ESSAYS ON INNOVATION

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Ensaios em inovação - Resumo

Esta tese apresenta-se como uma compilação de ensaios com um tema comum: a inovação. Este resumo apresenta-se na grafia pré acordo ortográfico.

O primeiro ensaio – Essay I – é uma abordagem taxonómica com o objectivo de entender as diferentes estratégias de colaboração encontradas no desenvolvimento de inovações.

O segundo ensaio – Essay II – analisa a indústria norte-americana de tractores através da perspectiva da dinâmica industrial. Usando uma base de dados original, são identificados três grandes avanços tecnológicos nesta indústria e testam-se as hipóteses de estes avanços terem influenciado a sobrevivência das empresas do sector.

O terceiro ensaio – Essay III – examina os efeitos das inovações no produto e no processo na sobrevivência de empresas na indústria cinematográfica norte-americana.

O quarto ensaio – Essay IV – estuda uma base de dados original da indústria do cinema desde 1982, onde se analisam os determinantes de fusões & aquisições e de liquidação ou falência.

Essays on Innovation – Abstract

This thesis is presented as a compilation of essays with innovation as a common theme.

Essay I is a taxonomic approach to the understanding of different strategies of collaboration in the development of innovations.

Essay II analyses the American tractor industry through an industrial dynamics perspective. Based on a completely original database, we identify three major technological breakthroughs in the American tractor industry and test the hypothesis that they influenced firms’ survival.

Essay III focuses on the effects of product and process innovation along the history of an industry. This paper examines the effects of these two types of innovation on the survival of firms throughout the whole history of the American feature film industry.

Essay IV studies the determinants of different firm exit modes. Using an original database on the film industry since 1982, the determinants of mergers & acquisitions versus liquidation are analysed.

Executive Abstract

This thesis is presented as a compilation of essays with innovation as a common theme.

Essay I is a taxonomic approach to the understanding of different strategies of collaboration in the development of innovations, a broad theme that includes open innovation, user innovation, open source software or even joint ventures. Through multivariate analysis it was possible to draw some interesting conclusions by identifying two general strategies of collaboration- a free revealing “democratic” strategy and a formal collaboration strategy. The first involves a proliferation of partners whose technical and creative skills are specific to the industry and the source of knowledge, and where the degree of interaction, play an important role. The second broad strategy of cooperation is linked to more formal collaboration, generally firm-firm collaboration; in this group we found a large focus on markets features, especially technological intensity.

Essay I has been published in the European Journal of Innovation Management and has already been cited by fifteen scientific works on innovation.

Essay II analyses the American tractor industry through an industrial dynamics perspective. Based on a completely original database, we identify three major technological breakthroughs in the American tractor industry and test the hypothesis that they influenced firms’ survival. We use the lognormal model and control for the effects of population density, market size, business cycles and entry timing. The results show that early entrants have lower hazard rates than firms that entered during the next development phase of the industry, a phase which was characterized by high technological uncertainty, experimentation and non-standardization. However they also suggest the existence of a second “window of opportunity” for entry, which occurred after the introduction of the general purpose tractor.

Essay III focuses on the effects of product and process innovation along the history of an industry. This paper examines the effects of these two types of innovation on the survival of firms throughout the whole history of the American feature film industry.

Essay IV deals with the question on whether the different exit routes a firm can take are influenced by innovations. In this essay it is proposed that two answers can be found to this question, depending on the type of analysis done. While traditionally industry dynamics has been considering the fate of firms as a choice between permanence as success and exit as failure, this essay proposes that exit should be studied as a heterogeneous event, distinguishing bankruptcy and liquidation from mergers and acquisitions.

Keywords:

I: Open Innovation, collaboration, taxonomy, strategy.

II: Innovation, tractor industry, dominant design, survival and hazard functions.

III: Product innovation, Process innovation, Firm survival, Motion picture production industry, survival and hazard functions.

IV: Firm exit, merger and acquisition (M&A), liquidation, product and process innovation, competing risks model, multinomial logit model.

Resumo Executivo

Esta tese apresenta-se na forma de compilação de ensaios com o tema comum Inovação. Este resumo apresenta-se na grafia pré acordo ortográfico.

O primeiro ensaio – Essay I – é uma abordagem taxonómica com o objectivo de entender as diferentes estratégias de colaboração encontradas no desenvolvimento de inovações. Este é um tema vasto, que inclui inovação aberta, inovação pelo utilizador, *open source software* e até *joint ventures*. Através de análise multivariada foi possível encontrar interessantes resultados ao identificar duas estratégias gerais de colaboração: democrática e formal. A primeira envolve uma proliferação de colaboradores cujas qualificações técnicas e criativas são específicas do sector e da fonte de conhecimento em questão e onde o grau de interacção tem um papel decisivo. A segunda estratégia de cooperação está ligada a uma colaboração mais formal, em geral entre empresas. Neste grupo encontra-se um grande foco em características de mercado e intensidade tecnológica.

Este ensaio foi publicado na revista European Journal of Innovation Management e já foi citado por quinze trabalhos científicos até hoje

O segundo ensaio – Essay II – analisa a indústria norte-americana de tractores através da perspectiva da dinâmica industrial. Usando uma base de dados original, são identificados três grandes avanços tecnológicos nesta indústria e testam-se as hipóteses de estes avanços terem influenciado a sobrevivência das empresas do sector. Foi usado o modelo *lognormal*, controlando-se para os efeitos de densidade populacional, dimensão do mercado, ciclo económico e tempo de entrada. Os resultados mostram uma menor mortalidade das empresas que entraram numa fase inicial em relação àquelas que entraram após a fase de desenvolvimento seguinte, caracterizada por incerteza tecnológica, experimentação e ausência de padronização. Encontra-se ainda uma segunda janela de oportunidade para entrada, que ocorreu após a introdução do tractor multifuncional.

O terceiro ensaio – Essay III – foca-se nos efeitos das inovações no produto e no processo ao longo da história de um sector. Este ensaio examina os efeitos destes dois tipos de inovações na sobrevivência de empresas através da história da indústria cinematográfica norte-americana.

O quarto ensaio – Essay IV – questiona se os diferentes modos de saída que uma empresa pode tomar são influenciados pelas inovações. Embora tradicionalmente a dinâmica da indústria tenha vindo a considerar o destino de empresas como uma escolha entre permanência como sucesso e saída como um fracasso, este ensaio propõe que a saída deve ser estudada como um acontecimento heterogéneo, distinguindo falência e liquidação de fusões e aquisições.

Palavras-chave:

I: Inovação aberta, colaboração, taxonomia, estratégia.

II: Inovação, indústria de tractores, design dominante, funções de risco e de sobrevivência.

III: A inovação no produto, inovação no processo , sobrevivência de empresas, indústria cinematográfica, modelos de duração.

IV: Saída do mercado, fusões e aquisições (M&A) , liquidação, inovação de produtos e processos, modelo de riscos concorrentes, modelo logit multinomial .

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ESSAY I: Separating the wheat from the chaff - a taxonomy of open innovation

Abstract

Purpose – The main objective of our work is to shed light on the confusion of terminologies related to open innovation through the development of an open innovation taxonomy. By analyzing published case studies using numerical taxonomy methods, we propose a taxonomic classification of open innovation.

Design/methodology/approach – We first review earlier work on firm collaboration and concepts related to open innovation in order to understand the main motivations and conditions behind open innovation-like strategies. We then proceed to collect and systematically analyze twenty published case studies, and using numerical taxonomy methods we produce a taxonomic classification of open innovation. As a first approach to taxonomy on open innovation strategies, the UPGMA methodology used seems very promising. The taxonomy of open innovation developed here can also be used as a decision making tool through the comparison of open innovation strategies inherent in the taxonomy.

Findings – Through the numerical taxonomy analysis we have been able to objectively create groups of similar cases, and strategies therein. This paper is able to draw some interesting conclusions by identifying two general strategies of collaboration- a free revealing "democratic" strategy and a formal collaboration strategy. The first involves a proliferation of partners whose technical and creative skills are specific to the industry and the source of knowledge, and where the degree of interaction, play an important role. The second broad strategy of cooperation is linked to more formal collaboration, generally firm-firm collaboration; in this group we found a large focus on markets features, especially technological intensity.

Research limitations/implications – This is a first attempt to use numerical taxonomy for the classification of open innovation strategies. A limited number of case studies are used to permit an intuitive understanding of the taxonomy, however inclusion of more studies would provide robustness to the conclusions. Within each of the two broad open innovation strategies, exist more specific strategies, which should be further analyzed in future research and the taxonomy should create nomenclature or archetypes of open innovation strategies.

Practical implications – The taxonomic classification of types of open innovation based on characteristics of firms and their environment allows the use of a classification grid to provide strategic orientation to firms wishing to pursue open innovation-like strategies.

Originality/value – This paper adds objectivity to the research of different open innovation strategies by using a method developed in the natural sciences. Based on a systematic review of literature, we are able to identify key characters describing features and come up with a taxonomy of open innovation, which goes a significant way to making sense of the plethora of terminology related to open innovation. Key features of different open innovation strategies are also revealed.

Keywords: Open Innovation, Collaboration, Taxonomy, Strategy. **Article Type:** Research paper

JEL: L24, O32

1. Introduction

Industrial innovation, during the 20th century, was based on the model of vertical integration, where the R&D division creates the basis to the innovations the firm would market.

The concept of open innovation is the opposite of this model relying on the observation that firms can use external knowledge, together with their own, to create products that can be sold to their market, a new market, or to some other firm. In this line of thought, R&D is seen as an open system, with several ways in and out, instead of a closed system, where there is only one way in for innovations – the R&D division of a firm – and one way out – the firm's market.

Corporate R&D roots from the observation that each firm has specific knowledge needs that would usually be easier and less costly to develop inside than to find outside the firm. This led to the closed R&D model. Nelson (1959) observed that this model creates spillovers that firms could not take profit from.

During the 20th century large enterprises supported their growth and dominance on size, market diversification and vertical integration. Large firms had a greater competitive advantage based on economies of scope and scale leaving fewer opportunities for new entrants to an industry or to small firms. Chesbrough (2003) studied high-technology firms and their practices in relation to innovation. This author observed differences in the strategic management of innovation that led him to propose two groups of innovation systems inside firms: closed innovation, where firms strongly protect all knowledge developed in their R&D departments and follow an inwards culture of independently developing their own products; and the open innovation, in which firms are open to all useful knowledge - either internal or external - they can incorporate in their products, and are also willing to license their internal research to others. Examples of firms engaged in open innovation are Nestlé, or Procter & Gamble (who devised a strategy coined "connect & develop" as an alternative to conventional R&D).

This change in paradigm has been fuelled by social factors like the increasing labour mobility among highly skilled workers; economical factors such as the access to venture capital (Chesbrough, 2003); and firm strategies, like the division of research work in increasingly specialized departments (Langlois, 2003).

West & Gallagher (2006) noticed though, that the open innovation theories had been based on the observation of high-tech industries and there are few empirical studies that can validate it as a substitute for the vertical integration and the closed model of innovation. Such industries range from ICT to pharmaceuticals and agro-biotechnology. However technological intensity is not the only factor in the adoption of open innovation practices.

Open innovation is the result of successful links with outside entities, such as other firms, universities, public research centres, competitors, clients, suppliers, even groups of product users as sources of innovations. The accomplishment of an open innovation strategy relies on a business model developed to retain the value of innovating (West, 2006). This requires the appropriability of the innovations in order to prevent imitation (Saviotti, 1998), which leads to the question of intellectual property rights (IPR). Patents and other forms of IPR are aimed at providing a temporary monopoly to the innovators and those who pay for the innovation, in order to recover the investment and prevent free riding by imitators. Thus IPR serves as an incentive for further innovation: without IP innovators would not be stimulated to innovate again. In fact, Laursen & Salter (2006) observed in a survey of British industries, that open innovation strategies are more present in industries with high appropriability, like pharmaceuticals.

Open innovation is derived from the collaboration and external links sought by firms or institutions. These firms and institutions provide specialized knowledge, goods and services. Vanhaverbeke (2006) focused on the networks these organizations have to establish so they can collaborate. This author further developed the concepts presented by Chesbrough (2003) by finding some new data on literature. He finds major advances from the initial ideas of open innovation, not only ICT firms can profit from open innovation and, as further empirical studies are published, it is expected to find a growing number of industries using open innovation. This author suggests instead of focusing on a central firm, research should encompass the whole network. In this case, the central firm has to manage the network, define the business model and connect all the different innovations along the development of new products.

The concept of open innovation has had a lot of promotion in recent years, although collaboration between firms has been happening for a long time, as in the case of joint ventures. Firm-university collaborations also are not a new phenomenon, nor are spin-offs. These observations leave an open path for further research: as more studies on open innovation are published, the confusion of terms used invariably would arise leading to an increasing need to clarify the terminology used. Although empirical studies are emerging, there is still a limited body of research on open innovation. Research tend to be case studies and or anecdotal, many of them limited to studies that are most of the times regional, national, or based on a particular industry, usually high-tech. Comparative studies are still scarce and theory still has to be further explored.

Besides the lack of theoretical research, another limitation felt on the current state of the art is a proper definition of what open innovation is supposed to be and a proliferation of terms. Pénin (2008) observed that over time, researchers have proposed a variety of terms that sometimes define the same, such as collaborative or distributed innovation, or are focusing on particular aspects of innovation collaborations, such as user innovation (von Hippel, 1976). Dahlander & Gann (2010) acknowledged the same confusion on terminologies used and engaged on a systematic review of all ISI publications on the subject in order to "clarify the definition of *openness"*. The main objective of our work is to shed light on the confusion of terminologies related to open innovation through the development of open innovation taxonomy. Collecting and analyzing published case studies using numerical taxonomy methods, in order to propose a taxonomic classification of open innovation. Taxonomy and systematics provide an objective way to analyse reality and are used every day by professionals and scholars from biology related fields as a tool to choose the best strategy to solve analogous problems.

In this paper, we first review earlier work on firm collaboration (in section 2) and concepts related to open innovation in order to understand the main motives and conditions behind open innovation-like strategies. Section 3 presents the methodology of numerical taxonomy and explains how it can be used in this context. Section 4 presents the data comprising of case studies and empirical papers used while section 5 presents the results of the numerical analysis in order to produce a taxonomic classification of open innovation. Finally, in section 6 we analyze the results of the taxonomic analysis and derive some conclusions on the processes different firms can engage to open their innovation and point to some directions of future research.

2. Literature Survey - historical review on firm collaboration and knowledge transfer

The theories of open innovation are built on previous work on firm collaboration strategies. Pénin (2008) observed that over time, researchers have proposed terms like collaborative-, disintegrated- (Kogut, 2008), distributed- (Coombs *et al.*, 2001), collective- (Allen, 1983; Nuvolari, 2004), or free innovation, open source software, open knowledge disclosure or free knowledge disclosure. These terms and concepts are connected, sometimes having the same meaning, and sometimes overlapping their context, which may generate conflicting analysis.

One of the most studied and coherent area of research in open innovation has been lead user innovation, having been a subject of analyses since the 1970's (von Hippel, 1976). This author found that 80% of key innovations on scientific instruments such as the transmission electron microscope had been invented, prototyped and/or tested by the users in a pattern he initially called "user dominated" innovation. Besides the dominance by users, he also observed dominance on the process of innovation that could be found in the manufacturers or in the suppliers of materials, additionally remarking that combinations of these three types could also happen[1].

What open innovation brings that is new, is how knowledge may become available freely. The concepts of user led or user dominated innovation already allowed this, but open innovation further includes free revealing of innovations (von Hippel & von Krogh, 2006) as another characteristic[2]. One should note however that this does not necessarily mean free access to knowledge. Interested parties may still have to pay for access. For instance, an innovation may be published in a scientific journal as a way of revealing, but those who wish to acquire that knowledge may have to pay a subscription to the journal. A particular case, where knowledge may be accessed for free, happens in open source software.

Free revealing, as used by von Hippel and von Krogh (2006), can be considered the equivalent of collective invention (Allen, 1983), a phenomenon observed among 19th century industrial firms to 21st century extreme sports. The difference according to Allen (1983) is that during the

[1] In this view, user innovation is a particular aspect of open innovation and a particular aspect of lead users is the case of open source. Following this line of thought, a hierarchy of terms starts to appear, making the case for taxonomy.

[2] As we will see later, a characteristic is used here to describe a combination of attributes particular to an individual and should not be misinterpreted as "character", which will be later described.

industrial revolution innovations were developed and released by the manufacturers, and thus these were manufacturer dominated innovations. On the other hand, collective invention is also a frequent practice among user communities of extreme sports, such as windsurfing (Shah, 2000). What we observe here is first, user innovation plays an important role on the development of new industries and technologies, from skateboards to medical imaging devices; second, free revealing, either originating from users or from manufacturers, is an important tool in disseminating knowledge and promoting new technologies that will later on prove lucrative for the innovating firm or user. As Allen (1983) observed, 19th century iron foundries had no advantage in keeping their innovations in furnace design for themselves not only because a furnace is something difficult to hide, but also because the contractors building the furnaces would disseminate the new designs anyway.

Thus collaboration, whether intentional or not, has existed for a long time. We may even say that the trend towards vertically integrate knowledge has existed since the second half of the 20th century, based on an increasingly *tight* IPR, is in fact what is new or recent and that open innovation is a return to the origins of industry collaboration. This idea is also shared in part by Dahlander & Gann (2010), who have observed that the novelty on the strategies followed by firms lie more on the variety of combinations between internal and external knowledge than on the existence of the collaborations.

In recent years, scholars and industry experts have observed a trend towards an increase in the use of patents (Dosi, *et al*., 2006; Orsenigo *et al.,* 2006). IPR has been used by market leaders as a means to allow rent appropriation, protection from competitors, as entry deterrence and even to create or maintain cartels (Arora, 1997). What has been observed is that this tendency may be counterproductive (Nelson 2004). The role of patents differs from industry to industry; strong IPR can be a cause and also a consequence of concentrated markets and competitive markets show a trend towards licensing. Another observation of these authors is that patents are only useful for large firms: small competitors cannot afford the legal costs to defend their intellectual property, so they turn to other strategies.

It may seem contradictory that open innovation relies on IPR and what we can observe is that a high appropriability regime creates a market for technology where innovators can sell their products through licensing instead of creating new ventures. Without an appropriability regime, innovators will tend to create their own ventures and innovative firms may tend to vertical integration (see for instance Fontana *et al.,* 2006).

Based on the growing literature on open innovation, empirical research is growing and researchers have analyzed from individual firms to industries or at a country level. Nevertheless these empirical papers are still scarce if one wants to understand this reality completely.

An increasing trend towards R&D collaboration among firms, universities and public research institutions has been observed at the country level in Japan (Motohashi, 2006) or the UK (Laursen & Salter, 2006), or at a European level (Fontana *et al.*, 2006). Other papers on open innovation have studied particular industries, such as life-sciences (Rothaermel & Ku, 2008; Belussi *et al.*, 2008) and microprocessors (Chesbrough *et al.*, 2007). These examples are summarized on Table I - 1. However these empirical studies provide only a partial view of reality and are difficult to compare.

In a complementary line of work, some authors have observed, among the diverse strategies of open innovation followed by firms and industries, similarities and differences, trying to find patterns of innovation and organizing them as typologies (van de Vrande *et al*., 2009; Perkmann & Walsh, 2006). Our line of work aims to explore beyond a simple typology of open innovation.

Dahlander & Gann (2010) have done similar research on the literature of open innovation, aiming to understand the different types of openness and how they affected the process and the results of innovation. They have reached a classification based on the processes of knowledge transmission, which creates four types of openness. Their classification was reached through bibliographic analysis, which provides an objective distinction between strategies, but lacks to explain how these strategies are constructed and differences between firms inside each of the four strategies. While the four types of resulting categories—Acquiring and Sourcing, Selling and Revealing, on the one hand has a virtue of simplicity, the richness of the dynamics of knowledge flows in our opinion, cannot be explained simply as inbound or outbound, nor the consequent implications captured in a two by two matrix.

The attempt to classify strategies of innovation is derived from the need to understand the relations between different strategies. When moving to a taxonomy, we are aiming to explain the causes behind the classification, that is, the variables or characters that allow the construction of a classification, the differences between strategies.

Table I - 1 Selected relevant empirical work on Open Innovation.

Name	**Industry**	**Data & Variables**	**Model/ method**	**Results & Conclusions**
Rothaermel & Ku (2008). *Intercluster innovation differentials: the role of research universities*	Medical devices (open innovation indirectly approached)	N. of patents is related to financial capital (VC+grants); Intellectual capital (research universities); human capital (graduates in engineering, biomedical); cluster size (employees); cluster density (firms per cluster); year fixed effects	Fixed effects negative binomial model.	Larger clusters are less innovative; more firms, venture capital or universities more innovation.
Laursen & Salter (2006). *Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms*	UK manufacturing industries	Innovative performance is related to external search strategies; R&D intensity; market orientation; size.	Survey. Double-truncated tobit model	External search depth is associated with radical inn; internal R&D and external search activities have a substitution effect
Motohashi (2006). *Licensing or not licensing? Empirical analysis on strategic use of patent in Japanese firms*	Japanese patent applicants	IP strategy (No-use, defence, use, license, cross, pool) is related to firm employment size; firm age; industry	Survey. Tobit model	No linear relation between license and firm size. When controlling cross-licensing, the relation is negative.
Belussi et al. (2008). *Managing long distance and localised learning in the Emilia Romagna life science cluster*	Life-science cluster of Emilia Romagna, both firms and public institutions	(Interviews; EPO and Pubmed databases) Research links(firm-firm, firm-PRO, PRO-PRO); number of patents; investment in R&D; size (nr employees); age; number of publications; innovative investments (funds and costs)	Correlation analysis between external relationship innovative-ness and R&D	O.I. is spread among the life-sciences cluster; Networking contributes for innovative output; 87% PROs have external partners; science and industrial collaboration are both important
Chesbrough *et. al* (2007). *Open Innovation and Patterns of R&D Competition*	Microprocessor	Patent citation analysis from 1976 to 2004.	Descriptive analysis	Periods of increased competition => greater patenting. Periods of cooperation not always with increased patenting behaviour in complementary areas
Fontana *et al* (2006). *Factors affecting university–industry R&D projects: The importance of searching, screening and signalling*	Food and beverages, chemicals, com. equipment, Telecoms services and computer service. SMEs	Vars: Number of collaborations; R&D (log); R&D Intensity (log); Employees (log); Process (dummy); Product (dummy); External Collaboration; Publications (dummy); Subsidies (dummy); Patents (dummy); External R&D	2000 KNOW survey, covering seven EU countries. probit model	Firm characteristics that can explain number of R&D projects with PROs: 1)absolute size of industrial partner; 2)willingness to search, screen & signal. Firms that outsource R&D, and patent to protect innovation and to signal competencies show higher levels of collaboration

3. Methods

This paper uses methods from another scientific field to provide a different look on the study of innovation and strategy. Taxonomy and systematics provide an objective way to analyse reality and are used every day by healthcare and pharmaceutical professionals, plant breeders and agronomists as a tool to choose the best strategy to solve analogous problems.

3.1. A taxonomy of open innovation

Taxonomy is the science of ordering things in a hierarchical manner. Originally developed for the classification of organisms, the term is now generalised and often used either as a synonym of classification or of systematics.

Etymologically, taxonomy means to "put in order" and systematics means to "put together". So when attempting to build taxonomies, one creates a special kind of classification that compares similarities between the objects of study, using systematics to make groups, based on the observed relatedness, and finally order them. The taxonomical groups are called *taxa* (the plural of *taxon*). The hierarchical classification will mean that *taxa* are organized as tree branches, or boxes inside boxes, and the base of the tree (or the big box containing all the other boxes) will represent the totality of the organisms studied[3].

Taxonomy, as used in the field of biology, aims to represent the evolutionary relations between organisms and approximate as much as possible to a natural representation of life.

To transpose taxonomy as a method of classification to a human creation will obviously mean one has to completely put aside the idea of natural relationship and interpret carefully the analogies to concepts like phylogeny, as they may not apply to the particular subject, in this case, open innovation.

[3]For instance, the field of botany studies all organisms contained in the kingdom *Plantae* and zoology studies kingdom *Animalia*, both belonging to the domain of *Eukaria*, together with other groups of organisms like fungi, algae, or protozoa. Inside the kingdom of animals, there are many other branches, for instance, arthropods contains all spiders, crustaceans and insects; insects belong to class *Insecta*, containing butterflies, ladybugs, or house-flies and so on.

The method adopted by biologists to analyse similarities and patterns in morphology, DNA and metabolites to infer a tree of life, provided us with the inspiration to construct a taxonomy of innovation based on their approach to study living systems.

3.2.Selection of characters used

Any classification is an exercise of correlating traits or characters. A character is a particular attribute that can be analyzed and interpreted independent from the whole (Sivarajan, 1991), for instance eye colour. The same character may have several character-states (brown, blue or green eyes).

When looking around at what surrounds us, there is a need to select the characters used to make a classification. Taxonomists call it *character weighing*. When starting to make a classification for the first time, we face an *a priori* weighing, having to choose characters before there is any evidence of their importance (Heywood, 1967 in: Sivarajan, 1991). In botany, taxonomists choose characters that are less prone to variation, like reproductive characters. How should we transpose this to the study of innovation?

Costa & Sarkar (2008) developed a classification of open innovation strategies. These authors used a knowledge-based approach, focusing on the information exchange flows. By doing so they are weighing *a priori* a group of characters that can be further used in taxonomy. They use six main dimensions to describe the flows (Miller, 2004): origin, destination, channel, content, form, and purpose. These dimensions capture a variety of innovation strategies, whether open or closed, and can be considered steady features of the strategy and process of innovation. Furthermore, they can be isolated from the whole process and are not influenced by the outcomes of those strategies of innovation. These types of characters are a good starting point for character weighing, but still very restrictive. However, these characters narrow the analysis to a very specific aspect, leaving out other characteristics of firms.

As with every classification, as new characters are observed they may be weighted and added to our research according to their pertinence. What we observe in some work on classification is a difficulty in separating cause from consequence. When weighing characteristics we have to distinguish the effects of an open innovation process from the characteristics of the process itself. The characteristics we choose have to describe the process of open innovation and cannot be influenced by it.

For a wider characterization of the processes of innovation, an assessment of empirical studies has been made. Different authors have focused on different aspects of firms, which affect the process of open innovation. By analysing these perspectives it is possible to create a list of characters to be used in this taxonomy. The following paragraphs display the way characters have been added to the taxonomy.

We first started from the knowledge-base point of view, with characters being chosen by pertinence. To do this, the list of characters made by Costa & Sarkar (2008) was tested against a group of case studies on open innovation analysing the correlation between characters. The first characters chosen by this method were related: Source of Knowledge, a group of characters related to the relationship structure (Interaction, Formality, Embeddedness and Orientation), the Innovation Stage and Newness. Based on these we further adapted each character to be used as “present = 1” or “absent = 0” in the numerical taxonomy analysis as will be explained later on.

We then included additional characters been based on an analysis of existing empirical work. The environmental groups of characters (Market, Organizational and Human) are based on observations made by Schroll (2009), which were further supplemented with more empirical studies in Table 2. Other characters are based on information encountered across different empirical studies and synthesised by the author(s). Table I - 2 summarizes the characters used in this taxonomy and the literature used as reference. A total number of thirteen characters used in our taxonomy, were selected as the main concepts identified on open innovation.

To infer the importance of the selected characters, we have analyzed a set of case studies encompassing different industries. The case studies were chosen bearing in mind the variety of industries where open innovation and related strategies have been observed. We also tried to have a proportional sampling from the most relevant publications, similar to Dahlander & Gann (2010) and also added other cases, which represented industries that are less studied on the main literature, like the food industry. For this analysis, we used fourteen articles, describing twenty case studies. These cases, besides encompassing different strategies and industries also include a reported “failure”.

Table I - 2 Summary of characters used in the proposed taxonomy.

Characters/Concepts	Descriptive keywords searched	References – empirical papers
Market	markets, technolog-[4], competit-, rival, opportunities	Schroll (2009); Laursen & Salter (2006)
Organizations	firm size, R&D	Schroll (2009); Motohashi (2006); Fontana *et al.* (2006)
Human	skill, productivity, networking	Schroll (2009); Belussi *et al.*(2008)
Phase	ideas, ideation, production, distribution, commercialization	Belussi *et al.*(2008); van de Vrande *et al.* (2009)
Collaboration /Strategy	explor-, interact-, exploit-	Chesbrough *et al.*(2007)
Type of interaction	mass collaboration, communit-, networks partnership	Belussi *et al.*(2008)
Knowledge origin	suppliers, users, competit-, research-	Costa & Sarkar (2008); Rothaermel & Ku (2008)
Newness	incremental-, new-, radical	Various authors
Type of innovation	product innov., service-, materials, new market, process innovation	Schumpeter; Fontana *et al.* (2006)
Orientation	vertical-, horizontal-, non-arms length	Costa & Sarkar (2008)
Formality	consorti-, M&A, joint venture	Costa & Sarkar (2008) ; Chesbrough *et al.*(2007)
Embeddedness	No keywords searched	Costa & Sarkar (2008)
Intellectual property	patent-, licens-, copyright	Costa & Sarkar (2008) ; Dahlander & Gann (2010)

We searched for an objective way to screen and analyse the importance of the characters used and chose the frequency of use of keywords as a measure. Using keywords that can describe the concepts and characters, we proceeded counting the frequency these words show on the case studies. For an easy and intuitive representation of the results, we made tag clouds, using the sum of frequencies for each keyword as an indicator of the importance of the concept.

[4] "technolog-" is the search term used and it stands for all words related to technology, such as "technology" or "technological". The same approach was applied to the other keywords presented this way.

Table I - 3 illustrates the tag clouds using eight cases. The frequency of occurrence of each concept is represented by the font size of the word.

Table I - 3 Tag clouds representing the relative importance of each concept/ character.

Von Hippel (2007)	Market Organisations Human Phase Strategy Interaction Origin Type-of-innovation Intellectual property
Baldwin, *et al.* (2006)	Market Organizations Human Phase Strategy Interaction Origin Type-of-innovation Intellectual property
Traitler & Saguy (2009)	Market Organisations Human Phase Strategy Interaction Origin Type-of-innovation Formality Intellectual property
Dittrich & Duysters (2007)	Market Organisations Human Phase Strategy Interaction Origin Type-of-innovation Formality Intellectual property
Piller & Walcher (2006)	Market Organisations Human Phase Strategy Interaction Origin
Dogson et al. (2006)	Market Organisations Human Phase Strategy Interaction Origin Type-of-innovation Intellectual property
Christensen *et al.* (2005)	Market Organisations Human Phase Strategy Interaction Origin Type-of-innovation Intellectual property
Goodrich & Aiman-Smith (2007)	Market Organisations Human Phase Strategy Origin Type-of-innovation

The first three characters are related to the environment of the firm. The character "market", based on Schroll (2009) and Laursen & Salter (2006) considers market conditions such as the technology level, competitive level, market uncertainty and technological opportunities that may arise in that market. "Organizational" character comprises the dimension of the firm, the R&D intensity, search breadth for partnerships, and innovation level. Character "human" relates to human resources involved in the partnerships and considers the importance of marketing and technological competences, and also productivity and networking abilities.

The innovation "phase" comprises of ideation, product development, production, distribution and interaction with the consumer.

"Colaboration strategy" (Chesbrough *et al.*, 2007), includes strategies aiming at initiation and scientific exploration, enterprise constitution, interaction and exchange of experiences, and exploitation (which relates to the concept of supplementary innovator of Afuah & Bahram (1995)). The character "interaction" aims to measure the dimension of the collaboration, from mass collaboration (as in idea contests) to dyads, including communities (usually of users) and networks.

The "knowledge origin" includes suppliers, users, competitors, or research institutions.

"Type of innovation" refers to the five forms of innovation presented by Schumpeter (1934) in the form of "new": product, market, process, services and sources of raw materials.

The character "formality" intends to show the contracts that may or may not occur in order to protect the role of each intervenient in the partnership. We divide them in informal contracts, research consortia, mergers and acquisitions, and joint ventures.

Finally, another form of protection is "intellectual property", including licenses, patents and other forms of protection, like copyrights.

These concepts and characters will be used on the interpretation of case studies, together with two other characters: "embeddedness", capturing the degree of involvement. Even though in many cases the character states for embeddedness, "strong" and "weak" seem mutually exclusive, we may find cases where different sources of innovation are used at the same time, with different levels of involvement with the innovating firm. This is likely to be observed in cases where user innovation may come from crowdsourcing and lead users at the same time, to fulfill the same objectives of the firm.

Finally, we also use the character "newness", to distinguish the novelty of the innovations to the world. Overall using our method of systematic analysis of the literature, a total number of thirteen characters were identified from which we further derived fifty character states used in our taxonomy.

3.3.Construction of a taxonomy of open innovation

Sivarajan (1991) identified three main steps in taxonomic research. The first step is to gather information on the subject studied. Then, identify the problems and the methods to solve them. Third, logical reasoning must be used to interpret the results.

The first and second steps have been described; the third - logical reasoning – will include the analysis of different methods of taxonomical analysis, the choice of the method that fits best to our data, and finally data analysis and the output of it in a graphical representation (dendrogram).

In Table I - 2 we present an example of the type of characters used and the character-states associated applied to a sample of case studies analyzed in this paper.

Case studies are used here as individuals to be classified, or in other words, to be put in a particular box or tree branch or our taxonomy. In an analogy to zoological studies these case studies are like unknown animal specimens we want to understand. By attributing a value "present (1)" or "absent (0)" to each character proposed, we make a list of traits for each case (specimen) that allows us to easily compare among specimens.

The next step in our reasoning is the choice of the method to compare the case studies and organize then - systematize - in a hierarchy of open innovation strategies. To do so, a range of methods of cluster analysis and numerical taxonomy were surveyed for their aptitude and adaptation to this particular set of data. The general idea of numerical taxonomy has been expressed in the following way:

> *There are two main types of analyses to reveal the taxonomic structure:* ***cluster analysis*** *and* ***ordination****. The result of the former is a treelike diagram or* ***dendrogram*** *(…), in which the tightest bunches of twigs represent clusters of very similar OTUs[5]. The result of the latter is an* ***ordination diagram*** *or* ***taxonomic map****, in which closely similar OTUs are placed close together. (...)*
>
> *In cluster analysis, the principle is to search the table of similarities for high values that indicate the most similar pairs of OTUs. These form the nuclei of the clusters and the computer searches for the next highest similarity values and adds the corresponding OTUs onto these cluster nuclei. Ultimately all OTUs fuse into one group, represented by the basal stem of the dendrogram. Lines drawn across the dendrogram at descending similarity levels define, in turn, phenons that correspond to a reasonable approximation*

[5] OTU – Operational Taxonomic Unit – In bacteriology it can be an unknown genus, species or strain. In this essay it is a particular open innovation strategy.

> *o species, genera, etc. The most common cluster methods are the* ***unweighted pair group method with averages*** *(**UPGMA**[6]) and* ***single linkage****.*
>
> Sneath (2005).

The process of numerical taxonomy classification follows five steps:

1) Data collection – In this paper, data from case studies regarding the set of characters chosen.

2) Data coding – When analyzing each case study, differences between characters - character states - are coded into a list of 0 and 1, as described previously, so to ease the analysis.

3) Calculate similarities between taxonomic units – The result is a similarity matrix. In this case similarity will be measured by correlation between all pairs of OTUs.

4) Analyse the similarity matrix for a taxonomic structure – In this case, UPGMA method will be used and a dendrogram will be generated for an easier analysis of the relation between case studies (OTUs).

5) Finally, characters may be further analysed for their importance in separating different taxa, and diagnostic characters may be selected for further identification of a broader set of OTUs.

4. Data

For the development of the taxonomy of open innovation two sets of data were collected. First, a survey of empirical and theoretical work on open innovation was analysed in order to select the main conditions for open innovation processes emergence and also the traits that best describe the differences between those strategies. This first set of data was used to make the list of characters and character-states that was later simplified into a list of character states

[6] Sokal and Michener, 1958.

that could be used as presence/absence of character on the observed case study (presented earlier in section 3.2).

The second set of data is a list of case studies describing different strategies of open innovation that are the OTUs in our taxonomy as presented in Table I - 4.

Table I - 4 Description of case study codes used.

Code	Firms/Users:	Industries:	Authors
A	Apache Software	Open Source Software	von Hippel(2007)
B	Users	Windsurfing	von Hippel(2007)
C	Nestlé	Food	Traitler & Saguy (2009)
D	Anonymous Firm	Video Games	Burger-Helmchen & Guittard (2008)
E	Users	Rodeo Kayak	Baldwin, *et al.* (2006)
F	Nokia	Mobile telephony	Dittrich & Duysters (2007)
G	Adidas	Sports equipments	Piller & Walcher (2006)
H	Procter & Gamble	Various industries	Dogson *et al.* (2006)
I	Users	Rodeo Kayak	Hienerth (2006)
J	Bang & Olufsen	Consumer electronics	Christensen *et al.*(2005)
K	Toccata/Texas Instruments	Consumer electronics	Christensen *et al.*(2005)
L	Bang & Olufsen/ ICEpower	Consumer electronics	Christensen *et al.*(2005)
M	Alcan Packaging	Pharmaceutical packaging	Goodrich & Aiman-Smith (2007)
N	Nokia tablet	Mobile communications	Stuermer *et al.*(2009)
O	SAPiens	Software, IT	Ebner *et al.* (2009)
P	Régie Aut. Transports Parisians	Transportation	Elmquist & Le Masson (2009)
Q	Ideation Deutsche Telekom,	Communications	Rohrbeck *et al* (2009)
R	Research Deutsche Telekom,	Communications	Rohrbeck *et al* (2009
S	Development Deutsche Telekom,	Communications	Rohrbeck *et al* (2009
T	Commercialisation DTelekom	Communications	Rohrbeck *et al* (2009

Table I - 5 shows a matrix of characters and OTUs used in this essay. The first column shows the main groups of characters used and, when applicable, the reference to the authors that first proposed those groups of characters. The second column presents the character states used for the taxonomy. It should be noted that they could be represented as a list of characters and then, the columns referring to the observations could show the character states. In this work, it was preferred to use a list of simplified character states and then only use presence or absence of those states when describing a case study.

Table I - 5 Characters, character states and case-studies.

	Case study code	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**
Market Conditions	High Technology level	1	0	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
	High competition	0	0	1	0	0	0	1	1	0	1	1	0	0	1	0	0	1	1	1	1
	High Uncertainty	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
	Technol.opportunities	0	1	1	1	1	1	0	1	0	1	0	0	0	1	1	1	0	1	1	0
Organizational characterization	Large Firm size	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
	High R&D intensity	0	0	1	0	0	1	0	1	0	1	1	1	0	1	1	0	1	1	1	1
	large Strategic breadth	1	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	1	1	1	1
	High Innovativeness	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
Human characterization	Marketing background	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
	Technical Background	0	1	0	0	1	0	0	0	0	1	1	1	0	1	1	0	1	1	1	1
	High Productivity	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	1	1
	Networking skills	0	1	0	0	0	0	0	1	0	0	1	1	0	1	0	0	1	1	1	1
Phase	Ideation	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	1	1	0	0
	prod. Development	0	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0
	Production	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0	1	0	0	1	0
	Distribution	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
	Consumer	1	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	0	1
Collaboration /Strategy	Initiation/exploration	0	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0
	Constitution	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	0	0
	Interaction/communic	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	1	0
	Exploitation	1	1	0	0	0	1	0	1	0	0	1	1	0	1	1	1	0	0	1	1
Type of interaction	Mass collaboration	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
	Communities (users)	1	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1
	Network	0	1	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	1	1
	Dyad	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0
Knowledge origin	Suppliers	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0
	Users	1	1	0	1	1	0	1	0	1	0	0	0	1	0	1	1	1	0	0	0
	Competitors	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	education/research	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0
	Others	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1
Newness	Incremental	1	0	0	1	0	1	1	1	0	0	1	1	1	1	1	0	0	0	0	1
	Really new	0	1	1	0	1	1	0	1	1	1	0	0	0	0	0	1	1	1	1	0
Type of innovation	New product	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1
	New market	0	0	1	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	1	0
	New produc. process	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0
	Services	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
	New sources of mater.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orientation	Vertical	0	1	0	0	1	1	0	0	0	0	1	0	1	0	0	1	1	0	0	0
	Horizontal	1	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0	1	1	0
	Non-arm's length	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1
Formality	Informal	1	1	0	1	1	0	1	0	1	0	0	0	1	0	0	0	1	1	0	0
	Licensing	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	1
	Research consortia	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	1	1	0
	M&A	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
	Joint ventures	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Embeddedness	Strong	1	1	0	0	1	1	0	0	1	1	1	1	0	0	0	0	1	1	1	0
	Weak	0	0	0	1	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	1
Intelectual property	Patents	1	1	1	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0
	Copyrights	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Licenses	1	1	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1

Other columns are the description of the OTUs themselves. As one objective of our work is to clarify the confusion of terms used to describe strategies of collaboration on innovation and the terms and definitions that are being used, it would not make sense to use any reference to those specific names in the identification of the OTUs, as they could be misleading. So they are identified by the publication reference on the first line. As seen before, the characterisation of the OTUs is made as a list of presences and absences of observed character states.

5. Results

As previously described, in our taxonomic analysis the method used is the UPGMA. After the collection and coding of data into Table 5, a similarity matrix was calculated where the similarity measure used is the value of the correlation between each two columns. The correlations may range from -1, meaning no similarity at all, to 1, meaning total similarity of the observed characters.

Using the UPGMA pairing analysis method, the following reasoning was applied the data:

- The pair with the highest similarity was selected: pair (G,M)
- A new matrix was made where the similarity between any other OTU and H and M was replaced by the average of the similarities between the OTU and G and the OTU and M.
- The next pair with the highest similarity was selected. And the process repeated until all OTUs had been paired.
- The results from this analysis are represented in the dendrogram in figure 2.
- On each node of the dendrogram is indicated the distance from each element of the pair to the node (i.e. the distance between the two OTUs divided by 2).

The cases were selected bearing in mind the pertinence of the publication and the industry studied, we also included a reported “failure”.

When looking at the dendrogram in Figure I - 1, the first observation is that the case studies reveal themselves to be divided into two main groups, with only 3% of similarities between them. The UPGMA analysis was able to separate the two main branches of open innovation, user and non-user open innovation. The case “Paris Bus” (Elmquist & Le Masson, 2009), reported as a failure appears separated from the rest of the cases, showing the ability of this methodology to distinguish open, from non-open or non successful open innovation strategies. This bus case study represents the attempt of the Régie Autonome des Transports de Paris in developing a new kind of bus. In that effort the firm cooperated with other firms, but it did not fulfill the objectives and did not develop a new bus. Nevertheless, the failure of the project was compensated by the development of a new local line service based on aspects learned during the project development.

The first group of nine studies (on the top half), consists only of cases involving free revealing, with “democratic” innovation.

Starting our analysis from the most similar, pairing we see that the two most similar cases are the ones of Adidas (Piller & Walcher, 2006) and Alcan (Goodrich & Aiman-Smith, 2007) strategies of open innovation. These two are cases of large firms, in the disparate industries of sportswear and equipment and pharmaceutical packaging. Despite the sectoral differences, these firms share similarities in their innovation strategies.

Both Alcan Pharmaceutical Packaging and Adidas are large companies that engaged in open innovation strategies by connecting to and gathering information from their costumers in order to develop new products.

The Adidas case describes the design and implementation of a toolkit for new product development by users. Traditionally the firm developed products involving a closed innovation process, but the observation of open innovation on the sports goods industry and other German firms in other industries inspired the opening of the process. The process consisted of inviting costumers of top-of the line shoes to participate on an on-line idea competition, most reward was the fun of participating and peer recognition. After the competition, Piller & Walcher (2006) found that 10% of the ideas submitted were ideas for radical innovations that could expand Adidas businesses.

As for Alcan, it appears to have pursued a more traditional strategy, where the firm used its contacts with its clients (pharmaceutical firms) directly through interviews, to understand their main needs and aspirations on the design and performance of the pharmaceutical packaging and develop products according to this information. Both Alcan and Adidas are also cases of strategies of open innovation developed by specialists inside the firm and not imported from an outside source. Both strategies can be considered crowdsourcing and imply direct contact with the costumers instead of more traditional approaches like observing general market trends.

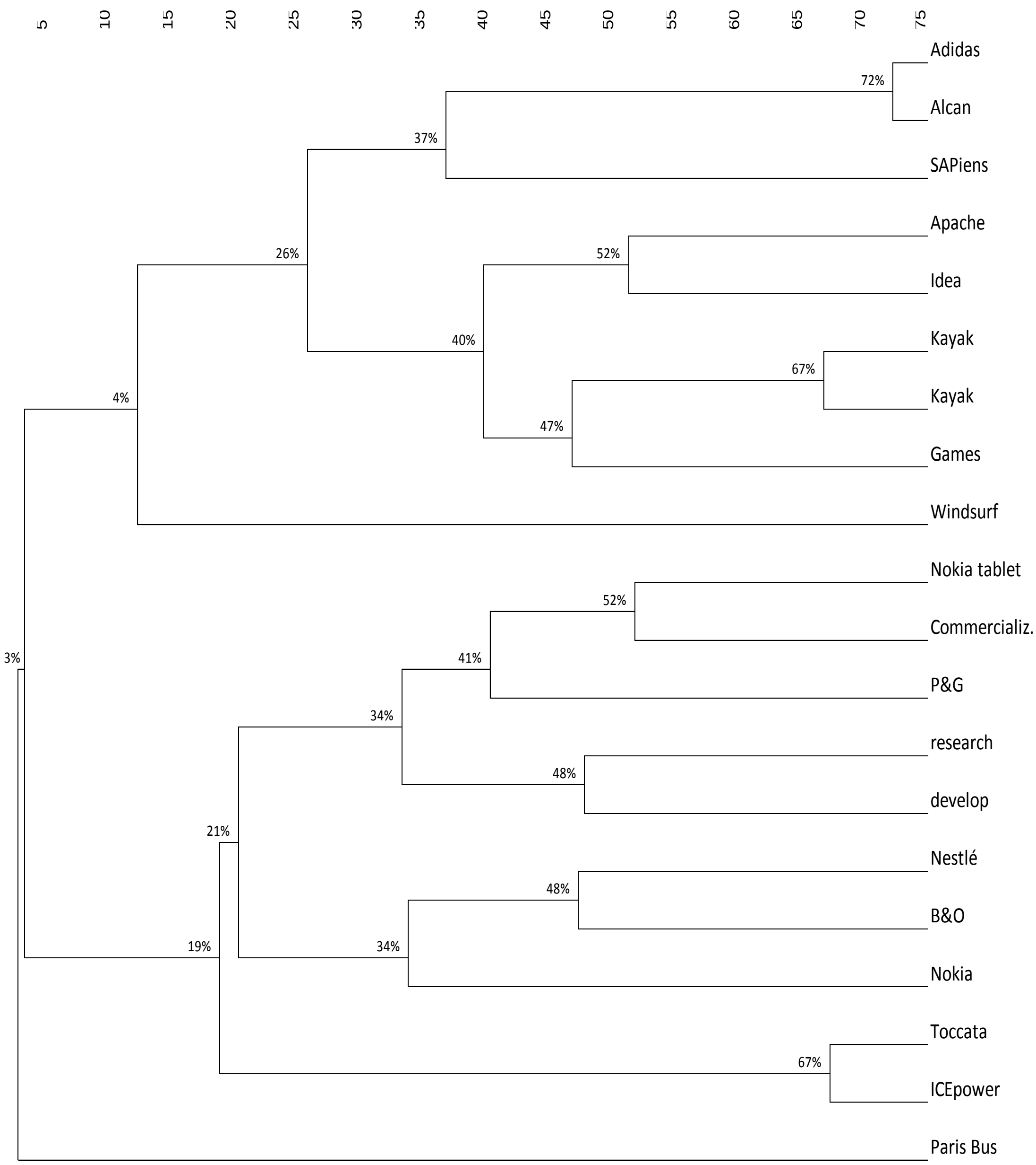

Figure I - 1 Dendrogram showing the similarities between case studies.

Alcan and Adidas are then grouped with SAPiens, a case of crowdsourcing, where a community of 60000 university members is screened for ideas, representing the search for new ideas in large groups of selected individuals or lead users in order to gather information for new product development.

The next pair of cases describes user development of an extreme sport, rodeo Kayak (Baldwin, *et al.*, 2006; Hienerth, 2006). We have intentionally used two case studies on the rodeo kayak industry as a control. If these cases were not paired by the UPGMA method, then probably there would be a problem on the characters used for the classification. These cases describe how lead users, in this situation, members of sports communities, developed the sport. Athletes from traditional kayaking experimented materials and techniques to further improve their performances and in doing so created an extreme sport, rodeo kayak. These athletes did the improvements on their own, while sports equipment firms were further improving the traditional designs. Only after the new designs were developed and communities of users were growing and new firms emerged did traditional firms start developing designs for these new sports as a means to compete in these new sporting areas.

The kayak pair is grouped with the open source video games case (Burger-Helmchen & Guittard 2008) and then with the pair Apache/Ideation phase from Deutsche Telekom (DT). The DT ideation case is different from the other cases from the same company, as only on the ideation phase, users are included on the process of innovation, with no intellectual property issues. The Apache software development is a typical case of open source software. As to the idea generation for DT, it is the case of costumer/user integration on the innovation process of the firm. Selected families are observed on their daily activities in order to gain insight of their needs both perceived and implicit.

This group of five cases shows OTUs related to each other, they all share a forty percent similarity, and one suspects that only adding further cases could we have a better picture of what really goes on inside this group.

Finally, the windsurf case is paired with the group of user innovation cases, although sharing little obvious similarities, it suggests some need to improve the characters used to classify these cases. In fact, the development of this sport is very similar to the development of rodeo kayak and we suspect that the specific differences between the two sports are being emphasized in this analysis, which points to the need for further improvement of the method. Nevertheless we can observe in this “democratic” strategy group, there exist two important openness strategies: crowdsourcing and lead user innovation.

The second half of the dendrogram does not include cases of user innovation, but instead is comprised of strategies of open innovation based on formal alliances or formal IP. The first group with higher similarity is a pair of studies on two Scandinavian small firms on consumer electronics, Toccata Technology and ICEpower, and their strategies to collaborate with larger firms respectively, Texas Instruments and Bang & Olufsen (Christensen *et al.*, 2005). These cases describe the beginnings of a new technology, from university research by PhD candidates, until a commercial product emerged.

The two small firms originated from university research on digital sound amplification. In order to develop the experimental designs of the founders/researchers of both Toccata and ICEpower into commercial products, they associated their knowledge with larger firms that could further exploit the new technologies. By licensing their knowledge to a supplier of components, in the case of Texas Instruments, and a would-be competitor, these small ventures assured the future of the technologies of digital sound. Toccata followed a strategy for developing chip-based solutions that would be adaptable to mass-markets and was eventually bought out by Texas Instruments and incorporated their R&D department. Another strategy was followed by ICEpower which by collaborating with B&O, and occasionally with other large firms, assured a high-end market for their innovations.

The small firm consumer electronics pair is then grouped with the rest of the "formal" strategies of innovation group.

The second group is comprised of eight cases of large firms. The next pairing that arises from the UPGMA analysis contains the cases of the Nokia tablet development and commercialization (Stuermer *et al.*, 2009) and the commercialization phase of Deutsche Telekom (Rohrbeck *et al.*, 2009), both cases of large firms developing high technology products and cooperating with outside partners to gain a better insight of the market needs. Although the Nokia tablet development is described as an open source project, the fact that part of the product innovation is protected by IP and not freely disclosed, places it outside the group of democratic strategies of collaboration. The Nokia tablet strategy is based on both volunteers providing free knowledge and also paid contractors. The commercialization phase strategy of DT, on the other hand is only based on licensing outside spillovers and also acquiring, thus outbound and inbound fluxes of innovation.

These two cases are grouped with the "connect and develop" strategy of Procter & Gamble, again a case where marketing aspects are important, especially those related to technological opportunities, and how it conditions the intention to collaborate. All the firms in this group are large and cooperate with smaller firms.

These three cases are then connected to the pair of the last two cases from DT, these cases describe the different strategies this firm developed for the research and development of their products. In the research phase, the firm relies on university-industry collaboration to produce costumer-driven innovations, in the development phase, the firm creates joint research programs with firms, universities and applied research institutions in order to create products and new services, aiming at customer retention. The main objective on both phases is to enlarge the resource base of the firm recurring to outside partners.

The next branch of the dendrogram also comprises of three cases of large firms. We begin analyzing the Nestlé – B&O pair describing the efforts of two established firms to change their model of product development from a closed model to an open innovation model. In these two situations, the character most responsible for this pairing is “interaction”.

Nestlé´s innovation strategy has been an example of the closed innovation model for decades. The importance of “interaction” is central on its strategy. In order to keep pace with the fast progress in the food industry, and accelerate the development of new products, processes, or ways to access new markets, Nestlé has been opening up its innovation processes, relying on partnerships with other firms or research centers. With regards to Bang & Olufsen, the case depicts its collaboration with smaller technology and university spin-offs with similar objectives as those pursued by Nestlé.

The case study of Nokia’s broad strategy to open up their innovation processes is found paired with these last two cases. Again we have a case where a firm pays great attention to interaction with other partners. The main difference between this case and the previous two is the way the objectives change throughout the period studied. At the beginning of the cell phone industry, this firm used collaborations in order to explore the technological possibilities that could lead to a successful industry. More recently, for the development of third generation mobile phones, this firm follows a strategy of exploitation of its resources, relying on partners to manufacture the technologies developed by the main firm

6. Conclusions

From the analysis of these results we can draw some interesting conclusions. We begin by identifying two general strategies for collaboration. First we find a distinct strategy of “democratic innovation”, characterized by a proliferation of partners, whose technical and creative skills are specific to the industry. The result of the interaction is related to the quality of the source of knowledge (users, supplementary innovators). In all these cases, there is a large importance on the interaction between partners, particularly communities of users.

The second strategy of cooperation is linked to a more formal collaboration, often firm-firm collaboration; in this group we found a large focus on markets features, especially technological intensity. In fact, it appears that companies that compete in high tech markets sometimes have difficulty in keeping up with technological developments in the markets. Collaboration with other companies providing technology allows a decentralization of the process of innovation and an exploitation of synergies.

We also conclude that open innovation strategies, whether formal or not, intend to increase the competiveness of firms, in particular the speed with which they introduce innovations in the market.

An interesting result that could be further explored is how small firms can profit from open innovation to put their products in the market and access new markets. The analysis of these cases shows that there are two ways to take advantage of open innovation partnerships in general, which are related to the direction of knowledge flows. Accordingly we have a first form of collaboration, where the companies use the knowledge of their customers and users to develop and commercialize new products. We also have an opposite flow of knowledge, when a small technology-based company works with a large firm with access to economies of scale and scope to develop and market products whose technological base has been developed by the smaller firm. In this case we have a diversification strategy, where risk is minimized. The risk of product development is borne by the supplier of technology, while the market risk is borne by the larger company.

As a first approach to taxonomy on open innovation strategies, the UPGMA methodology seems very promising. These results, using 20 case studies, showed that behaviorial characteristics ("characters" in UPGMA terminology) describe very well the reality of open innovation strategies.

The study suffers from certain limitations that any future work should take into account. First we believe that a test of robustness of the analysis should be performed, by including more case studies[7]. In this paper, we purposely decided to not include more cases, as the intuitive power in trying to explain how individual cases (and strategies therein) were encountered in the branches as well as the separation of the cases, would be lost when a large number of cases are used. Second an inclusion of more cases would enable a factorial analysis that can be

[7] See Appendix I-A for subsequent work, including the inclusion of more 15 case studies that demonstrated the robustness of the analysis.

used to infer the most important characteristics that define the distinguishing features of the cases. Third, each of the branches in the taxonomy reflects distinct strategies that should be clearly identified, which would define open innovation archetype strategies (or nomenclature). This leads us to the final consideration, where we believe that future work should attempt to develop a hierarchical classification of open innovation that may be used as a tool for decision making, where the factors can be used to create decision points on a decision tree.

The idea of using this classification for decision making is based on the use of dichotomic trees prevalent in the natural sciences. A firm, wishing to engage in collaborative strategies of innovation, may use the characters on Table I - 5 as a form of describing itself and be characterized. This characterization may then be subject to numerical analysis together with the rest of the case studies and the result of the pairing can be used as a benchmark for the strategy of open innovation in a firm.

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Essay II: Technology cycles, dominant design and firm survival in the tractor industry

Abstract

In this paper we identify three major technological breakthroughs in the American tractor industry and test the hypothesis that they influenced firms' survival. We use the lognormal model and control for the effects of population density, market size, business cycles and entry timing. The results show that early entrants have lower hazard rates than firms that entered during the next development phase of the industry, a phase which was characterized by high technological uncertainty, experimentation and non-standardization. However they also suggest the existence of a second "window of opportunity" for entry, which occurred after the introduction of the general purpose tractor.

Keywords: innovation; tractor industry; dominant design; survival and hazard functions; lognormal model.

JEL codes: L64, O33.

1. Introduction

The history of western economic growth, especially North American, has been strongly influenced by farm mechanization. Technological advances such as agro-chemicals as well as farm mechanization have made possible the increase of productivity to such an extent that while in 1910 an American farmer supplied food for eight people; in 1990 he or she could supply food for ninety people (White, 2000).

The dramatic increase in productivity which enabled the support of a hugely declining agricultural work force is due to a large extent to the arrival of farm motorization. In this, tractors, one of the most important components of a farm, have played a fundamental role. Which then leads us to quiz on what really were the major innovations in tractors that played such an important role in enhancing the productivity growth in agriculture?

In this paper we study the evolution of a major agricultural input and the cause for much of farm development, the humble tractor. Based on the concepts of dominant designs (Abernathy & Utterback, 1975) and technology cycles (Anderson & Tushman, 1990) our work aims to understand the mechanism behind the birth of new technologies that pushed agriculture forward. While the tractor industry shares a common history with the automobile industry, owing much of the advances in mechanics from the latter, the main advances in tractors are innovations specific to the industry such as the hydraulic (Ferguson) system.

To understand whether the evolution of the technology in the tractor industry has affected the survival of its firms, we have chosen the American tractor industry. The American market is a huge market where models have been developed to face costumer needs, where there is a variety of agricultural systems that affect tractor development, and where the main technological advances have been made in a relationship with the spread of agriculture through the continent. Using a unique data set of the American tractor industry we analyze the evolution of the tractor industry, major innovations and identify fundamental breakthroughs. We then study whether the competitive environment of the American tractor industry, and in particular the survival of its firms, was influenced by its technological evolution.

Using the opinion of industry experts combined with the analysis of the evolution of the tractor industry lead us to identify four important turning points in the technological evolution of the American tractor industry: the introduction of internal combustion tractors in 1902, the introduction of the Fordson in 1917, the introduction of the general purpose tractor in 1924 and the introduction of the three-point hitch system in 1939. These four dates are used to define five cohorts of firms depending on their entry timing. We then apply non-parametric and parametric survival analysis techniques to explore whether the survival probability of a firm is influenced by having entered before or after a given technological breakthrough.

Regarding econometric methods it should be noted that our paper provides a substantially more detailed analysis than most papers in the dominant design literature. Although survival analysis has been used many times before, the choice of the model and specific functional form has been left unexplained. Thus one cannot be sure that the model chosen was the most adequate one or if it was even valid (if the hypothesis behind the model were satisfied by the dataset). For example, in our case, we clearly rejected the proportional hazard assumption, an assumption that is behind the Cox proportional hazard model (Cox, 1972), one of the most commonly used in this type of analysis previously by other authors. For the American tractor industry the survival model that best fits the data is the lognormal model. An interesting property of this model is that it allows for a non-monotonic hazard function, a feature that holds for our dataset: the exit rate starts to be increasing but latter on it becomes decreasing.

Our results show that the early entrants have a significantly higher probability of survival than entrants in the second and third cohorts. Moreover, the introduction of the general purpose tractor was associated with a significant upward shift in the survival curve while the introduction of the three-point hitch system had a negative impact on the survival probability. Thus our results suggest that, from the view point of survival chances, entry was particularly favorable in the earlier period (first entrants) and in the period between the introductions of the general purpose tractor and the introduction of the three-point hitch system. In other words, using a terminology introduced by Christensen *et al*. (1998) it appears that there was a "window of opportunity" in the American tractor industry.

Our paper is organized as follows. In the following section, we review the concept and major studies of technology life cycles and dominant design used by scholars to study the emergence of new products in high technology industries and the consequent exit of firms. Then in Section 3, we present a short history of the major technology breakthroughs in the tractor industry in the United States. In Section 4, we describe the data collection and complement the previous section with an overview of the industry evolution in terms of firms' density as well as industry sales, leading to the identification of two important turning points. Section 5 describes the methodology that we have adopted for our analyses while Section 6 discusses the results of the estimated non-parametric and parametric models. Finally, in Section 7 we present the main conclusions.

2. Technological cycles, dominant designs and firm survival

The study of industry lifecycles reveals how products and processes evolve over time, and has been the focus of many researchers who have found that industries follow patterns of evolution, with phases of technological discontinuity followed by a high rate of innovation and, in a latter phase, standardization and focusing on process efficiency, cost reduction and incremental innovation. The turning point in this cycle can be identified with the emergence of a dominant design, a product that synthesizes the characteristics that will become a standard in a given industry. The emergence of a dominant design leads to a corresponding exit of many firms. Not all industries have showed dominant designs and most work has been done in high technology industries such as computers and airplanes. The concept of dominant design has been broadly used by scholars to study the emergence of new products in high technology industries. The popularity of the concept led to a number of papers on this subject based on several industries (Murmann & Frenken, 2006). In this section, we review the concept and highlight some major studies of dominant design, technology cycles and firm survival.

2.1. The concepts of dominant design and technology cycles

Utterback & Abernathy (1975) developed a model of the dynamics of innovation for both products and processes where the rate of innovation follows a general pattern over time. In their model these authors identified three phases: 1) Fluid phase: the rate of product innovation is higher in the early years of a new industry; there is a lot of experimentation with product design; the rate of process innovation is slower. 2) Transitional phase: the speed of product innovation decreases as products become standardized; major process innovations take place, reducing costs and improving manufacturing. 3) Specific phase: both product and process innovations decrease, being mainly incremental; industries focus on costs, volume and capacity. Analyzing several industries over one hundred years, Utterback (1994) found that this pattern repeats itself in waves of innovation with periods of stability in between.

A significant contribution of Utterback & Abernathy model is the concept of dominant design and that of enabling technology. Dominant designs are products that synthesize previous product innovations that may have been developed separately. The emergence of a dominant design is the result of the dynamics of product evolution based on experimentation, adaptation of technologies and customers choices, culminating in a set of product characteristics that is preferred over other combinations of product characteristics. Even if they are not the ultimate radical innovation, dominant designs change the path of innovation in an industry and mark the transitional phase. After a product is accepted as a dominant design, the industry tends towards standardization and the innovation focus moves on to on process, design, cost and performance. The number of competitors decreases either due to market failure or through mergers. Customized products may still exist as a niche market as the dominant design is satisfying the majority of average customers, but usually not the most demanding ones.

The concept of dominant design has been used to describe innovations of assembled products (e.g. automobiles, computers). For non-assembled products (e.g. paint, glass) process innovation is more important than product innovation, so instead of dominant design, Utterback (1994) defines *enabling technologies* as the turning point of an industry. An enabling technology is a process innovation – often involving the reduction of production stages - that represents a productivity and efficiency discontinuity. Companies adopting this new technology will have a competitive (efficiency) advantage over those who carry on the old production process.

Anderson & Tushman (1990) included the emergence of dominant designs as part of a technology cycle in their broader analysis of technology evolution. These authors observed that industries evolve mainly via incremental innovations, disturbed at intervals by technological discontinuities. Technological discontinuities have the same effects as the concept of disruptive innovations (Christensen 1997). They break the continuous line of incremental change in an industry or product. After the technological discontinuity there is a period of experimentation and competition between new and old technology. Competition between several models of the new technology also happens, until a version of the discontinuity is so perfected and/or accepted by consumers that it becomes a standard, a dominant design. Anderson & Tushman (1990) noted that these phenomena can happen both on products as well as on production processes and that the previous pattern may repeat itself.

2.2. Dominant Design and firm survival

The analysis of the factors that influence the long-term viability or firm survival is one of the most fundamental topics of business research and has been investigated from various perspectives. Broadly speaking we can identify three types of factors that influence firms' survival: external environment factors; technological change and a firm's capacity to adapt to the change; and firm specific and managerial choice factors. The influence of external factors has been highlighted, among others, by the scholars of population ecology, who defend that survival probabilities are affected by the population density at the founding period (for reviews see Hannan & Freeman, 1989; Singh & Lumsden, 1990). The effect of technological changes has been shown to affect survival (see among others, Tushman & Anderson, 1986; Suárez & Utterback, 1995). The influence of strategic choices has been considered, for example, by Christensen *et al.* (1998). In our study, we incorporate only external and technological factors, since we do not have data on firms' strategic choices.

Among the studies focusing on the influence of technological factors in the survival of firms it is important mention the studies that relate the emergence of a dominant design with the survival of firms. In particular, some of these studies (Utterback & Suárez, 1993; Freeman, 1994; Suárez & Utterback, 1995) have stated that the emergence of a dominant design is a turning point in the industry evolution that reduces the probability of a successful entry for subsequent entrants. However, from a theoretical point of view it is unclear why, for a given age profile, the firms entering after the emergence of the dominant design should have a lower probability of survival. In fact, one can think of forces working in opposite directions. On one hand, economies of scale become more relevant after the emergence of the dominant design. The established firms who are able to master the dominant design will be able to erect barriers to entry and to mobility, reducing the probability of survival for new entrants. On the other hand, firms entering before the emergence of the dominant design face a more uncertain technological environment and may end up choosing the wrong design. Moreover, the emergence of the dominant design may bring such technological and market changes that the skills acquired during the experimentation phase are not of much use in the new environment.

In this paper we consider that an industry may have a sequence of technological cycles and corresponding dominant designs. Moreover, we argue that the impact on the survival of firms may not be the same for all the dominant designs. In particular, we expect that earlier dominant designs increase the probability of survival as they reduce drastically the technological uncertainty. On the other hand, the effect of entry barriers and accumulation of collateral assets such as reputation, distribution channels and market knowledge will be more important on subsequent technological discontinuities. Thus the idea that firms entering after the emergence of the dominant design have a lower probability of survival is more likely to hold for the last technological cycles of the industry.

One important issue in the dominant design studies is the identification of the precise moment that a dominant design sets in. In their review of 24 papers on dominant design, Murman & Frenken (2006) found several approaches on this respect. For example, Suárez & Utterback (1995) identified the dominant design with the help of industry experts. On the other hand, Anderson & Tushman (1990) identified the emergence of a dominant design as the moment when one particular product design attained a 50% market share after a technological discontinuity happened. In yet another approach, Christensen *et al.* (1998), considered that the dominant design was set the moment a model featuring all the components of the dominant design reached the market. In our study we do not have data on market shares neither on the specific models introduced by the firms and their components, thus we identify the dominant designs with the help of industry experts and the analysis of the industry evolution.

3. The evolution of the American tractor industry

The tractor industry has evolved in different ways, depending on different national and regional conditions. To conduct an analysis of the tractor industry in the world without analyzing regional differences could mask these effects. Therefore our analysis will be held for the North-American industry, for which we were able to collect a complete data set since its birth until the present and containing all the firms that ever produced agricultural tractors in the United States.

3.1.Early development: from the steam tractors to the Fordson

Farm mechanization in the United States and Canada is deeply connected with the spread of agriculture through the continent. Most North American regions had never experienced agriculture previous to European colonization; also many of the settlers had never experienced such soils, which meant a lot of experiencing and innovation. To break the prairie soils required a lot of animal power and ingenious solutions for new machines. Two of the most important inventions in farm mechanization came from the United States and were the beginning of two of the most successful tractor manufacturers. The first was the 1837 self-scouring steel plough from John Deere, the second was the 1842 combine thresher from Jerome Case (Carroll, 1999). Both led to the creation of two of the most well-known farm tractor manufacturers of the 20th century.

The evolution of the tractor and automobile industries in the United States shared much common history. The initial years of the development of the internal combustion engines and the vehicles motorized by them were similar in these two industries, with some firms marketing kit conversions to adapt automobiles to do tractor work in the 1910's. In the United States, the first firm to successfully commercialize internal combustion tractors was Hart-Parr around 1902 and in 1906 the word "tractor" was used for the first time to describe Hart-Parr's machine.

The internal combustion engine had many advantages over steam: it was safer, needed ten times less fuel, forty times less water, produced 30% more energy and was lighter and easier to manoeuvre, needing only one operator while steam engines usually needed three men (Gray, 1954). Nevertheless older companies that thrived with the steam engines were not willing to change, and some kept producing steam tractors and rollers until the late 1920´s, yet at the same time investing in gas tractors. The first internal combustion tractors had models very similar to the steam traction engines; many of them simply adapted the structure to the new engine. Those early tractors were still very heavy machines, weighing around ten tons (White, 2001). During the first two decades of the 20th century manufacturers improved their models, reducing their size and cost by a factor of ten, while increasing the power needed to plough or pull other implements.

Until 1920 there was a huge variety of models and mechanical solutions for tractors. Gray (1954) describes 20 different ignition systems, 8 lubrication systems, 11 cooling systems, 17 carburetting systems, 15 power transmission mechanisms and 27 different wheel arrangements that emerged in the first two decades of the 20th century. From then on tractor design tended towards standardization. One newcomer, a crossover from the automobile industry, was Fordson. This tractor was launched in 1917 by Henry Ford. Rapidly, Fordson F took over the market to reach 75% of the American tractors sold in the beginning of the 1920's. Several factors came to help this domination, the Fordson F was a small, affordable machine designed to be the model T of tractors, Ford had a large chain of distributors all over the country and was known for the reliability of its products. The Fordson F was the first tractor to become an affordable alternative to animal power. They were light tractors, with a frame construction that allowed easy repair and maintenance, presented as capable to do the work of four animals (Wendell, 2000). In 1920, the value per head of a mule was $143 and a horse was $90 (US Department of Commerce, 1951) while the Fordson F cost less than $400, making it the first truly affordable alternative to animal traction. Sales of traction animals peaked in 1918 and since them followed a decreasing trend. This may represent the impact of the Fordson on the traction animal market. We may conjecture that the Fordson F market grew not from the substitution of other tractor types, but mostly from the substitution of traction animals to tractors.

Despite its enormous success, the Fordson did not affect deeply the designs followed by other competitors. From the beginnings of the traction engine industry, the main objective was to provide an easy source of traction power to the farm. Even though during this period there were many different designs, the main differences between tractors were on power, though most tractors in 1917 had the same power as the Fordson, which was equipped with a 20hp engine.

3.2.The 1920s: Nebraska trials, price-wars and the introduction of the Farmall

In the first two decades of the 20th century reliability was a major problem for farmers. An influential farmer from Nebraska, William Crozier, after having bought two poor quality tractors sponsored a bill to force tractor testing in his state. Thus, starting from 1920, the Nebraska State University tested every model to be commercialized in that state. The results had a big impact in the industry. In 1920 only 15.4% of the tractors tested really accomplished their manufacturer's claims. The next two years, the percentage of realistic claims would rise to 40% in 1921 and 80% in 1922 (Baldwin & Morland, 1998). While manufacturers that did not pass the Nebraska trials were leaving the industry, the small manufacturers presenting interesting innovations were being absorbed by the larger companies. In the 1920's the only manufacturer able to match Fordson's low price was International Harvester, an old firm originated on the beginnings of farm implements mechanisation. The competition between these two manufacturers proved to be momentous for the development of tractors. In 1922 International Harvester introduced the modern power take-off in its tractors and in 1924 this company introduced the Farmall, one of the most successful tractor models ever built. It was the first general-purpose tractor, designed for cultivating, ploughing and mowing. It was affordable to the average farmer and could work in a great range of crops. Soon other American companies followed the trend and the general-purpose tractor replaced the one-purpose tractors like the Fordson F. In fact Fordson´s production in the United States was discontinued in 1928, as Ford was by then concentrating its efforts in the production of automobiles

3.3.Emergence of three key designs in the 1930s

In the 1930´s, three important tractor features were introduced: tires, the Diesel engine and the three point hydraulic hitch system. Early tractors were equipped with steel wheels that had to be very large in the rear in order to support its weight, which made it hard to turn the tractor. Steel wheels were equipped with spikes that were capable to provide good traction in the field, but were very damaging to paved roads as well as damaging to superficial tree roots. It was in 1930 that Firestone presented the first tires specially conceived for agricultural uses.

The first internal combustion tractors used gasoline or other fuels like petrol or kerosene. Tractors equipped with diesel engines first appeared in Germany. From the nineteen thirties onwards, diesel became more and more common in tractors in Europe, but in the United States they were mainly used in large crawler tractors and only became widespread after the 1973 oil crisis. The third innovation of the thirties that defined the design of tractors was the three point hydraulic hitch system invented by the Irish tractor maker Ferguson. The Ferguson system covered over fourteen patents, registered between 1917 and 1939. It was a revolutionary system as the implements were mounted on the tractor instead of being dragged behind it. The two hydraulic arms could control depth and if the attached plough would hit an object it could be lifted easily, preventing the tractor from toppling backwards

(Ferguson Family Museum, 2006). In 1939 a gentlemen's agreement between Ford and Ferguson for the use of the Ferguson system had Ford returning to the American industry. The start of the war in Europe provided an opportunity for American firms to export their tractors. While the war continued there was little change or innovation in the industry. After the war the industry began recovering and again new companies entered the market offering new models. However, since 1948 the number of manufacturers has been decreasing.

4. Data

Our data collection was guided by the work of Suarez & Utterback (1995). In their survival model, Suarez & Utterback (1995) include the following explanatory variables: the industry sales at entry, the annual growth rate of industry sales at the exit year, the number of firms in the industry at the firm's entry and the logarithm of industry rank of entry timing. We collected data on all of these variables for the American tractor industry. Data collection was made with the help of collector books (Gray, 1954; Baldwin & Morland, 1998; Carrol, 1999; Wendell, 2000), institutional web pages, and web forums of farm tractors collectors. To capture the effect of individual design efforts, only firms developing original tractors were included for this research. From an initial list of 1012 American firms 760 were included for our data analyses.

An exhaustive list of tractor firms available in Wendell (2000) was complemented with data from Gray (1954). Based on this list all firms were researched for original models introduced and hence those that did not develop originals, but rather licensed models, were excluded. Further selection was made of firms that specialized in farm tools, lawn mowers, cultivators, combine harvesters, adaptations or kits to transform automobiles into farm tractors, but did not develop tractors. These were not included in the final list of tractor manufacturers. The collector books used, covered manufacturers and models produced until 1960. More recent companies and models were searched for in the internet. The list of tractor manufacturers from Wikipedia was a starting point. From this list all North-American companies that develop and manufacture original tractors were included in our set of data; multinational companies with headquarters in the United States or Canada were also included.

For the group of 760 firms, dates of entry and exit in the industry were collected whenever available. In Figure 1 the data on the number of companies entering the industry and exiting is presented together with firm density. As we can see there are two peaks, the first in 1920, with 209 firms and the second in 1948, with 104 firms. During the period from 1920 to 1943 the number of firms decreased, with a slight recovery from 1933 to 1940 (between the end of the Great Depression and the beginning of World War II) and a decrease until only 43 firms were still producing tractors in 1943. This may indicate that a new cycle has begun after 1943 and a new industry standard has been set around the time of the second peak. The context of the time has influenced this rebirth of the industry; in fact, after World War II was over agriculture underwent major changes. Productivity was the main priority in agricultural policies in the Western countries in order to feed a growing population that was increasingly moving to the cities. Family farms were being substituted by entrepreneurial farms of greater dimensions, while the first organic pesticides were being developed and a new era for agriculture was happening, where almost every task in a farm was becoming mechanized.

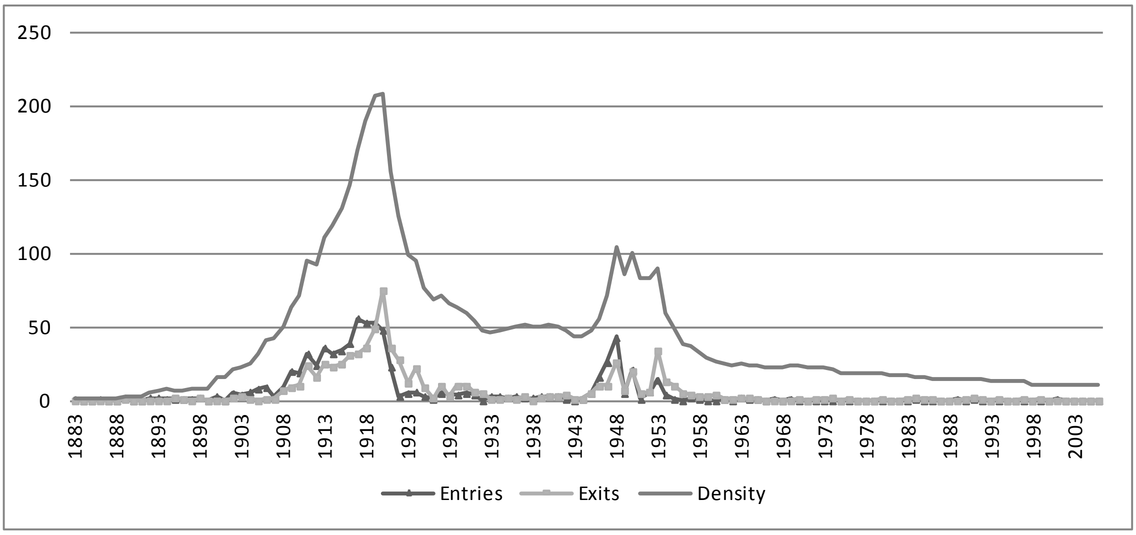

Figure II - 1 Number of firms in the American tractor industry.

An industry dominant design was searched for with the help of industry experts and mechanical engineers. According to White (2001), the Farmall tractor of International Harvester, commercialized in 1924 synthesizes the characteristics that became a standard in the tractor industry. It was a light tractor prepared to work in crops planted in rows that could perform a variety of tasks and could be attached to pull various kinds of implements. This was in contrast with earlier tractors that were made for a very limited set of uses, such as cultivating or harvesting. The Farmall was in production until the 70's with several incremental improvements made, such as the possibility to use tires since the 30's, different front axle distances and different models (the "letter series") based on engine horse-power. Other firms have developed similar models and the evolution in North America from then on was mostly an increase in size and horse-power.

Due to the immense success of the Fordson F model from 1917, we also tested the possibility that this model could have had a greater effect on industry competition than the Farmall, as described in section 5.2.

A direct interview with engineers and agronomists was also performed and a general idea of what a *dominant design* is and what were the objectives of this work were presented. This approach was meant to identify what was assumed as a dominant design in the case of tractors. These experts promptly identified the hydraulic system of the three-point hitch as a dominant design. The history of this innovation was researched for the technical bases of the system, the year it reached the American market, the firm developing it and what influence it had in agriculture. The three-point hitch or Ferguson system results of the combination of several inventions developed by Harry Ferguson for over twenty years. The first tractors with this system were built in England by Ferguson in 1933. In 1939 an agreement with Henry Ford allowed Fordson tractors to use the Ferguson system. In 1948 the agreement was broken at the time many Ferguson patents were reaching their term. Farm mechanization would benefit from a system that could perform a great number of tasks in farm using only a tractor. We also collected information on industry sales. For this variable a complete set of data was only available from 1909 to 1975, from the Agricultural Statistics of the Bureau of Census of the US Department of Commerce and Gray (1954). These years cover the first peak in industry density and the emergence of the dominant design identified by the experts (Figure II - 2). Sales growth is also included on our data. This variable can be used to analyze the industry growth in the year of exit of each firm and can provide insight into the external conditions affecting firm failure.

Since industry sales and sales growth are two of our explanatory variables, our survival analysis is restricted to the period 1909-1975. For the firms that exited the industry after 1975 their exact duration is not considered in the analysis, one just considers that they did not exit until 1975 (there is right-censoring of the data).

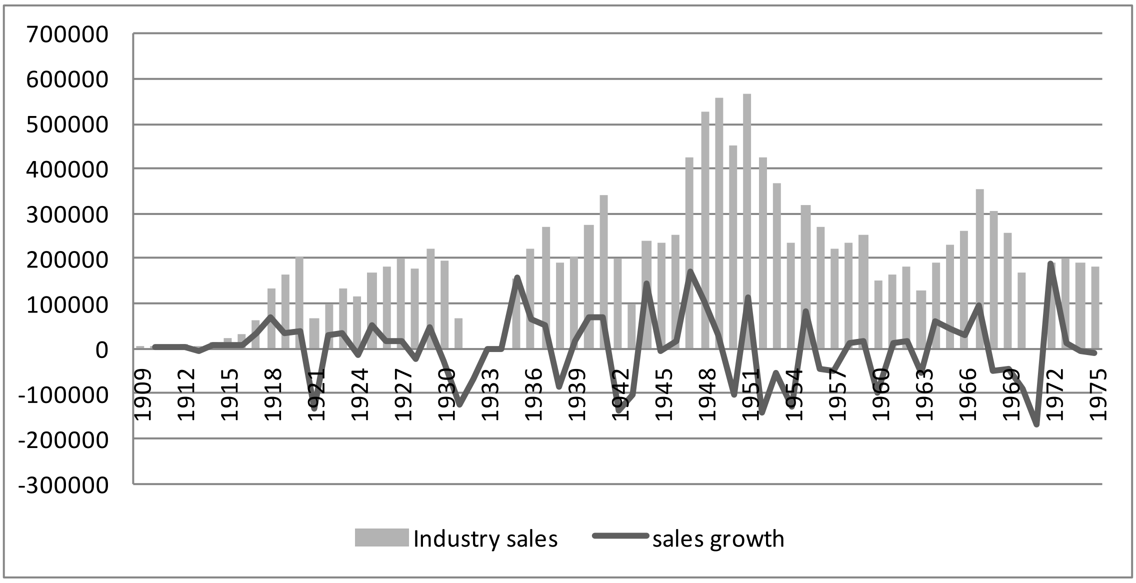

Figure II - 2 Tractors sales in the United States from 1909 to 1975 (in number of tractors).

5. Methodology

Our statistical methodology relies on survival analysis. This section presents a brief summary of some important concepts in survival analysis and then explains our model choice.

5.1. Survival analysis and selection of the survival model

In survival analysis we are interested in the behavior of the time to exit, *T*. The time to exit is a random variable and its behavior can be captured by its density function *f(t)* or by its cumulative distribution function $F(T) = \Pr[T \leq t] = \int_0^t f(u)du$. Curiously, in survival analysis it is more common to describe the behavior of *T* using the *survival function*, *S(t)*, which gives the probability that duration is longer than *t*, that is $S(t) = P(T > t) = 1 - F(t)$. Another key concept in survival analysis is the *hazard function*, *h(t)*. The hazard function indicates the conditional exit rate and it is given by:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta t | T \geq t)}{\Delta t} = \frac{\frac{\partial S}{\partial t}}{S_t} = \frac{f(t)}{S(t)}$$

A final related function is the *cumulative hazard function*, $H(t) = \int_0^t h(u)du$.

In the first step of our analysis we estimate the Kaplan-Meier survival function. This is a nonparametric estimator of the survival function which is very useful for descriptive purposes. The Kaplan-Meier estimator, like other survival methods we use, takes into account censored observations. In our case we have some right-censored observations, firms for which we know the entry time, but do not know the exit time (in the last year considered in our analysis they were still operating). It should be noted that the Kaplan-Meier survival function is an estimator of the *unconditional survival function*, it does not take into account the influence of variables that may affect the probability of survival. However, it is possible to compare the survival curves for different values of certain variables.

In the second step of our analysis we estimate survival regression models. These models assume that the hazard and related functions vary across individuals depending on their characteristics. Let $\mathbf{X} = (X_1, X_{2,\dots,}X_k)$ be the vector of *k* explanatory variables, now we denote the hazard function by $h(t,\mathbf{X})$, the survival function by $S(t,\mathbf{X})$, and so on. There are two types of models that can be used: the proportional hazard models (PH) and the accelerated time failure models (AFT). In a proportional hazard model, the hazard rate can be decomposed into two separate functions:

$$h(t, \mathbf{X}) = h_0(t, \boldsymbol{\alpha})\phi(\mathbf{X}, \boldsymbol{\beta})$$

where $h_0(t, \boldsymbol{\alpha})$ is the baseline hazard function which is a function of *t* alone and $\phi(\mathbf{X},\boldsymbol{\beta})$ is a function of the *k* explanatory variables alone ($\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are parameters to be estimated). Usually one considers $\phi(\mathbf{X}, \boldsymbol{\beta}) = \exp(\mathbf{X}'\boldsymbol{\beta})$, thus

$$h(t, \boldsymbol{X}) = h_0(t, \boldsymbol{\alpha})\exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k)$$

There are different PH models depending on the assumptions about the baseline hazard function, $h_0(t, \boldsymbol{\alpha})$. The Weibull and the Gompertz regression models are parametric PH models with baseline hazards given by $\alpha t^{\alpha-1}$ and $e^{\alpha t}$, respectively. On the other hand, the Cox proportional hazard model estimates the parameters $\boldsymbol{\beta}$ without specifying the baseline hazard, it is a semiparametric PH model. In a PH model, each regression coefficient indicates the proportional effect on the hazard rate of absolute changes in the corresponding covariate.

We may also consider specifications of $h(t,\mathbf{X})$ that do not have the proportional hazards property, such as the loglogistic model, the lognormal model or the generalized gamma model. The loglogistic and the lognormal models allow for non-monotonic hazard functions, a feature which might be important in our case. The generalized gamma hazard function cannot be written in closed form but it involves two shape parameters, $\boldsymbol{\kappa}$ and $\boldsymbol{\sigma}$, and it is very flexible in shape. One important property of the generalized gamma model is that it incorporates several other models as special cases. For example, when $\boldsymbol{\kappa}$ = 0 the lognormal model results, when $\boldsymbol{\kappa}$ =1 we obtain the Weibull function and when $\boldsymbol{\kappa} = \boldsymbol{\sigma}$ then one gets the standard gamma model. Thus the generalized gamma can be used to test model specification.

The accelerated failure time specification, assumes a linear relationship between the log of the survival time and the explanatory variables:

$$\ln T = \mathbf{X}'\boldsymbol{\beta}^{*} + \sigma u \Leftrightarrow T = \exp\,(\mathbf{X}'\boldsymbol{\beta}^{*})v$$

where $v = e^{\sigma u}$ and σ is a scale factor (which is related with the shape parameters for the hazard function). Different distributions for *u* lead to different AFT models. For instance, if *u* follows a normal distribution, then *T* follows a log-normal distribution; when *u* follows the log-gamma distribution, *T* is distributed according to the generalized gamma; and if *u* follows the logistic distribution, then *T* follows the log-logistic distribution. In terms of interpretation, an AFT regression coefficient indicates the proportionate change in survival time when the corresponding explanatory variable changes by one unit. The Weibull distribution, $h_0(t,\alpha) = \alpha t^{\alpha-1}$ is the only distribution for which both PH and AFT assumptions apply (the Weibull distribution correspond to assuming that *u* follows an extreme value distribution with two parameters), and one can show that $\beta_k^{*} = -\beta_k \;/\; \alpha$.

The AFT specification is equivalent to $T = \exp(\mathbf{X}'\boldsymbol{\beta}^{*})\,\exp(\sigma u)$**.** If individual *i* and *j* are identical except in the *k*th characteristic, then

$$\frac{T_i}{T_j} = \exp\left(\beta_k^{*}(X_{ik} - X_{jk})\right).$$

Moreover, if $X_{ik} - \mathrm{X_{jk}} = 1$ i.e. there is a unit change in X_k, then $T_i \,/\, T_j = \exp(\beta_k^{*})$. The exponentiated coefficient $\exp(\beta_k^{*})$ is called the *time ratio*. Note that their interpretation is particularly adjusted for dummy variables. One can also compute *relative time ratios* by comparing time ratios for different variables.

As explained above we may choose among two types of models (PH and AFT) and among several density functions. In order to make sure that our functional form choice was correct we started by estimating our model using the Cox proportional hazard model and testing the proportional hazard assumption. On

Figure II - 3 shows the graphical representation of the violation of the proportional hazard hypothesis in three dummy variables present in the estimated models. On the left graph, the log-log plot is represented, which should have parallel curves for the values of the dummy variable if the proportional hazards were verified. On the right, the Kaplan-Meier functions for the observed and predicted survival confirm the test, for the curves intersect.

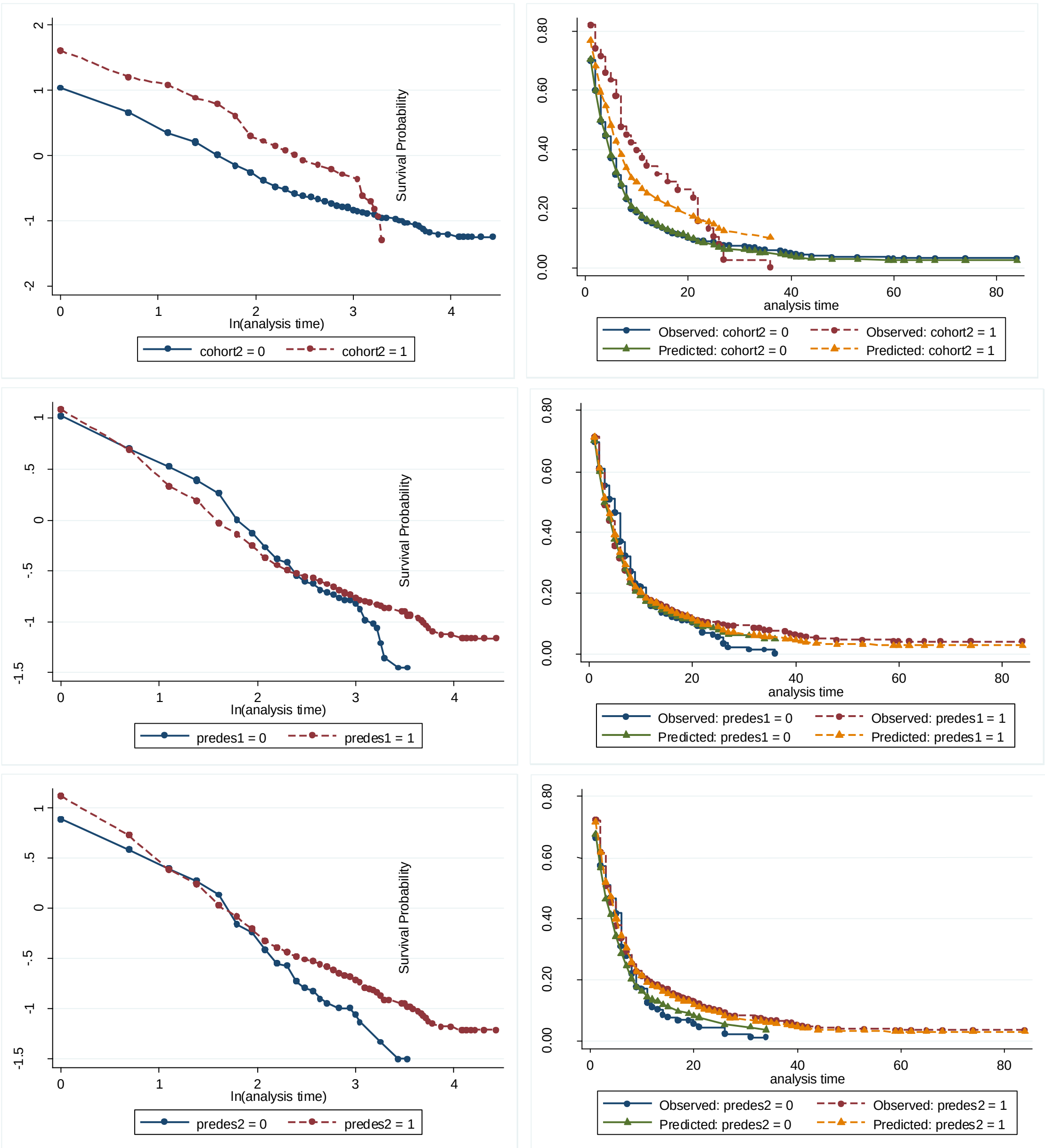

Figure II - 3 Log-log and Kaplan-Meier plots testing the violation of proportional hazards.

We proceeded to estimate a range of accelerated failure time models. We started by the generalised gamma model. As explained earlier, this model encompasses many other models as particular cases, thus it is particularly useful to test if these models fit the data well. However this model did not converge and we used more specific forms, the Weibull (we also observed the estimated parameter *p* suggested the exponential is not a proper specification), the lognormal and the loglogistic models, which have the advantage of allowing for non-monotonic hazard functions.

5.2.Estimated models

Section 4 suggests two important breakthroughs in the evolution of the tractor's industry: the introduction of the general purpose tractor in 1924 and the introduction of the three-point hitch in 1939. Although the last date has been indicated as the emergence of a dominant design (see for example, White, 2000) one should verify if survival analysis supports this assertion. Moreover, the existence of two breakthroughs raises several interesting questions: (i) which one of them has a larger impact on the survival of the tractor industry firms? (ii) should we speak about one dominant design in the tractor industry or is it more correct to say that there is a sequence of dominant designs? (iii) does the hypothesis that the probability of a firm surviving is greater for firms entering the industry before a dominant design emerges hold in the tractor industry?

In order to answer the previous questions, we started to divide the firms in our database in three cohorts according to their entry timing: (i) cohort 1 - firms that entered the industry between 1883 and 1923; (ii) cohort 2 - firms that entered the industry between 1924 and 1938; and (iii) cohort 3 - firms that entered the industry from 1939 to 1950.

In the first step of our analysis, we estimate the Kaplan-Meir survival functions for the three cohorts of firms. As explained above the Kaplan-Meier function is a non-parametric estimator of the unconditional survival function. Comparing the three unconditional survival functions gives us a first idea on whether there exists any difference in the survival probability for firms entering the industry in the three time periods. It may also indicate which of the two landmarks implied a larger change in the survival function. In the second step of our analysis we take into account the influence of variables that may affect the probability of survival. As explained in Section 5.1 we tested several survival models, but the log-normal model proved to be the best fitting one.

In order to answer the questions above we estimate several models. Most of our explanatory variables are the same than the ones used by Suarez & Utterback (1995), but we also include variables that take into account the specific history of the American tractor industry. In particular, we include one dummy variable to capture the effect of the period from 1920 to 1922, that was characterised by the beginning of the Nebraska trials and the effect of the price war. Our first model was designed to answer the first question we raised – which one of the two breakthroughs has larger impact on the survival of the tractor industry firms? The model (1), using the AFT specification, is the following one:

$$lnT_i = \beta_0 + \beta_1 density_i + \beta_2 salent_i + \beta_3 salgex_i + \beta_4 pw_i + \beta_5 cohort2_i + \beta_6 cohort3_i + \sigma u_i \qquad (1)$$

where T is the duration of the firm; *density* is the number of firms in the industry at the year of firm's entry; *salent* is the industry sales at the year of entry by the firm, capturing the effect of the market size at the firm's year of entry; *salgex* is the annual growth rate of industry sales at the exit year of the firm; *pw* is a dummy variable which is equal to 1 if the firm was active during the period of the price wars, which also includes the launch of the first Nebraska trials (1920-1922); *cohort2* is a dummy variable which is equal to 1 if the firm entered the industry in the period 1924 to 1938; and *cohort3* is a dummy variable which is equal to 1 if the firm entered the industry from 1939 to 1950.

The *density* of firms is a variable that explains the market competitive pressure at entry, as happens in biological populations. A higher firm density will provide more competition for survival, and will force worse designs or less competitive firms out. Since firms' density increases the hazard rate and the hazard rate is inversely related with survival probability, we expect β_1 to be negative.

For a given number of firms, we expect that the larger the market demand the higher is the probability of a firm surviving, an idea related to population ecologists and also economics. Thus we expect β_2 to be positive.

The variable *salgex* is related with business cycle effects. In periods of high growth we expect a higher survival probability while the reverse is expected in periods of low industry growth. Consequently, the expected sign of β_3 is positive.

The price war is expected to increase the conditional exit rate or, equivalently decrease the survival probability. On the other hand, the existence of the Nebraska tests probably generated a self-selection mechanism in the entry process. Firms producing tractors that were unlikely to pass the Nebraska test may have decided not to enter. As a consequence, the firms that entered or remained active during this period were the ones with better products and thus the ones who had higher survival probabilities. We expect firms that did not fail during this period have a lower probability of failing than others (which is in line with Swaminathan (1996)). Although the opposite effects of the events during this period could suggest an ambiguous combined effect for β_4, conditional on surviving this period, firms are expected to have a lower hazard rate on subsequent periods, or β4 to be positive.

The two dummy variables, *cohort2* and *cohort3* allow us to analyze whether there were shifts in the intercept term, with respect to the excluded cohort. For a firm entering the industry before1924, the intercept term is β_0 (as *cohort2* and *cohort3* are both nil). On the other hand, the intercept term for a firm in the first cohort is $\beta_0 + \beta_5$ while for a firm in the second cohort is $\beta_0 + \beta_6$.

Thus if β_5 or/and β_6 are statistically significant that means that there was structural shifts in the survival curve. The shift from the second to the third cohort is captured by ($\beta_6 - \beta_5$).

Our second model (Model 2) allows us to test the hypothesis that the probability of a firm surviving is greater for firms entering the industry before a dominant design emerges, assuming 1924 as the date of the dominant design. The estimated model (2) is the following one:

$$lnT_i = \beta_0 + \beta_1 density_i + \beta_2 salent_i + \beta_3 salgex_i + \beta_4 pw_i + \beta_7 predes1_i + \sigma u_i \tag{2}$$

where *predes1* is a dummy variable that takes value 1 if the firm entered the industry before 1924 and takes values 0 otherwise and the remaining variables are as defined above.

We argue that there is a relationship between the year of entry, the emergence of a dominant design and the survival probability. In principle, firms that entered before the dominant design will have a higher probability of surviving than those entering afterwards, since the first will have accumulated experience and have tried their different models when the industry was still at an era of ferment (Anderson & Tushman, 1990) when no design had a competitive advantage. Thus one expects β_7 to be positive.

The third model (Model 3) is similar to the second one, except that it considers 1939 as the emergence date of the dominant design. The estimated model is:

$$lnT_i = \beta_0 + \beta_1 density_i + \beta_2 salent_i + \beta_3 salgex_i + \beta_4 pw_i + \beta_8 predes2_i + \sigma u_i \tag{3}$$

where *predes2* is a dummy variable that takes value 1 if the firm entered the industry before 1939 and takes values 0 otherwise. Again we expect β_8 to be positive.

As the impact of the Fordson F also helped shape the industry, in order to be certain of the real importance of the 1924 event as affecting industry competition, in a subsequent analysis, we also compared the survival curves for the 1883-1909 cohort (*C1*), the beginnings of the traction engine industry, for a 1910-1917 cohort (*C2*) and a 1818-1924 cohort (*C3*), capturing the effect of the Fordson, and also two cohorts for the period 1925-1939 after the emergence of the Farmall (*C4*), and 1940-1975, after the Ferguson system innovation (*C5*). The estimated model (Model 4) is then:

$$lnT_i = \beta_0 + \beta_1 density_i + \beta_2 salent_i + \beta_3 salgex_i + \beta_4 C2_i + \beta_5 C3_i + \beta_6 C4_i + \beta_6 C5_i + \sigma u_i \quad (4)$$

The previous regression models are estimated by maximum likelihood, taking into account right censoring and assuming that *T* is distributed according to the log-normal distribution.

Our preliminary results show that the proportional hazard assumption is rejected in three of the four models estimated (Table II - 1). Although the violation of the hypothesis of proportional hazards does not hold on Model 3, we already observed that the graphical test rejects the proportional hazards in one of the variables and thus it suggests that one should not use proportional hazards models.

Table II - 1 Proportional hazards test

	Model 1	Model 2	Model 3	Model 4
PH Global Test Chi^2	11.9*	11.52**	6.3	22.26***
N. Observations	636			
N. Failures	567			

After a preliminary estimation, we also tested the possibility of heteroskedasticity and heterogeneity. We did not rejected the hypothesis of homoskedasticity, and thus perform the estimation without robust standard errors to correct for heteroskedasticity. As for unobserved heterogeneity or frailty, a common problem in survival models, we estimated frailty models, specifying a distributional form (gamma) for the parameters, and tested the hypothesis of the parameters being non-constant, which was rejected (Table II - 2).

Table II - 2 Frailty (gamma), test H_0: Theta=0

Chi2	Lognormal			Loglogistic		
Model 1	2.23	*	No frailty	0.00		Frailty
Model 2	2.21	*	No frailty	0.00		Frailty
Model 3	1.79	*	No frailty	0.00		Frailty
Model 4	18.68	***	No frailty	4.93	**	No frailty

The Cox-Snell plots test was also used in order to find out if there was any misspecification.

6. Discussion of the results

As described on section 5, the process of estimation of the models began with testing the existence of proportional hazards, rejection of that hypothesis, and selection of an AFT model.

In this section, we describe the results of the analysis of the duration models.

6.1.Kaplan-Meier survival functions

As explained above we started by dividing the firms in 3 cohorts according to their entry timing. Figure II - 4 shows the Kaplan-Meier survival functions for the three cohorts. A likelihood ratio test clearly rejects the hypothesis of equality of the three survival curves.

Figure II - 4 shows that the firms that entered between 1924 and 1938 have the highest survival probability and that this is the cohort with a more distinctive survival behaviour. The figure suggests that the survival probability increased with the introduction of the general purpose tractor, but it decreased with the introduction of the three-point hitch system to levels similar to the pre-Farmall period.

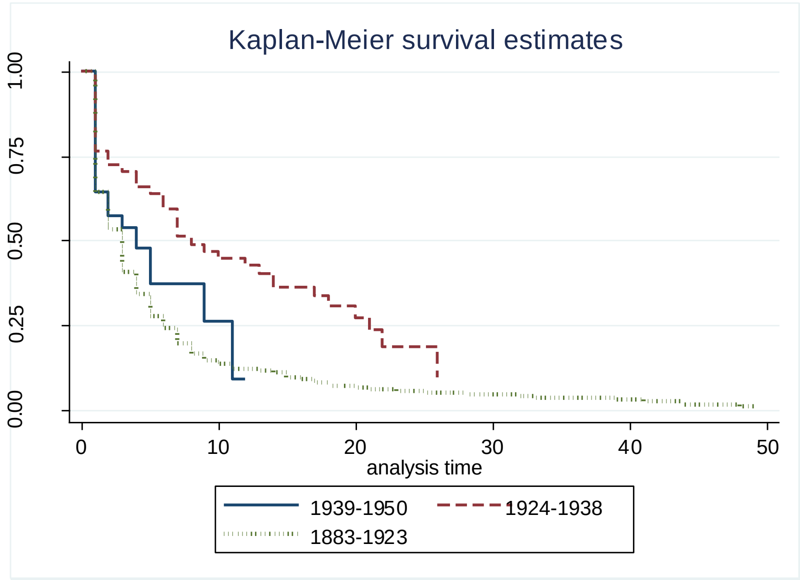

Figure II - 4 Kaplan-Meier survival functions for the three cohorts of firms.

As described before, we also compared the survival curves for firms entering the industry before 1917 and after (results not presented). The curves did not suggest any major difference between the firms entering before and after 1917, which reassured us that the 1917 Fordson tractor had a limited effect on the industry, which supports our conjecture that the introduction of the Fordson was more damaging to the traction animals market than to the tractor industry. This effect on the traction animal sales can be interpreted on a parallel with the automobile industry, where there were submarkets that converged on the Ford model T (Klepper, 2002). In the case of tractors, the Fordson F was able to absorb the market of traction animals into the tractor market.

6.2. Parametric survival models

The Kaplan-Meier survival curves do not take into account the influence of factors that affect survival probabilities, such as the size of the market, business cycles or the density of firms. Since these factors change over time, it is possible that the shifts in the unconditional survival curves reflect changes in these factors rather than the impact of the emergence of a dominant design. Thus a more careful analysis requires the estimation of survival curves using regression analysis. To answer the questions raised in Section 5.2 we estimated the regression models (1), (2), (3) and (4). The results of these regressions are presented in Table II - 3. Some general conclusions can immediately be drawn. First, all estimated models present a strong overall significance.

Table II - 3 Results of the log-normal survival regression models

	Model 1		Model 2		Model 3		Model 4	
density	-0.0109	***	-0.0109	***	-0.0138	***	-0.0046	*
	(0.00)		(0.00)		(0.00)		(0.00)	
salent	-0.0020	***	-0.0020	***	-0.0005		-0.0006	
	(0.00)		(0.00)		(0.00)		(0.00)	
salgex	-0.0007		-0.0007		-0.0010		-0.0023	***
	(0.00)		(0.00)		(0.00)		(0.00)	
pw	1.3947	***	1.3950	***	1.3050	***		
	(0.10)		(0.10)		(0.10)			
cohort2	0.8445	***						
	(0.21)							
cohort3	0.8373	***						
	(0.29)							
predes1			-0.8434	***				
			(0.21)					
predes2					-0.1523			
					(0.23)			
c2							-0.2588	
							(0.23)	
c3							-0.4861	*
							(0.28)	
c4							0.0672	
							(0.27)	
c5							-0.4294	
							(0.37)	
_cons	1.8901	***	2.7326	***	2.3236	***	2.1683	***
	(0.13)		(0.17)		(0.22)		(0.15)	
sigma	0.9728	**	0.9729		0.9887		1.1210	
loglikelihood	-851.63		-851.63		-859.53		-931.94	
Chi2	233.03	***	233.03	***	217.23	***	72.40	***

Notes: robust standard errors in parenthesis; *10% significant; **5% significant; ***1% significant.

Second, variable *density* is statistically significant in the four models, showing the predicted

effect. On

Figure II - 5, are represented the survival and hazard curves for the effects of variable density on model 1. We represent the curves at the minimum, maximum and average values of density observed.

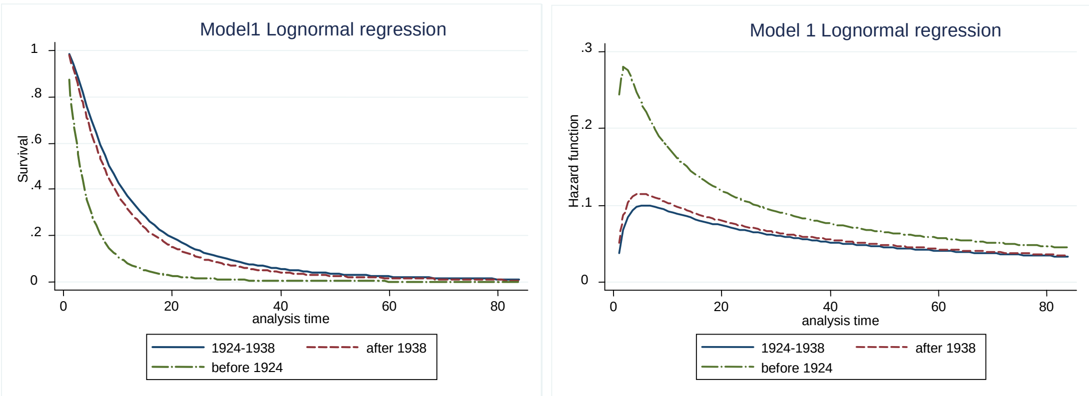

Figure II - 5 Survival and hazard curves for variable density (Model 1).

Third, the signs of the coefficients of the variable *pw* are the expected. This result leads us to suggest that the results from Geroski et al. (2010), for firms surviving highly concentrated markets, also hold for the effect of other adverse founding conditions, such as a price war. In Figure II - 6 the survival and hazard curves for *pw* in Model 1 are represented.

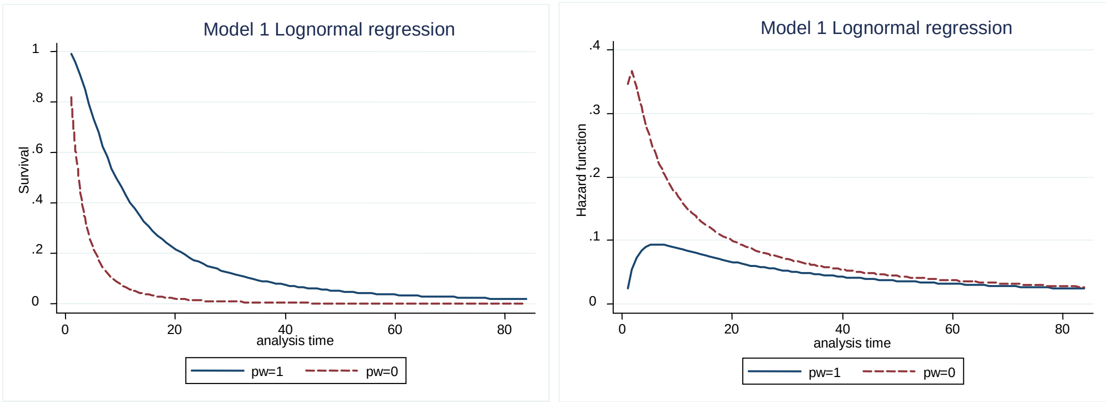

Figure II - 6 Survival and hazard curves for variable *pw* (Model 1).

Fourth, in all regressions the impact of the variable *salent* is the opposite of the predicted one, although it is only statistically significant in Model 1 and Model 2 and irrelevant from an economic point of view. As to the industry sales growth at the time of exit of the firm (*salgex*), we only find it to be significant in Model 4, influencing negatively the survival of firms, which is also the opposite of the expected effect.

Next we describe the results regarding the impact of the two landmarks of the tractor's history in the survival of firms, which allows us to answer our main research questions. The results of model 1 show the coefficient of *cohort2* is statistically significant and positive, indicating that firms that entered between 1924 and 1938 have a longer survival time than firms entering before or after this period. The coefficient for *cohort3* is also significant and positive, suggesting that there also an increase on the duration of the firms on the third cohort, when compared to the first.

The previous results are illustrated in Figure II - 7. This figure shows the survival curves of the three cohorts, after controlling for the effect of the remaining explanatory variables. Overall this suggests that the introduction of the general purpose tractor in 1924 implied larger changes on the probabilities of firms' survival than the introduction of the three-point hitch in 1939. It is worth comparing this figure with Figure II - 4. The survival probability increased substantially with the introduction of the general purpose tractor, but had a slighter decrease after 1939.

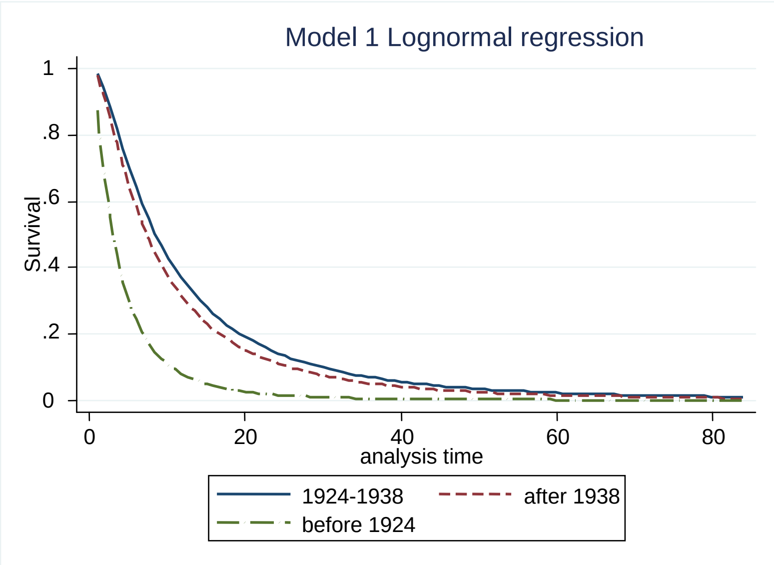

Figure II - 7 The survival functions for the three cohorts of firms in model 1.

The hazard functions for the three cohorts of firms are represented in Figure II - 8. It is interesting to note that the hazard functions are not monotonic. The hazard rate starts to be increasing, but after a certain point it becomes decreasing. Note that the hump shape of the hazard function is much more pronounced for the firms in the first cohort. Moreover, the hazard rates are substantially higher for firms that entered the industry before 1924, in the initial years of a firm life. The curves tend to be equal after the first ten years of activity of firms.

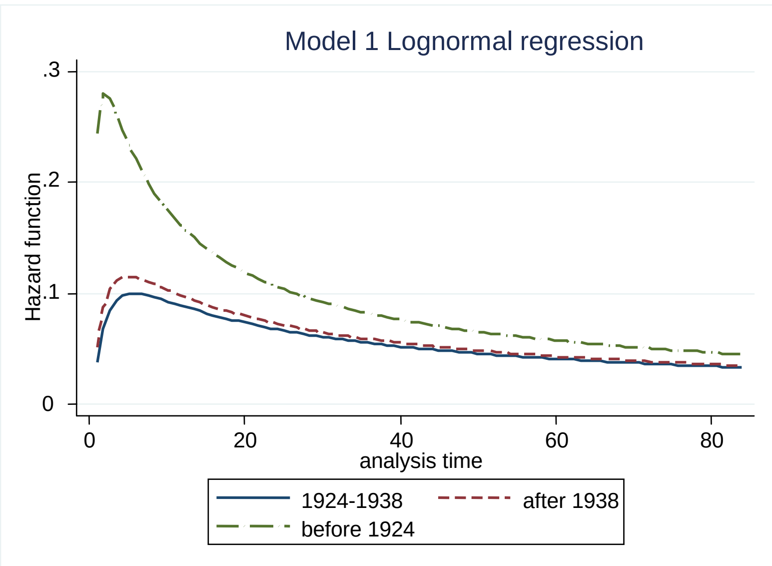

Figure II - 8 Hazard functions for the 3 cohorts of firms, after controlling for other explanatory variables (Model 1).

Considering 1924 as the emergence of the dominant design, our second regression includes a dummy variable that identifies the firms that entered before the dominant design emerged. This regression allows us to test Suarez & Utterback (1995) hypothesis that firms that entered before the dominant design have a higher probability of surviving than those entering afterwards.

The coefficient associated with the variable *predes1* is negative and statistically significant at the 1% level. Using the time ratio interpretation, one concludes that a firm entering the industry before 1924 has an expected duration which is 43% (exp(-0.8434)) of the expected duration of a firm entering after 1924. Thus the hypothesis that β7 is positive is clearly rejected when 1924 is taken as the emergence of the dominant design. Figure II - 9 shows the hazard functions for firms entering before and for firms entering after the emergence of the general purpose tractor dominant design. It is extremely clear that firms entering after the dominant design have a much lower conditional exit rate.

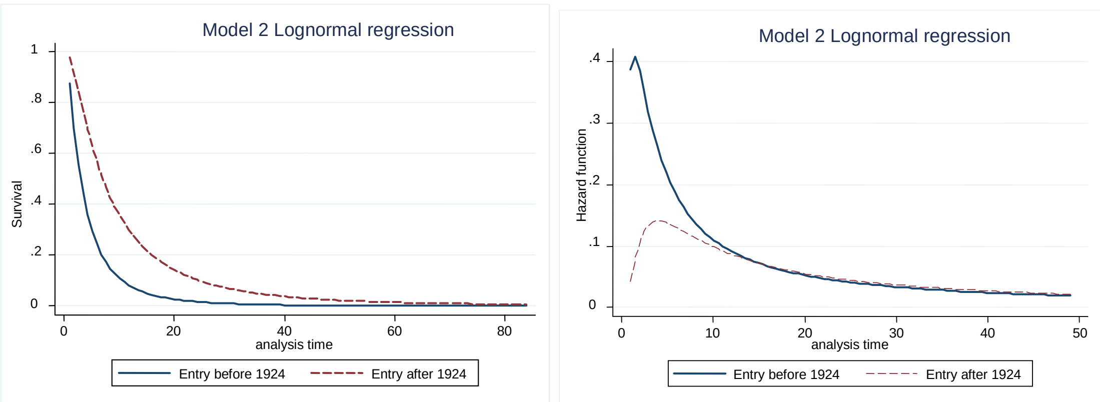

Figure II - 9 Survival and Hazard functions for firms entering before and after 1924, controlling for other explanatory variables (model 2).

How can we explain the fact that firms entering after the dominant design have higher survival probabilities? It is true that firms entering before the dominant design have more experience and may have been able to erect barriers to entry that bring difficulties to the late entrants and thus decrease their survival probability. But there is an important factor to point out in the opposite direction. Firms that entered before the dominant design may spend a lot of resources in experimentation and may end up choosing the wrong design. Many of these firms will not adapt sufficiently fast and will end up failing. On the other hand, the firms that enter after the dominant design is established will face a much less uncertain environment. This argument is particularly relevant for the first dominant design in the industry since it is then that the environment is more uncertain before the dominant design.

Model 3 is similar to Model 2, except that it considers 1939 as the date of emergence of the dominant design. In this regression we obtain quite different results. The coefficient associated with the variable *predes2* is positive but it is not statistically significant. Thus having entered before the second dominant design does not significantly affect the survival of the firm.

Model 4 considers the possibility of the industry suffering from different effects as new waves of innovation occurred. Five periods were considered starting with the beginnings of the traction engines, the early tractors, the Fordson, the Farmall, and the Ferguson system. Only C3, the dummy for firms entering the industry between 1918 and 1924 is significant, representing a lower survival time, compared to other periods. On Figure II - 10 we can observe the survival and hazard curves for the five cohorts, where is clear that this decomposition of cohorts does not provide any new results.

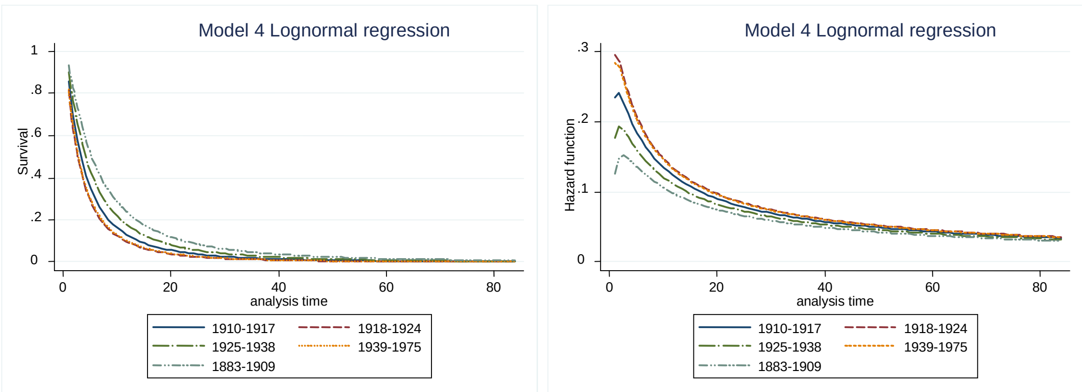

Figure II - 10 Survival and hazard curves for the five cohorts in model 4.

7. Conclusions

In this essay we explore the impact of the technological evolution in the American tractor industry on the survival of its firms. Using a unique data set of 760 firms developing original tractors, we identify two major turning points in the evolution of the American tractor industry: the introduction of the general purpose tractor in 1924 and the introduction of the three-point hitch or Ferguson system in 1939. We test the hypothesis that firm survival is affected by these technological breakthroughs. Our model includes control variables for the effects of population density, market size, business cycles and timing for entry.

One distinctive characteristic of our methodology is a very careful choice of the regression survival model. We tested several models and functional forms specifications and concluded that the lognormal model was the most adequate one. The lognormal model has the interesting property of allowing for non-monotonic hazard rates, a property which turned out to be important in our case. In fact, the conditional hazard rate in the American tractor industry is increasing for the first years of a firm life, but then it becomes decreasing. The hump shape of the hazard function is especially pronounced for the firms that entered the industry before the first technological breakthrough.

The results show that firms that entered the industry in the initial development phase, have a much lower expected duration than firms entering after the first major breakthrough. They also suggest the existence of a "window of opportunity", a period during which entry was particularly favourable from the point of view of survival probability. For given values of the control variables, the firms that entered after the first breakthrough but before the second one have the highest expected duration.

What are the reasons for firms that entered the industry before the "window of opportunity" having such low probability of surviving? Many of these firms may have spent a lot of resources in experimentation during a non-standardized and low volume phase of the industry, with the risk of ending up choosing the wrong design. Some of these firms did not adapt sufficiently fast and ended up failing, because their accumulated knowledge about markets and technology had become obsolete with the emergence of the dominant design.

It should be noted that this does not mean that entering in a very early phase of the industry development is a bad decision. Survival probability is only one dimension of a firm long run performance. It is possible that, while survival probability is lower for firms entering the industry earlier, profits and market share are higher for the early entrants that manage to survive. In other words, conditional on surviving, early entrants have a better performance. Thus, one is not sure about the optimal timing of entry without also exploring the impact of the entry timing in the other performance measures.

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Essay III: Innovation and industry dynamics in the American feature film industry

Abstract

It is broadly accepted that during the life-cycle of an industry there are waves of innovation that shape the destiny of firms. While product innovation plays an important role in defining the industry in an early phase, as industries mature process innovation is believed to become more important in the reduction of costs and improving efficiency. However, we find little evidence in previous literature on the distinctive effects of product and process innovation.

This paper examines the effects of these two types of innovation on the survival of firms throughout the whole history of the American feature film industry. We find evidence that sustains that process innovation is crucial on a mature phase when an industry is challenged by the emergence of new forms of competition.

We further derive some interesting results on the effects of market competition, firm size and executives' characteristics that reinforce previous empirical results from other industries.

Keywords: Product innovation, Process innovation, Firm survival, Motion picture production industry.

JEL codes: L82; O30.

1. Introduction

Industrial dynamics are the observed results of the interplay of changing market forces and technologies on the rates of entry, exit and permanence of firms in a given industry. From a Darwinian perspective, while biological populations evolve through adaptation (to environments and behaviours) and natural selection of the fittest, the dynamics of industrial populations can also be seen as evolutionary, for there is adaptation, through learning, innovation and adoption of technologies, and market selection of firms.

When studying innovation in any industry authors such as Abernathy & Utterback (1978) have noticed that a wave of product innovation is generally followed by a wave of process innovation (Figure III - 1).

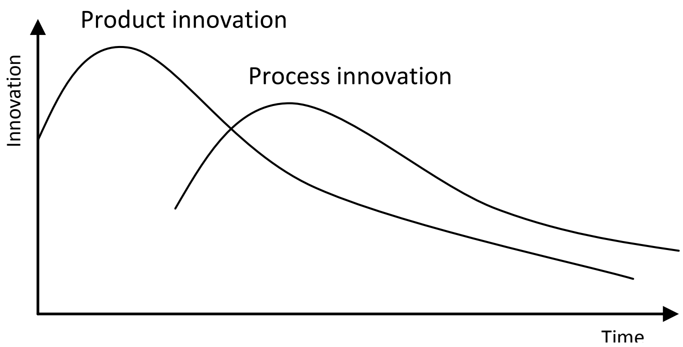

Figure III - 1 The dynamics of innovation (Abernathy & Utterback, 1978).

A sequence of periods in an industry lifecycle can be described as eras (Anderson & Tushman, 1990; Tushman & Anderson, 1987). After a technological discontinuity, an era of ferment initiates where experimentation happens and product variation occurs. This era ends with the emergence of a dominant design that sets off a new era of incremental change where most innovations are incremental, which build on the dominant design. As the era of ferment is focused on improving the product and process on the supply side, the era of incremental change is more demand focused and innovation is channelled to satisfy customer needs (Adner & Levinthal, 2001). The incremental era ends with a new technological discontinuity that sets off a new era of ferment and so on.

The concept of dominant design has been applied to describe innovations on assembled products (e.g. automobiles, computers). In non-assembled products (e.g. paint, glass) process innovation is more important than product innovation, so instead of dominant designs Utterback (1996) defines enabling technologies as the turning point of an industry. An enabling technology is a process innovation – often involving the reduction of production steps - that represents a productivity and efficiency discontinuity. Companies adopting this new technology acquire a competitive advantage over those who carry on the old production process. The enabling technology marks the end of the era of ferment that follows a technological discontinuity (Anderson & Tushman, 1990), which is a radically new form of producing the same product with higher quality and cost reduction.

Although a useful tool for understanding the role of innovation and technological change in industrial dynamics, dominant design theory has been criticised for being able to provide only *post hoc* conclusions (Baldwin *et al.*, 2006), for it cannot predict the emergence of the dominant design.

Another approach on industry lifecycles is based on the occurrence of shakeouts. A shakeout is the event that occurs when after a period of growth of the number of firms in a certain industry, the number of firms suddenly drop. This theory has been tested for industries such as tires, automobiles, televisions and penicillin (Simons, 1995, 2007; Klepper & Simons, 2000, 2005) and has connections with the theory of dominant designs, when the event triggering a shakeout is the emergence of an innovation.

Jovanovic & Tse (2010) observed that shakeouts happen earlier in industries where technological advance is faster. Their conclusions strongly support the case for studying innovation as an important factor behind the explanation of the industrial dynamics.

The effects of industrial evolution on the population also affect the decision to enter that industry. Entry time has been well studied for its implications on strategic decisions and the economics of new industries. Entry-timing is central when studying industry lifecycles, strategy, innovation management, and organizational theory (Suarez *et al.*, 2013). This stream of literature has evolved from the earlier notions of first mover advantage and entry order, to the challenges of technological uncertainty (Anderson & Tushman, 1990).

Fosfuri *et al.* (2013) reviewed entry-time literature to conclude that although there are a variety of studies on the subject, there is still work which needs to be done to incorporate disparate concepts, to build a general theory. Such effort could then guide firms on their decision of whether to enter a market.

The rich literature on entry provides support to study industry dynamics focusing on the technological aspects affecting firms at entry. However, as we can observe that most such industry dynamic studies are focused on a group of industries, namely automobile, television sets and computers, all of which share some characteristics such as being consumer goods and assembled products.

The choice of the industry to test a certain theory may result on biased conclusions, and this calls for the need to explore further into other types of industries, searching for similarities that support previous literature, and differences that may challenge existing notions and theories. Such industries like process industries based on nanotechnology or biotechnology, are spreading their influence in an increasing number of aspects of the economy and emerging as substitutes of older technologies. Another observable trend is the adoption of green technologies in order to reduce carbon emissions; these can be in the form of highly advanced technologies or even a return to the origins, as in the case of ecological agriculture and traditional building technologies. New processes of production can reduce costs and improve efficiency in industries where little improvement can be made to their products. . Such is the case of agriculture and fisheries, as well as in the case of high technology industries, for instance pharmaceuticals.

When approaching process innovation two questions may be posed. The first is the existence in fact of differences between product and process innovation. The second question deals with the impact that process innovation may have and how important or irrelevant it may be on firms and industries.

The importance of process innovation in non-assembled products is far greater than in assembled products. Processes like the tunnel kiln in cement (Anderson & Tushman, 1990), or float process in glass panels (Utterback, 1994) represent tremendous advances in productivity and cost reduction, whereas most process innovations in assembled products such as automobiles represent incremental innovations, with small, cumulative results in productivity (Utterback, 1994).

The lower impact of process innovations in assembled products is also due to a greater number of steps in production, so if one would cut two or three steps in a complex production process such as a car motor that would have little or no effect in cutting costs. Abernathy & Utterback (1978) measured the effects of cutting production steps on the Ford Taurus, the first automobile whose production process was designed to eliminate steps and improve productivity. According to Utterback (1994), the engineers at Ford Motors were able to reduce the panel assemblage steps from nine to two, reduced the number of components and uniformed the size of screws. While this effort clearly reduced assemblage costs, those authors observed it did not make significant improvements in competitiveness.

In the case of simple products, new process architectures can reduce both unit costs as well as production time. This generally happens due to the reduction or combination of production steps. For instance, in the glass panel industry there was a reduction from 5 to 2 steps, either due to combination or elimination (Utterback, 1994).

Major process innovations carry high costs and risk. Revolutionary process innovations that provide a new enabling technology are rare, but between two process architectures innovation keeps occurring in incremental, modular steps (Lakhani *et al.*, 2012, Langlois & Garzarelli, 2008).

In a review on industry life-cycle theory, Peltoniemi (2011) observed three potential special cases - services, complex products and systems, and cultural industries - which defied a uniform theory of industry life-cycles. In the case of cultural industries, a particular differentiating aspect is the importance of creativity as an input. While the importance of creative industries is widely acknowledged, they have so far attracted very little attention of researchers, much less so when it comes to explaining industry dynamics.

In this article, we will analyse the dynamics of the American motion picture industry, which is a cultural industry and besides offering a product it is also an entertainment service. These characteristics make it challenging to understand how common theory may apply to this industry and, at the same time, provide a complex yet rich ground to test it.

Some important studies have focused on particular eras and innovations, such as Gil & Lampe (2012) and Mezias & Mezias (2004). Other studies on cultural industries have analyzed the influence of creativity in product differentiation (Hsu *et al.*, 2012; Catani, 2008; Perretti &

Negro, 2007; Sedgwick, 2002) through an organizational perspective (Wenting, & Frenken, 2011). To our knowledge, this is the first time that industry dynamics is analysed for a cultural industry, focusing on the effects of technological innovation to describe the whole history of the industry evolution.

With the help of a unique database, we believe that our research helps us to understand the influence of innovations, both on product as well as on processes and their permanent effects on the industry dynamics that can be observed on the exit rates of firms and the overall outcomes of an industry.

On section 2, we review the industry dynamics literature while section 3 presents the American motion picture production industry and the process of data collection; on section 4 we review and discuss the methodology of survival analysis and on section 5 we analyse data and results. Finally, section 6, presents the conclusions, and points out to future directions of research.

2. Industry dynamics, innovation and the survival of firms

Industrial populations evolve through adaptation and market selection of firms. Firm populations within an industry are affected by environmental and individual factors that affect their permanence, or survival. Scholars have addressed the issue of firm survival in industrial economics, organisational theory and management in general. Economic history can also help explain these dynamics.

According to Jovanovic (1982), the learning and experience accumulated through production enables firms to gain efficiency and adapt to their environment, in terms of size. Following this line of reasoning, older firms are supposed to have more knowledge which allows them to keep surviving and growing. On the other hand, the size of firms then enters as an additional factor, increasing their probability of surviving.

Subsequent research on the effects of size and age on firm survival have been pointing out to a non-monotonic relationship. Audretsch & Mahmood (1994) found an inverted-U relation, with hazard increasing in the years after entry, but subsequently decreasing. The initial high hazard of firms however can be reduced by their size or initial growth rate (Mata & Portugal, 1994, 1995; Audretsch & Mahmood, 1995).

Organisational theory has also uncovered evidence of the effects of age and size throughout the lifetime of firms. Furthermore, this stream of literature also provides some insights into the importance of the environmental conditions of an industry at the time of entry of firms on their future outcome and ability to survive (Geroski *et al*., 2010; Henderson, 1999). In fact, two factors combine to enlarge the importance of entry conditions: while the industrial environment is composed of many structural conditions, organisations also tend to develop strategies that overestimate the structural aspects and hinder their adaptation to change. Yet, change in environmental conditions occurs, driven by the economic cycle and by technological evolution.

Industrial dynamics literature has explored how innovation can be a source of industry evolution and explain how it influences both the competitive advantage of the individual firm and the thriving of the population of firms that make up the industry. According to Utterback (1994), in the earlier stages of an industry, product innovations play an important role on the entry and survival of new firms. As industries mature, he argued that process innovation would become more important on the survival of firms. However, little empirical evidence exists, for industry studies focus mostly on the shakeouts occurring during the initial years of industries (see, for instance: Cabral *et al.*, 2013; Buenstof & Klepper, 2010), or on the general models of innovation and industry dynamics (Bertomeu, 2009).

Microeconomic theory suggests that the degree of concentration is another important factor affecting the competitive environment. While the effect of perfect competition on driving out inefficient firms may seem straightforward, empirical results so far, provide ambiguous evidence. Geroski *et al.* (2010) propose that, in a concentrated market, incumbents have the power to drive new entrants out, but the costs of that behaviour cannot be sustained indefinitely. New firms that survive the earlier years can then enter the incumbent group and become protected by the same effects that forced other entrants out.

3. Data

We have chosen the American feature film production industry, to study the importance of the succession of product and process innovation on the dynamics and evolution of the industry. This is a case of a mature industry, where both product and process innovation play important roles and where the recently emergence of digital filming technology and the competition with other media have been changing as well as defying the industry's status quo. Furthermore, the film industry provides substantial data on firm population, features produced and released, and revenues, which allow for a comprehensive analysis.

An additional motive comes from the fact that the motion picture production industry allows us to perform an analysis of an industry for a period of over a century, while most industry studies have used recent industries or only partial data. Our database allows us to observe the beginnings, a possible shakeout phase, and the mature phase, including several technological trajectories and periods.

3.1. A brief introduction to the American motion picture production industry

The motion picture industry has a group of particularities that make it an interesting subject to study through the perspective of industry dynamics. It is a mature industry that has been evolving continuously, both creatively and technologically, where both product and process innovations have played important roles through its history. It is also interesting to researchers in economics for it provides rich data.

This industry has been the subject of interest of industrial economists, as it reveals characteristics both of a creative industry, and also of an organised manufacturing industry, where film production firms are the `factories´. The motion picture industry has been the subject of interest, albeit scant, of innovation management scholars. For instance Hsu *et al.* (2012) analyzed the American film industry to study the effects of the adoption of different film genres as instances of product diversification and its effects on the firms' ability to compete. Perreti & Negro (2007) used the motion picture industry to analyse team composition and its effects on innovation, although their focus is mostly on creative aspects and less on technology.

The motion picture industry value chain is typified by three steps: production, theatrical distribution and exhibition. In our study, we focus our attention on the technical aspects of the production phase. The production of a motion picture is further divided into three phases, pre-production, production and post-production (Eliashberg *et al.*, 2006; Vogel, 2001).

3.2. Database and variables

For our analysis of the technological innovations the motion production industry has experienced, and their effects on the ability of firms to compete, a unique dataset was assembled. Data was retrieved on the number of firms in this industry since its inception in 1891 until 2012, a list of firms comprising entry and exit time, market size (measured by the number of features released per year) and timing of introduction of new products, such as feature films and talkies, as well as processes, such as big studio organization, cinematographic processes of motion picture capture and digital cinematography. Several sources were used in order to provide a database as complete as possible and, to the best of our knowledge, unbiased, as described on the following paragraphs.

3.2.1. Firm entry and exit

In order to analyse the effects of innovation on the American film industry, we started by collecting data on the number of firms entering and exiting the industry from its very inception up to the present. The primary source of data on studios was Slide (2001), who followed the industry from its origins in the 1890's, all the way through to 2000. We retrieved historical information on all types of firms, in terms of size, organization, founders origins, types of productions (genres and length), and in some cases even the total number of productions. For more recent firm data, we used the Internet Movie Database (IMDb.com) resources and crosschecked this data with official firm online sites.

To our knowledge, this gathered, collected, multi-source and harmonised data set is completely original. This effort does yield interesting results as it allows for the first time to assess the whole American film industry, thus reaching a global view since its inception in 1891 to the present. The process involved checking hundreds of movies, in historical archives, books among others. Even though the internet speeded up this process, the data gathering process took one year of continued effort and subsequent refinements continued. In Figure III - 2, we observe the patterns of entry and exit of firms in the film industry.

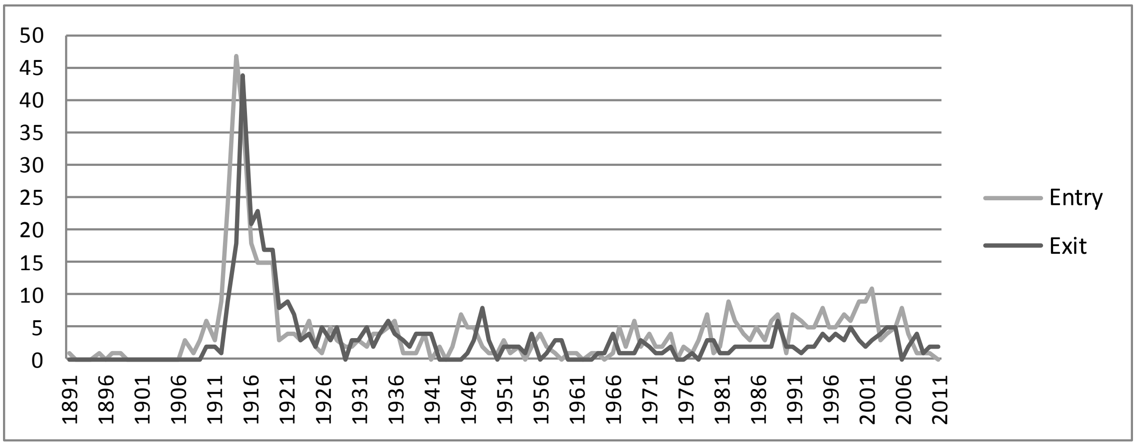

Figure III - 2 Number of firms entering and exiting the industry per year.

The American film industry started with few firms producing and testing the new technology that was at the time mainly developed in France. Films were short, less than five minutes, the length of a film reel or even less.

During the early years of the industry, the main events affecting it were the innovations related to the cameras and exhibitions technologies, mostly from Thomas Edison. Edison´s patents impeded an explosion on the number of producers, and also the evolution of the materials films were made of, from highly inflammable materials, to the acetate film, that proved the more secure form of capturing and storing images for the next decades.

The expiry of the Edison patents on filmmaking in 1913 and two court decisions, in 1915 and 1918, marked the end of the Edison age, allowing new players to enter the American market. At the same time, the war in Europe paralysed production in the most important producer and exporter country at the time, France, opening up a new market opportunity for fresh producers from the United States.

From Figure III - 3 we can observe the evolution of the number of film production firms in the United States. After a slow beginning in the late 19th century, the industry grew in terms of the number of producers, starting from 1909 and reaching a peak in 1913. Several technologies were experimented in the production phase, with many firms entering and exiting the industry in this period. Most of these new entrants, did not survive even one year with many only producing one film, during this period characteristic of a shakeout (Klepper & Simons, 2005). By 1920 the number of firms stabilized and then went onto experiment another wave of growth in the late sixties, prompted by the emergence of *New Hollywood* and the disruption with classical Hollywood filmmaking.

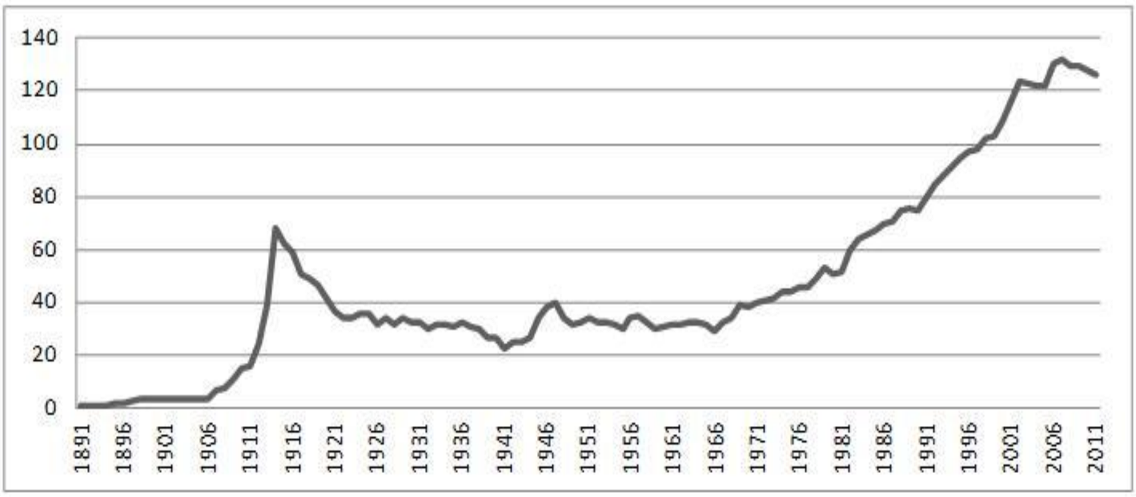

Figure III - 3 Evolution of the number of American motion picture production firms from 1891 to 2012.

By the twenties the feature film had became the standard in filmmaking, opposed to the very short one reel films, of the previous decades. More than the exact length of the film, the feature also meant a new way to consume cinema. In the early years of the industry, the movie was consumed as a part of a varieties program, where a few shorts could be presented.

Other technologies that proved important in the evolution of the industry were the introduction of colour films and sound. Experiments in the early years introduced and subsequently failed in attempts at bringing in other technologies, for instance to bring smell in the theatres (Slide, 2001). After 1927 and with the introduction of synchronised sound in films, the *talkies*, one can consider the industry to have entered its mature phase, with the Golden Age of Hollywood lasting until the end of 1950s (Slide, 2001). This was the period when the five largest production companies, the “Big Five” – MGM, Paramount, RKO, Warner Bros, and 20th Century Fox - acquired movie theatre chains, controlling the whole value chain from script writing to exhibition. It was also the era of the Studio System, characterised by studios employing on permanence all the technicians, directors, actors, writers, and everyone who would work on their productions. This period saw the creation of such classics as *Gone with the wind*, *Casablanca*, and *Snow White and the seven dwarfs.*

The end of this Golden Age was prompted by a federal antitrust action in 1948 (*United States v. Paramount Pictures, Inc. et al.)* separating production from exhibition as well as the end of block-booking – a practice whereby studios would sell to theatres all the production to be released for a whole year, preventing other companies to enter the larger theatres. Gradually the “Big Five”, released their staff of actors and directors, among others, and the distinctive creative aspects of each studio were gradually lost. Another event forcing the end of this period was the advent of television, one which created an entire entertainment industry competing for audiences with movies.

The following period of the industry has been called *New Hollywood*, for it also generated new creative forms of filmmaking and storytelling. In 1967, *Bonnie and Clyde* was released. This film, initially criticised for amorality and violence, became the symbol of a new phase. This was when young directors established themselves also as independent producers in order to gain full artistic control of their films. From this phase on, the number of motion picture production firms has been steadily raising, as the new organisation of the industry depends more and more on co-production.

The 1980´s and the emergence of the home video market allowed studios to compensate theatre losses which resulted from video releases. The industry tended towards a separation into two major types of movies: blockbusters, which were high budget films aimed at large audiences, and independent, low budget films, more inclined towards more demanding audiences, that could even serve as a display of an actor or a director´s talent. The rise of independent filmmaking acceptance meant a proliferation of small firms, co-producing with the larger ones.

Finally, since 1999, the advances in video and digital cinematography have been gradually enabling the production of motion pictures to be more cost-efficient. The lower costs of production using digital technology can have important impact on the ability of small firms to produce and survive competition from larger firms. In fact, since 1990, the number of firms entering the market each year has been higher than the number of firms exiting, with this process innovation provoking cost reductions, an important factor in this industry.

3.2.2. Industry revenues

For data on box office revenues, comprehensive estimates for the complete industry are available since 1926 (Figure III - 4). While these data related to the sales of exhibitors, they can still be informative on the market aspects influencing the production industry.

Throughout the 86 years of our time period of analysis, we can observe that in real terms, the box office volume had experienced an initial growth phase, interrupted by the Great Depression. In the early 1930´s the industry recovered its growth trend, in terms of box office results, and continued growing until 1946. This trend follows the Golden Age of the Studio System, characterised by the vertical integration of all aspects- from production to exhibition.

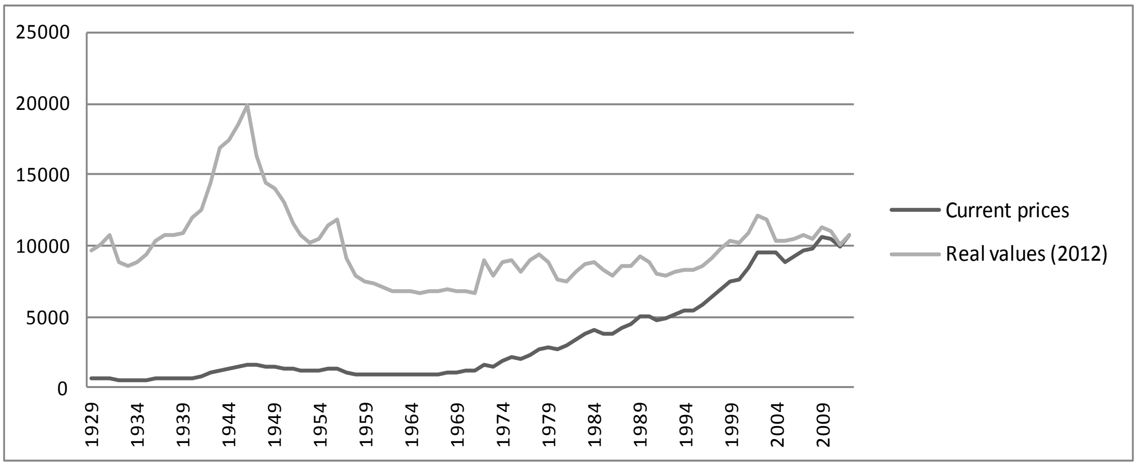

Figure III - 4 U. S. Box office evolution from 1926 to 2012. (Sources: Adapted from Motion Picture Association of America (2000, 2008, 2012); Vogel (2011, p. 87); Johnston (1926, p.20); National Association of Theatre Owners (2013)).

The decrease in box office revenues which occurred after 1946, is related to a combination of various aspects. These include factors related to the macroeconomic environment, including the end of the Second World War; migration of populations to suburbs away from the traditional theatre districts (Gil & Lampe, 2012). There were other aspects as well, which were specific to this industry, such as government regulation and the emergence of television as a competitor to cinema. From 1946 to 1950, average weekly theatre attendance declined from 90 million to 60 million.

In the 1960´s we can observe that the industry witnessed stagnation in sales, consistent with the economic and artistic transformations that motion pictures underwent, which affected audience response. Studios responded to the combination of the end of the Studio System and the emergence of television with a combination of products aimed at reducing risk. Compared to the previous decade, the biggest studios would produce on an average, less expensive productions, in order to reduce costs. This was supplemented with a strategy of producing a few very expensive, spectacular productions, which provided the sort of entertainment that could only be experienced in a theatre hall, thereby escaping competition from television. Still, this strategy did not prevent the continuous decline in box office receipts. In 1972, average weekly attendance reached a minimum of 15.8 million spectators (Sedgwick, 2002), only comparable to those numbers from the beginning of the century.

From then on, the impact of blockbuster movies has been a driver of audiences. More recently, the introduction of 3D has attempted to overcome competition not only from television, but also from videogames. The impacts of this technology are yet to be known, since the reactions of audiences are still mixed (Gil & Lampe, 2012). Possibly we are still observing the first or second phase of the diffusion of this innovation, as defined by Rogers (2003).

Figure III - 5compiles the feature film releases each year, since 1911, when the first feature produced in the United States was released. We can observe the rapid adoption of this format by producers. We note that until 1927 the number of features has large variations year to year. This happens mostly because of the classification of what a feature is. A feature can be any film lasting more than forty minutes, which makes it a broad classification and, in the early years, all lengths of features could exist. After 1927, the length of features tended to stabilize around two hours.

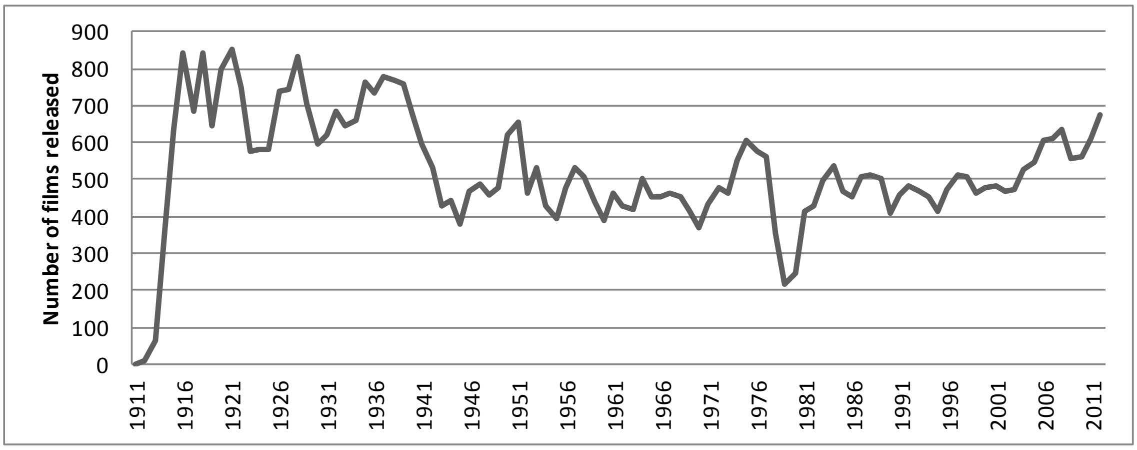

Figure III - 5 Feature films released per year. (Sources: adapted from Alicoate (1963, p.107); Brown (1995); MPAA (2011)).

From this figure we can also observe another important aspect. While on the side of consumption (Figure III - 4) one does not observe a negative fall-out from the Great Depression, from the production side, the decline is visible, with a drop in the number of releases from 834 in 1928 to 595 in 1930, a significant drop of close to 30% in only two years.

Another interesting aspect is how the increasing power of the Studio System meant a decrease in the number of releases, since the number of firms was also lower during this period. The recovery of the number of productions in the late 1940’s reached a peak with 654 releases in 1951, but did not sustain itself and the number of releases dropped to 392 in 1955. The number of releases stabilised around an average 450 per year until the 1970´s, when the number of new production firms began to increase. Still, the end of the decade saw the lowest number of releases since 1912, and in 1979, only 214 features were released.

The response to the decline of Hollywood began from 1980 onwards, with the growth in the number of productions and a positive response on behalf of audiences. According to Silver (2007) this was based on a combination of different aspects, namely: the emergence of a generation of film school-trained and exceptionally talented directors and producers like Spielberg, Lucas, and Cameron; the adoption of the blockbuster production and distribution strategy of worldwide releases and marketing campaigns; the use of new technologies, like home video, or video-on-demand as a form of further improving receipts; and the diffusion of the multiplex cinema, as a more convenient approach to audiences.

3.2.3. Concentration, firm size and regulation

Historically, the American film industry has historically been concentrated. Since its very beginnings, expressions such as “the big five”, or “the majors” have been frequently used to describe the largest, most influent film studios and producers in the industry.

As early as 1908, ten large firms dominated the American film market. Three of these were French firms that eventually would have American subsidiaries and the other seven American firms, based either in New York or New Jersey. In 1908 Tomas Edison created the Motion Picture Patents Company bringing together the largest film producers and distributors in the U.S. at the time, namely, Edison’s own American Mutuoscope and Biograph Company, Essanay, Gaumont, Kalem, George Kleine, Lubin, Gaston Méliès, Pathé Freres, Selig and Vitagraph. Also known as the Trust, it was a form of protecting the rights of Edison’s many patents on filmmaking (Slide, 2001). The Trust explicitly aimed to eliminate independent film producers, distributors and exhibitors.

Nowadays, according to *Variety* (2013) the expression “majors” applies to five studios that control of more than 70% of the total market share. Smaller firms that compete directly in the same markets with the largest studios are called “mini-majors” (Figure III - 6).

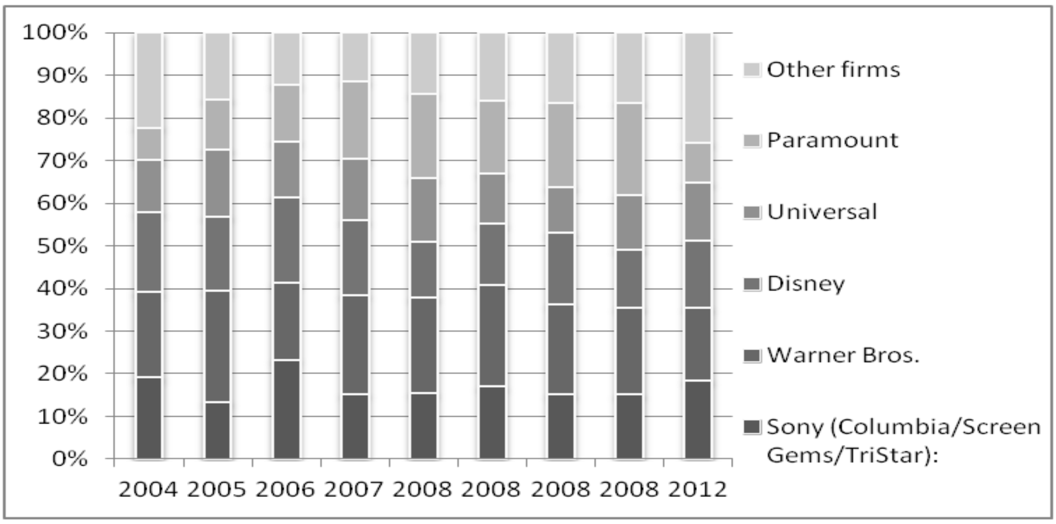

Figure III - 6 Market shares of the five majors (in distribution) compared to the whole industry. (Source: The Numbers/Nash Information Services (2004-2012)).

3.2.4. Product and process innovations over time

In the beginning of the film industry, films were short and were not necessarily projected on screens; some were developed to be seen individually and were part of other attractions and variety programs.

Unarguably, the development of the feature film marks the beginning of cinema as it is perceived as today. The term feature refers to a film long enough to be presented alone or as the main attraction in a series of films to be projected. However, the length of a film that is considered a feature is not the same around the world. In the United States, the American Film Institute and the Academy of Motion Picture Arts and Sciences consider a feature to be a film running for 40 minutes or longer, but other organizations specify different lengths. More than the objective running time of the film, it is the way it is made to be consumed that marks it as a feature, the feature created a new way to consume cinema and that is the main difference from the short film.

The first known feature film in the world is the Australian film *The Story of the Kelly Gang*, released in 1906. In the United States the first features were produced in 1911.

While the length of a film and its classification into a feature or not may depend on the distribution and exhibition stages, sound is a production decision and an artistic decision also. The emergence of films with sound dramatically reshaped the industry and also many careers. The first American produced *talkie* (as motion pictures with synchronised sound were initially called) was the 1927 film *The jazz singer*, a musical produced by Warner Brothers. The success of this film and acceptance by audiences was continued by the generalised adoption of the new technology by production firms and by 1929 talkies were the standard form of feature films.

Another innovation that affected production was colour capture. However, the adoption of colour followed a completely distinct path compared to the adoption of sound (Gil & Lampe, 2012). Sound took three years to become a standard, colour took ten times longer and in fact, we may argue it consisted of two steps in adoption, the first being the adoption of Technicolor and the second the adoption of Eastmancolor, which Gil & Lampe (2012) propose may explain why it did not follow a typical s-shape diffusion curve.

As a product innovation, colour movies have existed since the earlier years of the industry. Some short films would be coloured by hand, frame by frame, as would cartoons. The main advances in colour are in the process to obtain a colour movie. The most famous of all processes has been Technicolor, for which 1939 *Gone with the wind*, is the earliest success and it is still the highest grossing film in history in total revenues.

Technicolor is still considered the most reliable colour capture method, even though it is not used anymore. Roughly, the method used three lenses to capture green, red and blue, and then the colours would be combined in post-production. Besides the high costs of film and post-production, the method required intense light on set, even causing dehydration to actors and technical staff.

In 1965, Eastman Kodak developed a new colour filming method, Eastmancolor. In this case, only one lens would capture the whole spectrum of colour into one film reel, which allowed reducing costs of filming. It also does not require intense light, improving work conditions. It was after the introduction of the Eastmancolor method that the use of colour in motion pictures became more and more popular among directors and producers, leading to a generalised adoption from 1970 on (Gil & Lampe, 2012).

More recently, industry specialists have been debating the possible effects of digital cinematography on creating new opportunities for producers and filmmakers (Culkin, 2008), changing the competitive game (Mediavilla & Vences, 2009) and cost reducing.

Eliashberg (2006) observed that this new technology can have substantial impact in the three stages of production and change the power structure of the industry. According to his research, he expects "digital technology will lower the barriers to market entry by enabling almost anyone with a camcorder and a personal computer to create a feature-length film*".* In smaller industries, such as the Portuguese, that is becoming a real possibility.

Culkin (2008) considered that the film industry had recently reached the tipping point from where digital is expected to become a fully adopted technology. In fact, in December, 25, 2013, "The wolf of Wall Street" (Scorcese, 2013) was the first American feature to be released exclusively in digital format. However, we do not expect to be able to observe any significant effects of the adoption of digital cinematography on our data, as its impact on the industry dynamics is now starting to take effect.

4. Methods

In order to assess the effects of innovation on the dynamics of an industry, we will follow the usual methodology of studying firm survival.

Survival analysis is usually defined as the study of time to event data (for instance, the time to death in a biological population, time to failure in machinery, time to marriage) generally, in economics, the study of the time it takes a firm to exit the market, given certain determinants or covariates.

An important characteristic of survival data is censoring. When observing a population during a period of time, there are cases where there is no observation of the event under study for some individuals, for instance, a firm may be established before the beginning of the observations or during it, but with no known date, thus, being left censored and may not exit the market before the end of the period of observation, being right censored. Right censoring is the most common aspect of survival data in the social sciences.

Another characteristic that affects the choice of methods in survival analysis is the type of data observed, whether it is continuous or discrete. While most methods have been developed to analyse continuous data, many social sciences data sets are not continuous. Particularly, some data on duration may be of continuous nature, but only observed in discrete intervals. Intrinsically discrete data also exists.

4.1. Continuous *versus* discrete data

In the case of this study, the definition of the type of data is not obvious. Information on firm entry and exit is organised by year, while it is known there are firms being created and failing every day. This could characterise our data as continuous and observed in discrete intervals (interval censored). Jenkins (2005) proposes two types of models for dealing with such data, the complementary log-logistic and the logistic model. These binary response models however have the disadvantage to account only for the probability of survival instead of the effect of the explanatory variables on the time to failure.

On the other hand, as all other information for the industry is observed also year by year, there is no observable variation inside each interval that would affect the survival of firms. In this case, we can treat our observations as continuous, as other authors have done without compromising accuracy (see for instance: Suarez & Utterback, 1995).

The use of a survival time model for continuous data has the advantage to measure time to failure, providing more information on the effects on firms that affect their permanence in the industry.

4.2.Survival and hazard functions

We are interested on observing the survival time of firms, in particular the years of activity. This will be our duration variable. If we assume *T* to be a random variable measuring the number of years a firm survives until the end of our observations, and *F* as the cumulative distribution function of *T*, we have the duration distribution function

$$F(t) = P(T \leq t),\ t \geq 0\ .$$

This function gives the probability that duration *T* is less than or equal to *t*. In our case, the probability that a firm exits the American motion picture industry *t* years after entering. If we want to know the probability that a firm will survive *t* years after initiating activity, we have the survival function

$$S(t) = 1 - F(t) = P(T > t)\ .$$

An alternative form of interpreting survival uses the hazard function $h(t)$. The hazard function indicates the conditional exit rate and it is given by:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta t | T \geq t)}{\Delta t} = \frac{\frac{\partial S}{\partial t}}{S_t} = \frac{f(t)}{S(t)}$$

4.3. Variables

The dependent variable in our study is the survival time of a firm. Survival time is calculated for all firms that have ever had the activity of motion picture production in the United States. We calculate survival since the first year of activity as a motion picture production firm until the year it exits this activity.

We control for the competitive environment at entry for each firm with covariate *density*, and two proxies for the market size, measuring the number of feature films released at the entry year, *featent*, and the exit year, *featex*. We also control for the business cycle, using the average GDP growth during the five years after firm founding *GDPg*.

The previous experience of the founders of a firm is indicated by the dummies for *producer*, *director*, *actor*, and *spinnoff*. Firms founded by executives without any previous experience in the industry are the default class.

Firm size is accounted by dummy *independent*, for firms that are not associated to any media conglomerate; and by the dummy *majorstudio.* This dummy includes two categories of firms, “majors” and “mini-majors” (Variety, 2013), consistent with the trend for concentration felt since the early industry years and with common knowledge of the most important film studios, in terms of the number of productions released each year. Most firms considered “majors” by Variety Magazine belong to one of the media conglomerates originated in the “Big Six” studios that have been leading the industry at least since the 1930´s; the early entrants that made the “Edison Trust” are also included in this group. The same magazine considers “mini-majors” those firms which are described as smaller firms that also compete with the majors. As the term “mini-major” is recent and only catches firms that emerged on the latest 30 years of the industry and competing in the same market as “majors”, we include both types into one dummy variable. Not included in any of these classes, are subsidiary firms that are not related to any of these dummies.

The covariates we use to test the effects of waves of innovation on firm survival are all dummies for firms that enter the industry in the same year or the years after the innovation has become accepted by the industry. The covariates are *feature*, for firms entering the market after the first features were released in 1911; *sound*, affecting firms that entered after 1927, the release of the first talkie feature film; *eastman*, for firms entering after 1965, the year of the introduction of the Eastmancolor filming process; and *digital*, which includes firms entering after 1999, the year *Star Wars: Episode I*, partially produced using digital cinematography was released.

We also control for the period between 1948 and 1952, between two important events that challenged the industry: the anti-trust law of 1948 that dictated the end of the Studio System and the disaggregation of the conglomerates that controlled cinema from production through distribution to exhibition; and the generalisation of television broadcast in the United States which started in the East coast and reached the western coast in 1952, creating a new entertainment industry that competed with the motion picture industry. The effects of the changes during this period are represented by dummy – *attv* - representing those firms active during this period of change, which were affected by a change in firm competition due to regulation that was meant to provide a less hostile environment to new firms.

Finally, because the effects on competition during the period from the end of the Studio System and the emergence of television are expected to have been felt differently by firms depending on their size, we include the interaction terms between size and this period: *atxindy*, for the effects on independent firms and *atxmf*, for the effects on *majorstudio*. Table III - 1 summarises the variables used in this analysis.

The estimated model will then be:

$$\begin{aligned} lnT_i = \beta_0 + \beta_1 GDPg_i + \beta_2 density_i + \beta_3 featent_i + \beta_4 featex_i + +\beta_5 producer_i \\ + \beta_6 director_i + \beta_7 actor_i + \beta_8 spinoff_i + \beta_9 majorfirm_i \\ + \beta_{10} independent_i + \beta_{11} feature_i + \beta_{12} sound_i + \beta_{13} eastman_i \\ + \beta_{14} digital_i + \beta_{15} attv_i + \beta_{16} atxmf_i + \beta_{17} atxindy_i + \sigma u_i \end{aligned}$$

Table III - 1 Variable description

Variable	Description
GDPg	Variable for the economic cycle. The average GDP growth rate on the first five years of a firm in percentage.
Density	Variable for the competitive environment of industry. The number of firms active on the entry year of a firm.
Featent	Total number of features released in the American market on the entry year
Featex	Total number of features released in the American market on the exit year
Producer	Founder's experience. Takes value 1 for firms founded by producers and 0 for all other firms.
Director	Founder's experience.. Takes value 1 for firms founded by directors and 0 for all other firms.
Actor	Founder's experience. Takes value 1 for firms founded by actors and 0 for all other firms.
Spinoff	Founder's experience. Takes value 1 for firms that are spinoffs of other production firms and 0 for all other firms.
Majorstudio	Dummy for the size of a firm. Takes value 1 for firms identified as *major* or *mini-major* by *Variety* magazine and 0 for all other firms.
Independent	Dummy for the size of a firm. Takes value 1 for firms identified as *independent* by *Variety* magazine and 0 for all other firms.
Feature	Dummy for a product innovation. Takes value 1 for all firms that entered on or after 1911 and 0 for firms that entered before 1911.
Sound	Dummy for a product innovation. Takes value 1 for all firms that entered on or after 1927 and 0 for firms that entered before 1927.
Eastman	Dummy for a process innovation. Takes value 1 for all firms that entered on or after 1965 and 0 for firms that entered before 1965.
Digital	Dummy for a process innovation. Takes value 1 for all firms that entered on or after 1999 and 0 for firms that entered before 1999.
Attv	Dummy representing the period 1948-1952, capturing the period after "State *vs.* Paramount" and until the expansion of television broadcasting to the West coast. Takes value 1 for firms active during the period 1948-1952 and 0 for all other firms.
Atxmf	Interaction term for major studios active during the period 1948-1952
Atxindy	Interaction term for independent firms active during the period 1948-1952

5. Results and discussion

In this section we present the steps towards the model specification. Figure III - 7 presents the real data for failures per year. The left side of Figure III - 7 shows that the first exit from the industry due to failure occurred in 1910, the last observed one was during the last year of observations, 2012. The year with highest number of observed failures is 1915, when 36 firms exited the industry.

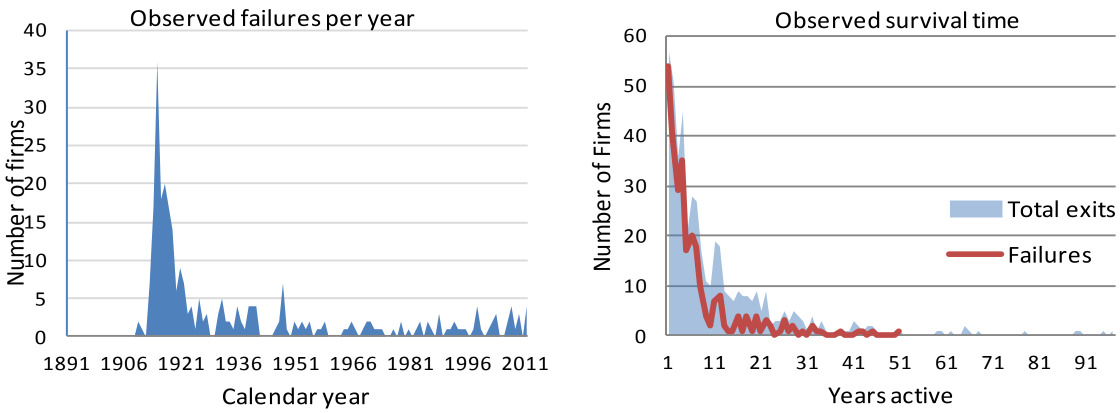

Figure III - 7 Observed data on firm failure (left) and survival time until exit (right).

On average, firms take twelve years until failure, on absolute numbers the highest number of failures occurs during their early years active: 54 firms failed during the first year of activity, 41, during the second. The firm with the longest duration is Paramount, founded during 1916 and still active; Warner Bros., active since 1918, has the second longest duration. The longest duration until exit by failure is 51 years, the oldest firm to fail was King International Corporation (founded in 1942); older firms have left the industry listings through mergers and acquisitions, which are not the subject of analysis on this essay, for we are only focusing on exit through bankruptcy or liquidation.

5.1. Preliminary analysis

We began by estimating the Kaplan-Meier survival curves for each variable and testing the proportional hazards hypothesis. We performed a series of graphical assessments of the proportional hazards assumption. For each covariate it is possible to obtain the “log-log plots” representing the –ln[-ln(survival)] curves over time (-ln(analysis time)). If the curves obtained for the different values of the covariates are parallel, we may expect that the proportional-hazards assumption has not been violated, if they converge or diverge, the opposite may be happening. Although the interpretation of these plots is somehow subjective, we may become informed on the suitability of the covariate to be included on a proportional-hazards model. The following figures, from Figure III - 8 to Figure III - 9 represent the log-log plot (on the left) and the Kaplan-Meier curves (on the right) for the dummies controlling for firm size. On Figure III - 8, the log-log plot for *independent* indicates the possibility of non-proportional hazards, since a portion of the curves is not parallel. Looking at the Kaplan-Meier survival curves obtained for the two values of the dummy, it is also possible to observe that while the predicted and estimated curves are very close, they cross, which should not happen under proportional hazards.

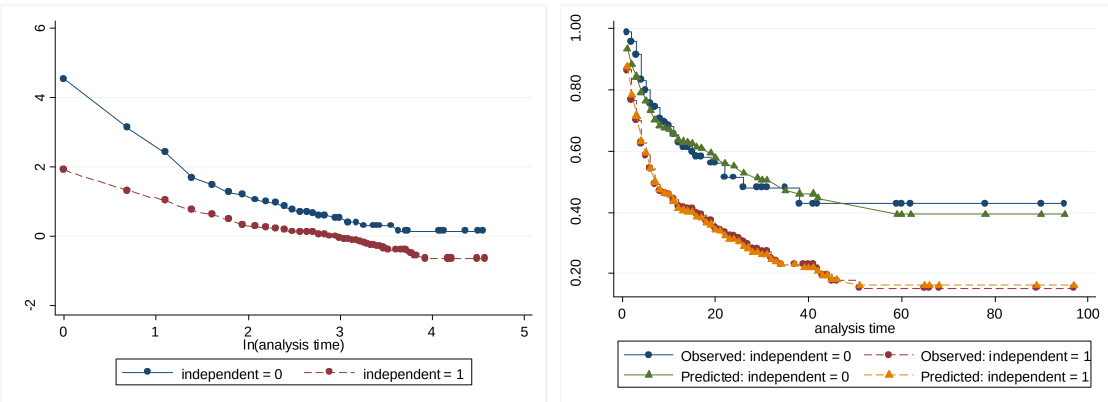

Figure III - 8 Log-log (left) and Kaplan-Meier (right) plots for covariate *independent.*

In addition to infer into the best specification to use on an empirical survival model, these plots can also indicate an expected effect of the variable on survival, predicting independent firms to have a lower survival, *ceteris paribus*.

On Figure III - 9, the violation of the proportional hazards hypothesis is more visible, as Kaplan-Meier curves for *majorstudio=1* are clearly separated and crossing. It is also expected that major studios have a higher probability of surviving keeping other factors constant.

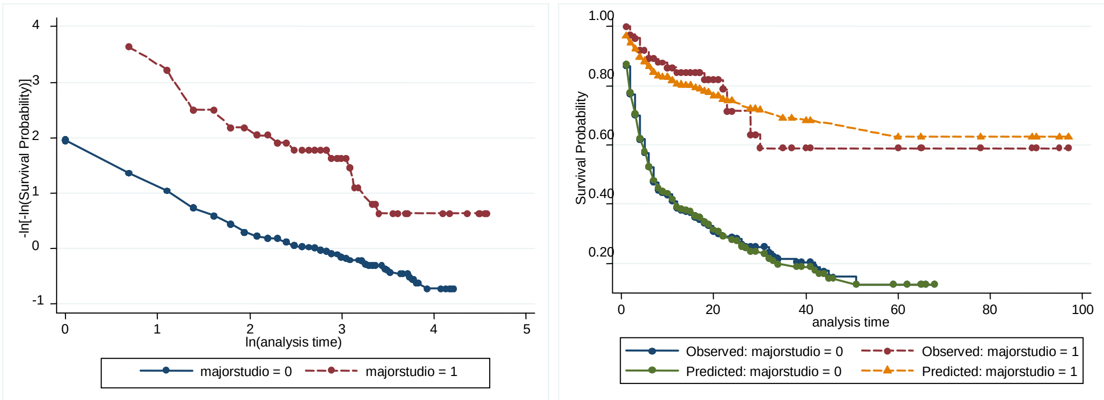

Figure III - 9 Log-log (left) and Kaplan-Meier (right) plots for covariate *majorstudio*.

From Figure III - 10 to Figure III - 14 we can also observe the log-log plots for the dummies representing the innovations in motion picture production and the also dummy *attv*, representing the firms active during the period from the end of the Studio System to the establishment of television as an industry that competed with motion pictures. In the four cases the Kaplan-Meier curves lead to possible non-proportional hazard rates.

On Figure III - 10 it is visible that the curves for firms entering the industry before 1911 and the introduction of features show a distinctive pattern of survival compared to firms entering after 1911. It is also possible to expect that a firm entering before the feature film was introduced would have an early life survival probability higher than a firm entering after the feature film. However, the intersection of the curves indicate that the probability of survival after twenty years active is higher for firms that entered the industry after the emergence of the feature film, keeping other factors constant.

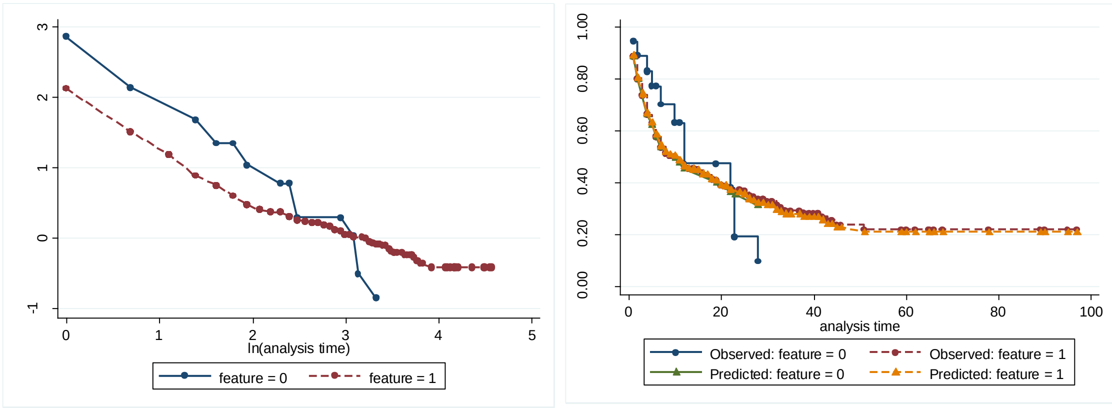

Figure III - 10 Log-log (left) and Kaplan-Meier (right) plots for covariate *feature*.

For the dummy representing the effect of synchronised sound on the survival of firms (Figure III - 11), we observe that the two curves obtained in the log-log plots for the two values of this dummy are not parallel, which may indicate a violation of the proportional-hazards assumption.

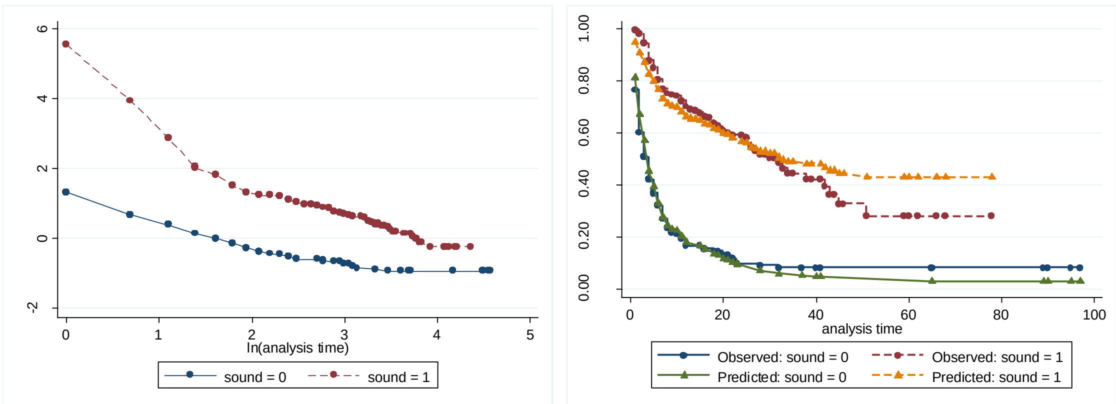

Figure III - 11 Log-log (left) and Kaplan-Meier (right) plots for covariate *sound*.

The plots representing the distinction between firms entering before and after Eastmancolor became fully adopted do not show a very distinctive pattern for the two groups of firms, yet, a close observation of the curves for firms entering after 1965 indicate a different evolution of the observed survival probability in the earlier years of these firms.

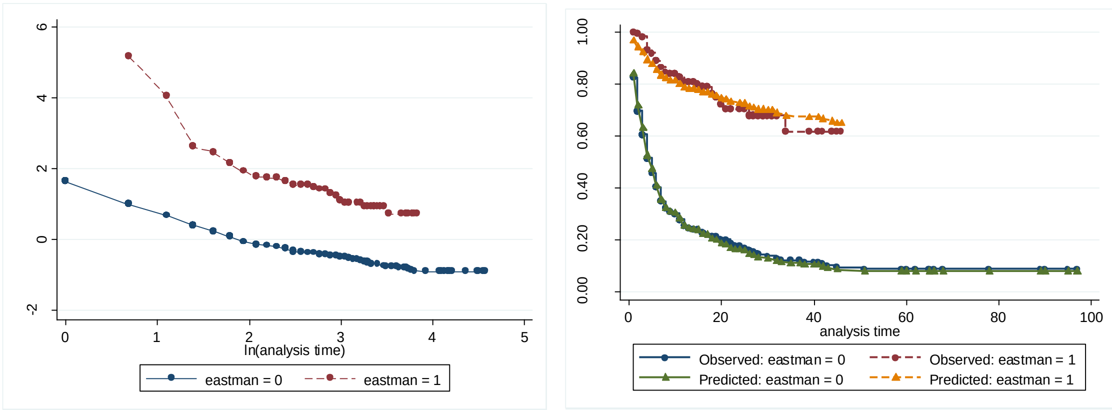

Figure III - 12 Log-log (left) and Kaplan-Meier (right) plots for covariate *Eastman*.

In terms of preliminary observations on the effects of entering after colour movies became usual, we tend to expect a higher probability of survival for these firms.

The plots for the effect of digital cinematography on the probability of survival (Figure III - 13) are similar to these obtained for Eastmancolor.

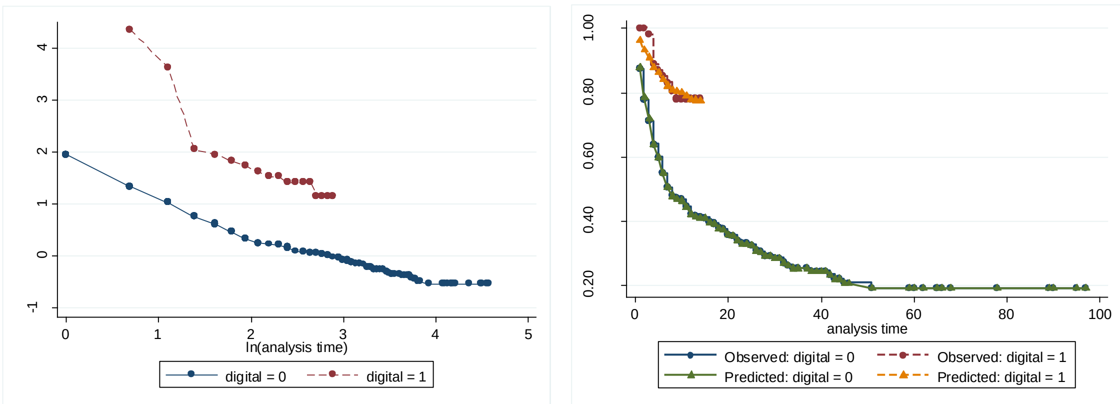

Figure III - 13 Log-log (left) and Kaplan-Meier (right) plots for covariate *digital*.

On Figure III - 14 the log-log plot points to a possible existence of proportional hazards, which could be confirmed by the proximity of the observed and predicted Kaplan-Meier curves. A preliminary result is the expected higher survival probability of firms that were active during the turbulent period after the State vs. Paramount decree to the emergence of television broadcasting.

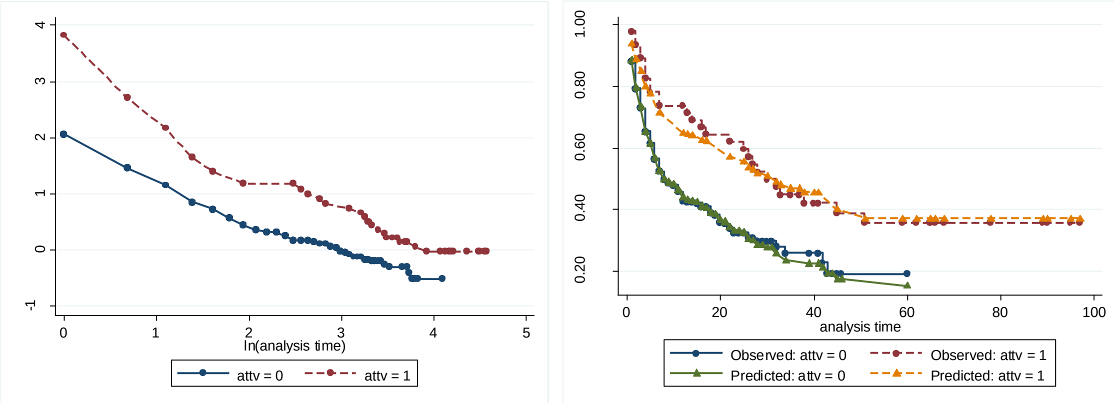

Figure III - 14 Log-log (left) and Kaplan-Meier (right) plots for covariate *attv*.

Finally, from Figure III - 15 to Figure III 18, the plots generated for the dummies representing the background of the founders show possible violations of the proportional hazards, for the dummies *producer*, *director* and *spinoff*.

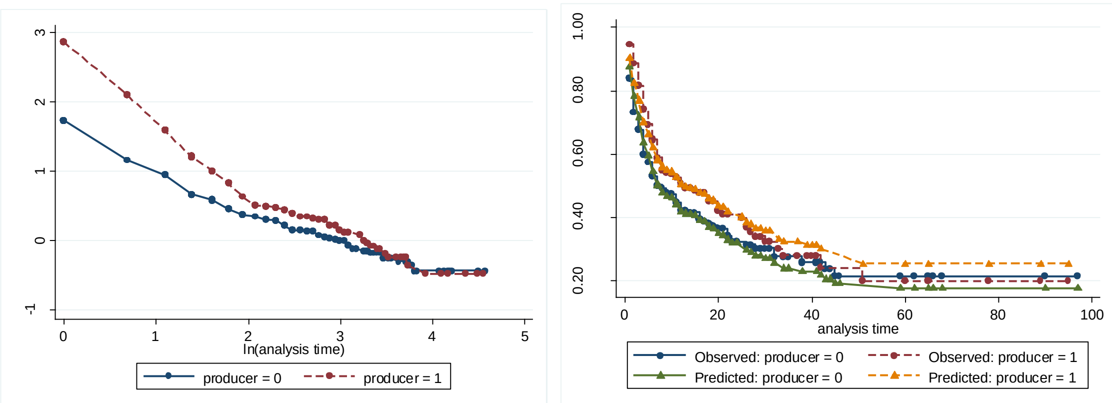

Figure III - 15 Log-log (left) and Kaplan-Meier (right) plots for covariate *producer*.

An interesting aspect captured on Figure III - 15 is a diluted effect of the experience as producer on the probability of survival, which is according to the expected learning processes of the founders that can overcome the lack of initial experience after a few years on the industry.

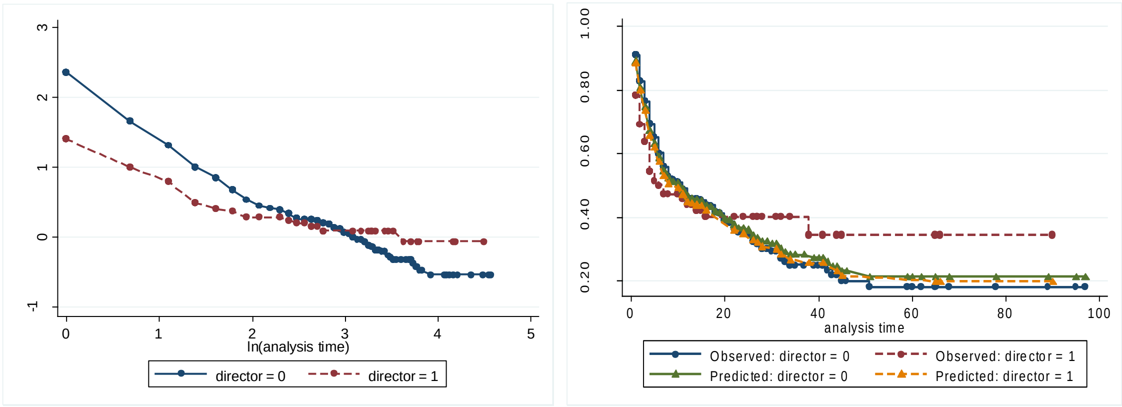

Figure III - 16 Log-log (left) and Kaplan-Meier (right) plots for covariate *director*.

Clearly this variable violates the proportional hazards assumption. However, being founded by a director does not seem to bring an expected advantage nor disadvantage, as the predicted Kaplan-Meier curves have very similar values.

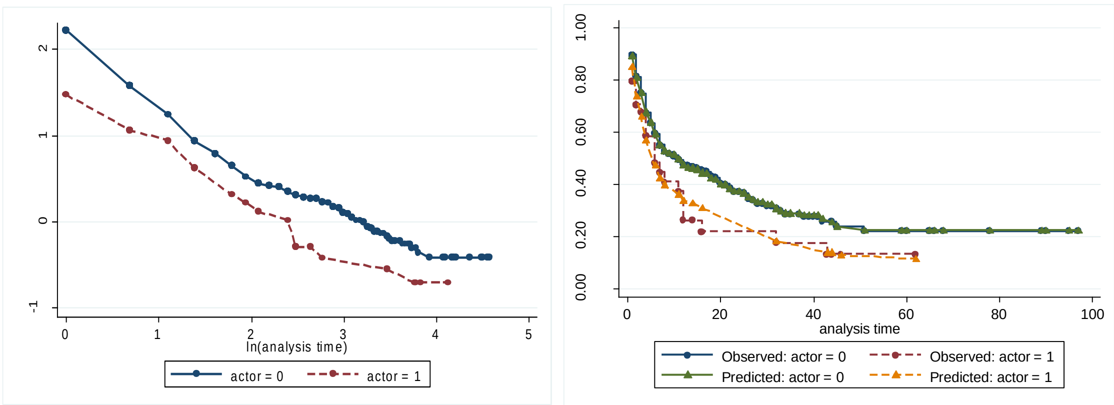

Figure III - 17 Log-log (left) and Kaplan-Meier (right) plots for covariate *actor*.

The dummy for firms founded by actors, contrarily to the other dummies for experience, seem to have proportional hazards, as represented by the parallel curves on the log-log plot. The same holds for dummy *spinoff* that measures the effect of being a spinoff from another firm from the film industry (Figure III 18).

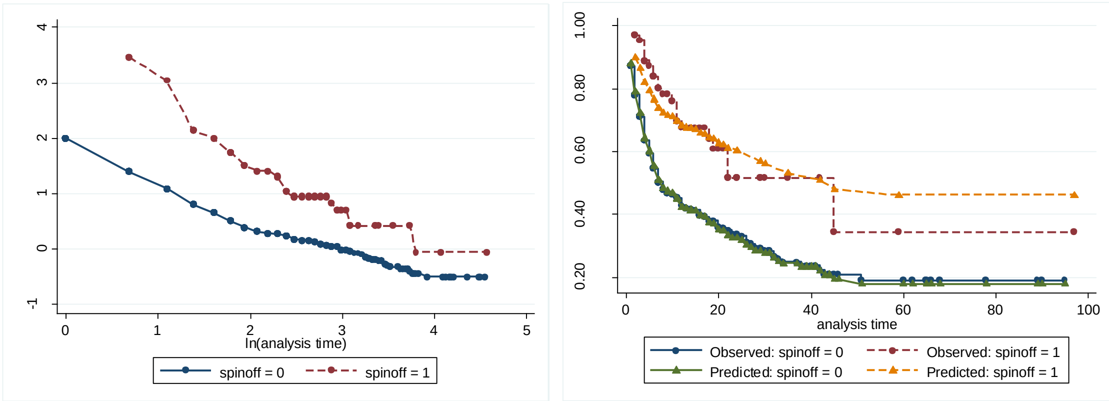

Figure III 18 - Log-log (left) and Kaplan-Meier (right) plots for covariate *spinoff*

The Kaplan-Meier plots are very informative and have an advantage compared with other types of models as they are non-parametric and the results are not affected by any possible misspecification of parameters. Still they cannot provide an analysis of a model including all controls and variables. For that reason they are useful as preliminary analysis, indicating possible paths for reaching a well specified empirical model. These curves can also inform on the expected effects of each variable by itself on the expected survival, in particular in the case of dummy variables.

5.2.Cox Proportional Hazards Model

In order to assess the effects of industry environment and innovations on the survival of firms, we proceeded by adjusting a Cox Proportional Hazards model and testing its assumptions again. Table III - 2 summarises the results of the Cox regression.

The Cox Proportional Hazards model (Cox, 1972) is semi-parametric, meaning that it assumes a parametric form for the effects of the covariates on the hazard rate, requiring that the hazard ratio for any two observations with different covariate vectors is independent on the survival time, but does not impose any functional form on the distribution of survival.

$$h(t) = h_0(t)\, exp(\beta_1 x_1 + \cdots + \beta_k x_k)$$

Table III - 2 Cox Proportional Hazards Model estimates.

Variables	Hazard Ratio	Standard Errors		Robust S. E.		P. H. Test	
						chi2	Prob>chi2
GDPg	1.0688	0.03	**	0.03	**	3.04	0.081
Density	1.0224	0.01	***	0.00	***	1.38	0.240
Featent	0.9997	0.00		0.00		0.63	0.428
Featex	1.0004	0.00		0.00		1.19	0.276
Producer	0.7640	0.13	*	0.12	*	2.47	0.116
Director	1.0133	0.21		0.20		3.85	0.050
Actor	0.8283	0.20		0.18		0.11	0.736
Spinoff	0.5498	0.14	**	0.14	**	2.10	0.147
Major studio	0.3555	0.10	***	0.10	***	0.38	0.536
Independent	0.7975	0.16		0.16		0.10	0.747
Feature	0.9631	0.41		0.38		0.85	0.357
Sound	0.7730	0.16		0.16		0.25	0.614
Eastman	0.0704	0.02	***	0.02	***	0.04	0.835
Digital	0.4703	0.20	*	0.19	*	0.31	0.575
Attv	0.1703	0.10	***	0.10	***	0.89	0.346
Atxmf	0.3089	0.25		0.26		1.51	0.220
Atxindy	7.2342	6.90	**	6.79	**	0.39	0.534
P. H. global test						30.33	**

Notes: *10% significant; **5% significant; ***1% significant.

On Table III - 2 we present the regression with the conventional estimates of standard errors and the results estimated with robust standard errors, to correct for the possibility of heteroskedasticity. We also include in this table the Proportional Hazards test, which shows that variables *GDPg* and *Director* violate the proportional hazards. Based on the global test we can conclude by rejecting the proportional hazards hypothesis.

5.3. Parametric models

In order to overcome the violation of the proportional hazards assumption, we will use parametric models, in the form of Accelerated Failure Time (AFT) models. In an AFT model, the natural logarithm of the survival time, $\log t_j$, is expressed as a linear function of the covariates, thus the linear model

$$\log t_j = x_j\beta + z_j,$$

where x_j is the vector of the covariates, β is a vector of regression coefficients, and z_j is the error. Contrarily to the Cox model, there is also a parametric form for the survival function.

Before proceeding to the analysis of the AFT models, one should note that comparison among AFT and PH models is not straightforward. The coefficients are not directly comparable, as they have different metrics. The Cox model calculates the hazard ratio which is easily interpreted as probability of failure. On AFT models the values of the coefficients represent an increase on the expected waiting time until failure, the higher the coefficient, the higher the increase in time to failure. On Table III - 3 are the survival functions of the parametric models used (Lancaster, 1990; Cleves, 2008).

The ancillary parameters in these models allow the hazard function to take different forms. In particular, the exponential model is a particular case of the Weibull, when the ancillary parameter *p*=1. Although these parameters can vary, we will consider them constant in our analysis.

Table III - 3 Survival functions of the parametric models.

Regression	Loglogistic	Lognormal	Weibull
Survival function	$S(t) = \left\{1 + (\lambda t)^{1/\gamma}\right\}^{-1}$	$S(t) = 1 - \Phi\left\{\frac{\log(t) - \mu}{\sigma}\right\}$	$S(t) = \exp(-\lambda t^p)$
Ancillary Parameters	γ	σ	*p* If *p*=1, Exponential regression

Table III - 4 presents the estimated coefficients of four AFT duration models, in the loglogistic, lognormal, exponential and Weibull forms. In these models we include all the control variables and the innovation dummies. We find by testing the value of *p* that it makes sense to reject the null hypothesis $H_0\colon \ln p = 0$ and expect the data to be better fit by the more general Weibull model than by the exponential model that considers hazard to constant over time.

All significant variables have the same sign in the four models, showing a very strong coherence, independently of the type of model or even different specifications, which does contribute to a higher reliability on this type of analysis, and thus allows us to execute further analyses.

Table III - 4 Estimates of four parametric AFT duration models.

	Weibull		Exponential		Loglogistic		Lognormal	
GDPg	-8.4416	***	-7.5567	***	-0.5974		-0.347	
	(2.30)		(2.80)		(2.19)		(2.31)	
Density	-0.0215	***	-0.022	***	-0.0206	***	-0.0193	***
	(0.00)		(0.00)		(0.00)		(0.00)	
Featent	0.0004		0.0004		0.0002		0.0001	
	(0.00)		(0.00)		(0.00)		(0.00)	
Featex	-0.0004		-0.0004		-0.0004		-0.0003	
	(0.00)		(0.00)		(0.00)		(0.00)	
Producer	0.1963		0.2318		0.3229	**	0.3007	**
	(0.14)		(0.16)		(0.15)		(0.15)	
Director	-0.0314		-0.0122		0.0049		0.048	
	(0.17)		(0.20)		(0.17)		(0.18)	
Actor	0.1915		0.1772		0.1546		0.1344	
	(0.20)		(0.24)		(0.22)		(0.22)	
Spinoff	0.5168	**	0.5673	**	0.5403	**	0.4702	**
	(0.21)		(0.26)		(0.23)		(0.22)	
Major studio	0.9945	***	1.1028	***	0.9575	***	0.8669	***
	(0.24)		(0.29)		(0.24)		(0.22)	
Independent	0.1509		0.2167		0.4003	**	0.3590	**
	(0.16)		(0.20)		(0.18)		(0.17)	
Feature	-0.0472		0.0112		-0.0303		-0.0937	
	(0.35)		(0.42)		(0.35)		(0.36)	
Sound	0.2932	*	0.2807		0.2705		0.2991	
	(0.17)		(0.20)		(0.20)		(0.19)	
Eastman	2.5426	***	2.7396	***	2.3892	***	2.2178	***
	(0.27)		(0.32)		(0.27)		(0.25)	
Digital	0.4982		0.6225		0.5191	*	0.5395	*
	(0.35)		(0.42)		(0.30)		(0.30)	
Attv	1.7946	***	1.9484	***	1.9302	***	1.7989	***
	(0.48)		(0.57)		(0.48)		(0.43)	
Atxmf	1.2834	*	1.4471	*	1.4798	***	1.5213	***
	(0.67)		(0.81)		(0.59)		(0.52)	
Atxindy	-1.9021	**	-2.2631	**	-2.6934	***	-2.6196	***
	(0.78)		(0.94)		(0.73)		(0.66)	
_cons	2.7304	***	2.6232	***	1.8795	***	1.9158	***
	(0.36)		(0.43)		(0.38)		(0.37)	
Ancillary Parameters	$\hat{p}$= 1.209				$\hat{\gamma}$ =0.5663		$\hat{\sigma}$= 0.9933	
LogLikelihood	-513.58		-521.21		-502.1		-501.35	
Chi^2	408.10	***	436.82	***	383.42	***	364.87	***
AIC	1065.16		1078.43		1042.19		1040.71	

Notes: standard errors in parenthesis; *10% significant; **5% significant; ***1% significant.

Based on the values of log-likelihood and the Akaike Information Criteria (AIC), the lognormal form of the duration model seems to be the one that represents better the type of data in this case. This result was somehow expected, as the data show a non-monotonic behaviour with an increase in hazard at the earlier years followed by a decrease, in a pattern common to populations of firms. We also tested for heteroskedasticity, to see if there would be any misspecification, concluding for the use of the original model.

In these parametric models we are assuming that parameters are constant among individuals, yet that is a simplification of reality. Parameters may in fact be heterogeneous and affect the model specification (Chesher, 1984). One may test the existence of heterogeneity both graphically or by estimating a frailty model and test. The latter consists on assuming a distribution for the parameters and testing the hypothesis that the variance of the parameters is zero. The results of the frailty tests (assuming the parameters follow a gamma distribution) for the lognormal and the loglogistic distributions (Table III - 5) show these models are well fitted to the data, as we cannot reject $H_0: \theta = 0$.

Table III - 5 – Results of the test to the variance of the parameters $\boldsymbol{H_0: \theta = 0}$.

Frailty Model	Chi^2	p-value
Loglogistic	0.30	0.292
Lognormal	0.61	0.218

Figure III - 19 is a graphical representation of the Cox-Snell residuals. A model that fits the data should retrieve a plot that is approximately a straight line with a slope of one. In this case, we consider the lognormal to be well fitted.

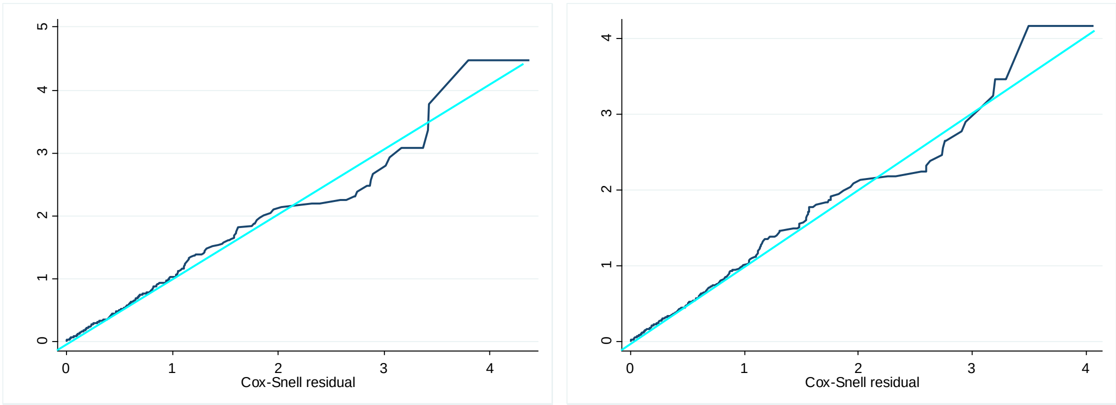

Figure III - 19 Cox-Snell residuals plots to evaluate model fit for the lognormal model. Left: original model; right: frailty model.

As seen on Table III - 4, ten of the variables in the lognormal model have significant effects. A positive coefficient means that the expected time to failure is increasing (decelerated failure).

An important result is the non-significance of the GDP growth in the non-monotonic models. This result points out to two remarks, the first on the decisive consequences of choosing the right model, since a monotonic model would have retrieved GDP growth as a highly significant variable. The second remark is on the characteristics of the feature film production industry itself. As a cultural industry, as Baumol & Baumol (1980) observe, it may respond to the business cycle differently from manufacturing industries, in particular, those authors observed that in times of economic stagnation, the public or private sponsoring of arts balances the negative effects of the business cycle. On the other hand, our data on theatre attendance point out to a rise in box office returns due to an increase in ticket sales during times of war and crises (such as the 1973 oil crisis).

Variable density, controlling for the competitive environment, significantly accelerates time to failure, which was expected, as a higher number of firms in an industry increase competition.

Other significant variables are dummies that have positive coefficients, which means that when they take value 1, they cause a delay in failure. Two of these variables are controlling for firm size: majorstudio and independent. Other two control for the founders experience: producer and spinoff.

Two of the four dummies for the effects of innovations are significant, these are: eastman and digital. The individual effects of each of these variables are explored further ahead.

The dummy for the period 1948 to 1952 - attv – has a positive coefficient, meaning that firms entering during this period are expected to survive longer. However when we observe the interaction dummies, we can see it is not indifferent to the size of the firm. A more detailed analysis of the results is presented in the next sub-sections.

5.3.1. General Model

On Figure III - 20, the hazard and survival curves generated by the lognormal regression are showed. We can observe a peak in hazard in the initial years of firms, consistent with the data, which on average firms fail during their twelfth year of activity. The speed of failure then decelerates.

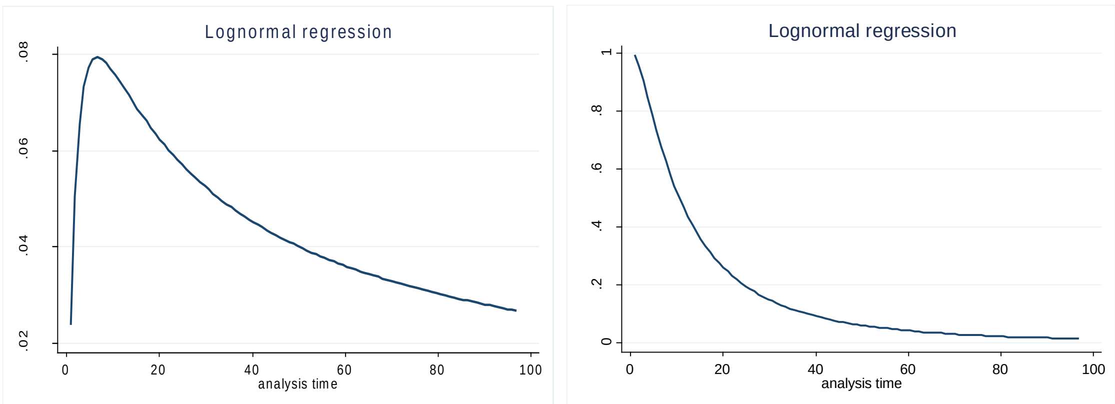

Figure III - 20 Hazard and survival plots from the lognormal model.

The next figures provide a more detailed analysis of the effects of variables on firm survival and time to failure.

5.3.2. Density and Competition

Firm population density and market size have been known to affect the competitive environment of firms. As discussed earlier, the competitive aspects of an industry at the time of entry are expected to influence the survival of a firm (Dosi & Nelson, 2013).

Figure III - 21 shows the estimated hazard and survival curves for firms entering the industry at population densities 1, the minimum ever observed, 60, the average, and 130, the maximum number of firms ever active at once.

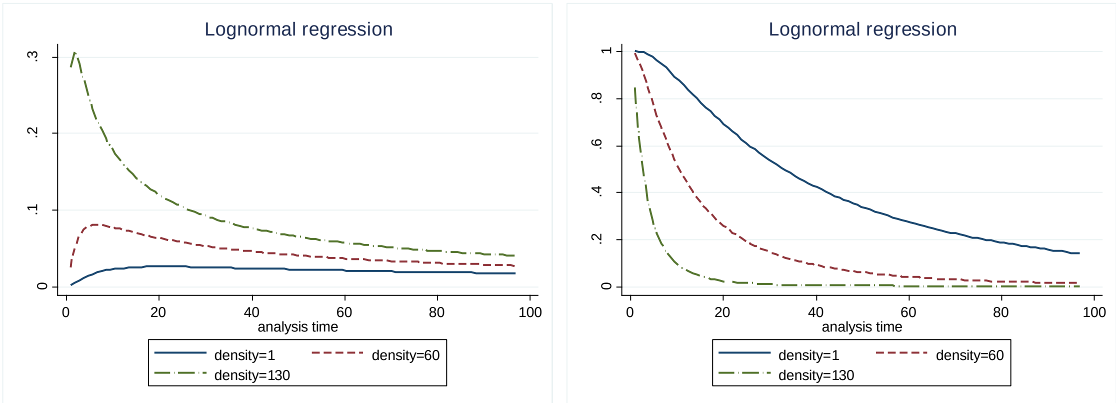

Figure III - 21 Hazard and survival curves estimated for *density* values of 1, 60, and 130 firms.

As expected, firms entering the industry at times of high firm density face more competition and fail more rapidly than firms entering at lower density, for this group of firms, survival probability decreases very fast with age. Firms entering when competition is lower survive longer, as supported by organisational ecology, which sustains that a low population density at entry positively affects firm survival (Carroll and Hannan, 1989).

In order to understand how the end of the Studio System affected industry competition, on Figure III - 22 we compare the survival and hazard rate of the firms that were active during the period immediately after the court decision that ruled the end of vertical integration of Studios with all firms that were not active during this period.

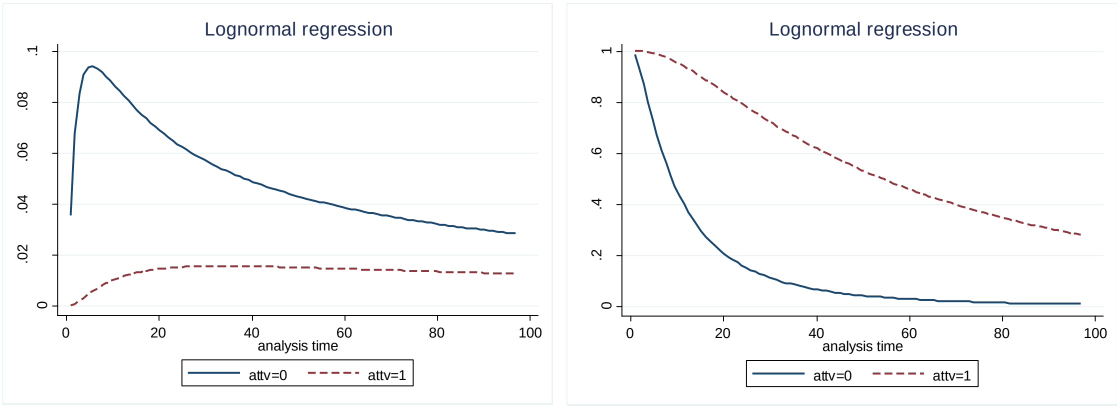

Figure III - 22 Estimated hazard and survival for *attv*=0 and *attv*=1.

We find lower hazard during this period, especially during the earlier years of firms. New firms, entering during this period, benefited from the reduction of market power of the major studios due to the antitrust law. In concentrated industries, incumbents difficult the survival of new firms, firms entering after the antitrust law, as expected, experienced lower hazard rates, especially a reduction of hazard during their first years. However, the effect of the end of the Studio System was limited in time and historians have found that major studios only had a temporary decrease in market power, which poses further questions. For that reason, we specified the interaction between this variable and the firm size, as is analysed further ahead.

5.3.3. Firm size

Firm size is known to affect a firm's capacity to survive. Here, we use the industry classification of firms by market share to proxy for firm size. We observe that the larger firms have a hazard and survival curve very different from the smaller ones. In fact, we have seen before that the difference in size and market share between major firms and all others is considerable. In Figure III - 23, we can see the curves for the size classes. We can observe that *majorstudio* have a higher survival rate than independent studios and both have higher survival that the rest of the producer firms. In terms of hazard, it is also interesting to observe that the *majorstudio* group does not have a hump shape as pronounced as the independent firms or the others, which supports the effect of size on preventing firm failure during the founding years.

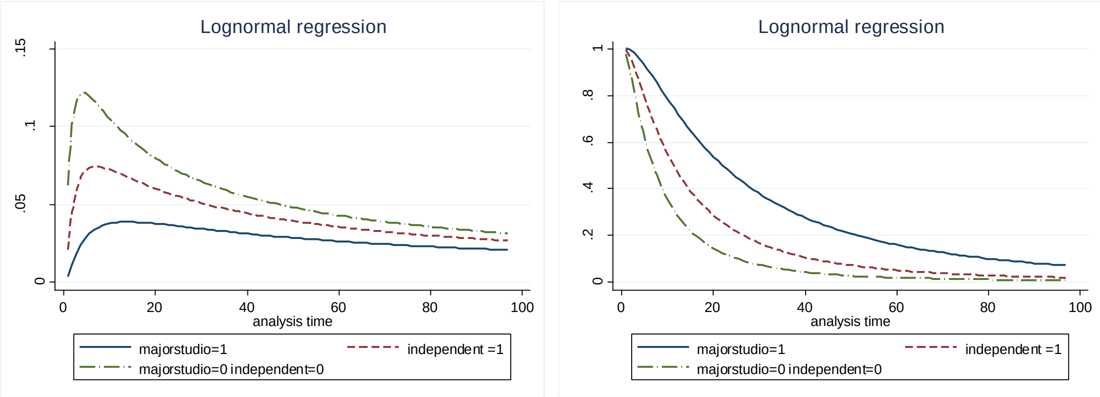

Figure III - 23 Estimated hazard and survival for *majorstudio* and *independent*.

Through the history of motion pictures, the power of the larger producer firms has been considerable. Even though several attempts to reduce their power over distribution and exhibition of motion pictures – including anti-trust laws - these firms have always tended to vertical integration of the three steps of the cinema industry, controlling which pictures end being exhibited in the most important cinemas and also which creative and genre aspects define an era.

5.3.4. Interaction

The interaction terms were also found to be significant (Figure III - 24). These results are particularly interesting, since they bring a new perspective into the period affected by the effects of the anti-trust law that led to the end of the Studio System and the diffusion of television broadcast in the United States.

The effects on firm survival were strikingly different, depending on the type of firm. Independent firms active during the 1948-1952 period had an initial high hazard, compared to the firms that were not active during this period, for which hazard shows little variation over time. This result is consistent with a “trial by fire” (Swaminathan, 1996). On the other hand, the survival time for major studios active and surviving this period is higher compared to majors that did exit before or entered after.

This result helps explaining the puzzling results already known: after the anti-trust Paramount decree of 1948 the major studios did not lose market share, although there has been a growth on the number of independents since then.

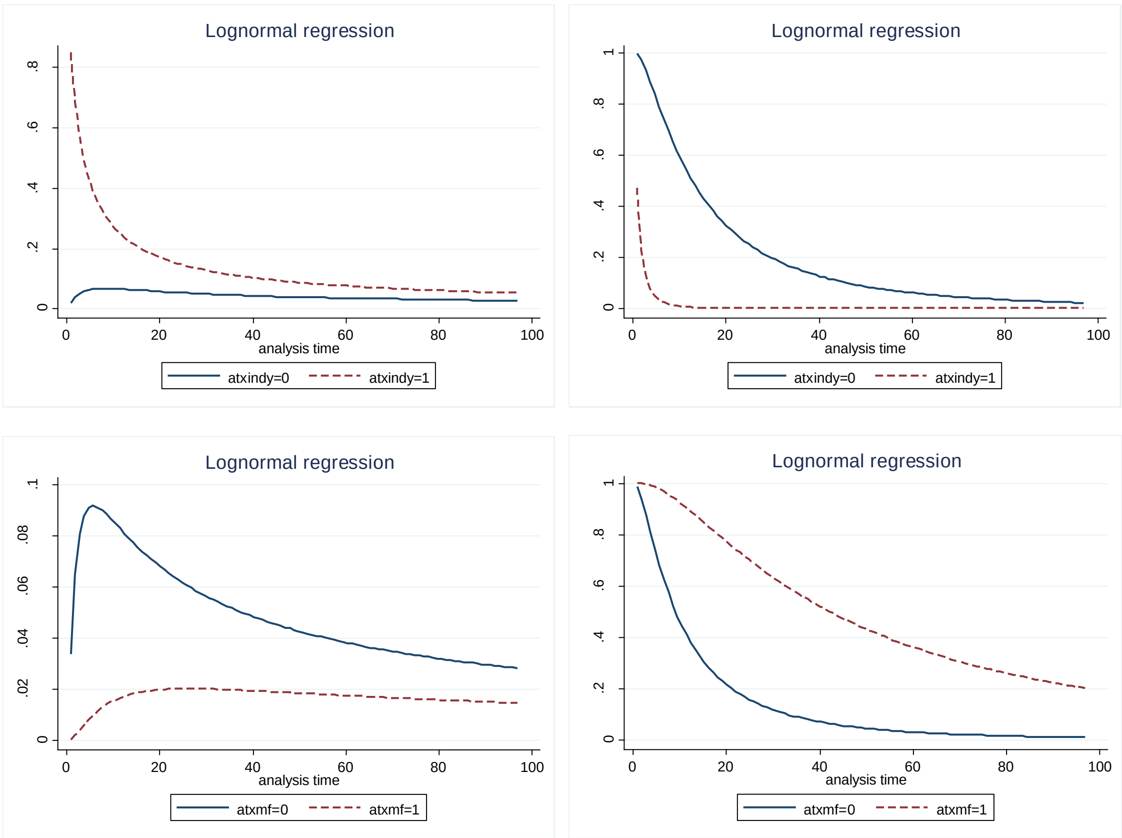

Figure III - 24 Estimated hazard and survival for *atxmf* and *atxindy*.

Sedgwick (2002) finds evidence that State vs. Paramount had limited effects on reducing the power of the major studios due to the social changes after the Second World War. In fact, the decrease in movie audiences felt during this period was more damaging to smaller firms.

One should also keep in mind that we are analysing only the motion picture producers, a part of the broader film industry. While exhibitors had the power to chose the portfolio of films since the Paramount decree ended the practice of block booking, major producers adopted a new strategy to overcome higher risk in releases. It was during the 1950´s that widescreen exhibition technologies emerged, such as Cinerama and CinemaScope (Gil & Lampe, 2012), in an attempt to differentiate and drive back audiences to theatres. Producers, especially the major studios, further responded with epic productions, often shot in expensive colour film, made for these larger screens (Sedgwick, 2002).

On the other hand, while the emergence of television broadcast could be considered a direct competitor to theatre attendance, affecting exhibitors, on the production side, the possibility to license features for television broadcast created a new market for feature films.

5.3.5. Production Experience

Previous experience of founders has been observed to influence the fate of firms (Cabral et al., 2013; Klepper, 2002). In our model, we find two types of founders to have a significant effect in decelerating the path to liquidation of firms. By observing Figure III - 25, we see the positive effect of previous experience as a production executive (producer) to be especially important in reducing hazard in the earlier years compared to non-producer founders. Results lead us to expect that after a decade in the industry the hazards of all types of firms become increasingly similar as the initial competitive advantage of experienced executives over non-experienced is lost by the accumulation of experience by the non-producers.

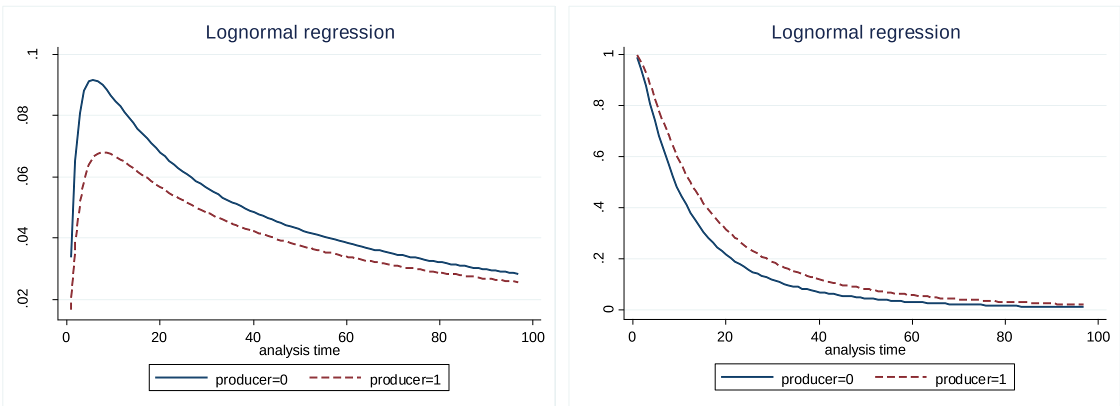

Figure III - 25 Estimated hazard and survival for *producer*.

The results for firms created as spinoffs of other firms from the motion picture industry are mostly similar to those we found for firms founded by producers. On Figure III - 26, we observe the initial advantage of spinoffs over other firms. The positive effect of being a spinoff however is slightly more long-lasting than the effect of previous experience as a producer. We suggest this may be related to an inheritance effect of both physical and human capital and also network effects that persist over time.

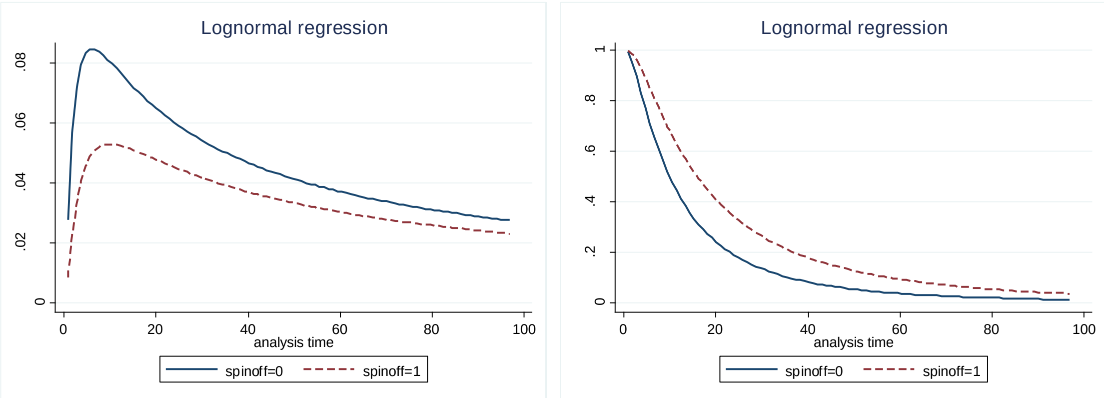

Figure III - 26 Estimated hazard and survival for *spinoff*=1 and *spinoff*=0.

5.3.6. Innovation

Finally, we focus on the effects of innovation on firm survival. First we analyse the effects of product innovation and then process innovation.

Process innovation has been less studied than product innovation. Yet authors, such as Utterback (1996) and Anderson & Tushman (1990) have indicated that on industries producing non-assembled products, it could have an important effect on firms, through significant cost reduction and gains on efficiency. Motion picture production industry is the first step on the value chain of cinema that provides a simple product, a film reel or electronic support, to the two service industries downstream: distribution and exhibition. While the final consumer will find it difficult to evaluate the effects of a process innovation on the final service it consumes (two hours of entertainment), the effects of process innovation on the production phase can be decisive on cost reduction and other gains of efficiency, as we will see next.

The effects of product innovation on the ability of a firm to survive are well studied. In our set of data we had defined two product innovations, feature films and synchronised sound. In our model, none of these dummies proved to be significant at 10%.

Figure III - 27 compares hazard and survival for firms entering before 1965, the year of the introduction of the Eastmancolor cinematographic process (eastman=0), and after (eastman=1). Firms entering the industry after this innovation are expected to have a longer time active until failure.

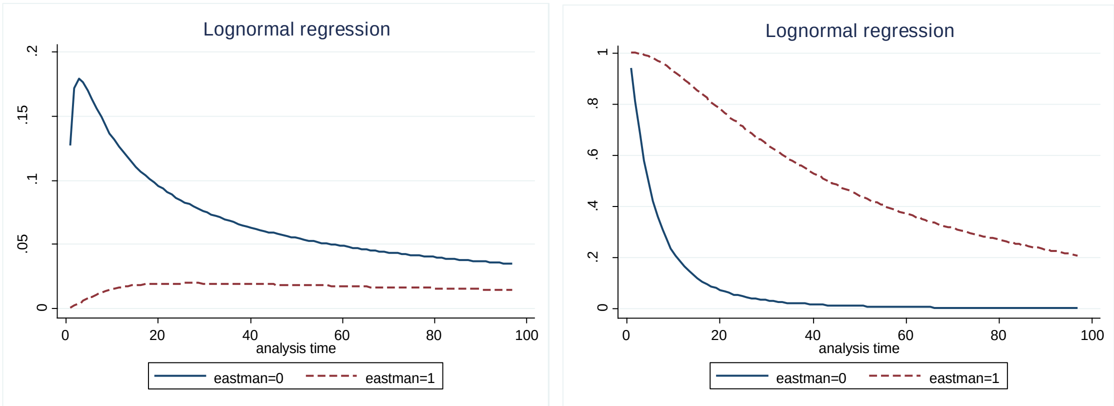

Figure III - 27 Estimated hazard and survival for *eastman*.

Until this new process was available, the most important colour capturing process was Technicolor, which was very expensive and only used in few productions, mainly by the major studios. The less expensive Eastmancolor allowed smaller firms to compete with the majors on colour movies. The timing of the introduction of the Eastmancolor photographic process was also crucial on the effect it had on the industry. Television in the 1960's had become an important source of entertainment. The colour movie had the capacity to attract viewers to movie theatres.

Firms entering after 1965 did not experience the initial failure acceleration as dramatically as did the ones of the previous period, for these are firms entering a mature industry, after a shakeout occurred. Yet, the effect of this innovation in survival is extremely visible and represents an important result, since this means that a process innovation can affect firms permanence in an industry to greater effect than a product innovation.

We have also analysed the effect of digital cinematography on the dynamics of the industry (Figure III - 28). Contrarily to our initial expectations, this variable proved to be significant in explaining the expanding time of survival.

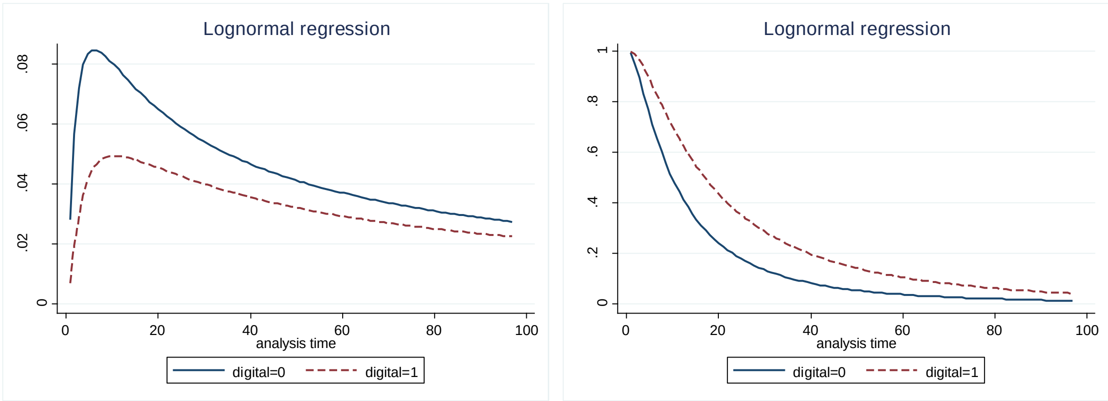

Figure III - 28 Estimated hazard and survival for *digital*.

6. Conclusions

It is broadly accepted that during the life-cycle of an industry there are waves of innovation that shape the destiny of firms. While product innovation plays an important role in defining the industry in an early phase, as industries mature process innovation is believed to become more important in the reduction of costs and improving efficiency. However, we find little evidence in previous literature on the distinctive effects of product and process innovation.

In this essay we studied the American motion picture production industry throughout its history to find evidence of the succession of different types of innovations and their possible effects on firm survival.

Because the dynamics of firm entry and exit are affected by other forces besides innovation, in our analysis we have also taken into account the competitive environment affecting firms at entry and exit, and the individual characteristics of firms and their founders.

Four important results should be highlighted. First, we find that the motion picture production industry, while affected by the particularities of a creative industry, is also affected by the general factors already proved to influence the dynamics of industries in general. Among these factors are population density and competition for resources and costumers (audiences), firm age, size and concentration. We also find that the business cycle does not affect this industry as would be expected to affect a manufacturing industry, confirming there are specificities to consider when studying a creative industry, since it is affected by the particularities of the response of audiences for art, as well as public support and sponsorship.

Second, we find a positive significant effect of executives experience as producers in providing knowledge and resources needed to improve the success of firms, compared to inexperienced executives. The specific human capital and assets that spinoffs bring from the mother firms are also capable of increasing the life of firms. On the other hand, technical and artistic experience does not affect the survival of studios. Thus, as expected, accumulated human capital, learning-by-doing experience and network effects are clearly crucial assets for filmmaking, reducing hazards and improving the survival expectations of firms.

Third, we were able to find empirical evidence on the succession of product innovations and process innovations and the positive effects both kinds of innovation have on the success of firms.

After the product became standardised, as predicted by theory, process innovation and cost reduction became more important. We found two process innovations to be significant: EastmanColor and digital cinematography. The first provided a low-cost alternative to Technicolor, the second, is becoming a low-cost alternative to acetate film itself.

Fourth, our analysis was capable to solve a puzzling event of history of this industry, related to the ineffective impact of the State *vs*. Paramount anti-trust case in reducing the market power of major studios, which has implications on our understanding of the effects of industry regulation. By analysing separately the impact of the decree on major studios and independent producers, we were able to observe that while the decree aimed on reducing the power of major studios, the post war social changes, including the movement of families to the suburbs of cities and the emergence of television broadcast, created an adverse environment to film production and exhibition that adversely affected the smaller firms. During this period, only the larger firms, with resources were able to adapt to the new situation, mainly through epic productions and thus overcome the difficulties. Whether if a different timing of the court decision would have generated more favourable conditions for small firms remains to be proven.

Usually cultural industries innovation is viewed in a creative and artistic perspective. We observe that this perspective ignores the causes behind. It would not be possible for directors to imagine the fantasy worlds of *Avatar* or *Star Wars* without the technological advances that created sound, colour, and special effects possible. Thus, we conclude for the importance of analysing motion picture production, as well as other cultural industries with the same methods used for other types of industries.

A note on the methodology used and on the choice of models should be stressed. All models estimated had high global significance, only a thorough selection method led to the final regressions used, which had the particularity of retrieving a non-monotonic distribution. The particular shape of the survival and hazard functions delivers another important conclusion that is the diluted effect of the variables on the survival of firms on later periods of time.

Data collection and the use of primary data were decisive on the type of information we were able to use. Only by the study of the particular history of each studio was it possible to know the origins of the firm and the background of its founders. It was also by this means that it was possible to have information on the firms exiting through liquidation or bankruptcy. Census and industry surveys cannot be as specific and usually only record exits of firms from industry listings leading to impossibility to distinguish firms that are closed from firms that are bought by other firms.

Finally, we consider that while we demonstrate the advantage of the analysis of an industry throughout its whole history, we also acknowledge that the study of specific intervals of time can retrieve important information, in the film industry in particular, we believe the current period of its history, since the breakup of the old Hollywood system, is of particular interest, for besides the emergence of new filming processes and new products and marketing strategies, such as the simultaneous release of 2D and 3D versions of the same picture, this period has also been characterised by a wave of mergers and acquisitions, which have led to more concentration, while at the same time, the importance of independent filmmaking is growing, as demonstrated by the increasing influence of independent film festivals such as Sundance.

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Essay IV: Innovation and exit modes

Abstract

How does the adoption of innovations affect the fate of firms in a mature industry?

In this essay it is proposed that two answers can be found to this question, depending on the type of analysis done. While traditionally industry dynamics has been considering the fate of firms as a choice between permanence as success and exit as failure, this essays proposes that exit should be studied as a heterogeneous event, distinguishing bankruptcy and liquidation from mergers and acquisitions.

We investigate the relationship between firm survival and innovation in the motion picture industry. We collect a unique dataset of 175 firms involved in production in the last three decades, a period of profound change and restructuring of the industry. Then, these data are studied using survival analysis methods to understand the determinants of different forms of exit. A subsequent robustness check to our results is done using the same dataset of firms with 2659 yearly observations, analysed with a multinomial logistic model.

We find that the determinants of different exit forms are not the same. Exit by liquidation or bankruptcy is determined by entry conditions such as age and industry density of firms that do not affect mergers and acquisitions. Firm size has opposite effects on determining the form of exit. Different backgrounds of founders predict different outcomes.

Finally we find that early adopters of innovations are more likely to avoid failure and that the early adoption of a process innovation can delay exit through M&A.

Keywords: Firm exit, merger and acquisition, liquidation, product and process innovation, competing risks model.

JEL codes: L82, O33

1. Introduction

Different firm exit modes are often disregarded in empirical studies. However, their causes and effects are different and have implications in the conclusions and lessons to be taken. Cefis & Marsili (2011) refer that most empirical studies on survival do not distinguish the different modes of exit of firms, mostly due to limitations in obtaining data. While exit by closure can be the result of bankruptcy or unsuccessful management, exit by acquisition can be the result of "being too successful" (Fontana & Nesta, 2009). Incumbents may obtain new knowledge, skills and intellectual capital while eliminating competitors by acquiring innovative firms. They also have the opportunity to test the innovations while not affecting their competitive potential. Treating exit as a homogeneous event can then lead to biased conclusions and confuse interpretations of the causes of firm success and failure.

We consider 175 firms that were active in the American motion picture production industry during the period from 1982 to 2012. We observe whether they have adopted two major innovations during this period: 3D production and digital cinematography. The two innovations studied are chosen based on the debate they are causing among industry specialists. We estimate two types of survival models to explain how the adoption of innovations affects the duration of firms. First, we estimate time to exit of a firm. We then estimate a competing risks model to understand the determinants of two general forms of exit: through closure (either liquidation or bankruptcy), or through merger or acquisition.

In addition, we also use a multinomial choice model in order to analyse how the annual variation of the industrial environment affects the probability of each form of exit.

This essay is organised the following way: section 2 provides a literature review on the determinants of exit, section 3 presents the data on the motion picture industry and the variables used in the econometric analysis, section 4 presents the methods, section 5 the results discussion and section 6 the conclusions.

2. The determinants of exit

The economic models accounting for firm survival and exit highlight the importance of processes of learning and selection in industry evolution (Jovanovic, 1982). This learning processes lead to the accumulation of knowledge and to innovation, which has been acknowledged since Schumpeter (1934) as a motor of competitive advantage for firms. Currently, three strings of literature, evolutionary economics, organisational ecology and the resource based view of the firm have been providing more insight into the causes of firm survival. Geroski *et al*. (2010) found these approaches to provide complementary explanations, in particular when focusing in the founding conditions firms face.

The study of firms exit is recognised as a fundamental part of industry evolution. However, there is scarce literature on the determinants of different exit forms. Firms may exit an industry by closure – either through voluntary liquidation or bankruptcy –, or by merger or acquisition. The consequences of different forms of exit are also different and have important impacts of the remaining industrial population and the economy (Schary, 1991). In general, exit by merger and acquisition allows the industry to retain the productive capacity of the firm. On the other hand, when a firm closes, either voluntarily or by bankruptcy, there is loss of productive capacity. While the consequences of different forms of exit on the industry and the economy are fairly well known, the causes are yet to be fully understood.

While the study of the factors that condition different types of exit is recognised as pertinent, there is still a small body of empirical work. Corporate finance literature has been pioneering the analysis of different exit forms, relying on the profuse financial data usually available. Yet, as Esteve-Pérez *et al.* (2010) observe, in general these studies are more interested in predicting probability of exit forms or time to exit rather than analysing the causes of different forms of exit.

Recently, though, other authors have been studying the determinants of liquidation (either voluntary or bankruptcy) and mergers and acquisitions, as can be observed on Table IV - 1. In order to simplify the analysis, two forms of exit are considered: mergers and acquisitions, as forms of successful exit; and voluntary liquidation and bankruptcy – closure -, as forms of unsuccessful exit. While this may be considered a simplification of reality, authors such as Freeman *et al.* (1983) have found these forms of exit are affected differently by firm characteristics (in their particular case, age of the firm).

Table IV - 1 Empirical articles on the determinants of different exit forms.

Authors	Data and period of analysis	Factor	Effect on M&A	Effect on failure	Effect on exit
Fontana & Nesta (2009)	121 LAN industry firms (1990-1999)	Distance to tech frontier	+	+	-
		Age at entry	-	-	
		Size	-	-	
		Spin-out		-	
		R&D intensity	-	-	
Esteve-Pérez et al. (2010)	2,998 Spanish manufacturing firms (1990-2000)	Age (years)	+ (>50y.)	- (11-25y.)	+ (>50y.)
		Size	+	-	-
		Technological intensity	0	- (medium tech)	- (medium tech)
		Labour productivity	+	-	-
		Price cost margin	0	-	-
		R&D	0	-	-
		Advertising	0	-	-
		Exports	-	0	-
Grilli (2010)	179 independent ICT start-ups established between 1995-2000 (industry crisis of 2000-2003)	Size of founding team	0	-	0
		Education	0	0	0
		Specific experience	+	0	+
		General experience	0	+	0
		Management experience	0	0	-
		Size	+	-	0
		Bank debt	0	0	-
		Age	0	0	0
		Internet services	+	+	+
Cefis & Marsilli (2012)	3275 Dutch manufacturing firms (1996-2003)	Innovator	+	-	
		Product innovation	+	-	
		Process innovation	-	-	
		Age	-	-	
		Size	-	-	

Two of these studies focus on specific high technology industries (Fontana & Nesta, 2009; Grilli, 2011); the other two use national surveys on manufacturing industries (Esteve-Pérez *et al.*, 2010; Cefis & Marsilli, 2012), the four data samples are European. From this first observation, we can retrieve how seminal these approaches are and how limited is the analysis in terms of industrial sectors and geographically.

In terms of their results, we observe that in such control variables such as size and age, there is not a conclusive linear pattern. In terms of innovation, there is an effect of R&D activities on delaying failure, as is also innovation, both product and process. An interesting result from Cefis & Marsilli (2012) is the opposite effect of process innovation on the two forms of exit, delaying failure and accelerating M&A.

A question is raised while interpreting survival models in previous studies on the impacts of innovation. That is the omission of control variables for the macroeconomic environment. Do the impacts of innovation stand equal when controlling for the business cycle? A notable exception is Grilli (2011), whose analysis is focused on a period of industry-specific crisis. However, there is no comparison with other periods of the industry life-cycle, nor a relation with the external economic conditions that may affect the industry crisis itself.

However, the pertinence of this analysis is supported by Battacharjee *et al.* (2009), who found that the macroeconomic instability has opposing effects on bankruptcy and on acquisition hazard, concluding bankruptcies increase during a period of instability or low economic growth, while acquisitions decrease.

3. New Hollywood

The American motion picture industry has its roots in the production of short films to screen as part of vaudeville and varieties programs. The introduction of the feature film in 1911 created a new form of entertainment, where the movie was the main attraction presented by the theatre. By the 1920’s the feature film was the prevalent form of movie and after the introduction of synchronised sound in 1927, we may consider the industry entered its mature phase. The number of firms stabilized and the golden age of Hollywood emerged, together with the studio system.

However, the post Second World War years brought a series of challenges that led to profound transformations in the way studios worked. Such challenges were the anti-trust laws that led to the end of the studio system and vertical disintegration, the generalization of television broadcast and subsequently of colour television (Christopherson & Storper, 1986), and also, we argue, the emergence of a new generation of filmmakers.

This essay takes a look closer into the most recent years of the American motion picture industry, frequently called “New Hollywood” (Nystrom, 2004), a period characterized creatively by the rupture with “Old Hollywood” aesthetics and storytelling, and by a set of new organizational and managerial practices. According to Scott (2002), six fundamental changes differentiate the last three decades of the American motion picture industry: the effects of the break-up of the studio system, the coexistence of two production systems (the blockbuster and the independent film), the geographic decentralization from Hollywood, new markets (such as home video), mergers of studios and other communication activities that created global media conglomerates, and computerized technologies. The latter group of changes can be further divided into two major innovations that have been creating a lively debate since 2000: digital cinematography and 3D motion pictures (Belton, 2002, 2012; Mediavilla & Vences, 2009; Gil & Lampe, 2012)

In terms of technological innovation, digital cinematography is a process of motion picture capturing that does not require the use of acetate film, nor even video tape. Images are captured by sensors and can be stored either on video-tape or on digital files. Image and data compression can also be used in order to reduce the amount of data storage needed. Digital cinema relies on the development of CCD technology for use in image capturing. The first commercial motion picture to be produced using this technology is believed to be *The last broadcast*, a horror movie released in 1998. The next year had the release of *Star Wars Episode I: the phantom menace*, which had global distribution and was also the first motion picture to be screened using digital projectors in four theatres specifically equipped for this event. Although initially the technology was considered as only fitting fantasy and sci-fi productions, during the next decade, the adoption of digital cinematography by producers and directors followed the technological evolution of cameras and storing systems and was gradually included in other genres. In 2013, Paramount became the first major to produce and distribute movies exclusively in digital format. On

Figure IV - 1 it is possible to observe that the cumulative adoption of digital in terms of the number of firms releasing new productions each year follows a “double-S” shape, which had also been observed on the adoption of colour (Gil & Lampe, 2012), the number of digital adopters first reached a peak in 2003 and dropped the next year, to grow again until 2006, when 19 studios released a digital production for the first time, totalling 73 firms adopting the technology. By 2012, 99 firms had already used this process.

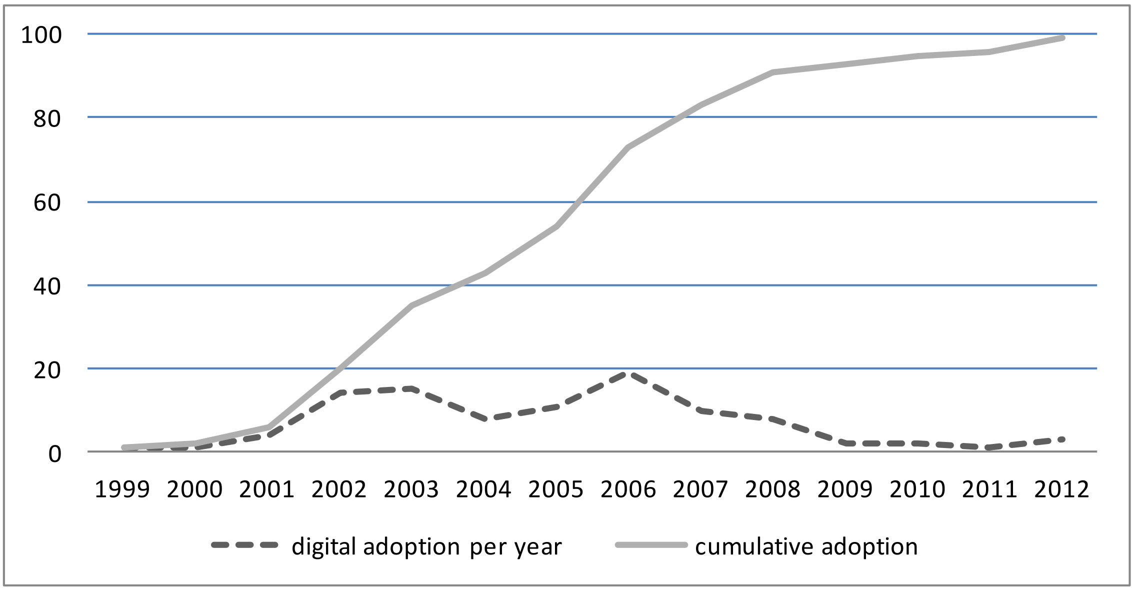

Figure IV - 1 Firms adopting digital cinematography.

Unlike digital cinematography, 3D pictures technology is as old as photography itself. However, the advances in computerised technologies, together with marketing efforts to bring audiences back to theatres, have been enhancing the importance of this kind of productions in recent years. In Figure IV - 2, it is possible to observe the relative importance of 3D productions since 1982 to 2012. Features based on 3D traditionally belonged to the horror genre, from which the 1953 film *House of Wax* is one of the most well known. However, since 2004 (with *Spy Kids 3-D: Game Over*), the technology has been increasingly used in adventure, sci-fi and animation films, allied to the use of digital. In fact, it is from 2003 on that the number of 3D productions starts gaining importance in terms of releases and box office results, culminating in *Avatar* released in 2009 and estimated to be one of the highest-grossing movies of all time, which may have benefited also from the higher prices of tickets sold for the 3D screenings.

Although the proportion of releases in 3D is still small, according to MPAA (2013), there is a trend of growth. In 2012, the proportion of total screens worldwide that were equipped with 3D digital technology increased to 35%, whereas in 2011 it was already 29% of all screens. The adoption of 3D and digital by exhibitors reflects the perceived need to provide entertainment that can capture audiences back to theatres as well as reinforces the demand for digital and 3D productions.

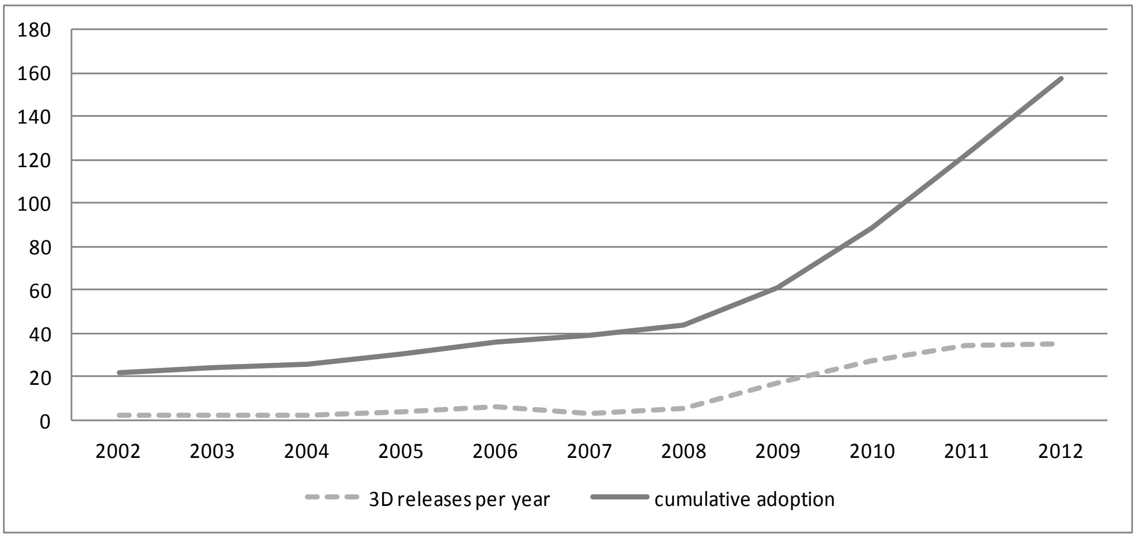

Figure IV - 2 Evolution of the number of 3D productions.

4. Data

An original database of 175 firms active in the motion picture production industry in the period between 1982 and 2012 was compiled in order to analyse the effects of adoption of innovations on firm survival in this industry. For information on firms until 2000, we relied on Slide (2001), for more recent information, we used the site IMDb.com. We searched for all American feature films produced between 1982 and 2012 and listed the firms involved in the production phase. This way, only firms active during this period were included and firms not listed as being primarily producers (such as distributors) were also included if they were featured on the films credits as producers. From this list of feature films, was also retrieved a list of those movies produced using digital cinematography processes as well as those which were 3D productions.

Two forms of exit are considered: M&A (mergers and acquisitions) and failure (including voluntary liquidation and bankruptcy). The description of the variables used is systematised on Table IV - 2.

In order to understand the effects of innovations on the survival of firms it is of extreme importance to control for the factors that are known by economists to affect firm survival. As Geroski *et al.* (2010) have observed current conditions as well as founding conditions affect firm survival in a variety of industries. On a previous essay on the American feature film industry, it was observed that entry conditions affected the duration of firms. As predicted by Geroski *et al*. (2010), founders experience was found to affect positively the survival of firms, as well as size. Founders experience in this context is a proxy for human capital, which has been found to be a provider of sustained competitive advantage to firms (Youndt *et al.,* 1996). In particular, in a cultural industry, such as motion picture production industry, it is expected that much of the knowledge embodied in founders experience to be tacit knowledge, therefore difficult to transmit and not tradable (Teece, 1998), giving each firm a particular, competitive advantage.

On the other, also as expected by theory, density at entry negatively affected survival. Density at founding has been found to have persistent effects on firms, predicting higher failure rates among firms founded under conditions of scarcity (Carroll & Hannan, 1989). These determinants are also controlled for in the present analysis.

Besides controlling for entry conditions, it is also important to keep in mind the effects of the business cycle on the survival of firms. As in this essay we are analysing the determinants of exit, we will focus on the GDP growth during the exit year, controlling for the effect of the business cycle as determinant of different forms of exit, as supported by Battacharjee *et al.* (2009).

Not only external factors affect the survival of firms. Intrinsic characteristics are also known to affect their efficiency and consequent probability of permanence in the market (Jovanovic, 1982). Two major characteristics of firms are known to affect their survival and controlled for in our analysis: these are firm size and firm age (Audretsch & Mahmoud, 1994; Geroski *et al*., 2010). Size is commonly found to affect negatively the probability and time to exit and has also been empirically found to have the same effect on exit by failure (Fontana & Nesta, 2009; Esteve-Pérez *et al.*, 2010; Grilli, 2010; Cefis & Marsilli, 2012).

Age is measured in terms of age at the beginning of the analysis that is 1982. It has been observed that there exists a non-linear effect of age on firm survival, for that reason, we also include the square of age.

Table IV - 2 Description of the variables used.

Variable	Description
GDP growth	GDP growth on the exit year of the firm (in %)
Age	Age at entry in the analysis in years
Age^2	Square of *Age*
Density	Number of firms active in production at the foundation year of the firm
Major studio	Dummy that takes value=1 if the firm is part of one of the major or mini-major studio groups
Independent	Dummy that takes value=1 if the firm is an independent filmmaker
Producer	Founders experience: takes value=1 if the founder has previous experience as producer
Director	Founders experience: takes value=1 if the founder has previous experience as director
Spinoff	Founders experience: value=1 if the firm is a spinoff from another studio
Actor	Founders experience: value=1 if the founder has previous experience as actor
Time to Digital	Time to adopt digital cinematography process, in number of years, after the first digital release in 1999 (*Star Wars Episode I*)
Time to 3D	Time of adoption of 3D production as distance to the first simultaneous release in 2D and 3D digital format in 2009 (*Avatar*)

As a proxy for size, we rely on Variety magazine industry's classification of firms as major, mini major, independent and, as default, the subsidiaries of groups not primarily involved in filmmaking or media, such as sports and religious groups. Following Mata et al. (1995), we consider the size of the firm at present time, or at the time of exit, to be a good predictor of firm exit.

Finally, in order to understand the effects of process and product innovation on the outcome of firms, we collected information for each firm on the year of adoption of digital processes of filmmaking and for the production of 3D motion pictures.

5. Methods

Previous literature on industry dynamics has used survival analysis to explain the duration of firms. Survival models are characterised by having a dependent variable which measures the waiting time until an event occurs, for this reason they are also called duration models. In industry dynamics studies, usually the dependent variable is time until a firm exits a market. Another characteristic of these models is censoring, which refers to possibility that the event in analysis does not occur during the period of observation – in this case, right censoring – or to the possibility that some individuals have existed before the beginning of the observations – left censuring, or left truncation. Finally, these models can be estimated using explanatory variables, to indicate how their effects affect the time to exit.

The waiting time to event can be represented as T, a non-negative random variable with probability density function $f(t)$ and cumulative distribution function

$$F(t) = P(T \leq t)$$

If we want to know the probability that a firm will survive t years after entering the period under study, we have the survival function that gives the probability that the event of interest has not occurred by duration t.

$$S(t) = 1 - F(t) = P(T > t)$$

Alternatively, the distribution of T can be characterised by the hazard function, which indicates the conditional exit rate, given by

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta \mathrm{t} | T \geq t)}{\Delta t} = \frac{\frac{\partial S}{\partial t}}{S_t} = \frac{f(t)}{S(t)}$$

In survival analysis regression models, a vector of explanatory variables X that explain survival time is included, thus the hazard rate is in fact $h(t, X)$. Two main groups of models may be considered: Proportional Hazards models, where hazard rate depends on two functions, one for time T and the other for the explanatory variables X; and Accelerated Failure Time models, which assume a linear relationship between the log of survival time T and characteristics of the explanatory variables X.

The definition of hazard rate presented above, only accounts for one possibility of exit and thus only measures time to one form of exit. In a competing risks analysis, time to exit is represented as the minimum of potential exit times: time to the event of interest and time to the competing events. Generally, one may consider m types of exit and the event of interest $j \in \{1,2, \dots, m\}$. So, for exit form j, a cause specific hazard rate can be defined as:

$$h_j(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta \mathrm{t}, \mathrm{J} = \mathrm{j} | T \geq t)}{\Delta t}$$

In our case, we will be observing time to firm failure and time to merger or acquisition, as two competing forms of exit from the industry.

6. Survival analysis and results

In order to study how the different modes of exit are influenced by the various determinants, we begin by estimating the duration of firms until exit and then compare how different forms of firm exit are determined. To begin the analysis, we observe and compare the Kaplan-Meier curves for each form of exit. The curves are adjusted based only on the definition of the variables measuring time and exit form (Figure IV - 3).

By observing the Kaplan-Meier curves it is immediately visible that there are differences on the survival and hazard estimates, depending on the type of exit under analysis, which demonstrates the rationale of distinguishing exit forms. The next subsections will estimate semi-parametric and parametric models for the three forms of exit in analysis.

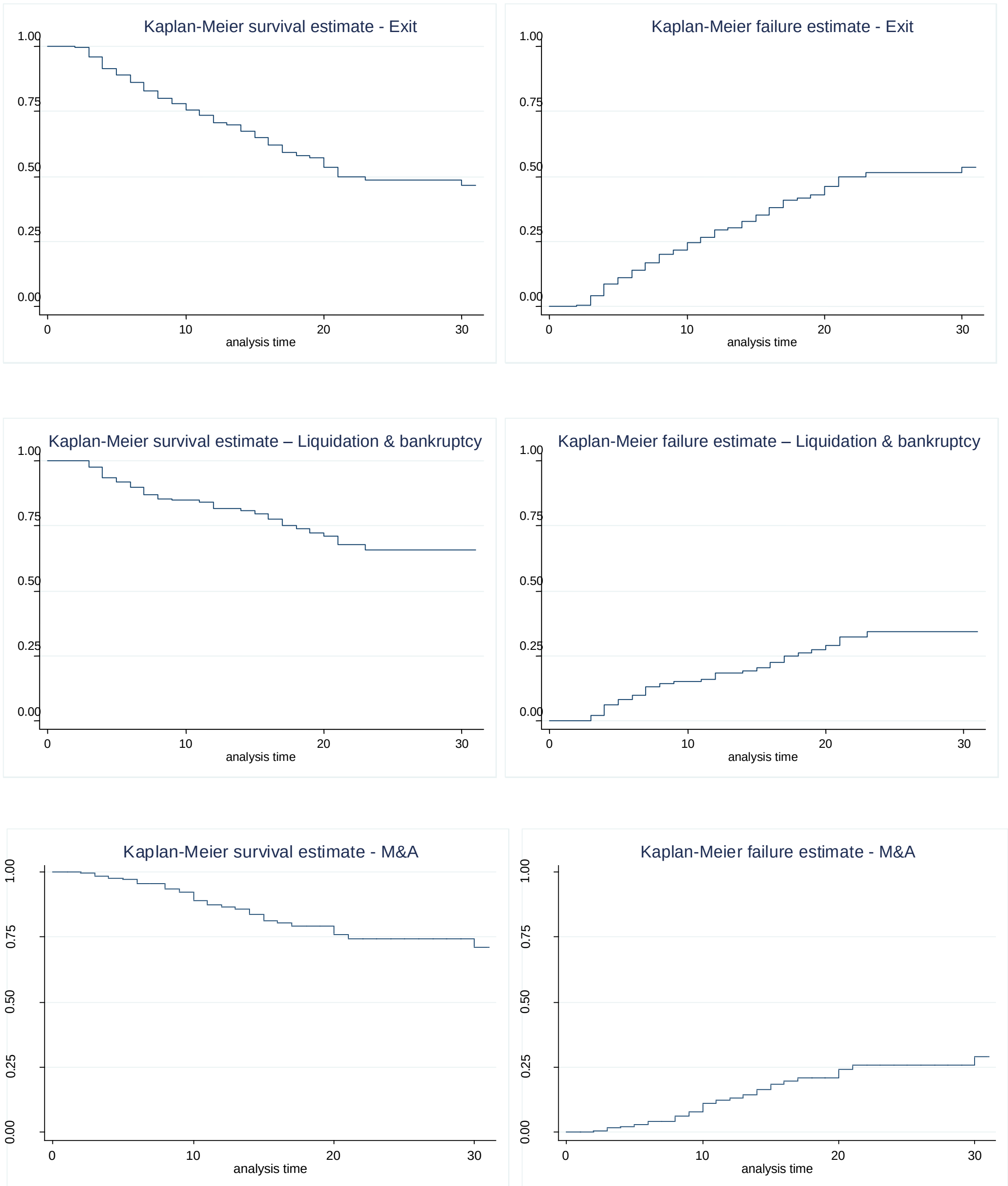

Figure IV - 3 Kaplan-Meier curves for the three forms of exit analysed: Homogeneous exit (first line), Failure (second line), and M&A (third line).

6.1. Exit as a homogeneous event

6.1.1. Cox proportional hazard model for estimating time to exit

We start by adjusting a model describing exit as a homogeneous event using the Cox Proportional Hazards regression (Table IV - 3), in order to be able compare our results with the traditional results of estimation on effects of innovation on firm survival with exit treated as a homogeneous event. In the Cox proportional hazards model (Cox 1972), the hazard is assumed to be:

$$h(t) = h_0(t)\, exp(\beta_1 x_1 + \cdots + \beta_k x_k)$$

A preliminary analysis begun by assessing the most adequate functional form, for that the first step was to test if it was correct to assume proportional hazards. We test the null hypothesis that the log hazard-ratio is constant over time, which can be performed on the global model, or for each variable.

The results of the global test (Table IV - 3) reject the proportional hazards assumption and do not support the choice of this model specification. More specifically, it is not desirable to perform any correction on the model, since the variable that violates the proportionality of hazards is one of the variables of interest in this study (*time3d*).

The Cox model was also tested for heteroskadasticity (Table IV - 3) and heterogeneity (graphically, using the Cox-Snell residuals plot, on Figure IV - 4), and none of these specification problems could be discarded.

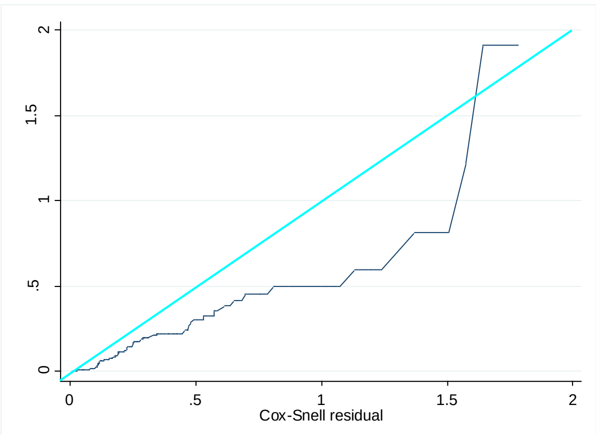

Figure IV - 4 Cox-Snell residuals showing the existence of heterogeneity.

One way of overcoming the presence of non-explained heterogeneity problem would be to estimate the Cox model with shared frailty, in other words, adding a term to measure within-group correlation. The resulting model was not satisfactory, since the same specification problems were present, reinforcing the conclusion that it would be inadequate to use this type of regression.

Table IV - 3 Cox estimates and test of proportional hazards.

	Cox PH model Estimates					PH Test	
	Hazard Ratio	S.E.		Robust S.E.		Chi^2	
GDP growth	1.1054	0.18		0.31		0.53	
Age	1.0554	0.05		0.05		0.89	
Age^2	0.9989	0.00		0.00		1.87	
Density	1.0081	0.01		0.01		0.03	
Major studio	0.7409	0.22		0.22		1.77	
Independent	0.8099	0.28		0.30		0.99	
Producer	1.1356	0.41		0.42		1.28	
Director	0.3716	0.23		0.21	*	1.95	
Spinoff	1.5257	0.65		0.68		1.22	
Actor	1.3161	0.94		1.03		3.73	**
Time to Digital	1.1440	0.04	***	0.04	***	8.05	***
Time to 3D	1.0105	0.03		0.03		0.01	
Log Likelihood	-314.320					**Global Test** 18.52	*
LR Chi^2	35.64		***				
Number of observations	175						
Number of exits	71						

Notes: *10% significant; **5% significant; ***1% significant.

6.1.2. Accelerated Failure Time regressions

Alternatively, Accelerated Failure Time (AFT) parametric models were estimated, beginning with the most general, the Generalised Gamma model. By testing parameter *k* in the generalised gamma model, we can conclude by rejecting H0: k=1 and so reject the Weibull model. On the other hand, we cannot reject H0: k=0, and so the Lognormal can be considered as a good specification. On Table IV - 4 is possible to observe the results for the Generalised Gamma, Lognormal and Loglogistic models.

Table IV - 4 AFT model estimates for Exit.

	Log normal		Log logistic	
GDP growth	-0.0262		-0.0443	
	(0.09)		(0.14)	
Age	-0.0445	*	-0.0406	
	(0.03)		(0.03)	
Age^2	0.0008	*	0.0007	
	(0.00)		(0.00)	
Density	-0.0087	**	-0.0080	**
	(0.00)		(0.00)	
Independent	0.1811		0.1940	
	(0.18)		(0.21)	
Major studio	0.0932		0.0663	
	(0.21)		(0.24)	
Producer	-0.0987		-0.1332	
	(0.25)		(0.27)	
Director	0.7736	**	0.7180	*
	(0.36)		(0.38)	
Spinoff	-0.2995		-0.3387	
	(0.29)		(0.32)	
Actor	-0.1806		-0.2667	
	(0.47)		(0.55)	
Time to Digital	-0.0938	***	-0.0962	***
	(0.02)		(0.03)	
Time to 3D	-0.0136		-0.0150	
	(0.02)		(0.02)	
_cons	4.7484	***	4.7777	***
	(0.56)		(0.64)	
Parameters	Sigma: 0.8819		Gamma: 0.5231	
Chi^2	45.40	***	33.70	***
Log Pseudolikelihood	-144.96835		-169.7349	
AIC	212.1544		323.3799	
N. Observations	175		175	
Exits	71		71	

Notes: standard errors in parenthesis; *10% significant; **5% significant; ***1% significant. Robust standard errors in parenthesis.

The next step after estimation of the models was to be completely sure of the correct model specification. The three regressions were estimated with robust standard errors in order to test the hypothesis of homoskedasticity, which was not rejected, as well as frailty models with a test to homogeneity, which was also not rejected, for the lognormal and the loglogistic regressions.

All models present a high global significance and all variables have the same signs. By comparing the Log likelihood and the AIC, we conclude by using the Lognormal model.

For the lognormal distribution, the natural logarithm of time follows a normal distribution. The lognormal survivor and density functions are

$$S(t) = 1 - \Phi\left\{\frac{\log(t) - \mu}{\sigma}\right\}$$

$$f(t) = \frac{1}{t\sigma\sqrt{2\pi}} exp\left[\frac{-1}{2\sigma^2}\{\log(t) - \mu\}^2\right]$$

where $\Phi(z)$ is the standard normal cumulative distribution function. The lognormal regression is implemented by setting $\mu_j = x_j\beta$ and treating the standard deviation, σ, as an ancillary parameter to be estimated from the data (in our case, $\hat{\sigma}$=0.838). The ancillary parameter defines the shape of the hazard curves, which are represented on Figure IV - 5.

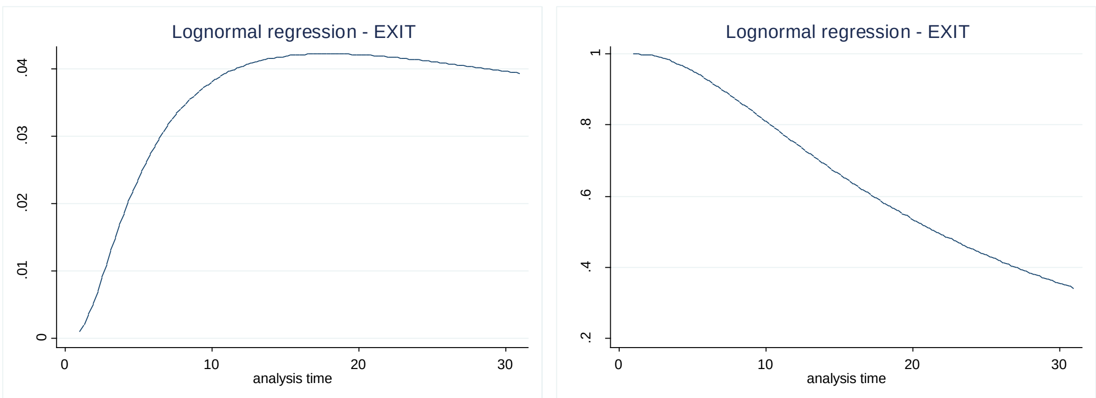

Figure IV - 5 Hazard and survival curves for the lognormal regression model of exit.

The results of the lognormal regression for exit as a homogeneous event have interesting information, which is analysed further in the next paragraphs. The observation of the estimates shows some puzzling and interesting results. The effect of GDP growth on the exit year is one of them, for it is not significant. One explanation for GDP growth not influencing the survival time of firms may be related to the long debate on the characteristics of arts and leisure as potential inferior goods (see for instance Baumol, 1973).

Age is found significant with a positive effect on exit, which also defies the expected result according to theory. As to the square of age at entry in this study, the effect is the opposite, which indicates an inverted U-shape of the effect of age on firm exit that is in line with Geroski *et al.* (2010). On Figure IV - 6, the hazard and survival curves for both *Age* and *Age*^{2} are represented. One should note that the curve for the maximum values of both variables refers to only one observation, Paramount Pictures.

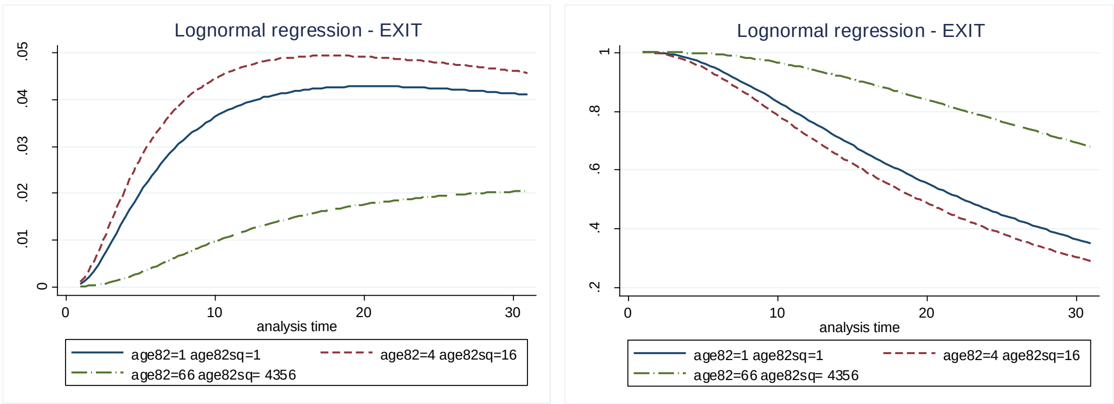

Figure IV - 6 Hazard and survival curves for the effect of *Age* and *Age*^{2}, at observed minimum, average and maximum.

We can observe that while the probability of exiting the industry increases slightly for younger firms, on older firms the opposite happens, in other words, the longer a firm survives, the longer it is expected to keep surviving, as long as it has surpassed an initial phase of higher hazard, a “liability of newness” (Freeman *et al.*, 1983).

Density at the time of firm foundation is significant and, as expected, increases the probability of exit, confirming the permanent effect of founding conditions on the future outcome of a firm. On Figure IV - 7 we present the hazard curves estimated for the effect of density at entry on the survival of firms. We observe that firms entering at highly populated times suffer an initial high hazard rate with a peak at the tenth year and then decrease. Firms experiencing lower density at entry suffer less from this increase in hazard in the early years.

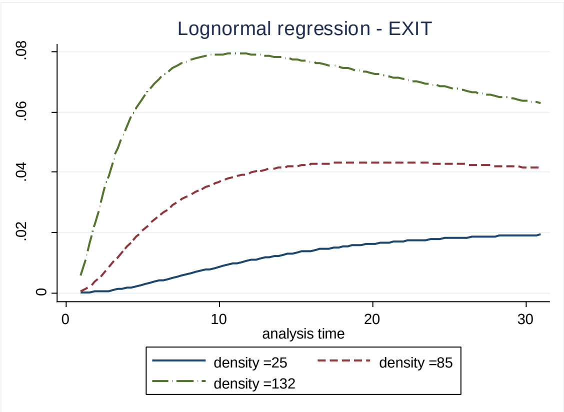

Figure IV - 7 Hazard curves for the effect of *Density* at observed minimum, average and maximum.

The variables controlling for size do not show significant effects at 90% confidence, however, at 89% confidence, we could find being an independent studio has an effect reducing hazard of exit compared to the control group.

An interesting result is that only one dummy controlling for founder experience, *director*, is significant, which may indicate that in a mature industry, the accumulated knowledge is already available to whoever enters and there is not a competitive advantage of being experienced in production. However, the specific technological and artistic knowledge accumulated as director is able to reduce the chances of exit of a firm (Figure IV - 8).

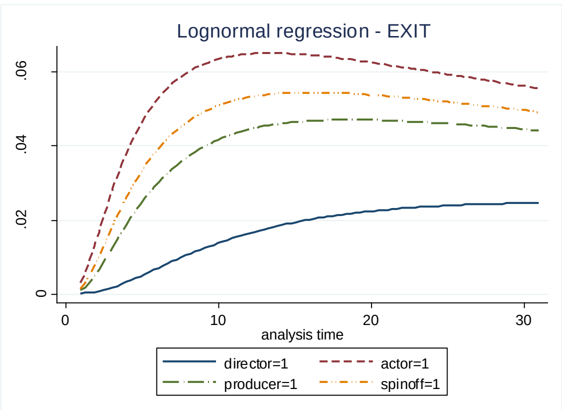

Figure IV - 8 Hazard curves for the effect of the experience of founders.

Finally, we find that the timing of adoption of digital technology is very significant and that the longer it takes a firm to adopt it, the higher the hazard rate of that firm, representing a strong evidence of the importance of this cinematography process in providing competitive advantage to firms adopting it (Figure IV - 9).

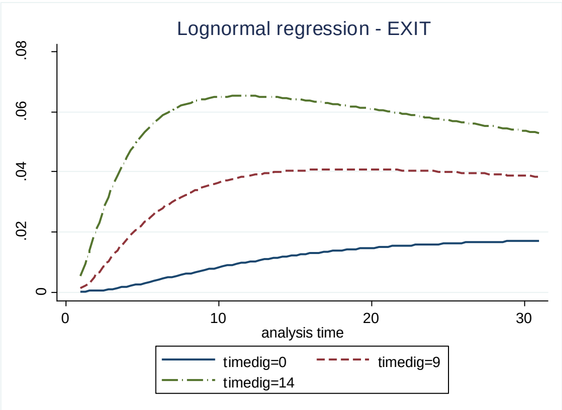

Figure IV - 9 Hazard curves for the effect of *Time* at observed minimum, average and maximum.

6.2.Estimating time to failure and to M&A

6.2.1. Competing risks models to estimate time to failure and to M&A

In this essay, besides knowing the time of survival of firms, there is also an objective to know which form of exit may happen earlier, failure or M&A, depending on the explanatory variables in study. To estimate duration of firms considering these forms of exit, we began by considering the use the competing risks model, based on Fine & Gray (1999), which assumes PH. Competing-risks regression assumes the following relationship between subhazard and baseline subhazard

$$\bar{h}_1(t) = \bar{h}_{1,0}(t)\ exp(\beta_1 x_1 + \cdots + \beta_k x_k)$$

As the competing risks model assumes proportional hazards and we have already found *time to 3D* to violate that assumption, this type o regression cannot be used in our analysis.

6.2.2. Independent competing risks models estimating Failure and M&A

The competing risks models estimate the partial hazard of exiting by one of two competing forms. While this is an interesting approach, it can only be used under proportional hazards. As was observed before, our data violate proportional hazards, and so we advanced to using accelerated failure time regressions to estimate models for Failure and M&A. Again the lognormal specification was considered the most adequate after testing parameters. On Table IV - 5 the estimates for the duration models using the Lognormal model are presented. One must note that this analysis is not directly comparable to that of the competing risks model, for this considers the hazards to be independent, while the other considered them to be competing.

We observe that when we estimate survival distinguishing outcomes failure and M&A, controlling for GDP growth on the exit year does not have a significant effect. In other estimated models that were not included in this analysis, we also controlled for GDP growth during the five years previous to firm exit, in order to account for its effects during all stages of production, and again it was not significant in determining the mode of exit. On the other hand, GDP growth was found significant in modelling the time to exit when it was treated as a homogeneous outcome. This contrast in results highlights the importance of analysing firm exit in its different forms for otherwise, the simplification of the survival models face a risk of finding significant effects that do not reflect the reality.

However, we should take a careful approach on the possibility of generalisation of this result in particular to other industries. One would expect that GDP growth would affect both bankruptcies and acquisitions with opposite signs, as proposed by other authors (for instance Bhattacharjee, 2009). In this perspective, the motion picture production industry can be an exception or, as we already considered, we could be observing the effect of arts and leisure being inferior goods, a discussion which is beyond the scope of this essay. Additionally, as the production industry is the first step on a value chain composed of production, distribution and exhibition, and highly dependent on financing, perhaps a more realistic measure of the effects of the business cycle on survival of firms would be the interest rate, as a measure of the access to credit by producers.

Table IV - 5 Estimates of lognormal models for firm outcomes Failure and M&A.

	Failure		M&A	
GDP growth	-0.0218		-0.0200	
	(0.12)		(0.17)	
Age	-0.1204	***	0.0262	
	(0.04)		(0.04)	
Age^2	0.0022	**	0.0000	
	(0.00)		(0.00)	
Density	-0.0191	***	0.0042	
	(0.00)		(0.01)	
Independent	0.8750	***	-0.5506	*
	(0.23)		(0.30)	
Major studio	0.8790	***	-0.7441	***
	(0.32)		(0.28)	
Producer	-0.1507		-0.1278	
	(0.29)		(0.41)	
Director	1.1324	***	0.3997	
	(0.44)		(0.55)	
Spinoff	-0.4920		-0.1886	
	(0.36)		(0.44)	
Actor	-0.4327		4.5924	***
	(0.50)		(0.74)	
Time to digital	-0.1030	***	-0.0769	***
	(0.03)		(0.03)	
Time to 3D	-0.1966	**	0.0050	
	(0.10)		(0.02)	
_cons	6.3473	***	4.8179	***
	(0.80)		0.78	
Sigma	0.9108		1.0738	
Chi^2	60.87	***	139.12	***
Log Pseudolikelihood	-92.0772		-81.8939	
No. Observations	175		175	
No. Events	41		30	

Notes: *10% significant; **5% significant; ***1% significant. Robust standard errors in parenthesis.

Age has a significant positive effect in increasing the hazard rate of failure and the square of age has a negative effect, which indicates an inverted U-shape of the effect of age on failures, which is according to the literature on the determinants of firm survival. On Figure IV - 10 the hazard curves for *Age* and *Age*^{2} on failure are represented.

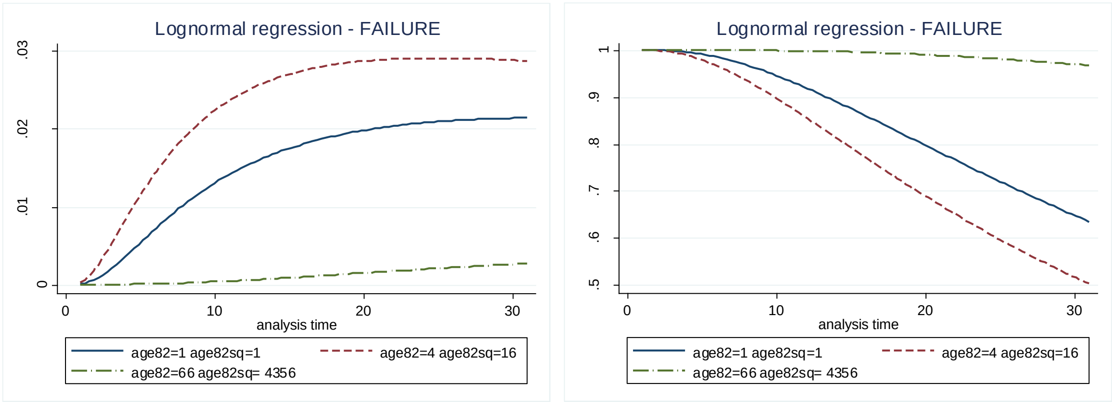

Figure IV - 10 Hazard and survival curves estimating the effects of *Age* (left) and *Age*^{2} (right) on time to FAILURE.

The evolution of the hazard rate of failure with age and its square are consistent with the results obtained for exit. The different effect of age on the M&A hazard of firms had also been pointed out by Freeman *et al.* (1983), who advanced the need to analyse these two types of exit separately. More recently, the empirical work of Bhattacharjee *et al.* (2010) and Balcaen *et al.* (2010) is also in line with our results.

Density at entry is also found to have the expected permanent effect on increasing firm failure. In contrast this factor does not affect M&A and which shows the pertinence of studying the determinants of M&A separately from those of firm failure. On Figure IV - 11, the effects of density at entry on Failure and M&A are represented. It is possible to observe that there are few differences on the hazard curves obtained for M&A, opposing the marked difference the number of firms active on the entry year have on the subsequent hazard of failure.

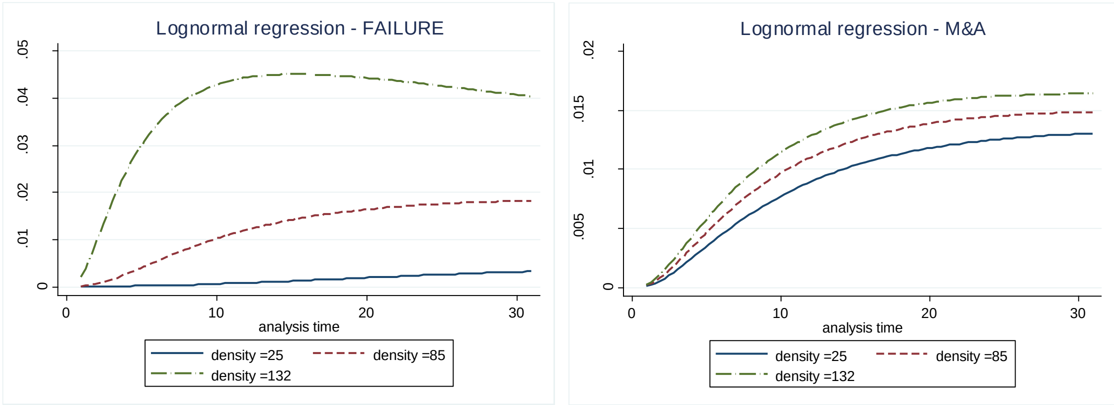

Figure IV - 11 Hazard curves for the effect of *Density* at observed minimum, average and maximum on time to FAILURE (left) and M&A (right, non significant).

The hazard rates of firm size dummies on exit (Figure IV - 12) show an interesting distinctive effect on the form of exit. We find *Independent* and *Major studio* have a lower hazard rate, reducing failures, consistent with Bhattachrajee (2009). The opposite effect is found on M&A, which seem to be more probable to happen to these groups of firms. This is line with the empirical findings of Balcaen *et al.* (2010), who further analyse the impact of being part of a group of firms, rather than independent, two traits that in our set of data are integrated in the definitions of *Major studio* and *Independent.*

If one compares these results with those on the model estimated in 6.1.2, one may find that analysing firm exit as a homogeneous effect may lead to misleading conclusions.

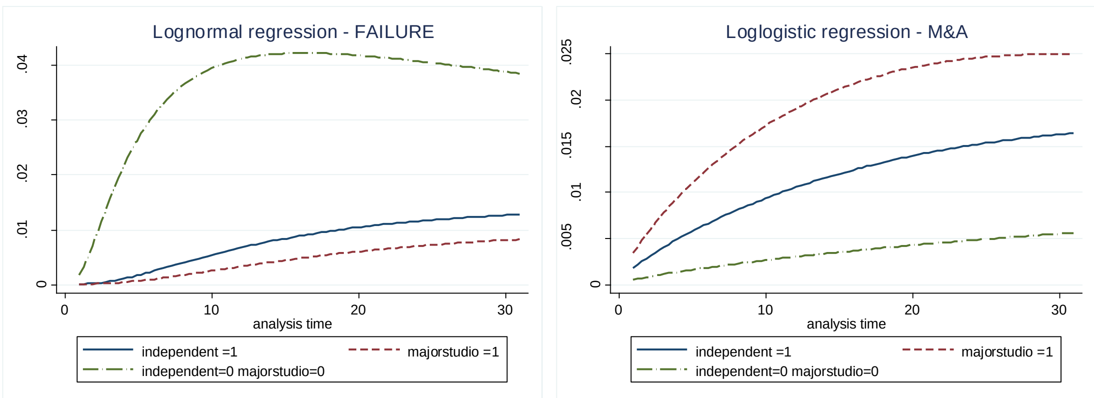

Figure IV - 12 Hazard curves for the effect of the proxies for size *Major Studio, Independent* and remaining firms on time to FAILURE (left) and time to M&A (right).

Founder experience has different effects on determining the different fates of firms, in fact the only significant experience in reducing failure is *Director* whereas M&A are affected by experience as *Actor* (Figure IV - 13). On the previous essay on the same industry, we found experience as a producer or a spinoff of a producer firm to be significant for the population of production firms observed during the whole history of the industry. Here we find these variables to be non significant, which is in line with the finding that hazard curves converged with time, predicting that the initial competitive advantage of experienced executives over the non-experienced would be lost by the accumulation of experience by the non-producers, through learning-by-doing. This result is also consistent with the existence of organisational forgetting (Besanko *et al.*, 2010).

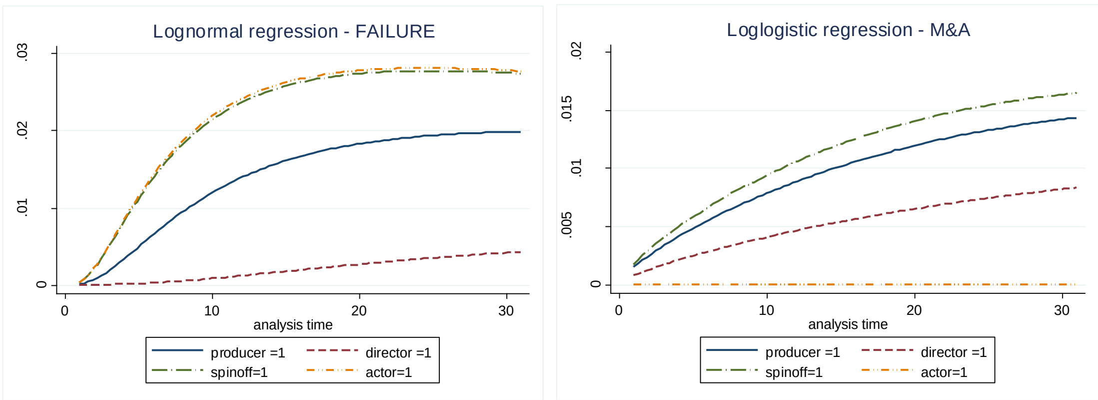

Figure IV - 13 Hazard curves for the effect of founders' experience on time to FAILURE.

The effect of previous experience as director on delaying firm failure during the period in analysis is consistent with the particularities of New Hollywood and the efforts to bring back audiences to theatres through the use of new technologies and also its roots on the emergence of the generation of film school-trained directors that eventually turned producers. On the other hand, film directors are proficient both in the technical and artistic aspects of filmmaking because they had formal training and are more capable to attract highly skilled human resources for the firm or, as Mata & Portugal (2002) state, be "an indicator of the quality of the land where the seed of human resource management is to blossom".

As to M&A, the significance of the dummy for founders whose background is acting, the results should be interpreted carefully and conservatively, for there are no mergers or acquisitions reported for firms founded by actors.

The influence of innovation on the choice of the form of exit has recently been capturing the attention and efforts of empirical economics. In our estimated model, we observe that the variables for the effects of innovation adoption on firm survival can in fact derive interesting results and reinforce the importance of analysing exit a heterogeneous outcome.

On Figure IV - 14 the hazards curves for variable *Time to Digital* are represented. We note that the two plots have different scales, representing a more pronounced effect of delaying the adoption of digital cinematography on the increase in the hazard of failure than happens with M&A. Gans & Stern (2003) find that while acquisition can be a desired outcome for new firms developing innovative technology, acquirers would value less a process innovation when evaluating a potential acquisition target.

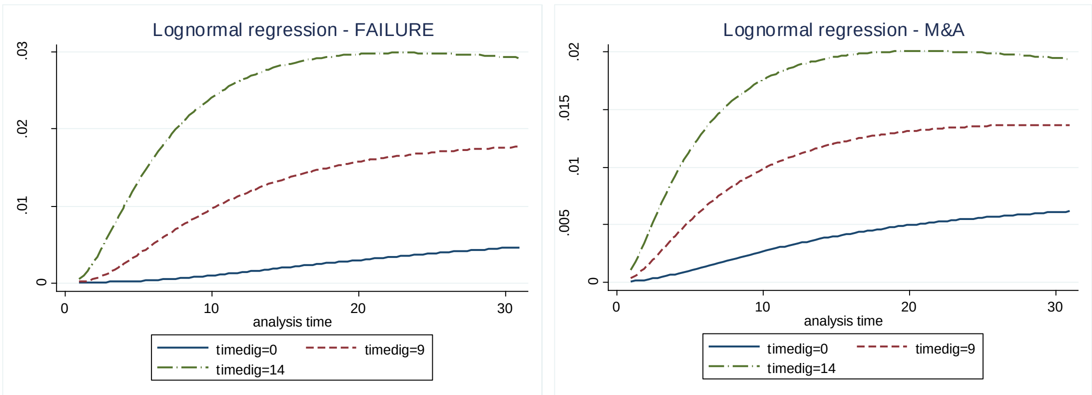

Figure IV - 14 Hazard curves for the effect of *Time to Digital* at the observed minimum, maximum and at the year zero, defined as 1999 (left: FAILURE; right: M&A).

Although this result is in contrast with Fontana & Nesta (2009) on high-tech industries, another aspect worth noting is that studies on innovation are mostly focused on high-tech industries. In fact, in low-tech industries Cefis & Marsilli (2011, 2012) also found a positive relation between innovation, both product and process and M&A.

While the estimates for time to adoption of digital after 1999 are very significant and have the same sign both for failure and M&A, the time to adoption of 3D was not initially found to be significant in determining exit. Yet, it has in fact a significant effect in increasing the probability of a firm exiting through failure as a consequence of delaying the adoption of 3D production. Similarly, Cefis & Marsili (2012) also observed a negative relation between product innovation and firm closure.

On Figure IV - 15 it is possible to observe that firms adopting 3D production very early (as early as 27 years before *Avatar*) have a nearly constant very low hazard, while laggards have the highest hazard rate, confirming the importance of product innovation on providing firms competitive advantage.

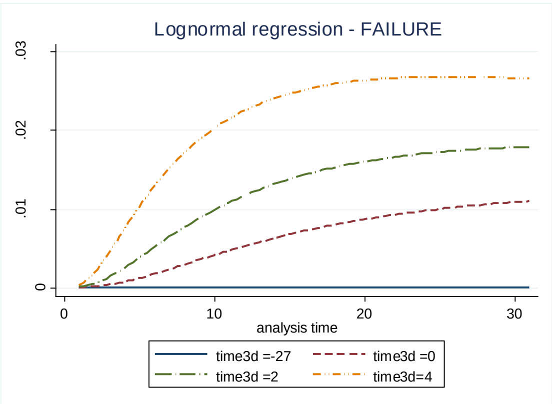

Figure IV - 15 Hazard curves for the effect of *Time to 3D* on FAILURE at observed minimum, maximum, average and at the year zero, defined as 2009.

6.3.Complementary analysis

The previous results compute the time to event, whether exit in general, liquidation or M&A. In this section we estimate the probability of the different types of exit occurring using a multinomial logit model. This approach allows the use of a more refined set of data that can account for yearly variation of conditions that may affect firm exit.

6.3.1. Data

In order to observe the yearly evolution of the industry and individuals through time and its effects on the probability of exiting either through failure or M&A, we constructed a panel with observations of all the firms active in production during the period 1982-2012. For each firm data was retrieved on its characteristics, as described on Table IV - 6.

To be able to compare the results with those of the competing risks model, we maintained dummies for size and experience of founders, as these are characteristics that do not vary with time. As to those characteristics that vary with time and on the previous models were measured either on the entry or exit year, here we have compiled their yearly variation. The only exception is density at entry, which we maintained for its effects are known to permanently influence the fate of firms. However, in order to confirm the pertinence of this variable, we also estimated a model using the industry's firm density each year of the life of a firm, which proved to be non-significant.

Table IV - 6 Description of the variables used on the multinomial logit model.

Variable	Description
GDP growth	GDP growth on the observed year (in %)
Age	Age of the firm in years
Age^2	Square of *Age*
Density	Number of firms at the foundation year of the firm
Major studio	Dummy that takes value=1 if the firm is part of one of the major or mini-major studio groups
Independent	Dummy that takes value=1 if the firm is an independent filmmaker
Producer	Dummy that takes value=1 if the founder has previous experience as producer
Director	Dummy that takes value=1 if the founder has previous experience as director
Spinoff	Dummy that takes value=1 if the firm is a spinoff from another studio
Actor	Dummy that takes value=1 if the founder has previous experience as actor
Adopt Digital	Dummy that takes value=1 if the firm had adopted digital cinematography on the observed year.
Adopt 3D	Dummy that takes value=1 if the firm had adopted 3D production on the observed year.

6.3.2. Multinomial logit model

The multinomial logit model, allows the estimation with *j* discrete dependent variables, in our case permanence in the industry, exit by failure, or exit by M&A. In this model we are calculating three possible outcomes, representing the probability of an exit mode to happen, depending on individual specific characteristics.

$$\Pr(y = j) = \frac{e^{X\beta_j}}{\sum_{k=0}^{j} e^{X\beta_j}}$$

This leads in our case to three equations. In order to solve the model, one of the outcomes is set to 0 and the coefficients of the other outcomes will measure the change relative to the base outcome (Greene, 1993). We will set outcome y=0, to 0 and so the probabilities we are estimating will be:

No exit: $\Pr(y = 0) = \frac{1}{1+e^{X\beta^{(1)}}+e^{X\beta^{(2)}}}$

Failure: $\Pr(y = 1) = \frac{e^{X\beta^{(1)}}}{1+e^{X\beta^{(1)}}+e^{X\beta^{(2)}}}$

M&A: $\Pr(y = 2) = \frac{e^{X\beta^{(2)}}}{1+e^{X\beta^{(1)}}+e^{X\beta^{(2)}}}$

Besides the possibility to analyse panel data, the multinomial logit has also the advantage to be an approximation to a discrete time hazard model, which allows confirming if the results hold under this different assumption.

As the estimated coefficients are not straightforward to interpret, we alternatively present on Table IV - 7 the marginal effects of each outcome, representing the variation of the probability of failure or alternatively M&A relatively to permanence in the industry.

Based on the likelihood ratio test, we can consider the model fits well the data. Observing the marginal effects for each mode of exit we notice that these are in line with the estimated results of the competing risks models. The estimates for the probability of M&A confirm that this form of exit is not affected by the adoption of innovations by firms, nor by individual characteristics of founders, as already observed on the survival model. Age and size have the expected effects on exit, in particular, under the multinomial logit model, these variables were significant. In the case of *Age* and *Age*^{2}, which in the multinomial logit model are measured each year, instead of on the entry year, the refined data demonstrated to be useful for it allowed for a more informative model.

Table IV - 7 Marginal effects of the multinomial logit model.

Marginal effects dy/dx	Failure		M&A	
GDP growth	0.16692		0.10348	
	(0.15)		(0.12)	
Age	0.00161	**	0.00109	*
	(0.00)		(0.00)	
Age^2	-0.00002	*	-0.00002	**
	(0.00)		(0.00)	
Density	0.00033	**	-0.00004	
	(0.00)		(0.00)	
Independent	-0.01642	***	0.01173	**
	(0.01)		(0.01)	
Major studio	-0.02017	**	0.01634	***
	(0.01)		(0.01)	
Producer	-0.00186		0.00091	
	(0.01)		(0.01)	
Director	-0.03217	*	-0.00790	
	(0.02)		(0.01)	
Spinoff	-0.00239		0.00181	
	(0.01)		(0.01)	
Actor	0.00683		-0.14336	
	(0.08)		(5.59)	
Adopt digital	-0.00095		0.00034	
	(0.01)		(0.01)	
Adopt 3D	-0.03462	**	-0.00758	
	(0.02)		(0.01)	
Log Likelihood	-343.598			
Chi^2	64.08	***		
Number of observations	2659			

Notes: *10% significant; **5% significant; ***1% significant. Standard errors in parenthesis.

As to the probability of failure, we observe similar effects on all variables, compared to the lognormal regression. As to the significant variables, the adoption of 3D production and actor background are not significant compared to the survival models. All other variables that were significant on the lognormal regression are also significant on the multinomial logit model.

7. Conclusions

While traditionally industry dynamics has been considering the fate of firms as a choice between permanence as success and exit as failure, this essay proposed that exit should be studied as a heterogeneous event, distinguishing bankruptcy and liquidation from mergers and acquisitions.

A careful review of literature found that only recently scholars begun to analyse firm exit as heterogeneous, which should be unexpected since the consequences of different exit forms are known for long to have different impacts on the remaining industrial population and the economy (Schary, 1991, Freeman *et al.*, 1983). In general, exit by merger and acquisition allows the industry to retain the productive capacity of the firm. On the other hand, when a firm closes, either voluntarily or by bankruptcy, there is a loss of productive capacity.

While a relevant aspect to firm management and economics, the different forms of exit have been elusive to scholars mainly due to scarcity of information on how firms exit a market. Usually these studies rely on industry surveys and census that do not directly aim to analyse different exit modes. Our analysis though uses primary data and relies mainly on an exhaustive search and study of the history of each firm included in our sample. This way, all entries and exits and their respective causes have been collected and a register of the mergers and acquisitions and the respective firms that came out of those operations has been made.

These comprehensive records obtained for the American motion picture industry during the period from 1982 to 2012 allowed analysing the different causes affecting different exit modes. In order to compare our approach with more traditional approaches to exit as a homogeneous event, we estimated survival models considering the two approaches. The results validated the pertinence of this analysis. We have analysed our unique datasets using survival analysis models and confirmed our analysis using a multinomial logit model.

Our findings show that firms that innovate or are early adopters have a higher chance of remaining active longer. In line with Cefis &Marsili (2012) we find that innovation, either digital process of 3D products, has an overall effect of delaying firm failure and closing down activity. On the other hand, mergers and acquisitions are accelerated by the delay in adopting a process innovation but not by product innovation.

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Appendix

I. Essay I - Subsequent work

Building on the results of Essay I, a subsequent review of literature of new case studies made possible to check the robustness of our previous analysis, from a total of 91 case studies selected for reading and analysis, we found 35 that studied all the aspects in our analysis (Table A 1).

Table A 1 Case studies used to confirm the robustness of the taxonomy of open innovation.

Case studies	Reference
COLUMBIA STEEL	Aylen, J. (2010). Open versus closed innovation: development of the wide strip mill for steel in the United States during the 1920s. *R&d Management*, *40*(1), 67-80.
KAYAK	Baldwin, C., Hienerth, C., & Von Hippel, E. (2006). How user innovations become commercial products: A theoretical investigation and case study.*Research policy*, *35*(9), 1291-1313.
GAMES	Burger-Helmchen, T., & Guittard, C. (2008). Are users the next entrepreneurs? A case study on the video game industry. *International Journal of Entrepreneurship Education*, *6*, 57-74.
ICE POWER, B&O, TOCCATA	Christensen, J. F., Olesen, M. H., & Kjær, J. S. (2005). The industrial dynamics of Open Innovation—Evidence from the transformation of consumer electronics.*Research policy*, *34*(10), 1533-1549.
P&G	Dodgson, M., Gann, D., & Salter, A. (2006). The role of technology in the shift towards open innovation: the case of Procter & Gamble. *R&D Management*,*36*(3), 333-346.
NOKIA	Dittrich, K., & Duysters, G. (2007). Networking as a means to strategy change: the case of open innovation in mobile telephony. *Journal of Product Innovation Management*, *24*(6), 510-521.
SAPIENS	Ebner, W., Leimeister, J. M., & Krcmar, H. (2009). Community engineering for innovations: the ideas competition as a method to nurture a virtual community for innovations. R&d Management, 39(4), 342-356.
PARIS BUS	Elmquist & Le MassonElmquist, M., & Le Masson, P. (2009). The value of a 'failed'R&D project: an emerging evaluation framework for building innovative

	capabilities1. R&d Management, 39(2), 136-152.
SWISS ENG	Enkel, E., Perez-Freije, J., & Gassmann, O. (2005). Minimizing market risks through customer integration in new product development: learning from bad practice. *Creativity and Innovation Management*, *14*(4), 425-437.
IBM, COATED COALSET, SOLON	Fichter, K. (2009). Innovation communities: the role of networks of promotors in Open Innovation. *R&d Management*, *39*(4), 357-371.
ALCAN	Goodrich, N., & Aiman-Smith, L. (2007). What does your most important customer want?. *Research-Technology Management*, *50*(2), 26-35.
KAYAK	Hienerth, C. (2006). The commercialization of user innovations: the development of the rodeo kayak industry. R&D Management, 36(3), 273-294.
TOKYO TECH	Lee, K. J. (2011). From interpersonal networks to inter-organizational alliances for university–industry collaborations in Japan: the case of the Tokyo Institute of Technology. *R&D Management*, *41*(2), 190-201.
CAMBRIDGE SPINOUT	Minshall, T. I. M., Seldon, S., & Probert, D. (2007). Commercializing a disruptive technology based upon University IP through Open Innovation: A case study of Cambridge Display Technology. *International Journal of Innovation and Technology Management*, *4*(03), 225-239.
ADIDAS	Piller, F. T. & Walcher, D. (2006).Toolkits for idea competitions: a novel method to integrate users in new product development. *R&D Management*, *36*(3), 307 – 318.
PRINTING, MOBILE, BEER, OSGV CAR, OSCAR,MEDIACENTER	Raasch, C., Herstatt, C., & Balka, K. (2009). On the open design of tangible goods. *R&d Management*, *39*(4), 382-393.
DEUTSCHE TELEKOM (idea to commercialisation)	Rohrbeck, R., Hölzle, K., & Gemünden, H. G. (2009). Opening up for competitive advantage–How Deutsche Telekom creates an open innovation ecosystem. *R&d Management*, *39*(4), 420-430.
VF ART	Stüer, C., Hüsig, S., & Biala, S. (2010). Integrating art as a trans-boundary element in a radical innovation framework. *R&d Management*, *40*(1), 10-18.
NOKIA TABLET	Stuermer, M., Spaeth, S., & Von Krogh, G. (2009). Extending private-collective innovation: a case study. *R&d Management*, *39*(2), 170-191.
AUTOCATALISTS	Tao, L., Garnsey, E., Probert, D., & Ridgman, T. (2010). Innovation as response to emissions legislation: revisiting the automotive catalytic converter at Johnson Matthey. *R&d Management*, *40*(2), 154-168.
NESTLÉ	Traitler, H. & Saguy, I. S. (2009). Creating Successful Innovation Partnerships. *Food Technology, 63* (3), 23 – 32.
APACHE, WINDSURF	Von Hippel, E. (2007). Horizontal innovation networks - by and for users. *Industrial and Corporate Change, 16* (2), 293-315

Using the same methodology we had used on Essay I, we were able to retrieve a classification into two main groups, which was able to demonstrate the robustness of the analysis, and a third branch emerged that contained two cases of failed attempts to develop a program of open innovation. In Figure A 1, the dendrogram with the 35 case studies is represented.

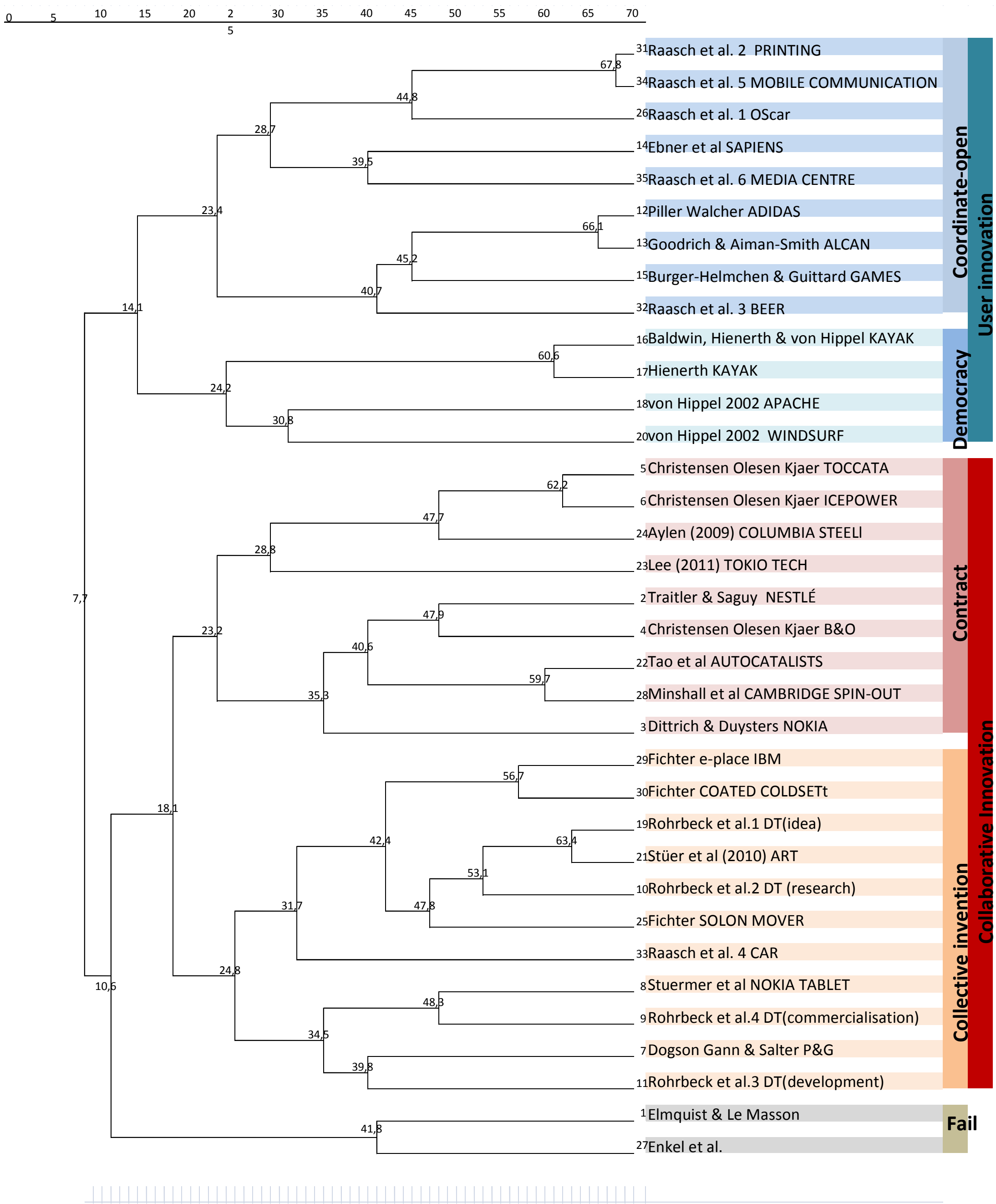


Figure A 1 Dendrogram grouping of cases of open innovation and a hierarchical classification of types of open innovation.

From the pairing and grouping of cases into strategies of open innovation, it is possible to observe distinctive patterns that allow for a hierarchical classification of strategies. We can divide open innovation strategies into two major groups:

Group 1, highlighted in blue, consists only of cases of free revealing and user innovation. We call it User innovation. It is possible to further divide this group of firms into two sub-groups and identify the underlying strategies:

Democracy: in this group it is possible to find cases of user innovation where groups of users freely reveal knowledge horizontally, in order to develop new products (Example: Rodeo Kayak and the cases of open source software and windsurf, where users are creating new industries or products)

Coordination: In this group, the user-innovators provide knowledge and ideas to one coordinator, possibly a firm, in order to develop innovations (example: Adidas, large companies that engaged on OI by connecting to and gathering information from their costumers in order to develop new products)

Group 2, highlighted in red, does not include cases of user innovation and has in general cases in high technology industries. We call it Collaborative innovation. It is also divided into two sub-groups.

Collective invention: here we find networks of firms that share information and develop new products together. The importance of “interaction” is central on its strategy.

Contract: As the name suggests, this is the most formal strategy, where it is possible to find a deliberate intention to formalise contracts and use intellectual property protection tools. Instead of networks of firms, we find mostly partnerships or dyads.

Table A 2 presents a synthesis of the strategies that characterise each group of case studies.

Table A 2 Summary of open innovation strategies

		DEMOCRATIC	COORDINATE-OPEN	COLLECTIVE	CONTRACT
INDUSTRIES	**Market**	low competition	trend: tech	high tech; low uncertainty	high tech
	Organizations	low R&D intensity	trend: innovativeness	all important	high R&D/ innovativenesss
	Human	technical background/ networking	technical background/ networking	networking skills	trend: technical background
WHO & HOW	**Type of interaction**	trend: communities	trend: mass collaboration	trend: networks	trend: dyads
	Knowledge origin	users	education, users others	no trend	trend: suppliers
	Collaboration strategy	no trend	trend: interaction	no trend	no trend
INNOVATION	**Phase**	idea, development, consumer	all phases	product development	product development
	Type of innovation	product	product, process	product	trend: product
	Newness	trend: really new	trend: incremental	no trend	trend: really new
RELATION	**Orientation**	no trend	trend: non-arm's length	no trend	trend: vertical
	Embeddedness	strong	weak	trend: strong	trend: strong
KNOWLEDGE	**Formality**	informal	informal	no trend	trend: research consortia
	Intellectual property	no trend	no IP	trend: no IP	patents and licenses

Based on Table A 2, we propose a graphical representation of strategies according to the position in terms of market competition and technological intensity (Figure A 2). In this representation, we synthesise the size of the collaboration in number of participants, represented by the size of the circles; the openness degree, in terms of knowledge disclosure and IP protection, by permeability of the lines that contain the circle; the arrows represent the source of knowledge, whether it comes from downstream users or upstream researchers and suppliers.

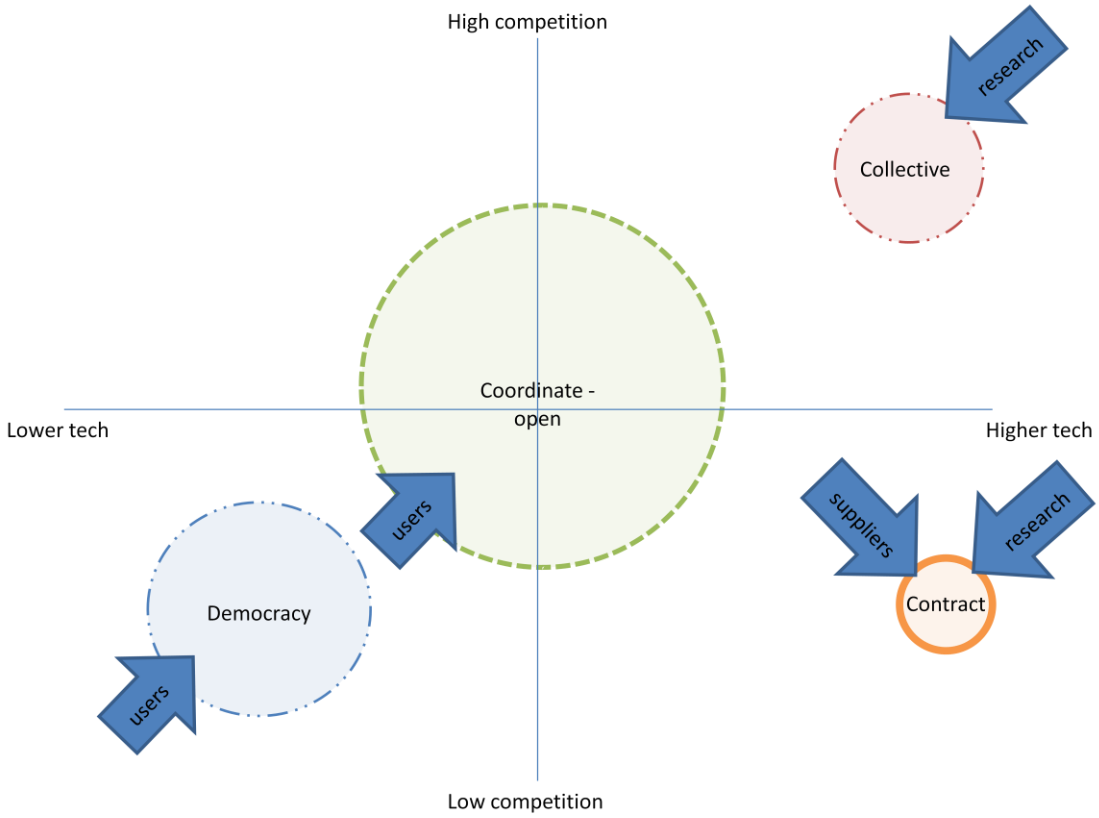


Figure A 2 Open innovation strategies represented in a Technology intensity vs. Market competition space.

II. Essay II

a. Correlation matrix

Table A 3 Correlation matrix

	density	salent	salgex	pw	cohort1	cohort2	cohort3	predes1	predes2	c1	c2	c3	c4	c5
density	1													
salent	-0.026	1												
salgex	0.089	-0.036	1											
pw	0.454	-0.235	-0.090	1										
cohort1	0.084	0.010	-0.003	-0.005	1									
cohort2	-0.084	-0.026	-0.060	0.009	-0.404	1								
cohort3	-0.042	0.004	0.038	0.000	-0.851	-0.138	1							
predes1	0.084	0.010	-0.003	-0.005	1.000	-0.404	-0.851	1						
predes2	0.042	-0.004	-0.038	0.000	0.851	0.138	-1.000	0.851	1					
c1	-0.538	-0.323	-0.022	-0.066	-0.031	0.112	-0.031	-0.031	0.031	1				
c2	0.165	-0.562	0.096	0.049	0.035	-0.070	0.002	0.035	-0.002	-0.273	1			
c3	0.656	0.019	0.017	0.458	-0.011	-0.024	0.026	-0.011	-0.026	-0.207	-0.429	1		
c4	-0.245	0.040	-0.096	-0.177	0.020	0.023	-0.034	0.020	0.034	-0.089	-0.184	-0.140	1	
c5	-0.319	0.859	-0.058	-0.384	-0.016	0.007	0.014	-0.016	-0.014	-0.193	-0.400	-0.303	-0.130	1

b. Descriptive statistics

Table A 4 Descriptive statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Entry	1922.89	15.53377	1883	1967
Exit	1929.528	19.41768	1889	2012
Fail	0.891509	0.311244	0	1
Years active	7.638365	13.49709	1	121
End	1928.939	17.47162	1889	1975
Density	88.4717	40.80811	1	154
Salent	145.9867	163.2054	0.001	558.694
Salgex	4.355523	63.13751	-142.733	189
Pw	0.342767	0.475008	0	1
cohort1	0.713837	0.452323	0	1
cohort2	0.061321	0.240107	0	1
cohort3	0.224843	0.417807	0	1
predes1	0.713837	0.452323	0	1
predes2	0.775157	0.417807	0	1
c1	0.116352	0.320899	0	1
c2	0.361635	0.480852	0	1
c3	0.245283	0.430594	0	1
c4	0.056604	0.231266	0	1
c5	0.220126	0.414657	0	1

c. Proportional Hazards tests

Table A 5 Model 1

PHTEST	rho	chi2	df	Prob>chi2
density	-0.0012	0	1	0.9785
salent14	-0.0616	2.13	1	0.1441
salgex14	-0.0509	1.68	1	0.1946
pw	0.0589	1.84	1	0.1754
cohort2	0.1076	6.31	1	0.012
cohort3	0.0616	2.13	1	0.1443
global test		11.9	6	0.0642

Table A 6 Model 2

PH TEST	rho	chi2	df	Prob>chi2
density	0.0055	0.02	1	0.899
salent	-0.1008	5.36	1	0.0206
salgex	-0.0505	1.65	1	0.1985
pw	0.0617	2.01	1	0.1567
predes1	-0.1061	6.01	1	0.0142
global test		11.52	5	0.042

Table A 7 Model 3

PH TEST	rho	chi2	df	Prob>chi2
density	-0.0669	2.45	1	0.1176
salent	-0.0026	0	1	0.9505
salgex	-0.0583	2.1	1	0.1473
pw	0.0526	1.53	1	0.2162
predes2	0.0045	0.01	1	0.9195
global test		6.3	5	0.2782

Table A 8 Model 4

PH TEST	rho	chi2	df	Prob>chi2
density	0.0800	3.42	1	0.0644
salent	-0.0178	0.16	1	0.6874
salgex	-0.0824	3.85	1	0.0497
c2	-0.0675	2.69	1	0.1008
c3	-0.0746	3.12	1	0.0771
c4	0.0927	4.64	1	0.0311
c5	0.0051	0.01	1	0.9077
global test		22.26	7	0.0023

d. Cox-Snell residuals and testing heterogeneity

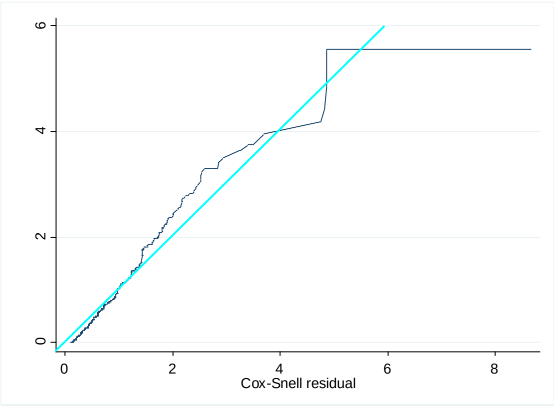
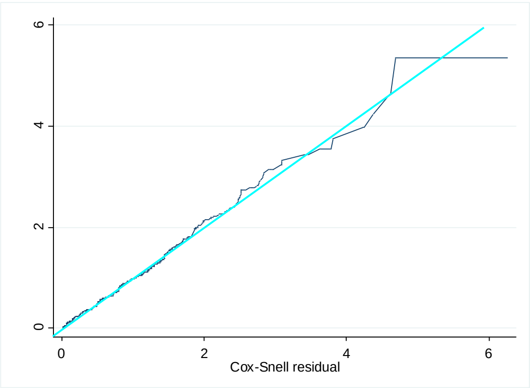


Figure A 3 MODEL 1 , Cox Proportional hazards model



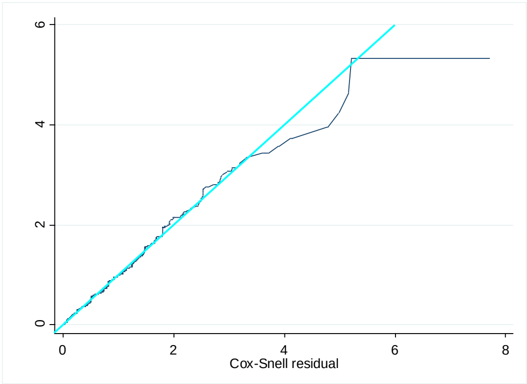


Figure A 4 MODEL 1, LOGNORMAL/ MODEL 1, LOGNORMAL FRAILTY

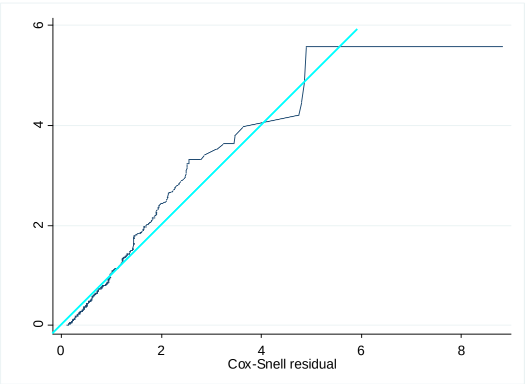


Figure A 5 MODEL 2, COX PH

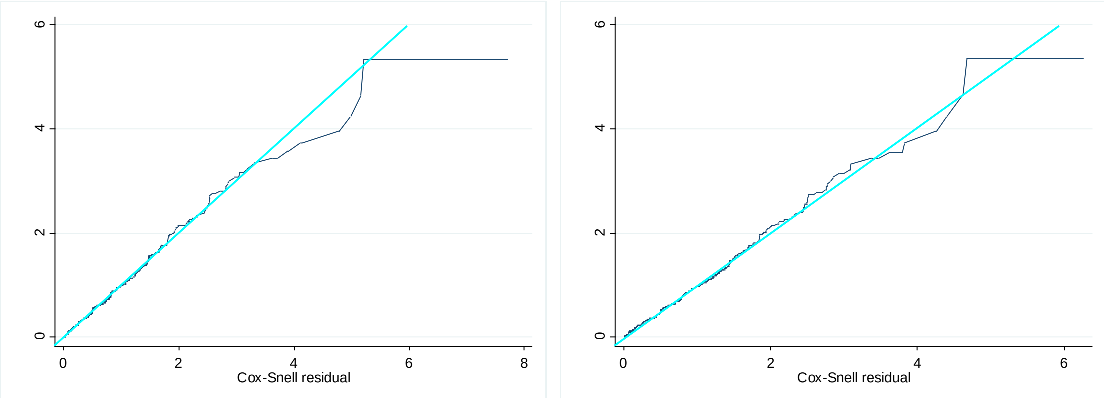


Figure A 6 MODEL 2, LOGNORMAL/ MODEL 2, LOGNORMAL FRAILTY

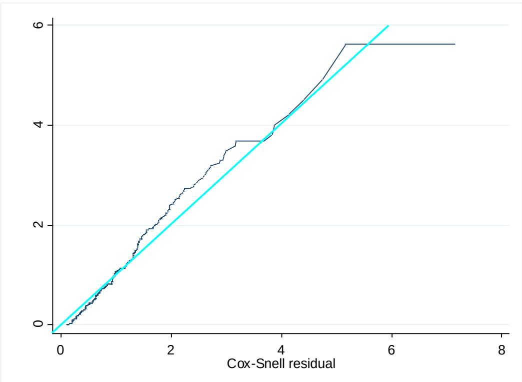


Figure A 7 MODEL 3, COX PH

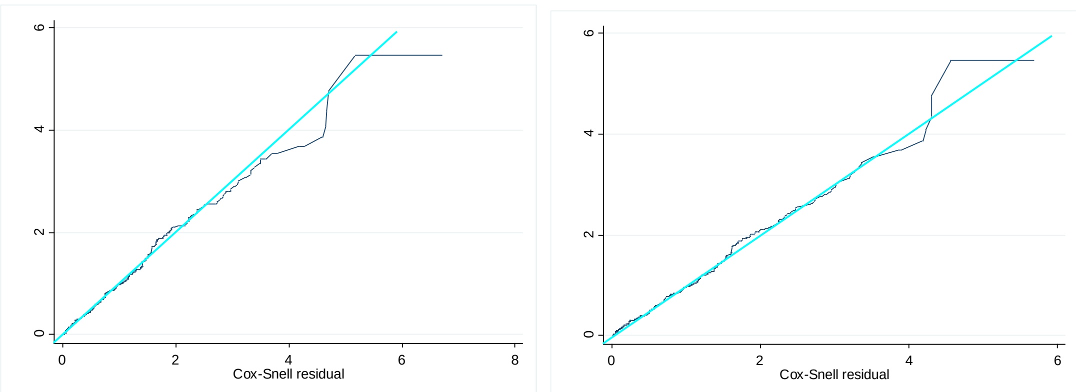


Figure A 8 MODEL 3, LOGNORMAL/ MODEL 3, LOGNORMAL FRAILTY

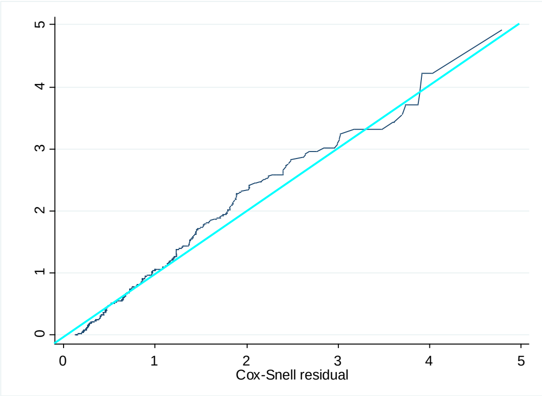


Figure A 9 MODEL 4, COX PH

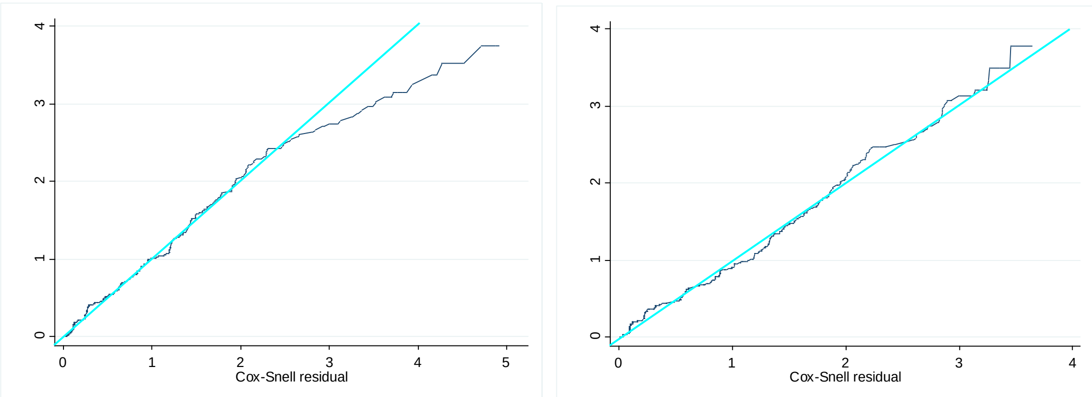


Figure A 10 MODEL 4 LOGNORMAL/ MODEL 4 LOGNORMAL FRAILTY

e. Heteroskedasticity

Table A 9 Model 1 estimated with robust standard errors

MODEL 1	Coef.		Robust S.E.
Density	-0.0109	***	0.00
salent14	-0.0020	***	0.00
salgex14	-0.0007		0.00
Pw	1.3947	***	0.09
cohort2	0.8445	***	0.24
cohort3	0.8373	***	0.34
_cons	1.8901	***	0.15
/ln_sig	-0.0275		0.03
Sigma	0.9728		0.03
Log pseudolikelihood	-851.6277		
CHI2	364.32	***	

Table A 10 Model 2 estimated with robust standard errors

MODEL 2	Coef.		Robust S.E.
Density	-0.0109	***	0.00
salent14	-0.0020	***	0.00
salgex14	-0.0007		0.00
Pw	1.3950	***	0.09
predes1	-0.8434	***	0.24
_cons	2.7326	***	0.19
/ln_sig	-0.0275		0.03
Sigma	0.9729		0.03
Log pseudolikelihood	-851.6282		
CHI2	364.25	***	

Table A 11 Model 3 estimated with robust standard errors

MODEL 3	Coef.		Robust S.E.
Density	-0.0138	***	0.00
salent14	-0.0005		0.00
salgex14	-0.0010		0.00
Pw	1.3050	***	0.09
predes2	-0.1523		0.28
_cons	2.3236	***	0.25
/ln_sig	-0.0113		0.03
Sigma	0.9887		0.03
Log pseudolikelihood	-859.5275		
CHI2	351.77	***	

Table A 12 Model 4 estimated with robust standard errors

MODEL 4	Coef.		Robust S.E.
density	-0.0046	*	0.00
salent14	-0.0006		0.00
salgex14	-0.0023	***	0.00
c2	-0.2588		0.25
c3	-0.4861		0.31
c4	0.0672		0.29
c5	-0.4294		0.40
_cons	2.1683	***	0.20
/ln_sig	0.1142	***	0.03
sigma	1.1210		0.03
Log pseudolikelihood	-931.9437		
CHI2	79.39	***	

III. Essay III

a. Correlation matrix

Table A 13 Corelation matrix

	GDPg	density	featent	featex	producer	director	actor	spinoff	major	indep.	feature	sound	attv	atxmaj.	atxindy	eastman	digital
GDPg	1																
density	0.006	1															
featent	0.018	0.151	1														
featex	-0.03	0.176	0.347	1													
producer	0.012	0.057	0.133	0.112	1												
director	0.015	-0.003	-0.035	-0.025	-0.42	1											
actor	0.02	-0.073	-0.079	-0.055	-0.264	-0.119	1										
spinoff	0.043	0.122	-0.07	-0.116	-0.374	-0.17	-0.11	1									
majorstudio	0	0.108	-0.074	0.052	-0.029	-0.068	-0.1	0.311	1								
independent	-0.02	-0.204	0.05	0.082	0.002	0.075	0.075	-0.327	-0.403	1							
feature	-0.05	0.329	0.452	0.152	0.102	0.056	0.011	-0.085	-0.152	-0.015	1						
sound	0.096	0.325	0.087	-0.173	0.188	-0.032	-0.05	0.13	0.136	-0.243	0.211	1					
attv	0.037	-0.268	0.102	-0.162	-0.03	0.07	-0.01	0.02	0.089	-0.034	0.063	0.159	1				
atxmajor	-0.02	-0.114	0.1	0.036	0.102	-0.029	-0.04	-0.018	0.348	-0.029	0.03	-0.08	0.471	1			
atxindy	0.024	-0.232	0.07	-0.137	0.002	0.052	-0.01	-0.037	0.052	0.138	0.054	0.131	0.862	0.386	1		
eastman	0.077	0.654	-0.072	-0.059	0.109	-0.019	-0.09	0.183	0.213	-0.297	0.149	0.707	-0.25	-0.116	-0.212	1	
digital	0.011	0.744	0.041	0.091	0.064	-0.039	-0.05	0.101	0.047	-0.137	0.072	0.341	-0.12	-0.056	-0.102	0.483	1

b. Descriptive statistics

Table A 14 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
entry	488	1947	35.4	1891	2012
exit	488	1958	40.81	1910	2012
yactive	488	11.86	14.31	1	97
density	488	59.60	29.96	1	132
feature	488	0.96	0.19	0	1
sound	488	13.25	0.50	0	1
eastman	488	7.80	0.48	0	1
digital	488	0.12	0.32	0	1
featent	488	497.04	215.54	0	854
featex	488	609.87	166.34	0	854
producer	488	0.48	0.50	0	1
director	488	0.16	0.37	0	1
actor	488	0.07	0.25	0	1
spinoff	488	0.13	0.34	0	1
attv	488	0.09	0.29	0	1
independent	488	0.80	0.40	0	1
majorstudio	488	0.16	0.37	0	1
atxindy	488	0.07	0.26	0	1
atxmf	488	0.09	0.34	0	2
GDPg	488	0.03	0.02	-0.05	0.14

c. Cox-Snell residuals and testing the existence of heterogeneity

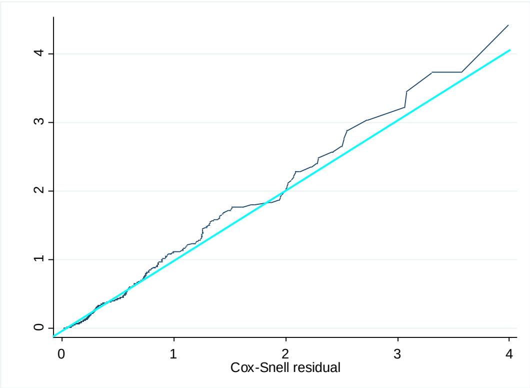


Figure A 11 COX PH FRAILTY MODEL

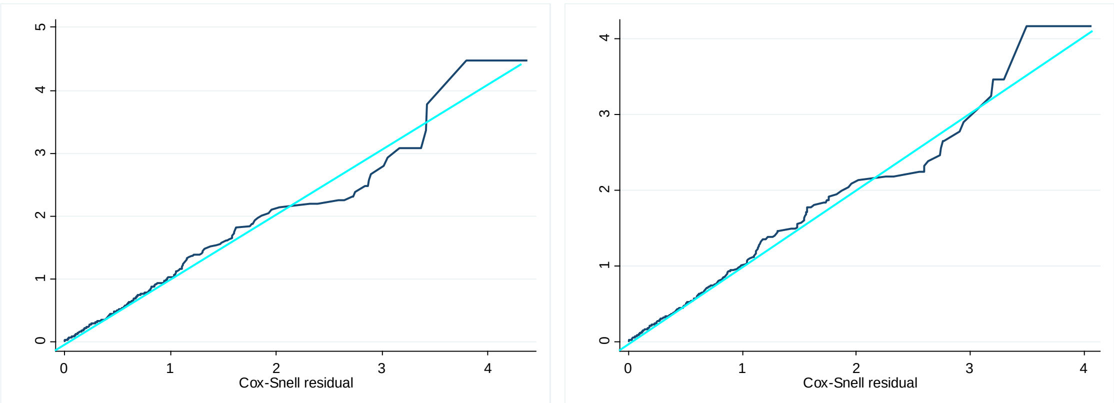


Figure A 12 LOGNORMAL/ LOGNORMAL FRAILTY MODEL

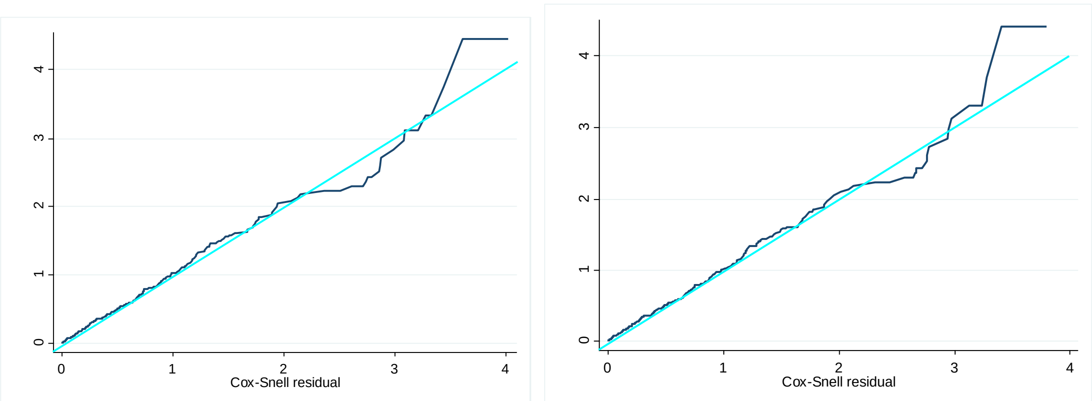


Figure A 13 LOGLOGISTIC/ LOGLOGISTIC FRAILTY MODEL

d. Heteroskedasticity

Table A 15 Lognormal model estimated with robust standard errors

	Coef.		Robust Std. Err.
gdpavgr5ent	-0.3470		2.06
density	-0.0193	***	0.00
featent	0.0001		0.00
featex	-0.0003		0.00
producer	0.3007	**	0.15
director	0.0480		0.17
actor	0.1344		0.22
spinoff	0.4702	**	0.24
majorstudio	0.8669	***	0.24
independent	0.3590	**	0.18
feature	-0.0937		0.35
sound	0.2991		0.21
eastman	2.2178	***	0.29
digital	0.5395	*	0.31
attv	1.7989	***	0.53
atxmf	1.5213	**	0.63
atxindy	-2.6196	***	0.78
_cons	1.9158	***	0.42
Log PseudoLikelihood	-501.3525		
Chi^2	442.02	***	

IV. Essay IV

a. Correlation matrixes

Figure A 14 Survival model

	producer	director	spinoff	actor	density	indepe~t	majors~o	age82	age82sq	gdpgrexp	timedig	time3d
producer	1											
director	-0.3782	1										
spinoff	-0.4980	-0.1699	1									
actor	-0.2149	-0.0733	-0.0966	1								
density	-0.0152	-0.1728	0.0659	-0.0931	1							
independent	0.0621	0.1159	-0.2368	0.0902	-0.0921	1						
majorstudio	-0.0204	-0.1118	0.1846	-0.1309	0.0643	-0.4451	1					
age82	0.0776	0.0618	-0.0725	0.0647	-0.5229	0.0075	0.2226	1				
age82sq	0.0951	0.0368	-0.0700	0.0013	-0.3529	-0.0269	0.2700	0.9508	1			
gdpgrexp	0.0559	-0.0483	0.0185	0.0565	-0.2769	0.0201	-0.0508	0.0316	-0.0179	1		
timedig	-0.0194	-0.0653	-0.0522	0.0151	-0.1430	0.1402	-0.1196	0.0013	-0.0785	0.1871	1	
time3d	-0.1281	-0.0189	0.0508	0.0731	0.1987	0.0681	-0.3184	-0.4434	-0.4387	0.0239	0.0583	1

Figure A 15 Multinomial Logit model

	producer	director	spinoff	actor	density	indepe~t	age	agesq	majors~o	GDPg	adopt3d	adoptdig
producer	1											
director	-0.467	1										
spinoff	-0.445	-0.192	1									
actor	-0.209	-0.090	-0.086	1								
density	-0.001	-0.222	0.115	-0.116	1							
independent	0.012	0.203	-0.326	0.128	-0.029	1						
age	0.090	0.118	-0.135	0.054	-0.582	-0.063	1					
agesq	0.122	0.060	-0.121	0.006	-0.418	-0.096	0.938	1				
majorstudio	0.043	-0.170	0.172	-0.124	0.015	-0.476	0.284	0.361	1			
GDPg	0.007	0.021	-0.020	0.008	-0.204	0.002	-0.032	-0.015	-0.007	1		
adopt3d	0.067	-0.070	0.054	-0.088	0.110	-0.222	-0.087	-0.104	0.178	-0.043	1	
adoptdigital	0.034	-0.022	0.039	-0.023	0.298	-0.108	0.091	0.074	0.092	-0.326	0.172	1

b. Descriptive statistics

Figure A 16 Survival model

Variable	Obs	Mean	Std. Dev.	Min	Max
origin	175	1988.886	17.67551	1916	2012
enterstudy	175	1993.006	9.011804	1982	2012
exit	175	2007.063	7.932296	1984	2012
exitpooled	175	0.405714	0.492439	0	1
fail	175	0.234286	0.424767	0	1
m&a	175	0.171429	0.377965	0	1
exitmode	175	0.577143	0.768296	0	2
producer	175	0.525714	0.500771	0	1
director	175	0.114286	0.319071	0	1
spinoff	175	0.182857	0.387659	0	1
actor	175	0.04	0.196522	0	1
density	175	85.54857	31.36615	25	132
independent	175	0.645714	0.479669	0	1
majorstudio	175	0.291429	0.455724	0	1
yactive	175	19.17714	16.74616	1	97
age82	175	4.12	11.83228	0	66
age82sq	175	156.1771	653.9996	0	4356
gdpgrexp	175	2.872451	1.034126	-2.80242	7.25898
timedig	175	9.377143	4.560644	-4	14
time3d	175	2.125714	5.245268	-27	4

Figure A 17 Multinomial Logit Model

Variable	Obs	Mean	Std. Dev.	Min	Max
origin	2659	1983.732	19.45438	1916	2012
exit	2659	2008.946	6.272055	1984	2012
enter	2659	1999.441	8.504227	1982	2012
fail	2659	0.015419	0.123237	0	1
m&a	2659	0.011282	0.105638	0	1
exitmode	2659	0.037984	0.243164	0	2
producer	2659	0.519744	0.499704	0	1
director	2659	0.167732	0.373699	0	1
spinoff	2659	0.154569	0.361562	0	1
Actor	2659	0.038736	0.193002	0	1
Density	2659	75.4419	28.90339	25	132
Independente	2659	0.660399	0.473663	0	1
Yactive	2659	26.21361	19.66911	1	97
Age	2659	15.70891	17.96547	0	96
Majorstudio	2659	0.277548	0.447873	0	1
Agesq	2659	569.4065	1375.863	0	9216
GDPg	2659	0.026416	0.019299	-0.028	0.073
adopt3d	2659	0.160211	0.36687	0	1
adoptdigital	2659	0.263633	0.440685	0	1

c. Estimations – Multinomial Logit model coefficients

Figure A 18 Estimated Multinomial Logit Coeficients

	Failure		M&A	
GDPg	11.2882		9.5542	
	(10.26)		(11.16)	
Age	0.1093	**	0.1001	*
	(0.05)		(0.05)	
Agesq	-0.0014	*	-0.0018	**
	(0.00)		(0.00)	
Density	0.0220	**	-0.0030	
	(0.01)		(0.01)	
Independent	-1.0893	***	1.0487	**
	(0.38)		(0.49)	
Major studio	-1.3364	***	1.4636	***
	(0.54)		(0.46)	
Producer	-0.1237		0.0807	
	(0.45)		(0.59)	
Director	-2.1638	**	-0.7482	
	(1.09)		(0.83)	
Spinoff	-0.1587		0.1620	
	(0.55)		(0.68)	
Actor	0.3201		-13.0074	
	(0.74)		(507.66)	
Adopt digital	-0.0635		0.0301	
	(0.43)		(0.54)	
Adopt 3d	-2.3277	**	-0.7211	
	(1.03)		(0.64)	
_cons	-5.7953	***	-6.3061	***
	(1.33)		(1.60)	