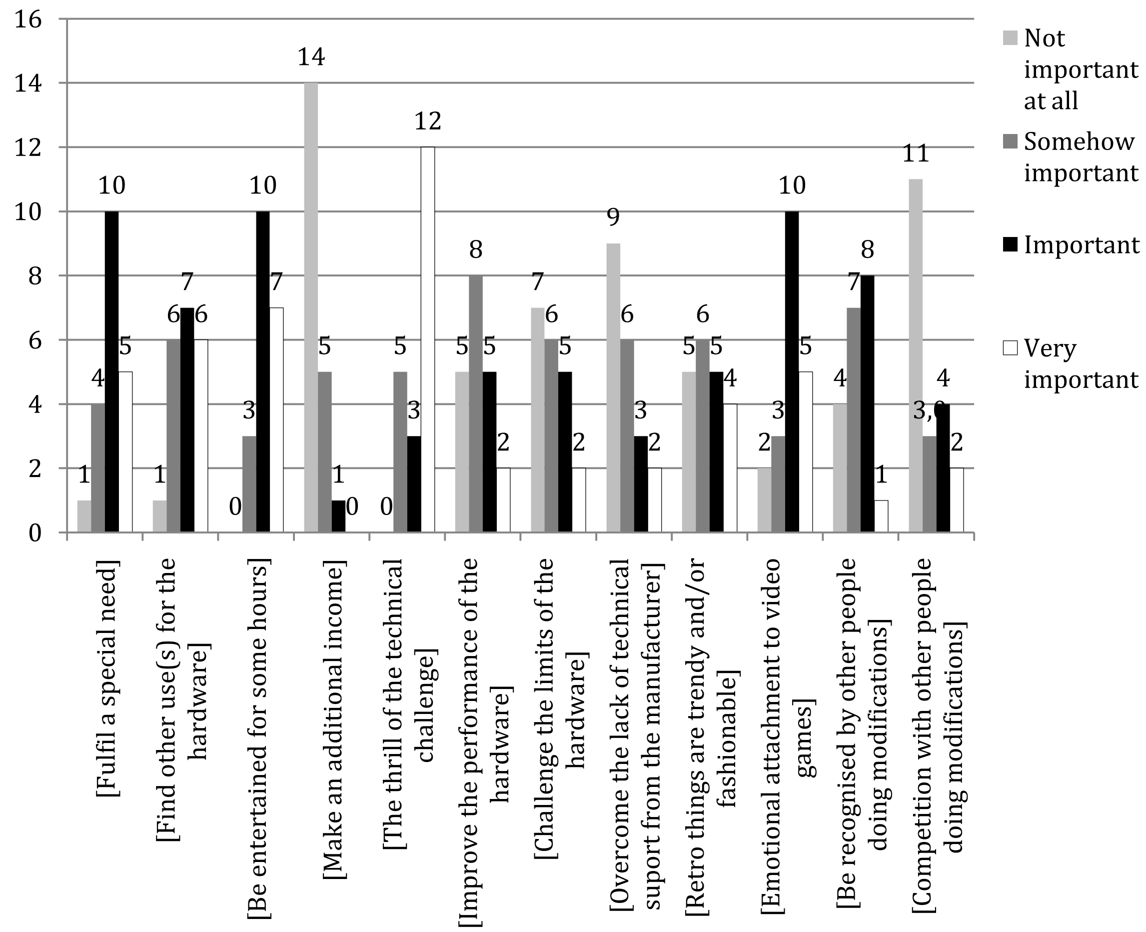

Figure D.6 – Question 2.2 "Rate the contribution of the items below to the success of the modification(s) in home video games hardware."

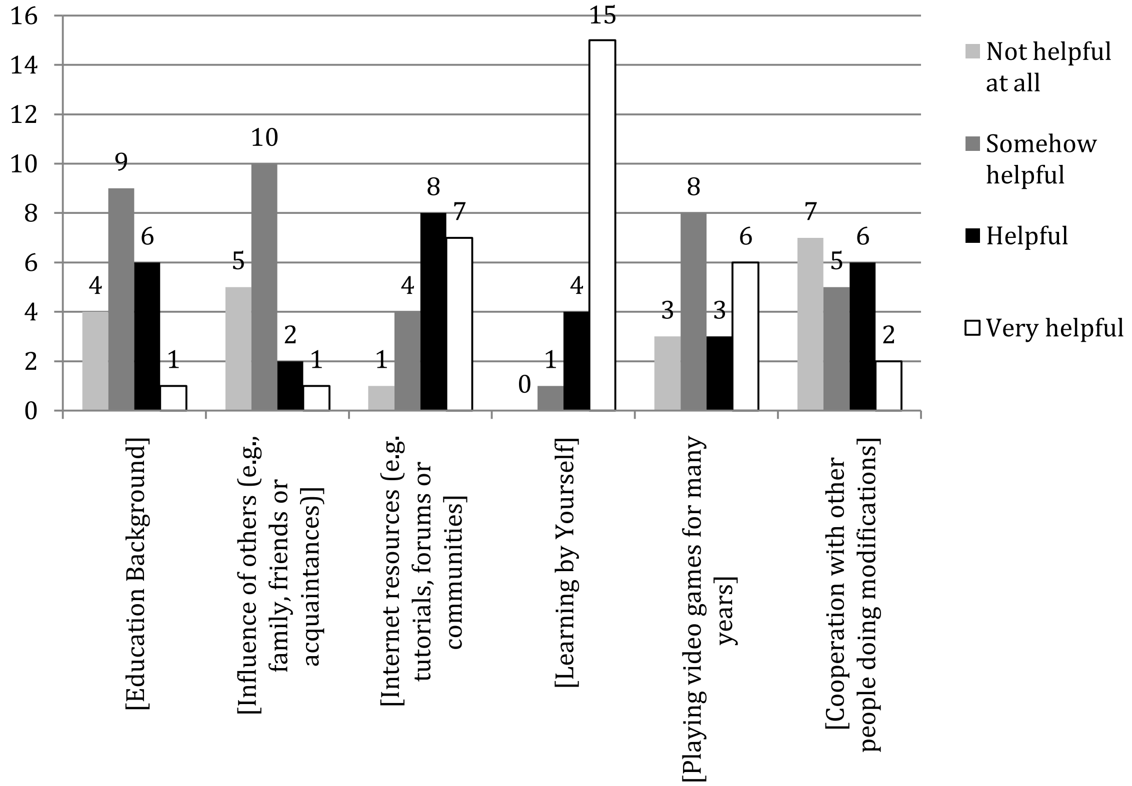

Figure D.7 – Question 2.3 "Do you specify any rules prior to a modification?"

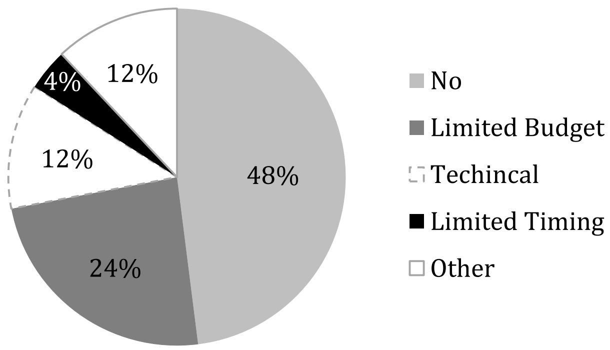

Figure D.8 – Question 2.4 "Do you modify or have modified other types of products?"

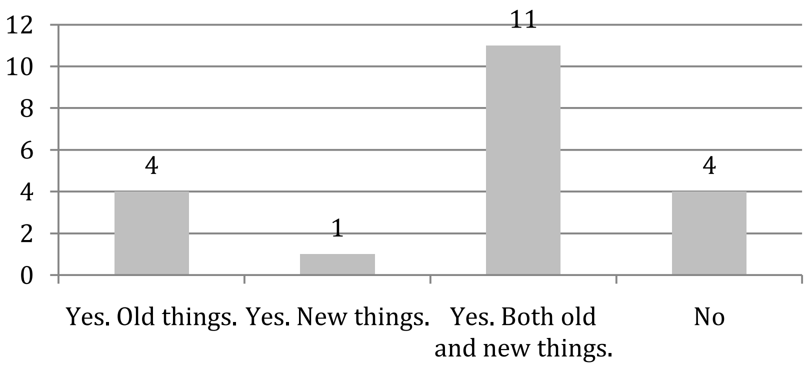

Figure D.9 – Respondents' sex

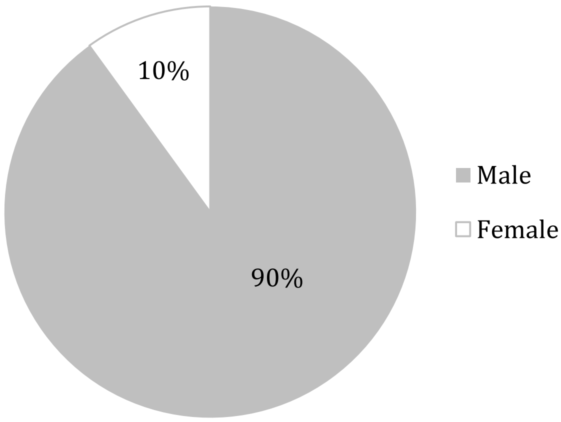

Figure D.10 – Respondents' age

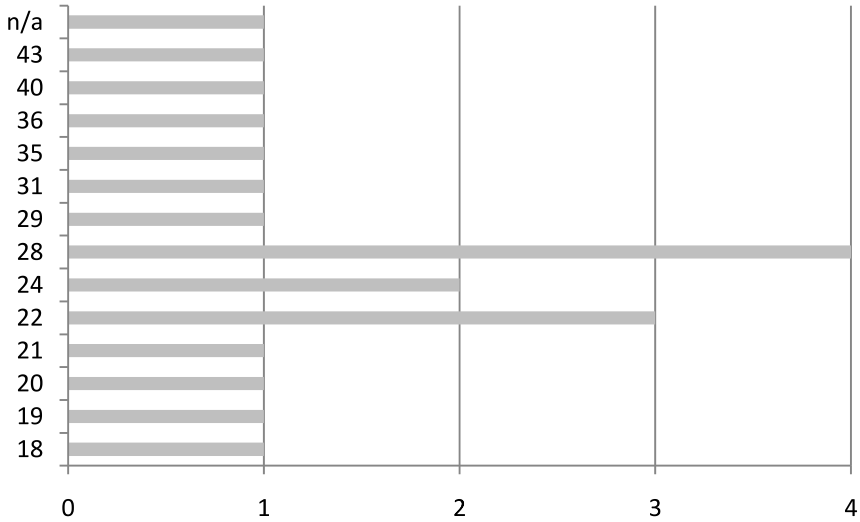

Figure D.11 – Respondents' location