MASTER THESIS

INVENTOR MOBILITY OVER THE INDUSTRY LIFE-CYCLE: CASE STUDY OF THE TELEVISION INDUSTRY

AN EMPIRICAL ANALYSIS

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ABSTRACT

Firms from the United States (U.S) were the original innovators of the television at the end of the 19th century. They were able to capitalize on their technological advantage and grow to be the leading innovators and producers of television sets till the 1960s. This changed with the entrance of foreign firms, namely the Japanese firms, who competed and eventually overtook U.S firms as leading innovators and producers by the 1970s. Today, U.S manufacturers of televisions are almost non-existent and largely irrelevant in a global context. This research paper utilizes the concepts of Vernon's (1966) product life-cycle model and theories from the field of inventor mobility to explore this phenomenon of lost technological dominance. So as to provide a better understanding of firm characteristics and industry dynamics that led to the decline of the original innovators of the television. The main findings of this paper show that inventor mobility is, higher for firms in the television industry when compared to firms of more "mature" industries. In addition, his paper will further explore firm characteristics and the effects it has on inventor mobility.

KEY WORDS: Inventor Mobility, Television, Firm level, Industry life-cycle

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1. INTRODUCTION

This research paper combines theories of inventor mobility and the product life-cycle model using the television industry as a case study. With globalization and foreign direct investment (FDI) increasing through the years, the reach of multi-national companies (MNC's) has dramatically increased in recent decades. This globalization and increase in global FDI has blurred the boundaries of markets and numerous free-trade agreements have made the world into more of a global market place where MNC's compete for a share of the global market. The focal point of this research paper will be inventor mobility, in the television industry, across the different stages of the product life-cycle model. Comparisons will be made to firms that are in "*mature*" industries so that comprehensive conclusions can be drawn.

Inventor mobility has received increasing attention by academics in recent years with the majority of these studies focusing on management and organizational perspectives. Inventor mobility can be described as the mobility of highly-skilled personnel across firms, academia, business sectors or geographic locations (Miguélez. E et al, 2009). A large branch of mobility theory suggests that knowledge diffusion or knowledge spillover is brought about by the mobility of skilled labour (Almeida & Kogut, 1999; Song et al.,2003; Kim et al., 2006). Literature also suggests that the global environment has shift towards a knowledge based economy and a "shrinking world" has led to an increase in mobility of employees that has numerous corporate implications (Chesbrough, 2003). This research paper will show how and which company characteristics affect inventor mobility in the television industry in the context of product life-cycle model.

There are several distinct periods in the TV industry that fit with Vernon's (1966) product life-cycle model. Vernon's model consists of three main stages, namely *innovation, maturity* and *standardization.* These stages are elaborated in greater detail in the next sections. For this research paper, the focus will be inventor mobility at the life-cycle stages of *growth* and *maturity.* Which, on a time scale, corresponds to 1960s onwards, this is the period of time which the U.S loses its' foothold in the TV production market.

The television (TV) industry can be traced to starting in the United States (U.S) and the United Kingdom in the late 1930's. There was a pause in the progress of the TV industry due to World War II, after which, the U.S was the leading innovator and producer of television sets globally. This market dominance by U.S firms ended in the late 1960's with stiff competition from Japanese firms, who overtook the U.S in production of both Black & White (B&W) and colour TV's (Appendix I & II).

Although research has been done in the fields of both inventor mobility and product life-cycle, little has been done to combine these theories. This research papers sets to answer and explore some of these questions empirically. This research finds that inventors and firms in the television industry have a significantly higher level of inventor mobility to "*mature*" industries. It can be theorized that high inventor mobility leads to high diffusion of knowledge which in turn contributed to Japanese firms becoming the leading innovators in the television industry displacing the original innovators of the television, U.S firms.

This paper will first provide a brief history of the television industry (section 2) followed by a literature review that will discuss existing theory of inventor mobility and the product life-cycle concluding with the hypotheses developed for this research (section 3). Section 4 and 5 will provide the data and methodology that are used for analyses and the testing of hypotheses. Results of this research paper are presented in section 6 followed by a brief section of additional analyses (section 7) that will present trends at the inventor level. This paper will be concluded in section 8 where the main findings are reiterated and possible further researches in the topic are discussed.

2. A Brief History of the Television Industry

In 1937, the coronation of King George VI and the Wimbledon tennis tournament were televised in England. During this period, only nine thousand television sets were sold in London. Until this period, televisions were more of a hobby and of an experimental nature. Up to the 1940's, commercial production of televisions was slow and there were approximately 7,000 television sets in the U.S in 1941. With the start of World War II, commercial production of televisions was halted but it rapidly picked up after WWII. By 1950, more than 9 million television sets had been sold in America which translates to about 9% of U.S. households[1]. The sales of televisions continued to grow exponentially and TV ownership in 2011 in the U.S was at 96.7%[2] .

The Radio Corporation of America (RCA) played an influential role in the birth and the subsequent growth of the television industry. RCA was first conceived in 1919 as a manufacturing patent pool by the leading firms in the producers of radio equipment. RCA enjoyed a dominant position for AM receiver patents and in a 1939 RCA publication boasted that "practically all domestic manufacturers of broadcast receivers" operated under RCA licenses. The patent position of RCA in VHF was even more dominant than in AM broadcasting. Major players in the industry such as Westinghouse, General Electric and other members of the RCA patent pool consolidated research for television in the 1920s and the company maintained the largest research staff in the industry through the 1930's (Boddy, 1993).

This strong relation between radio producers entering and being successful in the TV industry is highlighted in Klepper and Simon (2000). In their study, the authors find that during the formative years of the television industry, there was a large influx of entrants into market but firms with prior experience in the radio industry, who not only entered the TV industry earlier but were also more successful. They go on to show that although a large number of firms initially enter the TV industry in the initial stages, an industry shakeout occurred when a large number of firms were unable to continue being competitive and exited the market. It is shown that firms with prior radio experience were significantly more likely to survive this industry shakeout.

The 1950s is generally seen as the formative decade of American television industry, this is the period of time when the product and medium developed from its scientific origins to a ubiquitous consumer good, in addition to unique program forms and production practices. The 1950s marked the television most rapid growth that surpassed radio growth of the 1920s.

[1] Source: http://www.tvhistory.tv/Annual_TV_Sales_39-59.JPG [Accessed 21/10/2013]
[2] Source: http://www.nytimes.com/2011/05/03/business/media/03television.html, [Accessed 21/10/2013]

During this post-WWII period, the U.S electronics industry grew from $500million in sales in 1940 to over $2.5 billion in sales. Much of this growth can be attributed to growth in television equipment sales, with $1.35 billion of the total sales in 1950 being represented by television receiver sales (Broody, 1993).

Up until the 1970's, the U.S was the market leader responsible for the production of the majority of television sets globally. More specifically, U.S firms were leaders in production of B&W televisions till the mid-1960s. For colour television sets, U.S firms led in terms total production quantity till the late-1960s (Appendix I & II). However, as can be seen in Appendix I & II, U.S production for B&W began to decline after Japan had overtaken U.S production in the late 1960s, whereas for colour television sets, quantity of U.S production continued to increase steadily till 1994. One explanation is that, in order for U.S firms to lower their cost of production, many manufacturers began offshoring production, whereas, domestic production was focused on manufacturing more sophisticated TV's and higher value-added colour TV's (Gao & Tisdell, 2005).

This is a distinct characteristic of the *maturity* stage in Vernon's (1966) product life-cycle model. The U.S began colour TV broadcasting and sales of colour TV's grew to 5 million by 1966. This marked the initial phases of the growth stage for the U.S colour TV market, in which most of production was domestic (Gao & Tisdell, 2005). This was set to change when the license to produce colour TV was obtained by RCA and, later, Japanese companies acquired technology licensing agreements from Radio Corporation of America (RCA) and General Electric (GE). This enabled Japanese to rapidly achieve economies of scale and out manufacture their American counterparts.

During the 1980's, China imported more than a hundred production lines, 60% of which were from Japan. This rapidly increased China's technical knowledge and operational expertise of these technologies, which led to an exponential increase in capacity in production. By the mid 1980's, China replaced Japan in quantitative terms as the largest producer of TV sets (Gao & Tisdell, 2005). A recent report[3] finds that the top five companies in the flat panel TV's make up for ~62% of market share by revenues. Among these top five companies, three of these firms are Japanese and the top two are South Korean firms, much of these firms production happens in China. This is a clear indication that the original innovators of the television (U.S) are no

[3] Source: http://bgr.com/2012/06/21/global-tv-sales-lcd-shipments-down/ [Accessed 10th Oct 2013]. Data compiled by *Displaysearch.*

longer competitive in the market and this can be attributed to characteristics of the product life-cycle, globalization and foreign direct investment (FDI).

Ever since Japanese firms acquired licensing deals for television patents from RCA in the late 1960s, Japanese firms have continued to rapidly grow and are one of the leading innovators in the industry today. Japanese firms have successfully built upon patents that were developed by the initial innovators (U.S) more successfully than the incumbent firms. In the 1970s, Japanese firms set up production facilities in the U.S and this would mean hiring employees in the U.S. As will be discussed in the next section, knowledge spillovers will occur and Japanese firms will be able to learn from their counterparts. Literature suggests that employees of higher skilled labour have a higher level of knowledge spillover. Based on these theories, Japanese firms setting up facilities in the U.S market and attracting U.S inventors would greatly benefit the Japanese firm and, also, help explain the mechanics behind this transfer of innovation advantage from the U.S to Japanese firms; this will be explored in greater depth in following sections.

3. Literature Review

In this section, theories developed in the fields of product life-cycle and inventor mobility will be discussed, which will provide the framework for this research paper. Since the invention of the television in the late nineteenth century, the television has evolved from a science project to be in a majority of households around the world. Stage characteristics of Vernon's product life-cycle model can be clearly seen in the history of the television industry and these stages are further elaborated in section 3.1. As mentioned in the introduction, inventor mobility is an important aspect of this research paper and relevant existing literature of this topic are covered in section 3.2.

3.1 The Product-cycle Theory

Vernon (1966, 1979) constructed and developed the product-cycle hypothesis, according to Vernon, a product will go through a cycle that starts from innovation and eventually leads to a standardization of the product. There are three distinct phases in this theory; (1) *innovation*, (2) *maturing* and (3) *standardization*.

In the *innovation* stage, this is the first stage when the product is first conceived and the product's design and specifics are relatively unstandardized. The product is typically produced in a high-income country and produced & designed on a small scale (Vernon, 1966). This stage is also characterized by relatively low price elasticity of demand. Another characteristic of this stage is that a small number of firms are in the field and usually limited to their domestic markets. In the case of the television, this was the period pre-WWII, where the television manufacturing industry had just begun. Innovation and initial production of B&W television sets started and TV broadcasting began in 1936 by BBC and in 1941 in the U.S. The expected progression of TV development was halted with the onset of World War II.

The second phase of the product-cycle, *maturity*, is typically when a technology and product become relatively stable. As the demand for the product expands, some degree of standardization takes place. In this stage, demand for the product would have grown to a level where it is feasible for firms to produce the product locally; this could include various mechanisms such as foreign direct investment (FDI), technology licensing trade, science and technology agreements and technology import. During this time, the product may be re-exported to the innovating country which might have moved on to newer versions of the technology (Vernon, 1966).

The third phase of the product-cycle, standardisation stage, occurs when the original product becomes standardized and its production moves towards unskilled labour-intensive production. Consumers become familiar with the product and often time, numerous producers will introduce their version of the product to the market. This stage also characterizes movement of production as a result of FDI to seek cost benefits and market penetration benefits (Vernon, 1966).

In a later paper, Vernon conceded that due to the effects of international institutional change and globalisation, the product life-cycle theory was less effective at measuring and predicting interactions between industrialised and developing countries (Vernon, 1979). However, he pointed out that the product cycle concept continues to be valid and still be to explain certain categories of foreign direct investments. Since this time, several variations of product life-cycle model have been developed upon Vernon's model.

The product life-cycle model was further developed by Markusen et al. (1996) and Hirsh (1967, p. 23-45) divide the product cycle into three phases similar to Vernon. The first stage is characterised by low volume of production; this happens when the product is first brought to market. Producers usually opt for small scale production at the early stages and, hence, this phase has low levels of production and sales. Also, initial production tends to be skilled labour and have high costs.

The second phase begins when the product is successful, and growth is seen in production and sales. During this phase, production becomes more efficient with special machinery and mass distribution is implemented so as lower costs. In this phase, there is an increase in capital intensity and more firms are likely to enter the market. The Last phase, the standardized phase, is characterized by a plateau of production and sales. The product specifications become standard and there are less product and process innovations during this phase.

As can be seen the models of Vernon, Markusen and Hirsh are fundamentally similar but with globalisation and multinational firms are believed to lead to innovation being dispersed at a faster rate (Ronstadt, 1977; Lall, 1979). This leads to the stages of *maturity and standardization* being achieved quicker than before. In addition, product innovation occurs more rapidly leading to some products never reaching the standardised stage.

3.2 Industrial Trade Perspective of Product Life-cycle

A relevant perspective of the product life-cycle is one from the industrial trade point of view. Wells (1968) provides insights by illustrating a trade cycle model that consists of four phases. Wells take the point of view from U.S industries, these four phases are as follows:

Phase 1: U.S export strength
Phase 2: Foreign production starts
Phase 3: Foreign production competitive in export markets
Phase 4: Import competition begins

At the early stages of a products life, phase 1, the design of the product is in constant flux. This instability of product design and requirement for specialized producers argues for the production to be located close to the firm, in this case, would be in the U.S. At this stage, U.S manufacturers would have a monopoly in the market. At this stage, U.S exports of the products will start to grow, usually from demand from more affluent and developed countries (Wells, 1968).

Phase 2 starts when foreign countries begin production, this happens when product familiarity abroad increases and with it demand for the product increases in foreign markets. This provides incentives for foreign firms to enter because, by this time, the product has been shown to be successful and would require less investment for product development, in addition, foreign producers will now have a market close-at-hand. During this stage, U.S producers would still supply the majority of the world's markets but exports to certain countries will begin to decline (Wells, 1968).

Phase 3 is defined as foreign production becoming competitive in export markets. This happens as foreign manufacturers become more experienced and costs fall. They benefit from economies of scale and, often, have lower labour costs. This leads to foreign manufacturers becoming competitive at a global level, however, U.S producers tend to be protected in their domestic markets due to imports facing duty and overseas transportation costs. Another characteristic of this stage is that the growth rate of U.S export will continue to decline.

Phase 4, import competition begins, happens when foreign manufacturers reach mass production for both home and export markets. This cost benefits enable them to produce at lower costs than U.S manufacturers, this would lead to erosion of market share of U.S consumers in their domestic market. In addition, foreign producers have the ability to "dump" excess production capacity in the U.S market by undercutting U.S manufacturers. For all these reasons, U.S producers become less and less competitive

To conclude, it is clear that this model takes the perspective of the U.S manufacturer which is relevant for the TV industry and some clear correlations can be seen between this model and the TV industry. For this research paper, Vernon's product life-cycle will be referred to most frequently but will be used in combination with the insights of the industry cycle model.

A more recent study was done by Klepper (1996), in which he studies "Entry, Exit, Growth, and Innovation over the product life Cycle". What he found was that at the initial stages, a higher number of entrants would enter the market and these firms would compete in product innovation. However, as the industry developed, a large number of firms would exit the market and product innovation would decline. During which process innovation would increase, this was due to firms being able to achieve greater economies of scale and products would be more standardized. In a later paper (2000), Klepper and Simon would show that that producers with prior radio manufacturing experience would not only be more successful at transitioning to manufacturing television sets but also be more likely to survive the industry shakeout that occurred.

3.3 Mobility Literature

In both Vernon's product life-cycle model and industrial trade model, there are different levels of participation of the domestic and foreign firms in each of the stages/phases. As the product develops, technical know-how and knowledge diffuses from the original innovators to other firms as the industry goes through the different stages/phases of the product life-cycle and industrial trade model. The mobility of inventors is one of the key mechanisms for the diffusion of this knowledge and this section will provide greater insights into existing research in the field of inventor mobility.

A majority of research agrees that employee mobility is one of the most important contributors to the diffusion of knowledge between organizations. When employees move from one organization to another, they bring with them the knowledge they acquired at previous organizations. This positive correlation been demonstrated in numerous studies (Franco & Filson, 2006; Møen, 2000; Mccann & Simonen, 2005). Knowledge spillovers occur when information is exchanged between actors, this happens when people meet, interact, trade or cooperate (Maliranta et al., 2009). Research further suggests that this is especially true for highly skilled labour which is one of the main sources of knowledge spillovers- "knowledge tends to travel with people who master it" (Breschi & Lissoni, 2001)

Research has shown that several factors contribute to an increase in inventor mobility and knowledge diffusion. Geographic proximity is one of the most researched factors, Mccann & Simonen (2005) show that innovation is positively related to a firm having intense face to face relations with other firms and organizations, implying that the closer the proximity, the greater the knowledge spillover although the extent depends on the types of actors and type of knowledge (Breschi & Lissoni, 2001). In addition, there is also a *push & pull* theory that suggests that there are factors between developing and developed firms or countries that may push employees from their original location or firm and pull factors that pull them towards a developed country or established firm (Thorn & Holm-Nielson, 2008). This is especially relevant in today's knowledge based economy and globalization has made it easier for people to move between borders and firms.

Inventor mobility is found be beneficial both for firms and inventors. Trajtenberg (2005) found inventor mobility to have a positive impact on work performance, in addition, the patents by mobile inventors are shown to receive more citations implying a greater value of innovation. These findings were built upon by Hoisl (2007), where she finds that not only are mobile inventors more productive but mobility of inventors also allows for a better match between employee and employer which has a positive impact on inventive performance.

A variety of additional relationships with respect to inventor mobility have been studied. One such relationship was studied by Almeida and Kogut (1999), who showed that knowledge diffusion in the semi-conductor industry has a strong relationship with the mobility of key engineers and scientists. The authors posit that the knowledge transfer varies from across clusters and regions, citing the example of Silicon valley, New York triangle and Southern California. Stuart and Sorensen (2003) found that the effect of venture capital on the founding-rate of new bio-tech firms is strongly affected by the enforceability of non-compete. Non-competes allow for greater retention employees because when an employee agrees to a non-compete clause, they are unable to leave the firm to work for a competitor for a period of time. This allows venture capitalists to ensure that talented employees remain with a firm that they invest in or acquire. Song et al. (2003) suggest that attracting productive inventors from other firms may even help firms with a lower level of technological advancement to catch up. This research suggests that a firm is able to learn by hiring employees that possess technical expertise; the authors find that this is true regardless if engineers are hired domestically or internationally.

Literature on mobility acknowledges the importance of the movement of people especially high skilled labour. From the theories in the product life-cycle, it is clear that innovation shifts from the incumbent to foreign firms and, from mobility literature, it is known that inventor mobility plays a key role in the diffusion of knowledge. The goal of this research paper is to combine these two concepts and investigate the mobility of inventors in the TV industry when the dominance of U.S firms is eroded. The following sections will develop the hypotheses for this research paper bases on the literature background and theories that were discussed in this section.

3.3 HYPOTHESES

Based on the theories discussed previously and the research goals of this paper, 6 hypotheses were formulated and are as follows:

One characteristic in *growth* stage of the product life-cycle is that FDI and globalisation of production pick up. As discussed in the previous section, knowledge diffuses from the original innovators to other firms and countries as the industry go through the different stages/phases of the product life-cycle and industrial trade model. Inventors play a key role in this diffusion of knowledge and leads to newer entrants in the industry becoming more innovative. Another theory that is in play are *push & pull* factors (Thorn & Holm-Nielson, 2008), in the constant flux of the television industry, numerous *push & pull* factors would affect an inventors decision to move to another firm. A possible example for this could be, Japanese firms that become more innovative than U.S firms *pull* inventors, at the same time, U.S stagnation in the market *pushes* inventors out to seek better opportunities. This is a characteristic of an industry in the early stages of the product life-cycle and would imply that inventor mobility would be higher in the television industry compared to industries that are in *the maturity* stage of the product life-cycle model. Hence, hypothesis 1:

Hypothesis 1: *Inventor mobility in the TV industry will be higher in relation to more "mature" industries.*

Firms that are larger tend to be able to spend more on R&D. This would not only attract inventors but, also, be more likely to be able to retain inventors because a larger budget would imply larger projects that can only be entailed with greater spending power. There is also a positive correlation with R&D expenditure and innovation (Pavitt K, 1982), this all suggests that firms with a greater R&D budget/expenditure will better be able to retain inventors regardless of the stage of product life-cycle the industry is in, hence hypothesis 2.

Hypothesis 2: *Firms that have greater R&D budget/expenditure will be better able to retain inventors.*

Although hypothesis 2 is to be expected of a firm in general, it can be postulated that this relation between R&D expenditure and inventor retention would be less apparent in an industry that is undergoing a transition such as the TV industry. From hypothesis 1, it is expected that mobility in the TV industry will be higher because of other opportunities that exist in the earlier stages of the product life-cycle, therefore, expanding on hypothesis 2, it can be expected that R&D of firms to have a smaller impact on inventor mobility, hence hypothesis 3:

Hypothesis 3*: Firms in TV industry will have lower inventor retention with respect to R&D budget/expenditure compared to other industries.*

The following hypotheses (4 & 5) are similar to hypothesis 2 and 3 with the exception that instead of total R&D expenditure, hypothesis 5 and 6 make use of inventor R&D intensity. R&D intensity can be interpreted as the amount of R&D expenditure per inventor. This is intuitive as the greater the R&D budget for each inventor, the more likely the inventor will be able to undertake a project of his/her choosing, leading to hypothesis 4. It is hypothesized that for similar reasons R&D intensity would have a smaller influence on inventor retention in that TV industry, as in hypothesis 3.

Hypothesis 4: *Firms that have greater R&D intensity would be better able to retain inventors.*

Hypothesis 5: *Firms in TV industry will have lower inventor retention with respect to R&D intensity per employee compared to other industries.*

Based on the history of the television industry, it can be estimated that the transition from the *innovation* stage to the *growth* stage in the TV industry happened in the early 1960's. By the 1970's, foreign competition had increased and Japan was penetrating the U.S market. Due to the difficult nature to pinpoint an exact time a transition in the product life-cycle model occurs, this hypothesis will be generalized to the following: during these "early" years, the TV industry was in a state of flux and it would be expected that in these "early year", inventor mobility to be higher.

Hypothesis 6: *Inventor mobility in the TV industry is greater in the "early" years compared to "later" years.*

Based on these parameters, this research paper will explore and test these hypotheses.

4. DATA & SUMMARY STATISTICS

The data used for this research is obtained from the United States Patent and Trademark Office (USPTO). The data consist of all granted patents from the period of 1975 to 2005 in the United States patent office. In particular, the data consist of information for each patent such as the inventor(s), to whom the patent is assigned to, patent application date, patent grant date, patent citations and the nationality of the assignee. Another dataset used for this research paper is Compustat data, this dataset is published by Standard and Poor's. This dataset covers provides company information such as market capitalisation, capital expenditures, research & development expenditure, number of employees and others from the time period of 1975 to 2005.

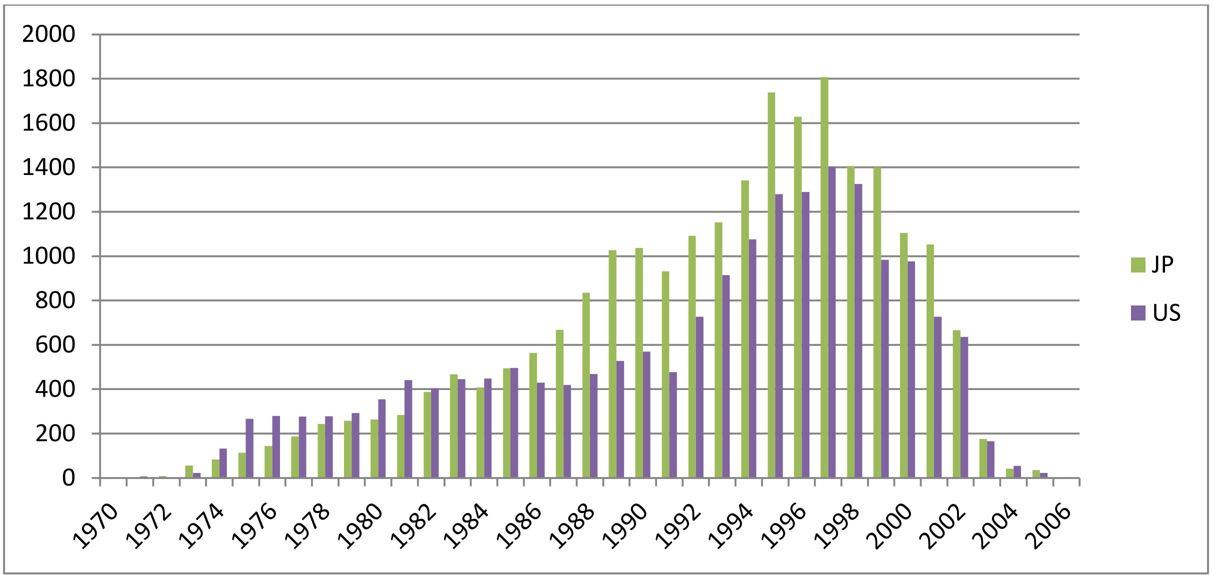
4.1 TV SUB-SAMPLE

Three main subsets were constructed, from the USPTO database, to allow for further analysis and comparison of both inventors and firms. The main sub-sample used for this research is that of the TV industry, this sub-sample was constructed by identifying each inventor with at least one TV-related patent and keeping all patent data with these inventors. In this way, the patenting history of inventors that had a patent in the television industry can be studied and mobility prior & after entering the industry can be studied. There are a total of 24,811 inventors within this sub-sample; between them they have a total of 301,910 patents in all fields. Of these patents, 49,408 patents belong to the television classification.

Of the 49,408 patents, a total of 41,738 patents can be attributed to firms belonging to either the US or Japanese firms, this translates to about 85% of patents. Compustat firms refer to companies that are within the Compustat database and these firms are often larger firms or listed companies. Of the 397 Compustat firms in this dataset which 11,823 patents are assigned to, US and Japanese firms account for 93.2% (370 firms) of them, these 370 firms account for 98.7% of patents that can be attributed to Compustat firms.

From the literature review, it is known that the two main players in the television industry are U.S firms and Japanese firms. The graph1 provides a graphical representation of the distribution of patents over the years. These patents are assigned to 1,517 unique U.S assignees (18,633 patents) and 367 unique Japanese assignees (23,105 patents). This would indicate that on average, Japanese firms have a higher concentration of patents compared to U.S firms that would encompass many smaller firms. This is mainly due to this dataset being from the USPTO and is representative of patents registered for the U.S, foreign firms that compete in this market would tend to be larger and more successful foreign firms.

Graph 1: TV Patent Distribution (USPTO)



Source: Compiled from USPTO database

*Graph 2 Note: variable used to measure inventor mobility is *moved_asg1,* representing a move if an inventor moves to another firm within a one year period since his/her last patent. SIC (27) industries are listed in appendix III and this excludes inventors in TV industry.

4.2 SIC (27) Dataset

In order to obtain a reliable comparison to the TV industry, a second sub-sample was constructed. For this subsample industries with comparable characteristics were selected based on their Standard Industrial Classification (SIC) codes. A total of 27 SIC codes were chosen to be included in this dataset. The majority of the selected SIC codes can broadly be categorized to represent computer or electronic equipment industries. These industries exhibit similar properties to the TV industry and it is hence assumed that they provide a sufficient basis for comparison. Please refer to Appendix III for a detailed list of the selected industries as well as their respective SIC codes. In addition to the 27 SIC industries, this sample also includes the TV sub-sample, therefore, this dataset consists all patents of the 27 SIC's (App. III) and patents of TV inventors. In the context of this paper, this will be referred to as SIC (27) dataset.

This dataset consists of 27 SIC codes chosen by the nature of the SIC, with the addition of TV patents. In total this dataset has 879,355 patents between the periods of 1975-2005. However, as the focus of this paper is the mobility of inventors, this dataset is reduced to the inventor level to measure inventor mobility. A summary of this information is provided in the table below.

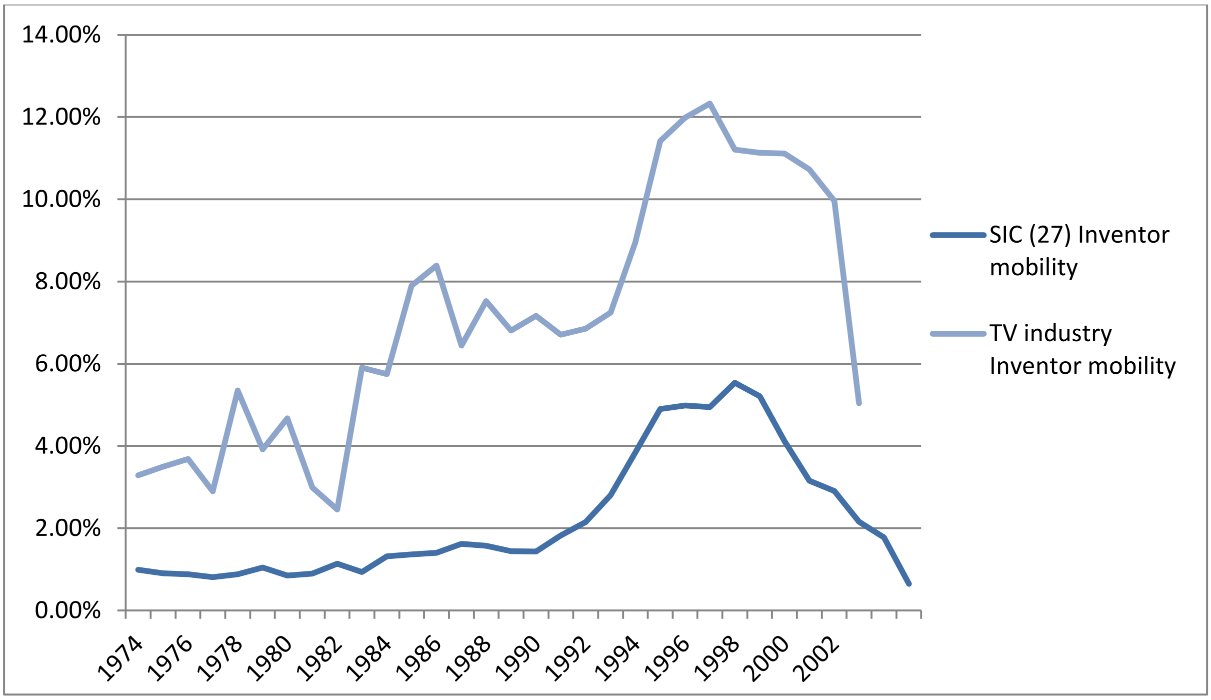
Table 1: Summary of Datasets

	Patents	Inventors	Compustat Firms
Television Industry	49,408	24,192	397
SIC (27) dataset	879,355	218,421	2,367
Telephone & Telegraph	17,952	8,081	97

*Table 1 Note: Telephone & Telegraph discussed in next section.

To measure inventor mobility, the variable *moved_asg1* was constructed, this variable indicates the if an inventor has moved to another firm within a one year window since his last patent. Graph 1 (below) plots the coefficients of for *moved_asg1* over each year for the SIC (27) dataset and the sub-sample of the TV industry. Although the trends of these lines correlate to a degree of 0.886[4], it can be seen that mobility in the TV industry is significantly higher as compared to other industries. This supports hypothesis 1 that TV inventors are more mobile compared to more "mature" industries.

Graph 2: Inventor Mobility: SIC (27) & TV Industry



Source: Compiled from USPTO data, 1975-2005

[4] Correlation obtained by comparing the coefficients of the OLS regressions and using a Pearson product-moment correlation coefficient (PCC) to obtain a correlation of 0.8859.

4.3 DATASET USED FOR FALSIFICATION TEST: TELEPHONE & TELEGRAPH INDUSTRY

The SIC (excl TV) dataset serves the purpose of providing a falsification test by using an alternative industry (SIC) to conduct the same analysis on as for the TV industry. This dataset is essentially, the SIC (27) dataset but excluding the TV patents. The falsification test allows for comparability between the results between the TV industry and an industry that is in the *maturity* stage of the product life-cycle model.

For this falsification test, an industry is chosen to act as a comparison to the television industry. The main criteria for selecting this industry would be that the industry is in a *maturity* stage in the product life-cycle model. Ideally, this would allow for a comparison between the television industry that is in the *growth* and early stages of *maturity* stage to an industry that is already in the *maturity* stage.

The SIC chosen is defined as "*Telephone and telegraph apparatus*" or SIC code: 3661. This industry was chosen because the U.S were the initial innovators in this industry with companies such as Bell telephone company and, later, AT&T dominating this industry. Although, U.S companies faced competition from foreign firms, U.S firms are still competitive in today's market, with two of the largest six companies being from the U.S, namely Lucent and Cisco[5]. Based on this information, it can be seen that the telephone and telegraph industry is significantly different from the TV industry and therefore, is used for the falsification test.

[5] Information obtained from: http://www.referenceforbusiness.com/industries/Electronic-Equipment-Components/Telephone-Telegraph-Apparatus.html [Accessed 20th Oct 2013]

5. METHODOLOGY

The following section comprises of the explanation of the econometric approach employed to test the outlined research propositions and further developed in the hypotheses. This section will cover the theoretical framework, the estimation model as well as briefly elaborate upon the different variables throughout this research paper.

5.1 THEORETICAL FRAMEWORK

Drawing upon the literature review (section 3.1), it can be established that the period of interest for this research is the *maturity* stage of the product life-cycle. This stage is characterised by a shift of domestic production (U.S) to offshore locations to leverage the benefits lower labour costs. During this same time, Japanese firms enter into the U.S market and become industry leaders in terms of production and innovation from the 1970's onwards. This is predominately by large multinational Japanese companies, which is also reflected in our dataset where the largest 22 Japanese companies account for 30.3% of patents in the data[6].

The main goal of this research paper is to identify and assess potential trends in mobility during this period. Furthermore an analysis is conducted to identify firm characteristics that affect the mobility of inventors in the TV industry. Subsequently, a comparison will be drawn between potential findings in the TV industry and other industries, namely the SIC (27) dataset companies.

5.2 THE ESTIMATION MODEL

The econometric model used will be the generalized linear model (GLM), GLM generalises linear regressions by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value. For this analysis, the dependent variable will be that of a fraction and, therefore, range between 0 & 1, the variables used will be explained in greater detail in the next section. Hence, the variation of the GLM used in this case is the binomial distribution with the link function being a logit; where logit represents a probability parameter. The estimation equation is presented below.

$$pr(move) = \alpha_0 + \alpha_1 R\&D + \alpha_2 R\&DxTV + \beta X + \varepsilon_{it}$$

Where α:coefficient estimate,
β: parameter estimates for control variables
X: various control variables,
ε_{it}: error terms

[6] Total patents assigned to the 22 Japanese Compustat companies are 91,494 of a total of 301,910 patents in the dataset which contains 396 unique Compustat firms.

5.3 VARIABLES

Dependent Variables

F_mover1 is the first dependent variable that will be used with the GLM model. This variable is defined as the fraction of inventors of a firm in year that will move to another firm in the next year. This variable is constructed by summing the inventors that will move to another firm in the next year divided by the number of unique inventors in each firm in the dataset per year. This variable ranges from 0 to 1, with 0 meaning that no inventors move to another firm within one year of their last patent and 1 indicating that all of the inventors in a firm move to another firm within a one year period.

For robustness, variables *f_mover2, f_mover3* and *f_mover4*, this was done to by expanding the time period of the move to two, three and four years respectively. In other words, *f_mover2* would be the fraction of inventors that were to move firms within two years of their last patent. For each GLM regressions that were done in this research paper, robustness checks using the above mentioned variables was carried out and can be found in the Appendix.

Explanatory Variables

All explanatory variables used, were constructed using company information that was obtained from the Compustat database. For these variables, a natural log of the variable is used, this is to improve model fit and account for the positive skew of these variables[7]. The table below provides an overview of the explanatory variables used.

[7] Obtaining the log of each variable was done by taking the log of 1 + the Compustat variable. e.g logxrd=log(1+xrd)

Table 2: Overview of Explanatory Variables

Variable	Description	Variable Formula
Logxrd	*xrd* represents a firms' R&D expense	logxrd=log(1+xrd)
Logemp	*emp* represents the number of employees in a firm	logemp=log(1+emp)
Logppent	*ppent* represents the net value of property, plant & equipment a firm holds	logppent=log(1+ppent)
Logsale	*sale* represents the net sales or turnover of a firm, by year	logsale=log(1+sale)
Logcapx	*capx* represent the capital expenditures of a firm	logcapx=log(1+capx)
logxrd_emp	*xrd_emp* represents R&D intensity or R&D expenditure per employee	Logxrd_emp=log(xrd/emp)

Source: Compiled from Standard & Poor's Compustat database

Logxrd is one the main explanatory used in this research paper as highlighted in the hypotheses. This variable is used because it is a good measure for a firms' focus on innovation, R&D often has a positive correlation with a firms' level of innovation (Pavitt K, 1982). *xrd* is also used to compute *logxrd_emp*, that represents R&D intensity, this is important to inventors because it gives a good indication of the budgets of projects an inventor is given. It is intuitive that inventors would want to work for a firm where the R&D intensity is high for inventors, this was hypothesized in hypothesis 4 and 5.

The table below provides summary statistics and a correlation matrix of the explanatory variables used.

Table 3: Summary Statistics and Correlation Matrix of Explanatory Variables

	Variable	Obs	Mean	Std. Dev.	Min	Max		1	2	3	4	5
1.	logxrd	242740	5.7044	2.5609	-0.004	8.9593	xrd	1				
2.	logemp	242740	3.3990	1.9417	0	6.7512	emp	0.54	1			
3.	logppent	242740	6.8601	2.9096	0	11.7603	ppent	0.324	0.807	1		
4.	logsale	242625	8.1177	3.0676	0	11.4752	sale	0.854	0.738	0.558	1	
5.	logcapx	242740	5.7349	2.6362	0	9.7876	capx	0.557	0.853	0.899	0.754	1

*Table 3 notess: Note that the correlation matrix uses the variable rather that the log of the variable.

6. Results and Analysis

This section will show the findings of the analyses described in the methodology and test the hypotheses of the research paper.

6.1 R&D Interaction

This sub-section will present the results of the GLM regressions (table 3) that were done for all of the three datasets mentioned previously. These regressions use the dependent variable *f_mover1* which indicates the fraction of inventors that move out of company in a given year. The explanatory variables used are from table 2. The regressions control for year fixed effects (FE) and industry (SIC) FE with the exception of the TV industry sub-sample that only controls for year FE.

In regression (1), (2) and (3), *logxrd* is has a negative magnitude and is significant at a 1%/5% significance level. This would indicate that the percentage of inventors that move out of a firm decreases as R&D expenditure of firms increase. In Appendix V, a robustness check was done by using different definition of the dependent variable *f_mover*, it can be seen from columns (13), (14) and (15) that the results and significance hold. This supports hypothesis 2 that increase R&D expenditure of firms increases inventor retention.

An interaction effect of *logxrdxTV* is used to identify the effect of *logxrd* in the TV industry in (1), *logxrdxTV* is positive and significant at a 10% significance level. This indicates that inventor mobility at firms in the TV industry is higher than that of other industries. This is corroborated by regression (2) showing a less negative coefficient for *logxrd* than (1). Therefore, it can be concluded that although a firm with greater R&D expenditure is better able to retain inventors across industries, this R&D effect is less so for inventors & firms in the TV industry. This supports hypothesis 3 that the TV industry has lower inventor retention with respect to R&D expenditure when compared to other industries.

These results suggest that R&D has a positive impact on retaining inventors but to a lesser extent for firms in the TV industry. This supports hypothesis 3 and a possible reason for this is the difference in stages of the product life-cycle the TV industry is in compared to the more "mature" SIC(27) industries. Another possible reason is that with the entrance of more foreign firms, *push & pull* factors come into play that encourages inventors to move.

Table 4: Inventor Mobility across Datasets: R&D Interaction

	SIC (27) (1)	TV (2)	SIC (27 excl. TV) (3)
VARIABLES	f_movers1	f_movers1	f_movers1
Logxrd	-0.412**	-0.310*	-0.406**
	[0.107]	[0.152]	[0.102]
logxrdxTV	0.202+		
	[0.109]		
logsale	0.107	0.015	0.155+
	[0.090]	[0.172]	[0.083]
logcapx	0.052	0.089	-0.04
	[0.133]	[0.170]	[0.122]
logemp	-0.474**	0.054	-0.501**
	[0.113]	[0.226]	[0.110]
logppent	-0.252+	-0.067	-0.193
	[0.147]	[0.204]	[0.133]
logxrdxTL			0.017
			[0.131]
Constant	-16	-18.424**	-13.767
Observations	201,908	6,317	196,829
Year FE	YES	YES	YES
Industry FE	YES	-	YES

Robust standard errors in brackets *** p<0.01, * p<0.05, + p<0.1*

*Table 4 notes: The method of estimation is the GLM with the binomial family and using a logit link. Regressions in this table account for year fixed-effects and for (1) and (2) industry fix-effects are taken into consideration.

For the falsification test, regression (3), *logxrdxTL* similarly represents the interaction term for the *Telephone and telegraph apparatus* industry. This interaction term shows a small positive and insignificant effect, whereas *logxrd* is negative and significant at a 1% significance level. As described in the literature review, it is plausible that this difference is due to the TV industry being in *growth* stage of the product life-cycle model whereas the *Telephone and telegraph apparatus* industry is in the *maturity* stage.

6.2 Inventor Mobility: Inventor R&D Intensity Interaction

In this set of analyses, R&D intensity will be used as an explanatory variable in place of *logxrd* and *logemp*. R&D intensity represents the amount of R&D expenditure a company makes per employee in the firm, this is represented by the variable *logxrd_emp*. Similarly, the interaction variable, *logxrdempxTV* represents the R&D intensity of firms in the TV industry.

From table 5, regression (4), it can be seen that R&D intensity has a negative and significant impact on the mobility of inventors across the 27 SIC industries. This is intuitive as the greater the budget/investment on each inventor, the more likely the firm is to retain its' inventors. This supports hypothesis 4.

The interaction term, *logxrdempxTV,* shows a positive and is significant at a 10% significance level. This shows that although R&D intensity increases the likelihood for firms to retain inventors, this is less so for firms in the TV industry as compared to the 27 SIC industries. These findings support hypothesis 5.

For the TV sub-sample, regression (5), *logxrd* has a similar coefficient as GLM regressions (4) & (6), however, is insignificant and has a larger standard error. This is due to the low number of observations in the sub-sample and that the dependent variable *f_mover1* is relatively narrow measuring mobility of inventors in a one year window from the time of his last patent. In Appendix VI, a more robust analysis is done using a wider range of measuring mobility, up to a four year mobility window since the inventors last patent. This is shown in column (30), (31) and (32) in Appendix VI, that shows the f_mover2 and f_mover4 result in significant results of *logxrd.*

(6) shows the falsification test using the *Telephone and telegraph apparatus* industry in place of the television industry. The interaction term *logxrdempxTV* has a positive but insignificant coefficient, this implies that inventors in the TV industry behave differently to the *Telephone and telegraph apparatus* industry. This is in line with the results from the previous analysis.

Table 5: Inventor mobility across datasets: R&D Intensity interaction

	SIC (27)	TV	SIC (27 excl. TV)
	(4)	(5)	(6)
VARIABLES	f_movers1	f_movers1	f_movers1
logxrd_emp	-0.212*	-0.2	-0.214**
	[0.086]	[0.145]	[0.082]
logxrdempxTV	0.219+		
	[0.118]		
Logsale	-0.048	-0.146	-0.016
	[0.093]	[0.150]	[0.089]
logcapx	-0.078	0.057	-0.165
	[0.134]	[0.160]	[0.126]
logppent	-0.560**	-0.104	-0.506**
	[0.161]	[0.217]	[0.147]
logxrdempxTL			0.361
			[0.340]
Constant	-13.777	-17.985	-15.594
Observations	197,381	6,316	192,456
Year FE	YES	YES	YES
Industry FE	YES	-	YES

Robust standard errors in brackets *** p<0.01, * p<0.05, + p<0.1*

*Note table **5:** The method of estimation is the GLM with the binomial family and using a logit link. Regressions in this table account for year fixed-effects and for (4) and (6) industry fix-effects are taken into consideration as (5) is a sub-sample limited to one industry (TV). Regression (5) shows insignificant results, this is due to the nature of the sample, refer to **Appendix VI** for a complete analysis.

These results suggest that R&D intensity has a positive impact on retaining inventors but to a lesser extent for firms in the TV industry. This supports hypothesis 5 that states that firms in the TV industry will have lower inventor mobility with respect to R&D intensity per employee compared to other industries.

6.3 R&D Interaction: Time Period Analysis

This section will conduct a similar analysis to 7.1, with the exception that the datasets will split the time period of the dataset of 1975-2005 into period of 1975-1989 and 1990-2005 sub-samples. By doing so, a better understanding of trends in the earlier years compared to the later stages of the product life-cycle. The results of the GLM regressions are as follows:

Table 6: GLM Regression: R&D interaction over time periods

	SIC (27)	SIC (27)	TV	TV	SIC (27 excl. TV)	SIC (27 excl. TV)
	<1990	>=1990	<1990	>=1990	<1990	>=1990
	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	f_movers1	f_movers1	f_movers1	f_movers1	f_movers1	f_movers1
logxrd	0.118	-0.452**	-0.055	-0.361*	0.129	-0.448**
	[0.314]	[0.111]	[0.218]	[0.174]	[0.311]	[0.104]
logxrdxTV	-0.193	0.212+				
	[0.217]	[0.118]				
logsale	-0.537*	0.188*	-1.080*	0.223	-0.510*	0.236**
	[0.210]	[0.093]	[0.496]	[0.184]	[0.207]	[0.084]
logcapx	-0.235	0.091	-1.188*	0.214	-0.058	-0.029
	[0.354]	[0.147]	[0.487]	[0.185]	[0.383]	[0.131]
logemp	-0.623+	-0.561**	0.113	0.119	-0.818*	-0.535**
	[0.340]	[0.132]	[0.784]	[0.233]	[0.412]	[0.121]
logppent	0.488	-0.330*	1.920**	-0.383+	0.417	-0.260+
	[0.361]	[0.161]	[0.374]	[0.220]	[0.361]	[0.144]
logxrdxTL					-0.388+	-0.012
					[0.210]	[0.150]
Constant	-12.388**	-5.170**	-18.585**	-3.663**	-12.522**	-5.392**
Observations	49,973	151,935	2,373	3,944	48,052	148,777
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES			YES	YES

Robust standard errors in brackets *** p<0.01, * p<0.05, + p<0.1*

For the GLM regressions (7), (9) and (11), pre-1990, all show insignificant coefficients for *logxrd* and *logxrdxTV,* with the exception of the *logxrdxTL* which further highlights the differences between TV industry and the TL industry. Column (8) that represents the period after 1990 shows a similarity GLM regression (1) in section 7.1. In both cases, the coefficient of *logxrd* is similar in magnitude, negative and significant effect on inventor mobility. This is also true but the interaction term, *logxrdxTV,* which in both cases is also similar in magnitude, negative and significant at a 10% significance level. When comparing the results to (10) for the TV industry post-1990, it can be seen that for the TV industry the coefficient of *logxrd* is slightly less negative, this suggests that inventor mobility of firms in the TV industry is higher than that of the 27 SIC industries. This corresponds to the findings in section 7.1 and hypothesis 3.

Based on the finding of table 6, hypothesis 6 cannot be supported. One limitation to conducting a time period analysis is the limitation of the time range of this dataset. It is certain that the *growth* stage of the television industry commences prior to 1975, however, this dataset only has data beginning from granted patents in 1975 onwards. Ideally, a wider time-series would be required to conduct more robust analyses. Additional limitations of this research paper are discussed in the next section.

6.4 Limitations

One of the main limitations of this paper is inherent from the nature of the dataset. The USPTO data used for measuring inventors and mobility is based on the granted patents, this means that an inventor only appears in the dataset when a patent is granted to him. It is not possible to discern where this inventor was between patents and what contributions to innovation he/she has made. Therefore, it is not possible to accurately estimate the number of inventors there are in a firm at a given time. In addition to patents, innovations can also be kept secret or publicly disclosed (Lichtman, D.,et al., 2000), based on all the above mentioned reasons, it is highly likely that there is an underestimation of inventors, innovation and mobility of inventors in this research paper.

Another limiting factor is the measurement used to measure R&D intensity, *logxrdemp,* this variable uses R&D expenditure divided by the number of employees in a firm. This will be underestimating the actual R&D intensity in a firm because only a percentage of employees in a firm are inventors that contribute to the innovation of a company. It is also true that different firms in different industries will have a different ratio of inventors to employees. This will lead to underestimation of R&D intensity.

This dataset does not contain any information of inventors such as age of inventor, gender or any other inventor details nor the social connections and interactions of inventors at each firm. Although this would have significant impact on an inventor's decision to move (Sorenson, 2010). This information would allow for more accurate control variables to be set up and increase the explanatory power of the model.

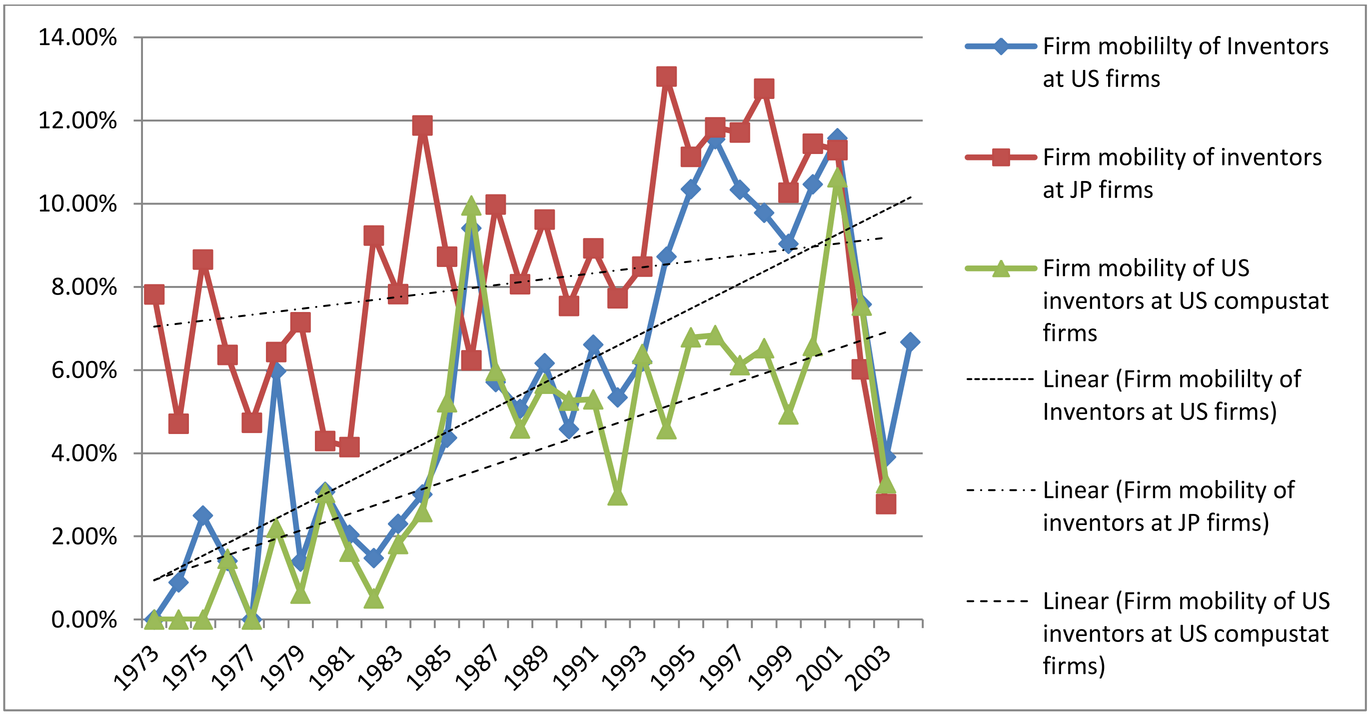
Another limitation is the scope of this research, this research is based on the premise of patents granted in the U.S and the Japanese firms represented in this dataset are likely to be larger firms with an international presence. Therefore, the data may not the representative of the television industry as a whole. At the same time, the time series of the dataset is limited to 1975 to 2005, whereas the exact date that the transition from *innovation* to *maturity* is unclear and could very possibly have been before 1975. Ideally, a longer time period of the dataset would be better and a more complete analysis can be conducted including trends in the *innovation* stage of the product life-cycle.

7. Further Analysis

The results and analyses section provides a company level analyses that provides insights into company characteristics and the effects they have on inventor mobility. From literature and the history of the television industry, it is know that the Japanese played a key role in influencing the television industry's development to the state it is in today. In this section, a deeper analysis of Japanese firms in the U.S television market will be conducted. This will show inventor mobility for U.S firms and Japanese firms through the period of 1975 to 2005.

The graph below shows inventor mobility for U.S firms, U.S Compustat firms and JP firms. Due to only a small number (22) of Japanese Compustat firms in the dataset, this was omitted from the graph. Trend lines were plotted to show the trend of inventors mobility through the years, it shows that the steepest trend line is the one that plots U.S firms' inventor mobility. U.S Compustat firms have a more gradual upward slope, this is in line with hypotheses 2 to 5 that suggest that firms with greater R&D budgets are better able to retain employees and because Compustat firms are generally larger firms, these results are in line with the hypothesis 1.

Graph 3: Inventor Mobility of U.S and JP firms



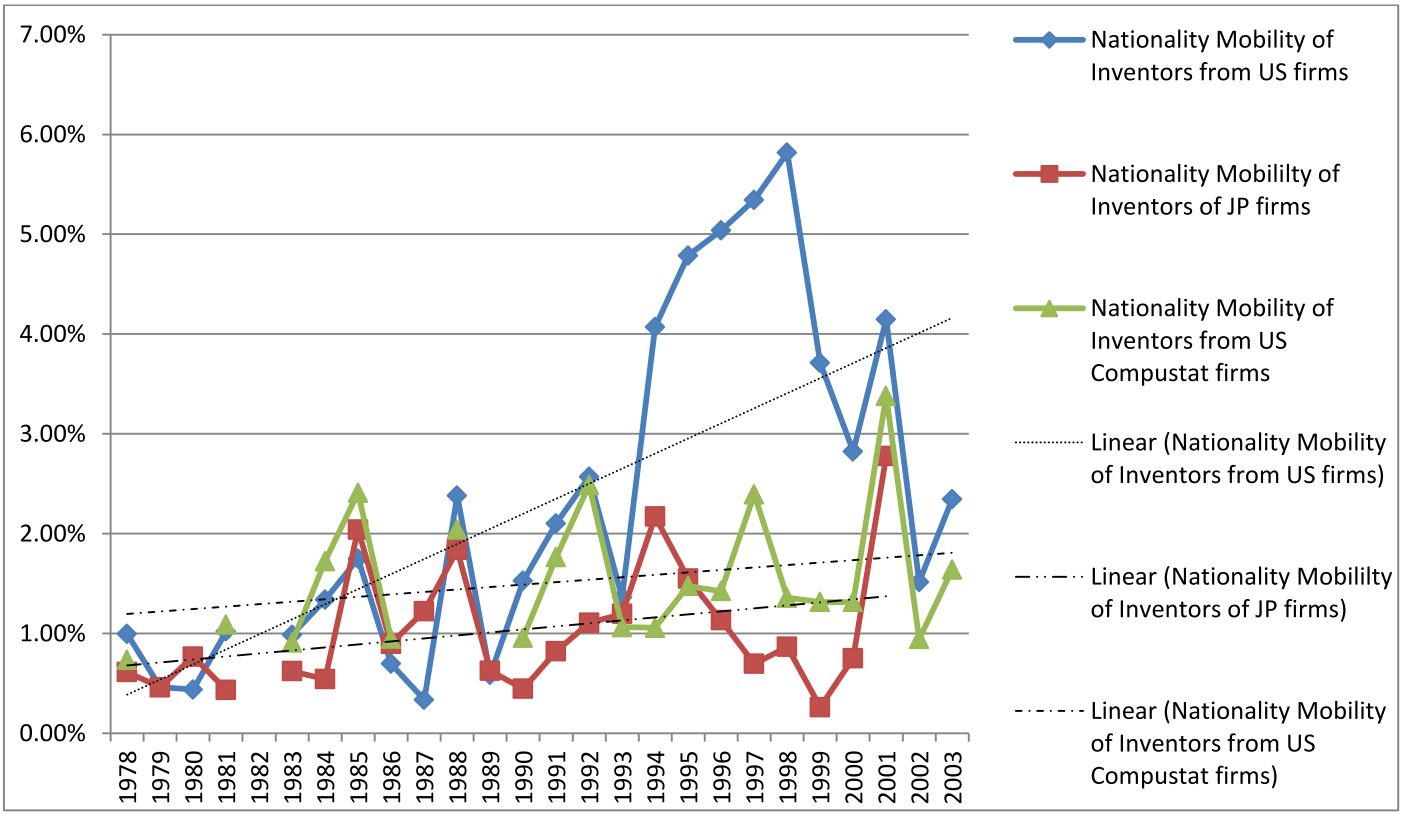
Source: Compiled from USPTO and Compustat databases.

*Graph 3 notes: variable used to measure inventor mobility is *moved_asg1*, representing a move if an inventor moves to another firm within a one year period since his/her last patent.

Japanese firms on the other hand have the least increase in inventor mobility over time, one possible explanation for this is because as Japanese firms became more successful in the television industry over time and, hence, Japanese firms are better able to retain inventors. However, it can also be seen that the trend line for Japanese firms begins at a higher point in the graph compared to U.S firms. This could be because as more inventors are joining JP firms from firms of other countries.

This is shown in graph 4, this graph measures the movement of inventors from the nationality of a firm to a firm of another firm nationality. This would mean that an inventor moving a U.S firm to a JP firm, and vice versa, would be recognized as a move. This graph shows that firm nationality mobility is highest for U.S inventors, this would support the proposition mentioned above, inventors that worked in U.S firms are more likely to join JP firms. For inventors from Japanese firms, the trend line for nationality mobility is the lowest magnitude and increases at the slowest rate compared U.S firms or U.S Compustat firms.

Graph 4: Firm Nationality Mobility of U.S and JP firms



Source: Compiled from USPTO and Compustat databases.

*Graph 4 notes: variable used to measure inventor mobility is *moved_country1*, representing a move to a firm of another nationality within a one year period since his/her last patent.

8. Conclusions & Further Research

The findings of this research paper show that inventors in the television industry have different mobility tendencies compared to the 27 selected SIC dataset. The findings indicate that firm characteristics have a smaller effect at retaining inventors in the television industry compared to other industries. This can attributed to the characteristics of the stage of the product life-cycle the TV industry is in *maturity* and, in later years, the *standardized* stage. Globalisation and FDI by foreign companies played a significant role in the television industry and even though the data was limited for U.S registered patents, these findings provide a good representation of the TV industry.

Hypotheses 1 to 5 of this research paper are supported by the analyses shown in section 6, whereas, hypothesis 6 cannot be confirmed due to limitations of the dataset. These results indicate that firm characteristics are important to the attracting and retaining inventors but have less of an impact in an industry that is in the early stages of the product life-cycle or industrial trade model. The constraints of the time range of this data series, from 1975-2005, limit the analyses to when the U.S firms are no longer the leading innovators and producers of television sets, furthermore, mobility during this period is expected to be higher than pre-1975 because of the new entrants that enter the market that set up facilities in the U.S. This leaves room for a deeper analysis with data that ideally ranges from 1900 – 2005 and covers all patents internationally. This would allow for a more comprehensive study of inventor mobility in the different stages of the product life-cycle.

The television industry has gone through many stages/phases since the invention of the telephonoscope[8] in 1878. Throughout this paper, it has been discussed as though the television is a single homogenous product and that the product life-cycle of the television can be strictly distinguished into three stages as Vernon, Hirsh and Markusen describe in their product life-cycle model. This is true for the most part, however, upon closer inspection at the data, the television can be divided into different classes that are in different stages of the product life-cycle. This can be better explained by looking at the history of the television industry, in 1948, after WWII, B&W television began to be produced and commercialized with the U.S being the largest producers for B&W TV's, this continued till the mid 1960's when Japan overtook the U.S in terms of B&W TV production (Appendix I). Just prior to this period of time, U.S companies began outsourcing the production of B&W TV's but began to focus their production on colour televisions. This can be interpreted as B&W television reaching the *standardised* stage in the

[8] The concept of electrically powered transmission of television images in motion was first sketched in 1878 and known as the telephonoscope.

product life-cycle, whereas, colour TV's is transitioning from the *innovation* to *maturity* stage. This happens with the introduction of hi-definition television (HDTV) and more recently the plasma or LCD TV. These new technologies enter the market and have unique product life-cycles, this might happen so rapidly that certain versions of the technology do not complete the produce life-cycle (Ronstadt, 1977; Lall, 1979).

This research paper uses the television as a homogenous product and builds the framework on the television industry having one product life-cycle. However, in reality this is not the case and this leaves room for deeper research into this topic. This can be done, for example by, taking into account the different versions of technologies and the phase of the individual life-cycle the version is in. In this way, inventors and firms who innovate the newer technologies can be identified and would provide for more insights into the industry.

To conclude, this research presents some interesting findings in terms of inventor mobility trends in the product life-cycle and firm characteristics that affect the mobility of inventors. There is room for much deeper and wider analysis. I believe the framework of this research can be implemented to other industries, allowing comparisons between industries to be made. This would answer the question if there is a consistent trend of inventor mobility in the different stages of the product life-cycle across industries.

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APPENDICES

APPENDIX I - Production of B&W TV sets in selected countries and for particular years (1000 units)

	1948	1955	1960	1967	1970	1975	1978	1981	1986	1990	1994	1998	2000
U.S.A.	975	7757	5708	4738	3734	1828	1015	57	---	---			
U.K.	91	1771	2141	1240	1743	552	604	171	---	25			
France	1	186	655	1279	1302	1020	196	196	12	9	5		
Germany		316	2164	1820	2064	1124	---	---	---	---			
Italy				1125	1989	1568	---	---	410	450	447		
Mexico		65	80	333	393	489	---	---	---	---			
Japan		137	3578	5756	7383	4980	5378	4330	904				
Taiwan				112	1226	2599	5040	5273	2228	1299	796	77	59
S.Korea				28	114	2300	---	---	6928	3568	229	5	3
Malaysia					44	102	150	159	17	69	300	80	68
China				5	1	98	279	2447	10444	15632	12762	6330	---
India						---	---	80	850	1150	5200	5500	5212

Note: Table from "Foreign Investment and Asia's, Particularly China's, Rise in the Television **Industry:** The International Product Life Cycle Reconsidered (2005)

Sources: UN Statistical Yearbook; UN Statistics Yearbook for Asia and the Pacific; Japan Statistics Yearbook, Statistics Yearbook of Republic of China; Korea Statistics Yearbook; some of EU countries and Asian NICs data from World Electronics Yearbook Data and China data from China Electronics Industry Yearbook.

APPENDIX II - Production of colour TV sets in selected countries and for particular years (1000 units)

	1956	1964	1967	1970	1974	1981	1986	1990	1994	1998	2000
U.S.A.	59	1340	4963	4564	6930	10025	12277	14500	14848	11495	8931
U.K.			32	471	1874	---	2755	2790	4002	---	
France			21	209	674	---	1742	2500	3043	---	
Germany			97	872	2363	---	3895	3226	3037	---	
Italy					311	---	1490	2115	2229	---	
Mexico			8	30	58	---	1742	2500	---	---	
Japan		57	1282	6399	7323	11630	13809	13243	11192	6567	4912
Taiwan				28	418	1650	3988	2403	1482	1066	1162
S. Korea					36	---	6996	12893	16999	10598	14408
Malaysia							884	2900	10700	13000	20211
China					2	150	4146	10229	16371	36430	38000[2]
India							850	1150	1330	3400	4269

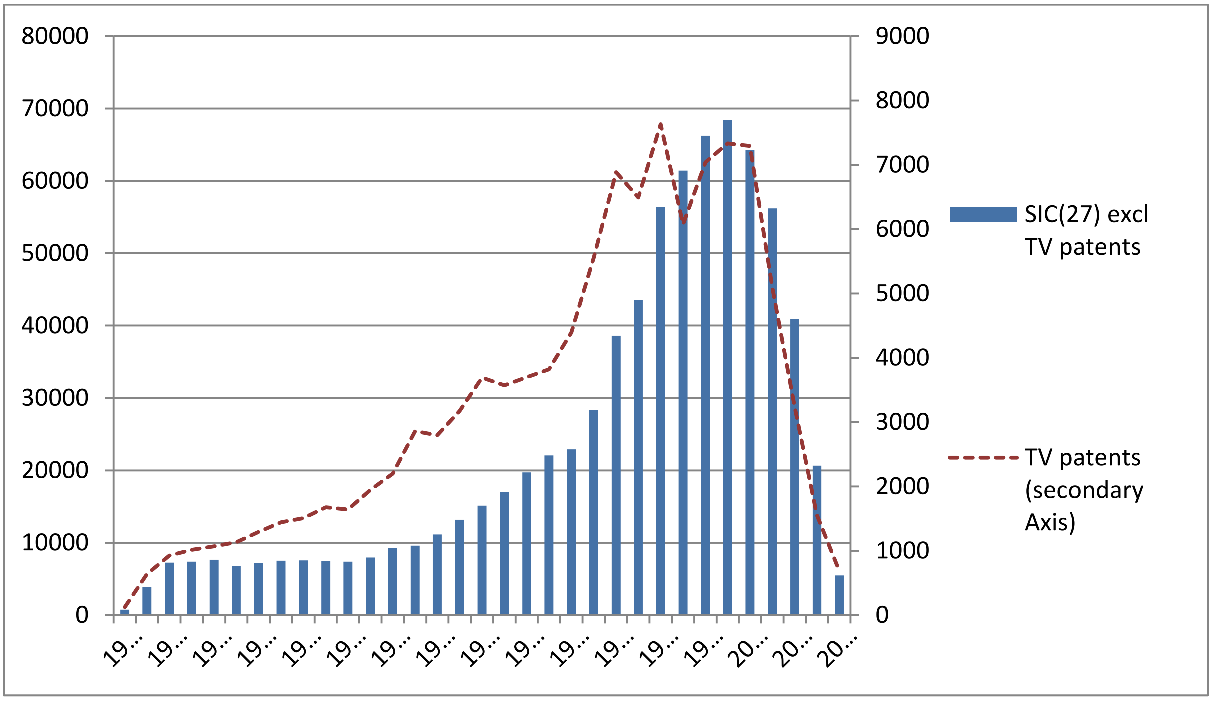
Note: Table from "Foreign Investment and Asia's, Particularly China's, Rise in the Television **Industry:** The International Product Life Cycle Reconsidered (2005)

Sources: UN Statistical Yearbook; UN Statistics Yearbook for Asia and the Pacific; Japan Statistics Yearbook, Statistics Yearbook of Republic of China; Korea Statistics Yearbook; some of EU countries and Asian NICs data from World Electronics Yearbook Data and China data from China Electronics Industry Yearbook, China data in 2000 is 2001 data, from *People's Daily*, September 3, 2002.

APPENDIX III - Standard Industrial Classification (SIC) that used for sub-sample

SIC code	Sic Description
3570	Computer & Office Equipment
3571	Electronic Computers
3572	Computer Storage Devices
3575	Computer Terminals
3576	Computer Communications Equipment
3577	Computer Peripheral Equipment, NEC
3578	Calculating & Accounting Machines - except Electronic Computers
3579	Office Machines, NEC
3600	Electronic & Other Electrical Equipment - except Computer Equipment
3661	Telephone & Telegraph Apparatus
3663	Radio & TV Broadcasting & Communications Equipment
3669	Communications Equipment, NEC
3670	Electronic Components & Accessories
3672	Printed Circuit Boards
3674	Semiconductors & Related Devices
3677	Electronic Coils, Transformers & Other Inductors
3678	Electronic Connectors
3679	Electronic Components, NEC
3690	Miscellaneous Electrical Machinery, Equipment & Supplies
3825	Instruments for Measuring & Testing of Electricity & Electrical Signals
3844	X-Ray Apparatus & Tubes & Related Irradiation Apparatus 3
3861	Photographic Equipment & Supplies
4813	Telephone Communications - except Radiotelephone
7370	Services - Computer Programming, Data Processing, Etc.
7372	Services - Prepackaged Software
7373	Services - Computer Integrated Systems Design

Appendix IV - Patent Distribution: SIC (27 excl. TV) & TV Industry



Source: Compiled from USPTO data

APPENDIX V - GLM Results with variations in mobility lead time: R&D interaction

	SIC (27) (13)	SIC (27) (14)	SIC (27) (15)	SIC (27) (16)	TV (17)	TV (18)	TV (19)	TV (20)	SIC (27 excl. TV) (21)	SIC (27 excl. TV) (22)	SIC (27 excl. TV) (23)	SIC (27 excl. TV) (24)
VARIABLES	f_movers 1	f_movers 2	f_movers 3	f_movers 4	f_movers 1	f_movers 2	f_movers 3	f_movers 4	f_movers 1	f_movers 2	f_movers 3	f_movers 4
logxrd	-0.412**	-0.335**	-0.260**	-0.271**	-0.310*	-0.433**	-0.404**	-0.416**	-0.406**	-0.325**	-0.257**	-0.264**
	[0.107]	[0.095]	[0.089]	[0.084]	[0.152]	[0.141]	[0.144]	[0.141]	[0.102]	[0.094]	[0.090]	[0.084]
logxrdxTV	0.202+	0.13	0.105	0.086								
	[0.109]	[0.100]	[0.089]	[0.084]								
logsale	0.107	0.145+	0.140*	0.132*	0.015	0.082	0.131	0.07	0.155+	0.179*	0.170*	0.158*
	[0.090]	[0.074]	[0.068]	[0.064]	[0.172]	[0.180]	[0.184]	[0.182]	[0.083]	[0.072]	[0.069]	[0.064]
logcapx	0.052	-0.051	-0.075	-0.135	0.089	-0.068	-0.077	-0.083	-0.04	-0.145	-0.156+	-0.204*
	[0.133]	[0.115]	[0.099]	[0.091]	[0.170]	[0.138]	[0.137]	[0.133]	[0.122]	[0.104]	[0.091]	[0.084]
logemp	-0.474**	-0.558**	-0.574**	-0.548**	0.054	-0.06	-0.139	-0.15	-0.501**	-0.605**	-0.626**	-0.587**
	[0.113]	[0.100]	[0.094]	[0.087]	[0.226]	[0.217]	[0.213]	[0.208]	[0.110]	[0.101]	[0.095]	[0.089]
logppent	-0.252+	-0.217+	-0.245*	-0.174+	-0.067	0.171	0.169	0.244	-0.193	-0.144	-0.170+	-0.117
	[0.147]	[0.118]	[0.105]	[0.098]	[0.204]	[0.196]	[0.190]	[0.188]	[0.133]	[0.109]	[0.099]	[0.093]
logxrdxTL									0.017	0.057	0.007	0.008
									[0.131]	[0.115]	[0.108]	[0.103]
Constant	-15.538	-14.268	-13.354	-13.28	-18.424**	-16.717**	-15.324**	-15.845**	-13.767	-14.668	-13.423*	-13.675
Observations	201,908	201,908	201,908	201,908	6,317	6,317	6,317	6,317	196,829	196,829	196,829	196,829
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	-	-	-	-	YES	YES	YES	YES

Robust standard errors in brackets *** p<0.01, * p<0.05, + p<0.1*

*Appendix V Notes: This table uses different definitions for the dependent variable, *f_mover*. With f_mover1 representing if the inventor moves within a 1 year window after his last patent, *f_mover2* representing a move within a 2 year period since an inventors last patent.

APPENDIX VI - GLM Results with variations in mobility lead times: R&D intensity interaction

	SIC (27) (25)	SIC (27) (26)	SIC (27) (27)	SIC (27) (28)	TV (29)	TV (30)	TV (31)	TV (32)	SIC (27 excl. TV) (33)	SIC (27 excl. TV) (34)	SIC (27 excl. TV) (35)	SIC (27 excl. TV) (36)
VARIABLES	f_movers 1	f_movers 2	f_movers 3	f_movers 4	f_movers 1	f_movers 2	f_movers 3	f_movers 4	f_movers 1	f_movers 2	f_movers 3	f_movers 4
logxrd_emp	-0.212*	-0.156*	-0.098	-0.105	-0.195	-0.240+	-0.206	-0.216+	-0.214**	-0.153*	-0.103	-0.109+
	[0.086]	[0.073]	[0.069]	[0.065]	[0.143]	[0.132]	[0.133]	[0.130]	[0.082]	[0.072]	[0.069]	[0.065]
logxrdempxTV	0.219+	0.139	0.113	0.11								
	[0.118]	[0.104]	[0.095]	[0.090]								
logsale	-0.048	0	0.021	0.006	-0.139	-0.204	-0.173	-0.247	-0.016	0.032	0.051	0.036
	[0.093]	[0.077]	[0.072]	[0.068]	[0.148]	[0.159]	[0.161]	[0.166]	[0.089]	[0.077]	[0.074]	[0.069]
logcapx	-0.078	-0.146	-0.154	-0.225*	0.054	-0.149	-0.167	-0.179	-0.165	-0.251*	-0.246**	-0.298**
	[0.134]	[0.117]	[0.102]	[0.094]	[0.159]	[0.143]	[0.141]	[0.135]	[0.126]	[0.107]	[0.095]	[0.088]
logppent	-0.560**	-0.547**	-0.561**	-0.475**	-0.106	0.125	0.12	0.198	-0.506**	-0.478**	-0.500**	-0.432**
	[0.161]	[0.131]	[0.118]	[0.109]	[0.217]	[0.218]	[0.211]	[0.208]	[0.147]	[0.120]	[0.111]	[0.103]
logxrdempxTL									0.361	0.323	0.202	0.152
									[0.340]	[0.269]	[0.241]	[0.210]
Constant	-13.777	-15.472*	-14.537	-15.732**	-18.250**	-16.015	-14.601**	-15.098**	-15.594	-16.066+	-14.558	-14.662**
Observations	197,381	197,381	197,381	197,381	6,317	6,317	6,317	6,317	192,456	192,456	192,456	192,456
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	-	-	-	-	YES	YES	YES	YES

Robust standard errors in brackets *** p<0.01, * p<0.05, + p<0.1*

*Appendix VI Notes: This table uses different definitions for the dependent variable, *f_mover*. With f_mover1 representing if the inventor moves within a 1 year window after his last patent, *f_mover2* representing a move within a 2 year period since an inventors last patent.