The Influence of Local R&D Tax Benefits on Irish ICT Inventions

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Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university. I further declare that this research has been carried out in full compliance with the ethical research requirements of the School of Computer Science and Statistics.

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Jaqueline Barreto Ciorlia

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1st September 2016

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Abstract

This quantitative research focuses on the analysis of ICT Irish invention production, invention value and inventive performance in response to the tax environment for R&D laid out by the Irish Government, as one of the strategies for developing a better research and innovation ecosystem. It contributes to the body of knowledge by investigating ICT innovation through different perspectives through the examination of 2207 patent applications from the Irish ICT industry filed to the USPTO from 2004 to 2015. The main findings suggest that inventive performance, invention quantity and quality in Ireland responded positively to more generous R&D tax credit rates, but trends did not show that Irish experienced inventors had a higher engagement with patents over time. The results found in this investigation provide an insight on patents from the ICT sector as an outcome of the actions taken to establish Ireland as “The Innovation Island”.

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Abbreviations

DJEI Department of Jobs, Enterprise and Innovation

EPO European Patent Office

ICT Information and Communications Technology

NACE Rev. 2 Nomenclature Statistique des Activités economiques dans la Communauté Européenne (Statistical nomenclature of economic activities in the European community)

OECD Organisation for Economic Co-operation and Development

R&D Research and Development

RQ Research Question

USPTO United States Patent and Trademark Office

1 Introduction

1.1 Background to the Study

Over the past century, European authorities have been engaged in enhancing the levels of technology performance of their countries to increase economic competitivity. As per Bloom et al. (2002, p.2), this lead to “an intellectual movement in economic theory which emphasises the conscious accumulation of R&D and human capital in explaining economic growth”. Knowledge and information have become significant sources of wealth creation and competitive advantage in the New Economy (Forfás, 2004). Subsequently, Intellectual Property (IP) has an increasing global noteworthiness for fostering innovation, creating jobs and growth and helping companies to triumph in markets.

It has been found by recent researches that 26% of employment in the EU (57 million Europeans) and 39% of total economic activity (GDP, €5 trillion annually) is created by IP-intensive sectors, and that jobs in these sectors enjoy a 40% higher wage in comparison to non-IP-intensive sectors (DJEI, 2015).

As a way of attracting companies and entrepreneurs, many countries have created tax measures for Research and Development (R&D) aiming to encourage innovation (Bloom et al., 2002), including Ireland. The state has stimulated business-level innovation in different ways. Financial support for entrepreneurs such as funding schemes, grants, low corporate tax rates and R&D tax credits are examples of the aids provided by Irish Authorities (Enterprise Ireland, 2016; IDA, 2016). A tax credit scheme for R&D was introduced by the Finance Act in 2004, with financial support progressively increasing over the following years to back up the goal of maintaining the country as an appealing location for foreign direct investment (Department of Finance, 2013).

Ireland has established itself as a global technology hub in the past decades (IDA, 2016). The Information and Communications Technology (ICT) industry plays a key role in the country’s global competitiveness with computer services representing 39% of the total service exports (Forfás, 2013) and approximately 85,400 people employed in the sector by the end of 2015 (CSO, 2016). Not surprisingly, it is in the best interest of the Irish government to promote indigenous growth, attract more ICT foreign companies and retain the ones that are already established by providing an environment that is favourable to their competitive advantage (IDA, 2016).

Notwithstanding the increasing incentives for innovation in Ireland, a report for Forfás/DJEI (DJEI, 2014) shows that the number of patents filed by inventors residing in Ireland has progressively dropped from the beginning of this decade across all sectors of industries.

Questions now arise as to the effect that the Irish tax credit rates have had on the ICT field when it comes to invention creation, invention value and inventive performance.

1.2 Relevance of the Study

This research has the purpose of better understanding whether the Irish R&D incentives have positively affected invention creation, invention value and inventive performance for companies in the ICT industry that are established in the state.

In 2004, Forfás (2004) disclosed its concern about the belated progress of the Irish innovative capacity after statistical analysis showed low numbers of patents originating in the country and low levels of investment in R&D in contrast to international standards. One decade later, DJEI (2014) reviewed the IP activity of firms based in Ireland and noted that between 1999 and 2013 patent filing reached its peak in 2008, followed by a year-on-year decline.

Based on data from the European Patent Office (EPO), DJEI (2014) reports that patenting in Ireland is sectorally concentrated in pharmaceuticals, medical devices and ICT hardware, with a smaller representation from the food and drink sector. Statistics from the material published by DJEI (2015) reveal that "the pharmaceuticals sector is a major contributor to the decline in patent filing" (p.82), considering that it is also the sector with the biggest representation in Irish patents registration overall. Thus, it is natural that numbers from this industry carry more weight in general statistics.

In order to find out if trends show a different picture in the technology domain, this dissertation will target inventions from the ICT sector in isolation.

Differently from existing papers, data from the United States Patent and Trademark Office (USPTO) is used to carry out this study. Inventions from companies with business in computer programming, software publishing, manufacture of computers and peripheral equipment, manufacture of communication equipment, information service activities and telecommunications are taken into account.

It is hoped that this experimental research can bring a deeper insight into the ICT innovation in Ireland through the analysis of patenting activity in the Irish ICT industry and that it can provide a new vision on the software and computer programming inventions, known to be more popularly registered with the USPTO instead of the EPO.

1.3 Research Questions

The research questions (RQs) below will be investigated in this study:

RQ1. Did changes in the Irish R&D tax scheme influence invention production in Ireland's ICT industry?

RQ2. Did changes in the Irish R&D tax scheme result in more valuable inventions in the Irish ICT industry?

RQ3. Did changes in the Irish R&D tax scheme culminate in an improved inventive performance for Ireland's ICT industry?

RQ3.1. Have experienced Irish inventors become more engaged with inventions from 2004 to 2015?

1.4 Scope of this Research

As previously mentioned, this quantitative research focuses on the analysis of ICT Irish invention production, invention value and inventive performance in response to the tax environment laid out by the Irish Government for R&D as one of the strategies for developing the continent's best research, innovation and commercialisation ecosystem.

For the purpose of this research, patent data was collected from the USPTO where only patents created by inventors residing in Ireland – referred to as Irish inventors – and belonging to ICT companies or subsidiaries based in Ireland were examined. The NACE Rev. 2 industry classification was used to identify companies in the ICT sector. The time frame under study starts in January 2004, when the Irish tax credit regime started favouring R&D more emphatically, and it finishes in December 2015.

1.5 Beneficiaries of this Research

This investigation provides an insight on Irish ICT innovation levels as an outcome of the actions taken to establish Ireland as “The Innovation Island”. Thus, it can be of interest of the Irish government and agencies, such as the IDA Ireland. It is relevant to academics and researchers investigating the subject. It is also pertinent to ICT companies that are already based in Ireland and want to find out where they stand in relation to general patent application statistics or companies looking for a location to establish an innovation and research centre.

1.6 Dissertation Roadmap

Chapter one introduces the research questions examined in this thesis and it presents the pertinence of this study by outlining its background, its scope and its beneficiaries.

Chapter two gives an overview of important background concepts that serve as a basis for this research topic. This chapter offers a review and critical analysis of theories on how R&D tax credits can impact the patent production of a given geography, followed by the identification of gaps in existing literature that are addressed by the present study.

Chapter three defines the methodological base that embodies this research and describes more deeply the rationale behind the chosen research methodology as well as a thorough clarification on the data collection process utilized. An assessment of the statistical method chosen for the quantitative analysis is also presented.

Chapter four shows the analysis of secondary data collected for the thesis and it depicts the findings for each research question, both from a quantitative and statistical perspective.

Chapter five concludes the research by emphasizing the study’s key findings and contribution to the body of knowledge. The chapter portrays the known limitations of this dissertation and opportunities for future research related to this topic.

2 Literature Review

2.1 Introduction

The objective of chapter two is to assess undertaken research that is relevant to this topic by reviewing theories on how R&D tax credits can impact invention production, invention value and inventive performance in a given geography. It also determines the gap in existing literature to be addressed by this study. The chapter is structured as follows:

Section 2.2 poses the concept of patents as well as the definition and relevance of research questions variables, such as patent inventorship, patent ownership, first named inventor and patent family size.

Section 2.3 explores how companies benefit from the R&D tax credit scheme in Ireland with an overview of changes in the Irish R&D taxation rules over the course of the past twelve years.

Section 2.4 contains literature review supporting different points of view on how R&D tax benefits can stimulate patent production in a given region. The section is concluded by expanding on a government report that concentrates on Irish metrics.

Section 2.5 concludes this chapter by positioning this dissertation in the context of the reviewed literature and it identifies a gap to be addressed in this research.

2.2 Patent Indicators and Definitions

This section has the purpose of explaining jargon relevant to this study through concepts defined by other authors and through examples of how some of these as indicators are used in existing academic research.

2.2.1 Patent Definition

According to Carr (2004), in the current knowledge-intensive economic scenario, a company must continually create new ideas in order to obtain and preserve its competitive advantage and profitability over time. As a means to this end, R&D investment is required to support the creation of new, differentiated products. After a successful R&D project, the next step is to protect the products' uniqueness from imitation, otherwise, the value created will be short-lived. This is where patents become essential, as they provide a way of sustainable competitive advantage by protecting a product's unique features from being copied for a certain period of time (Nissing, 2013).

Intellectual property (IP) refers to Copyright of literary works and Industrial Property such as trademarks, industrial designs, geographical indications and patents (WIPO, n.d.). A patent is a form of intellectual property that grants exclusive rights to its holder for a process or a product containing a new, non-obvious inventive step or that solves a problem with a novel technical solution (Shippey, 2002; Brougher, 2013; Nissing, 2013; WIPO, n.d.).

Patent infringement happens when an entity that does not have the rights to a patent practices each and every component of the claimed invention without the consent of the patent owner (Nissing, 2013).

Legal monopoly of patented inventions have a maximum duration of 20 years through which an invention cannot be commercially exploited in any way by other parties, unless there are agreed legal terms with the patent holder. After legal protection ends, the invention enters the public domain (Scotchmer, 2004).

For the scope of this study, it is important to analyse in more depth the aspects of patents that serve as essential parameters when collecting data to answer research questions as, for example, the definition and relevance of patent ownership, patent inventorship, first inventor and patent family, which follow below.

2.2.2 Patent Ownership

Patent ownership recognises proprietary rights over an invention. According to the Nissing (2013), the patent owner or proprietor has the right to exclude others from using, producing, importing or commercializing the claimed invention in every way.

Shippey (2002) affirms that in circumstances where IP creators do not give up their rights to others willingly or through contracts, they become IP inventors and owners at the same time. However, the owner and the inventor of a patent may not necessarily be the same party.

The European IPR Helpdesk (2013) states that it is a common situation for organisations to own creations instead of the employed inventors themselves, due to contracts or employment agreement terms between them. In fact, it is advisable for organisations that have innovation development as a core business to have an assignment system in place allowing them to acquire all the IP generated by their employees, because this will avoid later disputes on IP rights ownership (European IPR Helpdesk, 2013). At the same time, the fact that an employer may own inventions of an employee does not affect "inventorship", a concept that is further discussed in Section 2.2.3.

In the event that other parties have contributed to the same patent creation, they can obtain joint proprietary ownership for being co-inventors. Each party holds an equal share except if otherwise has been agreed by contract by all involved (Brougher, 2013). As per Shippey (2002), if there are no contractual provisions, then each co-inventor may use or sell the invention without the permission of the others. However, the profits derived from the patent must be equally shared between themselves.

A party can also sell their IP rights to another owner. This type of transaction is referred to as assignment. Patent acquisition is a strategic move done by many companies nowadays. Frequently, the acquisition of valuable IP rights in a domain drive company merger decisions, "resulting in one company expanding into the pre-made market of the other, or even taking over that market and eventually closing down a competitor" (Shippey, 2002, p. 29).

Patent Offices around the world often refer to patent owners as Applicants or Assignees. The concept of patent assignee is relevant to this thesis when determining whether patents are owned by an ICT company based in Ireland or not.

2.2.3 Patent Inventorship

Patent inventorship and ownership have two very different definitions. Ownership recognises the possession of proprietary rights, as described in Section 2.2.2, while inventorship identifies the creator or creators of an invention.

A mandatory requirement to properly classify someone as an inventor is for this person to have actively contributed to the invention and its claims. In other words, anyone who contributes to the elaboration of what goes into the patent in written form is an inventor (European IPR Helpdesk, 2013).

Although there is no limit specified to the number of inventors of a single patent (Nissing, 2013), an individual cannot be deemed an inventor if his/her participation is summarized as simply carrying out work under the direction of others (European IPR Helpdesk, 2013). Individuals who have not added clear contributions to the patent claims or to the idea itself cannot be considered an inventor, no matter how influential this person is or how much she/he has been involved in the project when the participation did not involve tasks related to the idea's conception (Nissing, 2013).

Table 2.1 shows the key differences between the participation of an individual who should be considered an inventor and someone who should not:

TABLE 2.1 - Examples of contribution characteristics that define an inventor (European IPR Helpdesk, 2013, p. 3)

Inventor / Joint-Inventor	**Not Inventor**
Conceives the idea	Puts forward hypothesis
Materially contributes to the conceptual development of the invention	Passively follows the instructions imparted
Provides solutions to problems	Performs routine tasks
Implements the innovation	Executes results testing

Some authors (Brougher, 2013; Nissing, 2013; Graham et al., 2015) highlight that the criteria for defining patent inventorship are significantly different from those relating to academic authorship. Authorship for journal or academic publications is rather inclusive. Commonly, the project lead, the researcher who runs the laboratory or the head of the department are listed as publishers even though they did not contribute to the conceptual completion of the published research or paper. The standard for patent inventorship is more narrowly defined, where reciting inventors simply out of professional courtesy is not the norm.

Correctly assigning patent inventors is of extreme importance. As a result of improper inventorship, harsh consequences may incur as, for example, patent invalidation or loss of patent rights (Brougher, 2013; Nissing, 2013; Graham et al., 2015).

Nissing (2013) recommends that determining patent inventorship should be done with the advice of an attorney, as it can be controversial, especially when a number of people worked exclusively on the reduction to practice of an invention, but not on its conception.

Patent inventorship is one of the strongest parameters when determining whether a patent will be included or not in the sample of this dissertation. The proposal is to examine purely inventions from the Irish ICT industry with at least one inventor residing in Ireland, referred to as “Irish inventor” in parts of this thesis.

2.2.4 Patent First Inventor and Inventive Performance

Nowadays, it is very common for patents to be created conjointly by inventors located in different countries. When calculating their official statistics, organizations like the USPTO (United States Patent and Trademark Office) and EPO (European Patent Office) keep with the convention that the country of residence of the first inventor is the assigned country of a patent (OECD, 2009). Jaffe and Trajtenberg (2002) suggest that this convention relies on the fact that the main work and innovative force of an invention takes place in the country of residence of the first inventor. For this reason, patents with the first inventor residing in Ireland will be used to measure Irish inventive performance.

About the importance of the first inventor listed in a patent, Stolpe (2002) gives more weight to the relevance of this principle by claiming that inventors are not listed in alphabetical order when it comes to inventions “which suggests that those listed first made a more important contribution to the invention and thus have more knowledge to spread” (p.1192).

In their analysis of Europe and Central Asia (ECA) patents, Goldberg et al. (2008) follow this same convention. The authors also regard the first inventor as the most important contributor when concluding that ECA citizens listed in the first position of a patent application had a greater contribution to an invention.

On the other hand, authors with a stronger background in law, such as Graham et al. (2015, p.4), state that “in contrast to scientific publications, the order of inventors listed on a patent is irrelevant” because joint inventors have equivalent rights to their patent, unless otherwise has been agreed. One major drawback of this interpretation is that Graham et al. (2015) regard patent inventors as also being patent owners, which is proven to be the least common scenario.

Analogous to the report by DJEI (2014), this investigation will first look at patents with inventors residing in Ireland at the time of filing, regardless of the inventors order. Subsequently, data will be filtered down in a way that only patents with an Irish first inventor will be examined. This second stage of analysis has the objective of identifying inventions that most likely originated inside the country, as per model proposed by Goldberg et al. (2008). Irish first inventor will be the parameter interpreted as a measure of inventive performance.

2.2.5 Patent Family

A patent family is a group of patent equivalents filed in different countries to protect the same invention (DJEI, 2014). The size of a patent family expresses the number of jurisdictions in which patent protection has been pursued on top of the location where the invention was originally filed (OECD, 2009).

Naturally, extending patent protection across borders involves additional costs for each and every jurisdiction, plus extra costs required to maintain this protection over the years. OECD (2009) and Fischer and Leidinger (2013) state that the creation of a patent family establishes a sign of economic value for the protected idea, for the owner's readiness to bear the cost is a strong indication that the invention is worth the expenses.

According to OECD (2009, p.142), "the geographical scope of protection, as reflected in international patent grants for a given invention, reflects the market coverage of an invention". This means that the more jurisdictions are covered, the greater the potential for revenue generation and commercial activities. Which makes the investment in promising patent families an important part of patent filing strategies and market expansion for companies seeking to thrive from innovation (DJEI, 2014).

Consequently, the existence of a patent family and the family size are proven indicators of invention quality and value (OECD, 2009; Fischer and Leidinger, 2013; DJEI, 2014), with the advantage of allowing measurements early in the life of a patent application when compared to other indicators, such as forward citation, which is an indicator that requires years to allow time for patents to be recognized as important and then cited.

Applications made in international jurisdictions generally lapse one year after the national patent application has been filed (OECD, 2009), which means that patent families could be formed from within one year. When it comes to forward citations, it is standard practice to observe the indicator for each patent in a dataset for the time span of five years after publication. This practice forces researchers to exclude recently filed patents from their studies (Fischer and Leidinger, 2013).

In this research, trends of patents with families containing at least one member in a foreign jurisdiction will be measured across the time-series under investigation as the invention value indicator. Further information on the construction of this quality indicator is presented in Section 3.4.2.

2.3 R&D tax credit schemes in Ireland

In response to the Global Recession in 2008, the Irish government published an Economic Recovery Plan "Building Ireland's Smart Economy" (Revenue, 2010). As part of the objective of turning Ireland into an European innovation and commercialisation hub, this plan aimed at encouraging the development of the knowledge economy by promoting the country as a great location for the management and exploitation of intellectual property and by provisioning a stronger R&D associated tax support to the indigenous enterprise sector and to foreign companies with potential to create high-quality employment along the way (Department of the Taoiseach, 2008).

More meaningful changes in the Irish taxation system favouring innovation and patent creation started a few years before the Economic Recovery Plan. In a report released by Forfás (2004), it was admitted that Ireland did not have a favourable tax regime towards R&D expenditure when set side by side with other Organisation for Economic Co-operation and Development (OECD) countries. Starting in 2004, there has been a considerable degree of priority given to research prioritisation, technology, and structural reform to redress corporation tax incentives for Irish-based IP (DJEI, 2015).

Together with the industrial development agencies, Forfás proposed a tax credit scheme for R&D introduced in Finance Act 2004 with the purpose of mending the declining growth and improving the intensity of investment in R&D in Ireland (Forfás, 2004). In following years, the Finance Act 2009 significantly enhanced R&D tax arrangements, in conformity with the intended actions described by the Government's Economic Recovery Plan published in 2008 (Revenue, 2010).

As better detailed in Table 2.2, for the past decade the Irish government has introduced a number of changes to the R&D tax support system including the closure and re-assignment of funding that affect Irish-based IP creation (Department of Finance, 2013; Revenue, 2013; Revenue, 2014). There are researchers (Alstadsæter et al., 2015) that consider the patent royalty tax exemption abolished in Finance Act 2011 as an Irish patent box. DJEI (2015), however, claims that Ireland had no direct explicit public support schemes for invention creations when compared to other European nations and, instead, companies based in Ireland could only indirectly benefit from supports with a limited coverage, such as tax system instruments and general R&D grant programmes for qualifying patents.

Despite the fact that benefits provisioned by the Irish R&D tax scheme became incrementally more generous over time, a number of other OECD countries offer more advantageous and explicit IP support schemes/programmes. DJEI (2015) suggest that based on this comparison, there is room for improvement for better supplying firms – the small ones, particularly – with resources, and to include financial and non-financial supports for IP management capability. The authors add that Ireland can also benefit from making available to firms more solid education and guidance on IP (DJEI, 2015).

TABLE 2.2 - Amendments to the R&D credit since its introduction in 2004 (Department of Finance, 2013; Revenue, 2013; Revenue, 2014).

Changes to R&D Tax Credit Scheme in Ireland	
Year	**Changes to R&D Tax Credit Scheme**
2004	The scheme was announced based on a 20% credit on R&D expenditure in excess of R&D spend incurred by a company in 2003.
2005	There were no amendments in 2005 for R&D.
2006	A share of the costs of plant and machinery associated with R&D is eligible for the tax credit.
2007	Change from the previously proposed ‘rolling base year’ approach to fixing a base year. The R&D tax credit enables a company to claim tax credits valued at 20% of its R&D expenditure in any given year, on the basis that its expenditure was incremental to expenditure on R&D activities in 2003 until 2009.

	Businesses sub-contracting R&D to non-associated parties have their expenditure eligible for the credit where they do not exceed 10% of total costs in one year.
2008	The base year at 2003 now fixed until 2013. For accounting periods after 2013, a ten year look-back provision made was made between the year the credit is claimed and the base year R&D expenditure.
2009	The rate of relief on eligible R&D expenditure was increased from 20% to 25%. The base year now fixed at 2003 indefinitely. R&D tax credit allowance for a portion of expenditure on mixed used buildings and structures, subject to a 35% minimum use of these structures and buildings for R&D activities taking place over a period. Full discharge of R&D tax credit over a three year period as an offset against corporation tax or as cash payments in the event of insufficient or no corporation tax. New incentive introduced allowing relief to acquisition of qualifying intangible assets, such as qualifying patents.
2010	Modifications to handle base year expenditure issues under the tax credit scheme where R&D is undertaken by a company in two separate premises in Ireland and one of those premises is eventually closed down.
2011	Abolishment of the tax exemption for distributions from patent royalties made by companies from exempt patent income. Abolishment of tax exemption for income received by an individual or company from patents.
2012	25% R&D tax credit on the first €100,000 of qualifying R&D expenditure. The tax credit will continue to apply to incremental R&D expenditure in excess of

	€100,000 in the base year 2003. Companies in receipt of the R&D credit can use a proportion of the credit to reward key employees who have been involved in the development of R&D. The outsourcing annual ceiling for sub-contracted R&D costs are being increased to the greater of 5 or 10% as appropriate or €100,000, to better support smaller companies who may have greater need to outsource R&D work in comparison to large multinationals.
2013	25% R&D tax credit on the first €200,000 on a full volume basis, without reference to the 2003 base year.
2014	25% R&D tax credit on the first €300,000 on a full volume basis, without reference to the 2003 base year. The annual ceiling on the amount of qualifying R&D expenditure that can be outsourced to another company was increased from 10% to 15%.
2015	The tax credit regime base year (2003) restriction was completely removed.

Within the time scope verified in this study, Ireland's tax exemption on qualifying patent income was only active from 2004 to 2011, while the R&D tax credit scheme was active throughout the whole term under examination. This investigation is limited to the effects that R&D tax credits had on ICT inventions in Ireland, since this benefit covers the full period. Corporate tax rates and other tax exemptions are not examined.

For reference, Figure 2.1 depicts the variation in the Irish R&D tax credit rate percentage for the time span encompassed in the scope of this study.

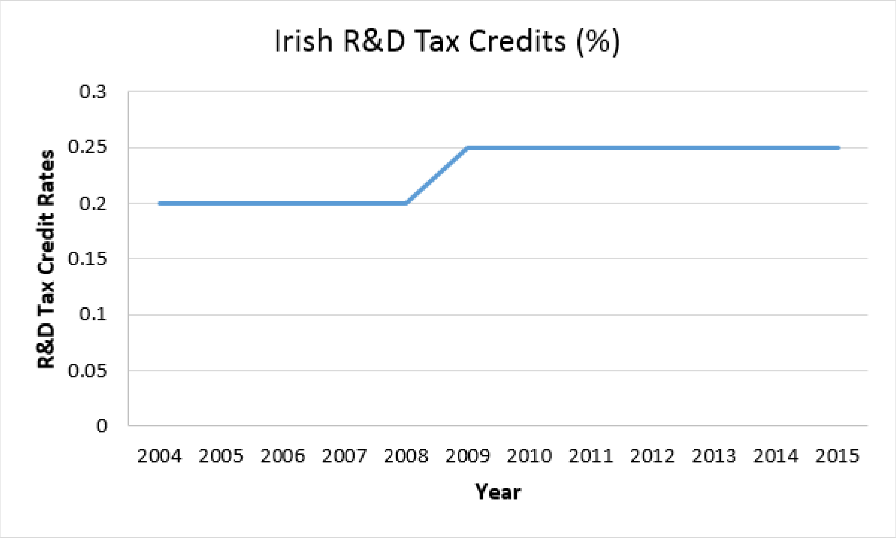

FIGURE 2.1 - Variations in R&D Tax Credits in Ireland from 2004 to 2015

Following the period covered in Table 2.2, the Irish Budget 2016 announced the creation of a patent box called Knowledge Development Box (KDB). From January 2016 on, this package allows companies in Ireland to earn profits, avail of low patent income taxes and tax credits from copyrighted software or patents that were created as a result of R&D activities that occurred in the State (Revenue, 2015). The results of this recent change do not yet reflect patent data, thus, this new and more significant measure cannot be covered by the present study.

The body of knowledge reviewed in section 2.4 covers effects of low patent income taxes and of R&D tax credit schemes in various locations.

The source of tax information for other researchers were the OECD, Taxation of Corporate and Capital Income (Ernst and Spengel, 2011), Ernst & Young's corporate tax guides and International Bureau of Fiscal Documentations (Ernst et al., 2014). Since this study concentrates in Ireland, the tax information sources used are mainly Department of Finance and Irish Revenue Commissioners.

2.4 Literature Review of Existing Body of Knowledge

Over the past century, European authorities have been engaged in enhancing the levels of technology performance of their countries to increase economic competitivity. As per Bloom et al. (2002, p.2), this lead to "an intellectual movement in economic theory which emphasises the conscious accumulation of R&D and human capital in explaining economic growth". Knowledge and information have become significant sources of wealth creation and competitive advantage in the New Economy (Forfás, 2004). Subsequently, Intellectual Property (IP) has an increasing global noteworthiness for fostering innovation, creating jobs and growth and helping companies to triumph in markets.

As a way of attracting companies and entrepreneurs, many countries have created tax measures for R&D aiming to encourage innovation (Bloom et al., 2002). Literature in this area more extensively quantifies the effects of subsidies on firms' R&D expenditure and business activity in general, such as research carried out by Lokshin and Mohnen (2007), Kasahara et al. (2013) and Einiö (2014), to name a few. Other part of literature focuses on how R&D tax rates influence firms' choice of location for their intellectual property (Dischinger and Riedel, 2010; Böhm et al., 2012; Karkinsky and Riedel, 2012; Siedschlag et al., 2013; Griffith et al., 2014). After examination, both these strands of literature were considered to be tangential to the main topic of this dissertation and, therefore, will not be discussed in further detail.

This study aims to investigate if changes in the national R&D subsidies affected patent quantity, quality and inventive performance in the Irish ICT sector in isolation. To date, there is limited research evidence in this topic, even if considering a broader geographic scope for analysis. Literature directly related to this field is thin and it is briefly overviewed in Table 2.3.

The existing body of knowledge finds evidence that R&D tax schemes have a positive effect on patent quantity (Ernst and Spengel, 2011; Ernst et al., 2014; Bronzini and Piselli, 2015) and negative effect on patent quality (Ernst et al., 2014). Ernst and Spengel (2011) found that R&D tax schemes increase the likelihood of firms investing in R&D and their patenting activity. Bronzini and Piselli (2015) found that R&D benefits had a positive effect on the patent applications count of participating firms in Northern Italy. The smaller the firm, the more significant the impact of the Italian program. While Ernst et al. (2014) found that both low patent income taxes and R&D tax credits raise patents quantity, the scholars observed that quality only increases with low patent income taxes. High R&D tax credits had the opposite effect, reducing patent quality. Cappelen et al. (2011) had distinct findings, it was found that the Norwegian tax credit scheme SkatteFUNN does not contribute to firms' patenting activity neither negatively or positively. To finalize, the only report that investigates Irish patenting activity uncovered that the patent registration volume dropped from 2008 to 2013, however, it did not review the Irish R&D tax schemes over the period examined (DJEI, 2014).

TABLE 2.3 - Brief overview of studies analysing the effect of R&D tax benefits on patents.

Authors	**Sample**	**Variables**	**Methods**	**Relevant Findings**
Ernst and Spengel (2011)	- 20 European countries - 161,945 patents (EPO, 1998-2007) - Firm count is not mentioned	- Combined statutory corporate income tax rates (1998 - 2007) - Patent quantity - Firms' number of employees (control variable) - Firms' total assets in the balance (control variable)	- B-Index on R&D costs	- Patent quantity reacts positively to R&D tax incentives. - Patent quantity reacts negatively to corporate income tax rates.
Ernst et al. (2014)	- 29 European countries - 160,790 patents (EPO, 1995-2007) - Firm count is not mentioned	- Patent income tax rate - Tax credit and allowances measures - Patent quantity - Patent quality (family size, forward citation) - Firm size	- B-Index on R&D costs	- R&D tax credits raise patents quantity and decreases quality. - Low patent income taxes raise patents quantity and quality.

Bronzini and Piselli (2015)	- Italian region Emilia-Romagna - Patent count is not mentioned (EPO, 2005-2011) - 612 firms	- Local R&D subsidy program - Patent quantity - Firm size (control variable)	- Poisson and negative binomial models - Regression discontinuity method	- R&D benefits had a positive effect on patent quantity. - Smaller companies react more significantly.
Cappelen et al. (2011)	- Norway - Patent count is not mentioned (Statistics Norway, 2001-2004) - 1689 firms	- SkatteFUNN, local R&D subsidy program - Patent quantity - Firm size (control variable)	- Binary regression models	- Patent quantity did not react to the tax scheme. - Increase in innovative production processes. - Increase in new products.
DJEI (2014)	- Ireland + Top 5 countries in European Innovation Scoreboard - 9,601 patents with Irish inventors (EPO, 1999-2013) - Firm count is not mentioned	- Patent quantity - Patent quality (family trends)	- Data was queried with SQL coding and analysed using a proprietary tool. - Statistical analysis was not executed	- Steep decrease in patent quantity from 2008 on. - Mild decrease in patent quality from 2011 on.

Conclusions on Table 2.3 are consolidated at the end of this chapter. With the intention of identifying gaps in the current body of knowledge, a more detailed literature review examining individual studies follows below.

The research paper by Ernst and Spengel (2011) investigated the effects from tax incentives for R&D inputs. A link between R&D activity and patenting was established so that patent applications could be used as a proxy for the scale of R&D inputs in their analysis. Their study compared tax subsidies as inputs in the R&D process from years 1998 to 2007 and it measured patent applications counts as an output. It is hypothesized that firms invest more in R&D and apply for more patents when R&D tax incentives are abundant. Another hypothesis tested is that there is a negative effect of the combined statutory corporate income tax rate on the count of patent applications. This means that the higher the taxation on the R&D resulting IP, the less attractive a country becomes as the chosen location for R&D projects.

Secondary data from the European Patent Office's Bulletin was collected by Ernst and Spengel (2011) with the purpose of validating the hypotheses, where the count of patent applications that a particular firm submitted in a specific year was the dependent variable. Instead of selecting patents by inventors, the researchers used applicants and matched patent applications with data from the Amadeus-database in order to find out firm-specific information, such as the number of employees or total assets in the company's balance. The data analysed was from firms based in 20 different European countries (AT, BE, CZ, DE, DK, ES, FI, FR, GB, GR, HU, IE, IT, LU, NL, NO, PL, PT, SE, SK).

The results of this study supported Ernst and Spengel (2011) hypotheses. The scholars found that "firms' patenting activity reacts positively to R&D tax incentives as they increase the propensity to invest in R&D and to patent" (Ernst and Spengel, 2011, p.6), the tendency of rather small firms to start patenting is also increased. According to the authors' expectations, the results showed that a higher corporate income tax rate decreases the count of patent applications, especially for larger companies. These firms chose to locate their R&D activities in countries with lower corporate income tax rates.

In comparison to the purpose of this thesis, the main weakness with the paper by Ernst and Spengel (2011) is that besides Ireland, the study covers other 19 other European countries. Many of these territories have a tendency to dominate figures because they have a more significant level of patent registration. With this, the conclusions drawn cannot be interpreted as the actual Irish reality. In addition, this paper was done based on relatively older data from the European patent office and it only considers patent quantity, leaving quality and inventive performance out of the scope. The sample data covers all industries, it is not possible to visualize figures by individual sectors.

As a continuation of the study reviewed above, Ernst et al. (2014) investigated the impact of R&D tax schemes on two quality indicators: the quality of R&D projects using project innovation – measured with patents – and project profitability before taxes. The researchers argument that both indicators are positively correlated and hypothesize that the increase of R&D tax credits decreases the average profitability, thus, also the innovativeness of projects undertaken in a country.

The data interpreted consisted of patent applications from firms of 29 European countries to the European Patent Office (PATSTAT Database) between 1995 and 2007. In order to measure innovation quality, this study examined a patent's family size, its number of forward citations and the number of industry classes that are stated on the patent. Subsequently, patent information was merged with firm-level data available in AMADEUS database. In addition, the data analysis took into consideration national R&D tax schemes (Ernst et al., 2014).

The scholars found that both low patent income taxes and R&D tax credits raise patents quantity. However, there is a contrast when it comes to tax impact in project quality. It is observed that "while low patent income taxes raise average project quality, generous R&D tax allowances/credits tend to reduce it" (Ernst et al., 2014, p. 697). Across industries and countries, Ernst et al. (2014) quantitatively observed that when patent income tax rate decreases the patent quality will boost by around 1–5%.

In spite of the fact that Ernst et al. (2014) evaluated patent quantity and patent quality, the authors' sources and sample are very different from what the present dissertation proposes to analyse. The investigation by Ernst et al. (2014) was based on data of past decades from the EPO and patents from all industries were investigated. Sectors with a higher patent registration tend to overpower research figures, thus, conclusions cannot be safely extended to the ICT sector in isolation. Furthermore, the geography covered by the research included other 28 countries besides Ireland.

In another paper, an econometric research done by Bronzini and Piselli (2015) explored the effect that local R&D incentives program had on the output innovation activities of beneficiary firms in the Italian region of Emilia-Romagna. The hypothesis investigated is that subsidies have been more effective in increasing R&D investment of smaller firms rather than larger firms.

Bronzini and Piselli (2015) ran their analysis on the numbers of patent applications submitted to the EPO by 612 firms subsidized by the program from 2005 to 2011 and estimated the effects of local R&D benefits using the Poisson and negative binomial regression models. Bronzini and Piselli (2015) found that R&D benefits had a positive effect on the patent application count of participating firms. The smaller the firm, the more significant the impact of the program.

Limitations of the research are that enterprise innovations are not always patentable, consequently, part of the local innovation may not be part of this study. Another limitation is that the R&D incentives program may have influenced innovation of companies that were not part of the sample (Bronzini and Piselli, 2015).

A drawback of the investigation by Bronzini and Piselli (2015) is that it only took into account patent counts to measure tax schemes efficiency, disregarding quality. The focus of this paper was very specifically to analyse if R&D subsidies affected patent registration from the Italian region Emilia-Romagna, and the EPO was the only data source examined. All sectors of local industries were examined. Even though the goal of understanding if R&D tax schemes had an impact in patent registration is the same as the one of this thesis, the data source, region and sample under investigation differ.

Another research that is relevant to this thesis is the one executed by Cappelen et al. (2011). The authors used an econometric approach to evaluate how SkatteFUNN, a Norwegian R&D tax credit scheme, impacted firms' innovation activities like the creation of new products, new production processes and patenting activities.

The researchers use micro data on R&D statistics collected annually by Statistics Norway, where the period from 2001 to 2004 was analysed. When answering this survey, companies disclose of information on new products that it had released to market, production processes that had been innovated, the number of patents that it had applied to and other R&D expenditures (Cappelen et al., 2011). The total of 1689 firms was included in the study sample after disregarding companies that did not have enough information on the variables of interest.

The investigation findings showed that the tax credit scheme does not notably contribute to firms' patenting activity, given that there was no evidence that SkatteFUNN negatively or positively influenced the probability of a firm filing for patent applications. Production process innovation is the variable that was mostly affected positively followed, to a smaller degree, by the creation of new products (Cappelen et al., 2011).

In contrast with all the other papers, this study did not use data from the EPO. The authors analysed patent quantity solely based on respondents of a Norwegian survey. The data was not filtered by any industry sector. Interestingly, it was the only research that did not find evidence that an R&D tax scheme influences patent registrations, either negatively or positively.

In 2014, DJEI (2014) released a report that provided insight into the Irish IP Activity of firms in different sectors. With the purpose of visualizing how Ireland performed in terms of innovation, the study compared Irish IP statistics with the 5 countries in leading positions on the European Innovation Scoreboard: Sweden, Germany, Finland, Denmark and Singapore.

From the invention perspective, the report concentrated on patent production and patent family trends as a quality measure, where data from 1999 to 2013 was collected from the EPO database (PATSTAT) for analysis. The inspection of 9,601 granted patents with Irish inventors showed an increase in activity until 2008. From this year on a continuous decline was observed in the quantity of patent filings (DJEI, 2014). A similar trend was noted for patent family filing, however, with a less considerable drop from 2011 on. The authors note that "there exists a publication lag which can manifest itself in an apparent drop off in patenting activity over the most recent years" (DJEI, 2014, p. 25).

DJEI (2014) also evaluated patents volume by industry sectors according to NACE codes - a business activity classification system used in Europe. Throughout the time period investigated, it was found that the top of the ranking was occupied by the pharmaceutical and medical devices sectors. The closest NACE code to the ICT industry displayed in the report shows the progress of patents from companies classified with NACE code "30 Office machinery and computers" from 1999 to 2013. There was an increase on the patent volume for the respective code up to 2010, with a continuous drop in filings after the end of year 2011.

This report does not take account of operating R&D tax schemes in the investigated countries. Similar to other literature reviewed in this chapter, the source of patent data used to generate the report was the EPO. The study by DJEI filtered companies by NACE codes, making it possible to have a minimal insight on the Irish ICT patent activity. Yet, the present thesis considers a bigger variety of NACE codes related to ICT, especially codes more strongly related to software and hardware manufacturing.

2.5 Conclusion

This chapter's content cover patent related definitions that are relevant to the research questions investigated in this thesis. The R&D tax credit regime from 2004 to 2015 in Ireland is also covered. During the review of literature pertaining to this topic, the gaps discussed below were identified and are proposed to be filled in by this study.

While Ireland is the main location under analysis in this thesis, none of the researches reviewed above – summary available in Table 2.3 – aimed attention at the ICT sector in this geography, exclusively.

All the reviewed researchers selected sample data covering all branches of commercial activity, where industries with a more significant participation in patent registration have a stronger influence over research figures and can, therefore, distort any conclusions for the ICT sector.

Most of the studies analysed the effects of R&D tax regimes on patent quantity alone, whereas this research will take into account patent quantity, quality and inventive performance in Ireland, partially comparable to the paper and report written by Ernst et al. (2014) and DJEI (2014), respectively.

In addition, none of the studies analysed data from the USPTO; the majority rely on data from the European Patent Office. Software is patentable in the EPO where the invention's contribution to the art is strictly technical. If the inventive step lies more heavily on the business side of the patent, it is harder for inventions to be filed with the EPO than with the USPTO (Beresford, 2001). Moreover, evidence found by DJEI (2014) suggest that it makes more sense for USPTO data to be used when investigating Irish inventions, their report claims that "Ireland, the US and the EPO are the three main filing locations for Irish applicants and Irish inventors. With the US emerging as a dominant location in 2004"

(DJEI, 2014, p.7). Hence, the present research will focus on patents filed with the USPTO instead of the EPO.

This dissertation adds to the existing body of knowledge by investigating the ICT Irish patent production with the USPTO in terms of quantity, quality and inventive performance in response to the tax environment laid out by the Irish Government for R&D from the years of 2004 to 2015. The theoretical considerations show that R&D tax schemes generally increase patent registrations, but the same is not true when it comes to quality.

The next chapter describes the research methodology that shapes this thesis, the methods utilized to collect data and an assessment of the statistical method used for the quantitative analysis.

3 Methodology and Fieldwork

3.1 Introduction

This chapter describes the research method that frames the execution of this investigation and it presents argument on why this is deemed to be the most appropriate research methodology to be followed. The chapter encompasses clarification on the type of data being used, on how it was collected and it details the steps followed to assess the statistical method used for data analysis. The chapter is organized as follows:

Section 3.2 contains a brief description of the research questions that are later tested with the support of the chosen methodology.

Section 3.3 defines the method of research used in this study and the rationale behind the selection of these methods. The goal of this experimental and quantitative research is to correlate quantity and quality of Irish patents, as well as the Irish inventive performance, with the changes in the Irish R&D tax scheme over the last decade. A deductive approach was followed, in line with the positivist school of thought.

Section 3.4 describes the data used in this investigation and its sources. It brings further explanation on how data was collected and it comprises information on the tools used to obtain more accurate data counts.

Section 3.5 shows how the statistical model used in Chapter 4 was chosen. The options analysed were the Poisson Regression and Negative Binomial Regression models. Based on the results for data assumption tests obtained with SPSS software, the later is the statistical procedure sought to analyse data and obtain credible results in this study.

Section 3.6 concludes this chapter with a summary of the methods pursued.

3.2 Research Questions

The research questions (RQs) below will be addressed through the methodology outlined in Section 3.3, based on the interpretation of patent data from the US Patent Office and R&D tax benefits detailed in Section 3.4.

RQ1. Did changes in the Irish R&D tax scheme influence invention production in Ireland's ICT industry?

RQ2. Did changes in the Irish R&D tax scheme result in more valuable inventions in the Irish ICT industry?

RQ3. Did changes in the Irish R&D tax scheme culminate in an improved inventive performance for Ireland's ICT industry?

RQ3.1. Have experienced Irish inventors become more engaged with inventions from 2004 to 2015?

3.3 Research Methodology used in this Research

Three main sources were used as a foundation for choosing the research methods selected for this thesis: Remler and Ryzin (2015), Saunders, Lewis and Thornhill (2012) and Rudestam and Newton (2007). Due to the logical flow and systematic approach that it provides, the layers of the 'Research Onion' model by Saunders et al. (2012) will be used to outline this section. However, all the references mentioned are taken into account when discussing the options chosen for each 'Research Onion' layer.

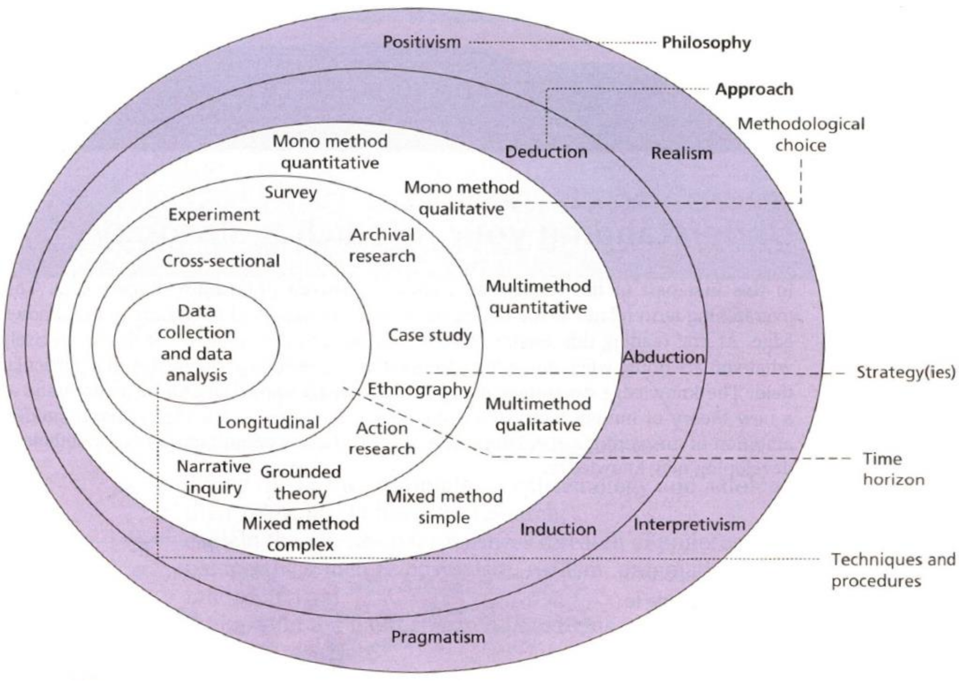

FIGURE 3.1 - Research Onion (Saunders et al., 2012).

3.3.1 Research Philosophy

According to Remler and Ryzin (2015), positivism is the research philosophy that allows the most pragmatic approach to problem solving. In this study, statistical analysis will be conducted on secondary data in order to determine the effects that Irish R&D tax credits may have on Irish ICT patent production. Public quantitative data will be gathered objectively for analysis, as further described in section 3.4. This means that the researcher will be external to the process of data collection, not interfering with the data content. This method is compatible with objectivism and with the positivist tradition of research, as per Saunders et al. (2012).

While investigating other philosophies, it has been noted that one strong characteristic of interpretivism is to subjectively interpret socially constructed realities and that acceptable knowledge can only be composed by people's perception of the world, most often collected with qualitative data (Saunders et al., 2012). Since this research is carried out on objects, not on people or social phenomena, interpretivism is not suitable in this case.

Pragmatism and Realism are other main philosophies in the outer layer of the Research Onion. Pragmatists are not exactly committed to a given research philosophy, they focus on practical applied research with flexibility to use either objective and subjective approaches, quantitative or qualitative techniques or both, as long as it is the best approach for achieving credible and well-founded results. Whereas Realism is similar to positivism in developing knowledge scientifically, however, it has focus on realities that exist independently of the human mind and are interpreted through social conditioning (Saunders et al., 2012). Neither of these philosophies are consistent with the context and methods used in this investigation.

Although it is understood that positivism does not consider the interpretation of multiple or of socially constructed realities and it does not consider situational reactions that characterize social phenomena as other philosophies do, the goal of this thesis is to statistically extract findings based on relationships between variables in the proposed research questions. Therefore, objectivism and positivism are, respectively, the ontology and epistemology adopted in this dissertation.

3.3.2 Research Approach

The first step taken in the present study was to create questions and a logical explanation for effects that R&D Tax Schemes may have on ICT invention production, invention value and inventive performance in Ireland. Data collection and methodology to answer research questions follow after. This is aligned with the deductive approach, which is associated with the positivist school of thought, where researchers move from the theory towards data results (Remler and Ryzin, 2015).

The inductive approach goes in an opposite direction, thus, it has not been employed in this investigation. Inductive reasoning learns from experience, researchers begin with an observation of the environment before developing a theory that explains what has been examined. This approach is often linked to qualitative research (Saunders et al., 2012).

3.3.3 Research Methodological Choice

Rudestam and Newton (2007) state that quantitative research seeks objectivity, it deals with numerical data and tends to use statistics or other numerical measurements that handle quantifiable data. While qualitative research values subjectivity, it handles non-numeric data originated, for example, from surveys with open questions and interviews.

Authors (Remler and Ryzin, 2015; Saunders et al., 2012) defend that, nowadays, the combination of both methods offer more advantages in producing high quality papers, as multiple methods allow scholars to confirm findings and achieve stronger results.

Although it is understood that the usage of measurements does not make a paper more scientific, the mono method quantitative design is the most appropriate methodological choice, or research design, for this study given that patent data is gathered with the purpose of obtaining count data for analysis.

3.3.4 Research Strategy

The experimental strategy observes whether changes in the independent variable (Irish R&D Tax Credit) have an impact on the dependent variables (invention production, invention value and inventive performance) and, for this reason, it was the chosen strategy for this research. As per Saunders et al. (2012), the independent variable is the variable the suffers modifications and the dependent variable may respond differently as a result of these variations.

The creation of control or experimental groups do not apply to this thesis. Due to the nature of the independent variable, it is not possible to have a group of companies under the influence of an unchanged R&D tax credit scheme (control group) while it varies for the remaining firms (experimental group). The same tax benefits are applicable to all the ICT companies throughout the time series under investigation.

Survey and Case Study strategies were considered at the early stage of dissertation proposal, but disregarded for a couple of strong reasons. The outcome data generated with these strategies would not be as rich in providing answers for this topic as the secondary data combined with experimental strategy. Second, intellectual property is directly related to competitive advantage and corporate strategy. It is a sensitive subject which most companies are not willing to disclose information on or discuss openly.

3.3.5 Time Horizon

As secondary data dated from 2004 to 2015 was available for this research. The variables behaviour could be monitored for an extended period of time, which correspond to a longitudinal time horizon.

Data collection for cross-sectional studies happens for a shorter and, generally, fixed snippet of time (Saunders et al., 2012). Therefore, it is not the best option for the present research.

3.4 Research Data

As previously mentioned, in order to investigate the research questions in this dissertation, secondary data is used. It was collected from the Irish Department of Finance, Irish Revenue Commissioners, United States Patent and Trademark Office (USPTO) and FAME databases.

Secondary data is data that has been previously gathered for means other than this research and made accessible to the public by different organizations or researchers (Remler and Ryzin, 2015). Some disadvantages of secondary data are that the researcher has no control over its quality and the data might not be a hundred percent fit for a study's purpose. However, these disadvantages are not a concern given the reliability of the sources chosen for this research and how up-to-date data is.

FAME is a well regarded database of companies covering over 9 million firms in the UK and Ireland (Bureau van Dijk, 2016) often used by highly respected scholars. The USPTO is the American federal agency that registers trademarks and issues patents in the United States of America (USPTO, 2016). The Irish Department of Finance and Revenue Commissioners are official governmental organizations in Ireland.

3.4.1 Patent Data Set

This data set collection technique is comparable to the ones used by DJEI (2014), Ernst et al. (2014) and Ernst and Spengel (2011). However, in this thesis data from the USPTO is preferred over the European Patent Office (EPO). Although, the platform offered by the EPO is more convenient for its ease of use, the US Patent Office database is more suitable in the context of this study for three main reasons: 1) Software patents are a big part of the research scope and are known to be filed with the USPTO more frequently than with the EPO, in general; 2) From 2004, the US has been the dominant patent filing location for Irish applicants (DJEI, 2014); 3) Previous researches conducted on this topic (Ernst et al., 2014; DJEI, 2014; Griffith et al., 2014; Siedschlaga et al., 2013; Böhm et al., 2012; Spengel, 2011) have not yet used data from the USPTO for analysis. Different data sources could lead to different findings.

Invention applications registered between 2004 and 2015 with at least one inventor residing in Ireland state the total basic population of 8835 patent applications, extracted from the USPTO Patent Database (AppFT) at http://appft.uspto.gov/netahtml/PTO/search-adv.html. Each patent application record consists of detailed information on the invention itself, on the patent applicant or assignee, patent inventors and their country of residence, patent family and filing dates, among other pieces of information as depicted in Figure 3.2 and Figure 3.3.

The reason why the use of patent applications was preferred over granted patents is that a patent application is enough for companies to prove that R&D work has incurred in a given year and whether it qualifies for tax credits. Moreover, an application is normally published 18 months after filing, but the lag between filing and grant can vary from two to eight years (OECD, 2009).

It is important to highlight that the date parameter used to query the database was the patent priority date. OECD (2009) claims that this is one of the most significant patent dates from an economic and technological perspective, because it is the closest to the date of invention. In other words, the priority date is the first date of filing of a patent application, then the invention remains secret until it is published within 18 months after priority, generally (OECD, 2009). This characteristic creates statistical difficulties for analysts, because data related to patents filed in the last 18 months is likely not to be fully available to general public. Naturally, this characteristic affects this dissertation findings too.

Despite of this obstacle, if compared to the publishing date, the priority date is a closer match to the tax year when the R&D effort actually took place and resulted in a patent application. In addition, OECD (2009) states in its Patent Statistics Manual that “when compiling patent statistics to reflect inventive activities, it is recommended to use the priority as the reference date” (p. 53). Priority date is also referred to as “Filed date” later in this paper.

The examined data set was restricted to corporate inventions by applicants that perform primary activities in the ICT sector and that exist in Ireland as either the holding company itself or a subsidiary of an ICT firm. ICT related inventions owned by natural persons and universities were discarded from the study, as they do not benefit from R&D corporate tax schemes. For cases in which the Assignee was omitted from the application, patents were queried by their title in another USPTO database: PatFT at http://patft.uspto.gov/netahtml/PTO/search-adv.htm in an attempt to identify the invention’s owner. ICT patents that had either law firms as their assignees or had information on the assignee missing in both AppFT and PatFT databases were disregarded from the data set, because it was not possible to accurately trace the assignee back to an Irish based ICT enterprise.

With the means of identifying active ICT firms established in Ireland, the FAME database (Bureau van Dijk) was used. FAME classifies companies according to the European standard classification of productive economic activities, NACE Rev. 2. The database was first queried for all active companies containing Republic of Ireland as their primary trading address or registration office address and then queried for the NACE Rev. 2 codes listed below:

582 - Software publishing

61 - Telecommunications

62 - Computer programming, consultancy and related activities

63 - Information service activities

262 - Manufacture of computers and peripheral equipment

263 - Manufacture of communication equipment

The final list extracted from FAME contained 10,490 Irish based ICT firms.

The Companies Registration Office (https://www.cro.ie/) was also considered as a complementary source of Irish ICT firms. However, on the grounds that the public records did not contain any type of economic activity classification per firm, this intention was abandoned.

TABLE 3.1 - Query criteria used for filtering companies in FAME

Criteria		Step result	Search result
1.	All active companies (not in receivership nor dormant) and companies with unknown situation	3,683,573	3,683,573
2.	Country: Prim. trading address, R/O address: Republic of Ireland	574,170	197,224
3.	NACE Rev. 2: All codes: 262 - Manufacture of computers and peripheral equipment, 263 - Manufacture of communication equipment, 582 - Software publishing, 61 - Telecommunications, 62 - Computer programming, consultancy and related activities, 63 - Information service activities	586,202	10,490

Notes: “Criteria” column contains the description of the search step. “Step result” column shows the number of companies that an individual search step has selected, independently of any previous filters. “Search result” column displays the number of companies taking into consideration the combination of previous filters.

As a final step, the company name on either the Assignee field or the Correspondence Address field in the 8835 patents with inventors residing in Ireland was matched against the list of 10,490 Irish based ICT firms, resulting in 2207 matching patents. These 2207 patents compose the data set used in this research. In total, it has been identified that approximately 25% (= 2207 total ICT patents / 8835 total Irish patents) of the corporate applications to the USPTO with Irish inventors were from the ICT sector.

In the time series under examination, the count of patent applications is the first dependent variable in this research representing invention production.

3.4.2 Invention Value Indicator - Family Trends

The size of a patent family expresses the number of jurisdictions in which patent protection has been pursued on top of the location where the invention was originally filed (OECD, 2009). Extending patent protection across borders results in added costs for each jurisdiction with filing and examination fees, translation and patent attorneys, plus the cost of maintaining the invention in all markets. This effort should be worth the extra expenditure, therefore, the value of a patent increases according to the number of jurisdictions where protection is sought (Ernst et al., 2014; Fischer and Leidinger, 2013; Böhm et al., 2012). Based on this rationale, patent family trends are used as the patent quality indicator in this dissertation, representing invention value.

When a patent is first filed, “the date of filing is also known as the priority date, and the applicant then has up to 12 months to decide what other jurisdictions they intend to file in to seek patent protection” (DJEI, 2014, p.22). In their report, DJEI (2014) adopts the concept of a patent family being formed when applicants register the same invention in other jurisdictions within the subsequent 12 months and these inventions are tied to the same family ID and the same priority date. In this thesis, a less strict definition will be used. The chosen definition states that every patent application that is linked by Family ID and directly or indirectly linked by a priority date belong to the same family (OECD, 2009). This means that patents with the same Family ID and different priority dates will be considered.

The second dependent variable in this study consists of the count of family IDs submitted by Irish inventors with at least two patents linked together and it will be analysed in a separate calculation from the first dependent variable. Inventions belonging to the same family can be filed in different years. In cases where families contain the same Family ID but different filing dates, the filing date from the second family member will be assumed as the R&D tax year, because that is the year when the patent family was first formed.

As an example, Figure 3.2 and Figure 3.3 show two inventions that belong to the same patent family. Even though different application numbers and publishing dates are displayed in their immediate headers, they containing the same Family ID and Filing date values.

USPTO PATENT FULL-TEXT AND IMAGE DATABASE

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Images

(10 of 12)

United States Patent **7,809,162**
Steinberg , et al. **October 5, 2010**

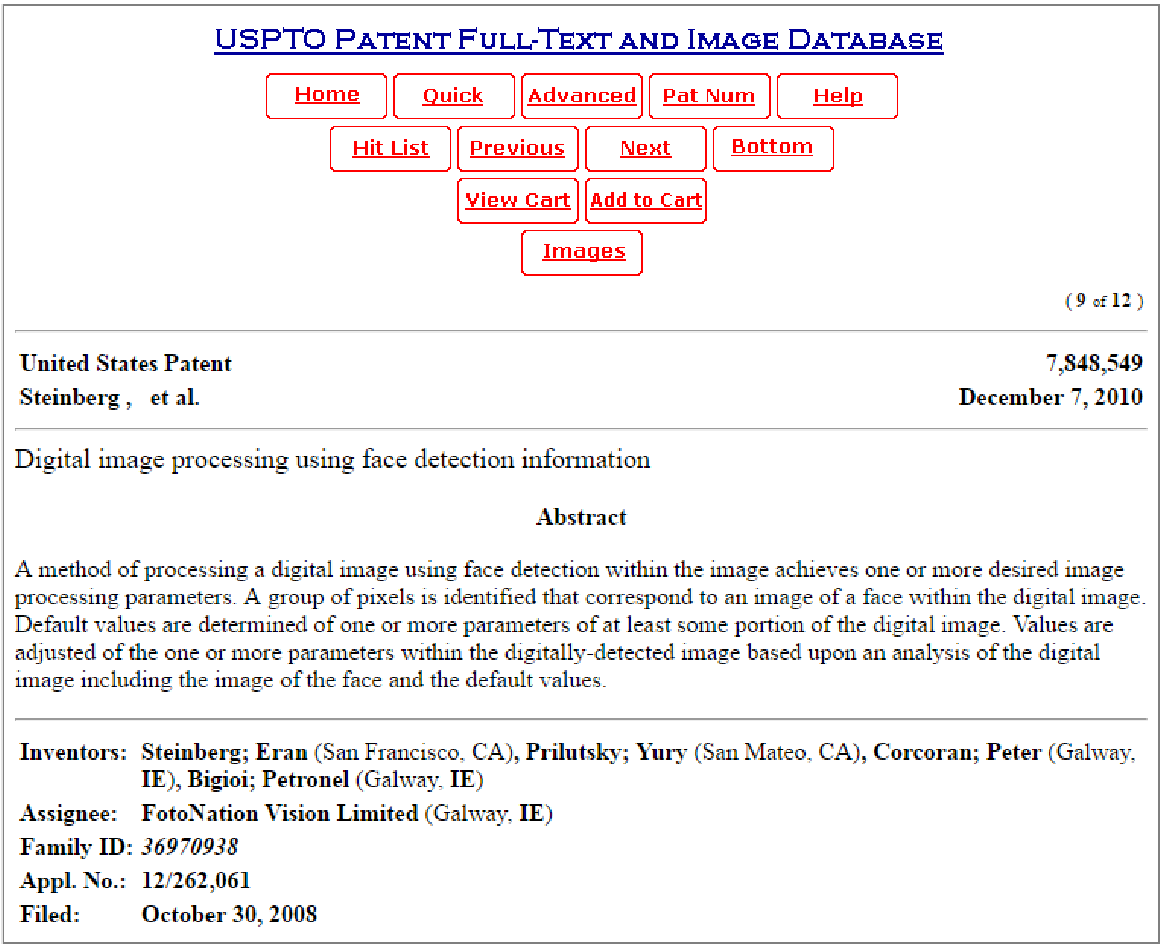
Digital image processing using face detection information

Abstract

A method of processing a digital image using face detection within the image achieves one or more desired image processing parameters. A group of pixels is identified that correspond to an image of a face within the digital image. Default values are determined of one or more parameters of at least some portion of the digital image. Values are adjusted of the one or more parameters within the digitally-detected image based upon an analysis of the digital image including the image of the face and the default values.

Inventors:	**Steinberg; Eran** (San Francisco, CA), **Prilutsky; Yury** (San Mateo, CA), **Corcoran; Peter** (Galway, IE), **Bigioi; Petronel** (Galway, IE)
Assignee:	**FotoNation Vision Limited** (Galway, IE)
Family ID:	*36970938*
Appl. No.:	**12/262,024**
Filed:	**October 30, 2008**

FIGURE 3.2 - Example 1 of a patent that is part of the same family.



USPTO PATENT FULL-TEXT AND IMAGE DATABASE

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Images

(9 of 12)

United States Patent **7,848,549**
Steinberg , et al. **December 7, 2010**

Digital image processing using face detection information

Abstract

A method of processing a digital image using face detection within the image achieves one or more desired image processing parameters. A group of pixels is identified that correspond to an image of a face within the digital image. Default values are determined of one or more parameters of at least some portion of the digital image. Values are adjusted of the one or more parameters within the digitally-detected image based upon an analysis of the digital image including the image of the face and the default values.

Inventors: **Steinberg; Eran** (San Francisco, CA), **Prilutsky; Yury** (San Mateo, CA), **Corcoran; Peter** (Galway, IE), **Bigioi; Petronel** (Galway, IE)
Assignee: **FotoNation Vision Limited** (Galway, IE)
Family ID: *36970938*
Appl. No.: **12/262,061**
Filed: **October 30, 2008**

FIGURE 3.3 - Example 2 of a patent that is part of the same family.

3.4.3 Patents and Inventive Performance

As mentioned in the literature review, when calculating their official statistics organizations like the USPTO (United States Patent and Trademark Office) and EPO (European Patent Office) keep with the convention that the country of residence of the first inventor is the country where the patent originated (OECD, 2009). It is understood that inventors listed in the first position had a greater contribution to a patent and, naturally, the innovative force took place in his or her country of residence (Goldberg et al., 2008).

In addition, OECD's (2009, p. 63) recommendation is "to use the inventor's country of residence to compile patent statistics aimed at reflecting inventive activity". This recommendation was followed when collecting and filtering data to investigate research question 3.

Hence, the first inventor listed in patent applications will be the indicator used to measure Irish inventive performance, the third dependent variable in this study.

3.4.4 Patent Data Analysis

With the purpose of analysing patents by different criteria according to each dependent variable, a Natural Language Processing text analysis engine was built specifically for this thesis using the IBM Watson Content Analytics Studio toolbox. The text analysis engine programmatically extracts key information from single patents, such as the names of Irish inventors and Irish first inventors, Publishing and Filed Dates, Applicant names, and Patent family information.

The complete set of patent data collected was then ingested into IBM Watson Content Analytics to programmatically process and filter bulk data by the criteria programmed in the text analysis engine.

These tools were used to obtain patent counts more accurately. Automated analysis was preferred over manual procedures, which tend to be more error prone.

3.4.5 Tax Data

As described in section 2.3 of Chapter 2, this dissertation will assess the impact of the Irish R&D tax credit scheme as an incentive instrument for patent production, focusing on the ICT industry. In other words, any effects that variances of the independent variable may have on the dependent variables is what is being observed (Saunders et al., 2012), which makes R&D tax benefits the independent variable of this thesis.

Revenue (2015, p.5) explains that “the R&D tax credit was originally designed to incentivise incremental R&D expenditure” and the year of 2003 was defined as the base year for all accounting periods. This way, only the amount exceeding what a firm had spent on R&D in 2003 qualified for the tax credit in years that followed.

A summary of how the tax scheme varied from years 2004 to 2015 is depicted in Table 3.2, where the “R&D Tax Credit” column displays the percentage of credit applicable to allowable expenditure and values in the “Base Year Restriction” column show to which degree this restriction was waived over the years. The sources for tax information were the Department of Finance and Revenue Commissioners website.

TABLE 3.2 - Summary of R&D Tax Incentives in Ireland (Revenue, 2015; Department of Finance, 2013).

Year	R&D Tax Credit Rate	Base year restriction
2004	20.0%	Full base year (2003) expenditure
2005	20.0%	Full base year (2003) expenditure
2006	20.0%	Full base year (2003) expenditure
2007	20.0%	Full base year (2003) expenditure
2008	20.0%	Full base year (2003) expenditure
2009	25.0%	Full base year (2003) expenditure
2010	25.0%	Full base year (2003) expenditure
2011	25.0%	Full base year (2003) expenditure
2012	25.0%	Full base year (2003) expenditure €100,000
2013	25.0%	Full base year (2003) expenditure €200,000
2014	25.0%	Full base year (2003) expenditure €300,000
2015	25.0%	Base year (2003) completely removed

R&D tax credit rate is the independent variable examined in this study. Base year restriction will be tentatively examined as a predictor.

3.5 Statistical Analysis Model Assessment

Statistical tests are designed in accordance with variable data types, thus, choosing a statistical method that is not the most appropriate for the data examined in a given paper can jeopardize the study validity. When deciding the most suitable statistical method for data analysis, the quantity and nature of variable types must be taken into consideration (Wetcher-Hendricks, 2011). In this thesis, the dependent variables consist of count data and the independent variables will be transformed into categorical variables. A detailed investigation on the most appropriate statistical model for these variable types follow below.

The Poisson Regression was initially assessed, but as shown in tests results, two of the data assumptions were violated. In this event, the Negative Binomial Regression model was identified as a better fit to the data under analysis. These statistical models were also selected by Bronzini and Piselli (2015) as the most appropriate for their paper, reviewed in Chapter 2.

The initial process of choosing a statistical model involves validating its data assumptions. The five assumptions for the Poisson Regression listed by Laerd Statistics (2016) are stated and tested below:

Poisson Regression Assumption 1 - The dependent variable data type is count data.

Count data is the data type for all three dependent variables in this study. Irish ICT patent counts from 2004 to 2015 were computed for invention production, invention value and inventive performance.

Poisson Regression Assumption 2 - There exists one or more independent variables of continuous, ordinal or dichotomous types.

Given the limited time and scope of this research, the corporate annual taxation spend from individual companies was not collected to be used as information that forms the independent variable, thus, corporate tax spend is not measured against the country tax rates. For this reason, the actual R&D credit rate percentage set by the Department of Finance (see the second column in Table 3.2) is not mathematically taken into account in calculations described in Chapter 4.

Table 3.2 shows that there are only two possible values for R&D tax credit rates from the period of 2004 to 2015. Saunders et al. (2012) explain that when only two values exist for a variable, it is classified as dichotomous data and it may be transformed into an indicator (or dummy) variable that would represent these two categories with the values 0 and 1. For this type of variable, the category order does not matter. As suggested by Remler and Ryzin (2015) indicator variables are commonly used as independent variables and “can be treated sometimes as quantitative variables” (p.128). Therefore, R&D tax credit rate will be treated as an indicator variable with the values of 20.0% and 25.0% corresponding to 0 and 1, respectively.

Additionally, the Base Year Restriction (see the third column in Table 3.2) will be transformed into a categorical ordinal variable in an attempt to understand if this aspect of the tax scheme also influences inventions in Ireland. This data type, also known as ranked data, is characterized by its accuracy when compared to other categorical data due to the fact that its values are ranked (Saunders et al., 2012). Therefore, the order in which the values of ordinal variables are listed represent meaning, but the actual numbers that these values may contain are not taken into account (Remler and Ryzin, 2015).

Base Year Restriction as an ordinal variable has five different possible values in accordance with Table 3.3, where rank 1 represents the least beneficial position and rank 5 symbolizes the most favourable position.

TABLE 3.3 - Base Year Restriction as a categorical ordinal variable.

Ordinal Category	**Base year restriction**
1	Full base year (2003) expenditure
2	Full base year (2003) expenditure €100,000
3	Full base year (2003) expenditure €200,000
4	Full base year (2003) expenditure €300,000
5	Base year (2003) completely removed

Poisson Regression Assumption 3 - None of the observations should provide information on another observation, in other words, there should be independence of observations.

In this study, none of the patents counted and measured in a given year overlap with patents either from the same year or from a different year.

Poisson Regression Assumption 4 - The distribution of counts must be in agreement with the Poisson distribution.

SPSS software was used to test this assumption. After running a Poisson Regression for each research question, the *Value/df* values for the *Deviance* and *Pearson Chi-Square* statistics in Tables 3.4, 3.5 and 3.6 below should be near 1.0 in order to be acceptable for a Poisson regression (IBM, 2014).

In these tables, the *Deviance Value* equals two times the difference of the log likelihood for the maximum achievable model and the log likelihood under the fitted model. *Pearson Chi-Square Value* is equivalent to the squared difference between the observed and predicted values divided by the variance of the predicted value, then summed over all observations in the model. *DF* stands for Degrees of Freedom, which is equal to n-p, where n is the number of observations used and p is the number of parameters estimated. Finally, *Value/DF* is the ratio of *Deviance Value* and *Pearson Chi-Square Value* and *DF*. This ratio should be about 1.0 to fit the data model well, where ratios greater than that indicate overdispersion (IDRE, 2016).

TABLE 3.4 - Goodness of Fit for RQ1

Goodness of Fit[a]

	Value	df	Value/df
Deviance	184.404	6	30.734
Scaled Deviance	184.404	6	
Pearson Chi-Square	187.487	6	31.248
Scaled Pearson Chi-Square	187.487	6	
Log Likelihood[b]	-133.797		
Akaike's Information Criterion (AIC)	279.594		
Finite Sample Corrected AIC (AICC)	296.394		
Bayesian Information Criterion (BIC)	282.504		
Consistent AIC (CAIC)	288.504		

TABLE 3.5 - Goodness of Fit for RQ2

Goodness of Fit[a]

	Value	df	Value/df
Deviance	51.609	6	8.601
Scaled Deviance	51.609	6	
Pearson Chi-Square	44.421	6	7.404
Scaled Pearson Chi-Square	44.421	6	
Log Likelihood[b]	-51.094		
Akaike's Information Criterion (AIC)	114.188		
Finite Sample Corrected AIC (AICC)	130.988		
Bayesian Information Criterion (BIC)	117.098		
Consistent AIC (CAIC)	123.098		

TABLE 3.6 - Goodness of Fit for RQ3

Goodness of Fit[a]

	Value	df	Value/df
Deviance	117.864	6	19.644
Scaled Deviance	117.864	6	
Pearson Chi-Square	122.384	6	20.397
Scaled Pearson Chi-Square	122.384	6	
Log Likelihood[b]	-97.290		
Akaike's Information Criterion (AIC)	206.579		
Finite Sample Corrected AIC (AICC)	223.379		
Bayesian Information Criterion (BIC)	209.489		
Consistent AIC (CAIC)	215.489		

Again, the fact that *Value/df* values for *Deviance* and *Pearson Chi-Square* are greater than 1.0 is translated into overdispersion (IBM, 2014). This is the case for every research question, therefore, Assumption 4 is not satisfied. Hilbe (2014, p.9) affirms that “overdispersion occurs in data where the variability of the data is greater than the mean” and states that this criterion is often violated, generating results that cannot be trusted as they would lead to wrong conclusions. Due to overdispersion, the Poisson regression will not be used in this research.

Poisson Regression Assumption 5 - The variance and mean of the model should have the same value, expressing equidispersion.

Assumption 5 is a consequence of Assumption 4 (Laerd Statistics, 2016). Hence, this assumption is also rejected for every research question. *Variance* and *mean* values were expected to be equal in order to fit the Poisson Regression, but figures are very different from each other as depicted in Tables 3.7, 3.8 and 3.9 below.

TABLE 3.7 - Variance and Mean for RQ1

Descriptive Statistics

	N	Mean	Variance
PatentCounts	12	183.92	7146.265
Valid N (listwise)	12		

TABLE 3.8 - Variance and Mean for RQ2

Descriptive Statistics

	N	Mean	Variance
PatentCounts	12	30.08	789.538
Valid N (listwise)	12		

TABLE 3.9 - Variance and Mean for RQ3

Descriptive Statistics

	N	Mean	Variance
PatentCounts	12	107.08	2530.447
Valid N (listwise)	12		

The most popular alternative for dealing with assumptions 4 and 5 not being satisfied due to overdispersion is to use the Negative Binomial Regression model instead. This statistical model has the same assumptions as the Poisson Regression with the key difference on how it handles dispersion (Hilbe, 2014). Negative Binomial Regression allows more flexibility because it has an extra parameter that adjusts extra variability in the data (IDRE, 2016; Bronzini and Piselli, 2015). For this reason, the later model was chosen and how it is applied to this dissertation will be further described in Chapter 4.

3.6 Conclusion

This is an experimental research that examines whether changes in the Irish R&D Tax Credit Scheme have an impact on invention quantity, invention quality and inventive performance.

The chosen methodology belongs to the objectivist and positivist schools of thought. Research questions were formulated before any observations were carried out, in conformity with the deductive approach. Next, secondary data was collected throughout a longitudinal time horizon for quantitative analysis and the Negative Binomial Regression model, also used by Bronzini and Piselli (2015), has been selected as the most appropriate statistical method for this thesis after passing data assumption tests.

The following chapter graphically presents the data collected in the context of each research question and statistical analysis is carried through with the goal of building a basis for conclusions to be drawn.

4 Findings and Analysis

4.1 Introduction

This chapter describes findings pertaining to each research question after data collected from secondary sources was quantitatively and statistically analysed within the context of the addressed topic. This is how the chapter is structured:

Section 4.2 defines the empirical strategy used for statistical analysis and the reasons behind it. It summarizes the various steps that were taken into account so that readers can be reasonably assured that the results are solid.

Section 4.3 descriptively expresses quantitative findings through charts and comments, followed by a statistical interpretation of data for each one of the research questions.

Section 4.4 highlights the key findings revealed by this research in parallel to a review of findings by other researchers studied in the literature review chapter.

Section 4.5 closes the Findings and Analysis chapter.

4.2 Empirical Strategy

As the number of patents is a discrete count, a parametric model applicable for count data is used to assess effects of changes of the Irish R&D tax scheme on patent applications from different perspectives, such as variance in quantity, quality and inventive performance. Resembling to methods described in literature for similar ends (Bronzini and Piselli, 2015), the Negative Binomial Regression model is applied as described in Section 4.3 to account for overdispersion in all the counts and the possible presence of zeros.

The Negative Binomial Regression model probability distribution function (PDF) is defined in literature (Hilbe, 2014) as:

$$f(\gamma;\mu,\alpha) = \binom{\gamma_i + \frac{1}{\alpha} - 1}{\frac{1}{\alpha} - 1} \left(\frac{1}{1+\ \alpha\mu_i}\right)^{\frac{1}{\alpha}} \left(\frac{\alpha\mu_i}{1+\ \alpha\mu_i}\right)^{\gamma_i}$$

Where α is the negative binomial dispersion parameter. Gamma (γ) consists of patents counts formed of non negative integers and it must allow for the possibility of 0 counts. γ_i represents the patent counts of one year and μ_i is the expected mean of the distribution of γ_i . This is, of course, an oversimplified explanation of a regression model that is known by statisticians for its high complexity. This regression model is proficiently explained by experts who are competent in statistics. Readers are referred to Hilbe (2014), Lord and Park (2010) and Greene (2008) for the full explanation on it.

It is important to verify that data under analysis is well-fitted for the chosen model before interpreting calculations, otherwise results can lead to false conclusions (Hilbe, 2014). This is done with statistical significance tests which verify that relationships between predictor and response variables, also known as independent and dependent variables, exist and are real. In such way, predictors that are statistically significant can be interpreted with accuracy, but the opposite is not true (Remler and Ryzin, 2015).

After carrying out significance tests for both R&D Tax Credit Rates and Base Year Restriction as relationship predictors, it was identified that Base Year Restriction was not statistically significant for any of the validated models and research questions. In other words, it has been found that there is a high probability of a reliable relationship not existing between Base Year Restriction and Patent Counts. Consequently, further analysis was not carried through with this independent variable.

For reference, evidence of Base Year Restriction significance tests are presented in Appendix 1 and significance tests for R&D Tax Credit Rates are presented in Section 4.3.

While reading the research findings in Section 4.3, it is useful to keep in mind that the R&D tax credit rates changed from 20% to 25% in 2009, as depicted in Figure 4.1.

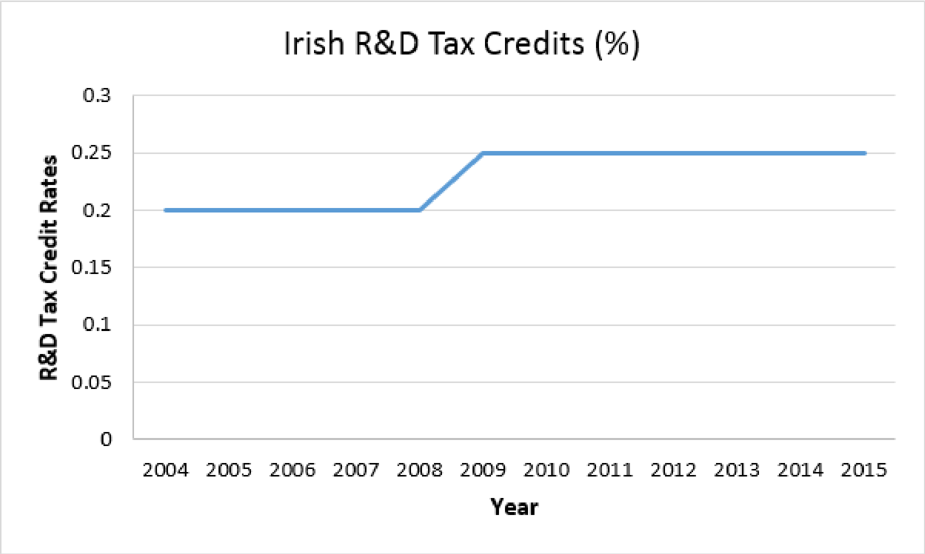

FIGURE 4.1 - R&D Tax Credits in Ireland from 2004 to 2015

4.3 Findings and Analysis per Research Question

Section 4.3 was broken into different subsections dedicated to each one of the research questions and its findings. The collected data was described and organized in charts for better visualization. As a final part of analysis, statistical inferences were drawn using a statistical software package, IBM SPSS.

4.3.1 Invention Production in the Irish ICT sector

In order to answer research question one, ICT Irish patent application trends need to be analysed first. There was a total of 8835 Irish patent applications filed and made available to the public between 2004 and 2015 in USPTO databases from all industries. Figure 4.2 represents annual numbers of Irish patent applications from the ICT sector in relation to all sectors. It is possible to observe the number of ICT patents increasing in the first 5 years and oscillating between 22% and 33% of total Irish patents from 2007 on, with a decrease in 2015.

Overall, the ICT trend follows the total applications trend, with the exception of years 2006 and 2008, when the number of ICT applications increased slightly in comparison to a modest decrease in the total applications number.

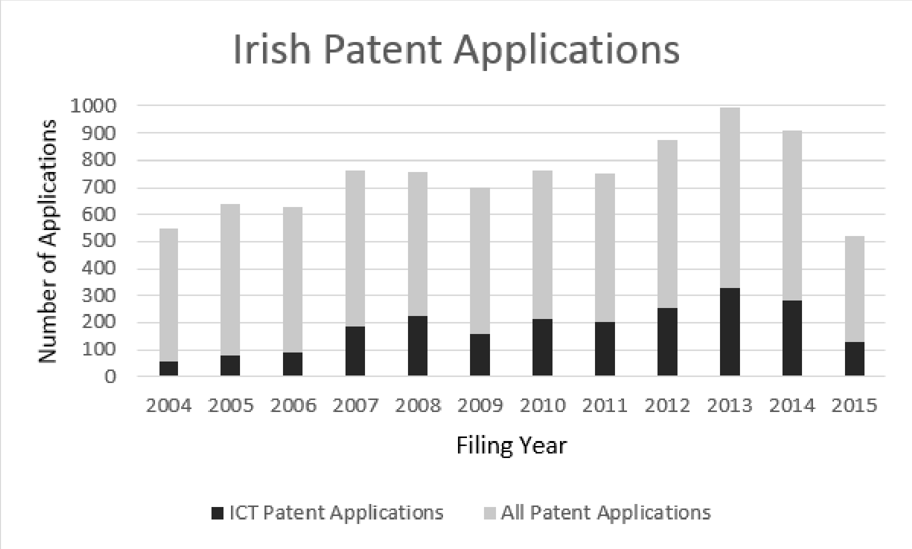

FIGURE 4.2 - ICT Irish patent applications in relation to all industry sectors from 2004-2015.

From the 8835 Irish patent applications, it was identified that 2207 belong to ICT companies present in Ireland. A closer look at ICT Irish application figures reveals that 2013, 2014, 2012 and 2008, respectively, were the years with most applications, representing approximately half the total of applications filed over the full period analysed.

The decrease observed in 2015 can be attributed to the fact that patent applications take on average 18 months after the filing date to be published. This means that most applications filed in June 2015 will be available in the USPTO open database by January 2017.

While interpreting data, it is also important to bear in mind that at the same time that some applicants may request their patents to be published early, others may file their application with a non-publication request, which affect counts (OECD, 2009).

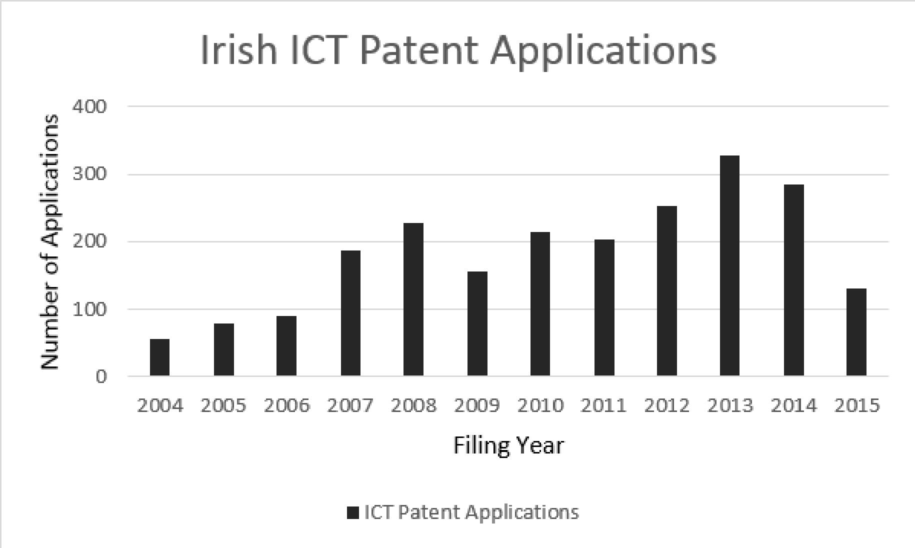

FIGURE 4.3 - ICT patent applications by Irish inventors from 2004-2015

RQ1. Did changes in the Irish R&D tax scheme influence invention production in Ireland's ICT industry?

Similar to previous papers (Ernst et al., 2014; Ernst and Spengel, 2011; OECD, 2009), invention production is measured through patent counts as the dependent variable. Patent applications were collected based on the priority date, ICT as industry and Ireland as the country of residence of at least one inventor, regardless if it is the first inventor or not.

A Negative Binomial Regression model was applied to answer this question considering R&D Tax Credit Rate as the only predictor (independent variable). The values for *AIC/BIC* and *log-likelihood* seen in Table 4.1 are less than other alternative count models considered previously (see Table 3.4), and the *Value/DF* of *Deviance* and *Pearson Chi-Square*, values that account for dispersion, are as close to 1.0 as possible. According to Hilbe (2014), these are some of the requirements that a well-fitted negative binomial model has to satisfy before being interpreted.

TABLE 4.1 - Goodness of Fit for Negative Binomial Regression in RQ1

Goodness of Fit[a]

	Value	df	Value/df
Deviance	12.356	9	1.373
Scaled Deviance	12.356	9	
Pearson Chi-Square	11.998	9	1.333
Scaled Pearson Chi-Square	11.998	9	
Log Likelihood[b]	-67.637		
Akaike's Information Criterion (AIC)	141.275		
Finite Sample Corrected AIC (AICC)	144.275		
Bayesian Information Criterion (BIC)	142.730		
Consistent AIC (CAIC)	145.730		

Based on the most common significance level of $p < 0.05$ (Remler and Ryzin, 2015), the predictor is interpreted as statistically significant given that the p-value in the *Sig.* column is 0.048, as shown in Table 4.2. For these reasons, it is possible to proceed to interpret the results from this model with confidence.

TABLE 4.2 – p-value and Incidence Rate Ratio for RQ1

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	4.826	.1672	4.498	5.154	833.120	1	.000	124.714	89.866	173.076
[TaxCredit=0]	-.517	.2611	-1.028	-.005	3.914	1	.048	.597	.358	.995
[TaxCredit=1]	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1[b]									
(Negative binomial)	.188	.0790	.082	.428						

When interpreting values in Table 4.2, Tax credit rate coded 0 (equals tax rate of 20%) is being compared to Tax credit rate coded 1 (equals tax rate of 25%). Tax credit 1 has β (column *B*) equal to 0[a] since no regression coefficient value was computed for it. It is used as a baseline for comparison with Tax credit 0, which has a regression coefficient value corresponding to -.517, value that is used to calculate the figures in column *Exp(B)*. The incidence rate ratio (Exponentiated β, column *Exp(B)*) reflects the negative regression coefficient, since 0.597 is smaller than the reference 1. As a conclusion, the incidence rate of patents is 40% smaller (1 - 0.597 = 0.40, multiplied by 100% = 40%) in years with a tax rate of 20% than in years with tax rate of 25%.

4.3.2 Valuable Inventions in the Irish ICT Industry

Patent families extend protection for the same invention in different territories and they are normally only created for valuable patents. For this reason, patent family trends are used as a patent quality indicator in this study when investigating research question 2. This type of measurement was also seen in reviewed papers (Ernst et al., 2014; Fischer and Leidinger, 2013) when researchers studied innovation quality.

The filing trends depicted in Figure 4.4 show that ICT patent families by Irish inventors did not exist at all in the first years analysed in this research. ICT patent families have been emerging since 2006 with bigger emphasis from 2012 on, apart from the slight drop in 2014.

Although the total number of families with at least two members is 361, a total of 793 patent applications constitute all these families. That stands for approximately 36% of the whole data set of ICT applications.

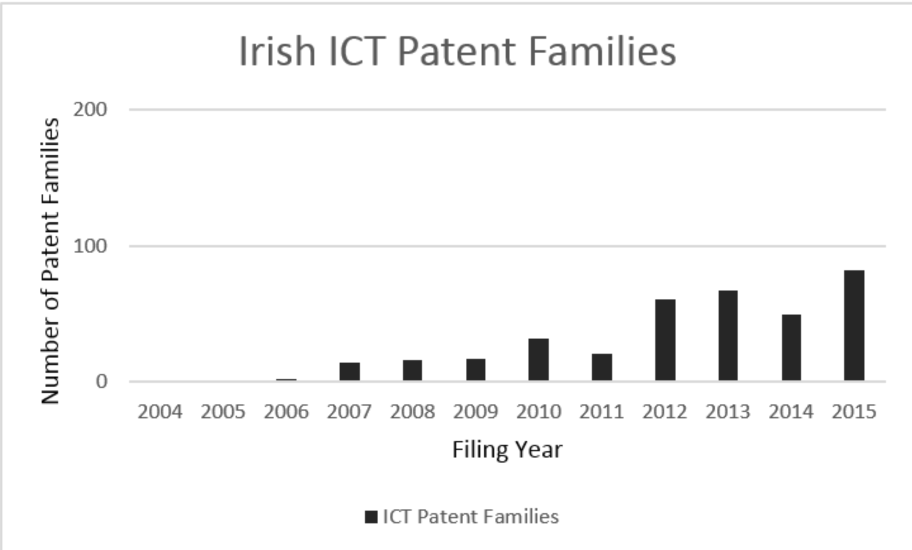

FIGURE 4.4 - The annual emergence of ICT Patent families by Irish inventors from 2004-2015.

RQ2. Did changes in the Irish R&D tax scheme result in more valuable inventions in the Irish ICT industry?

Given the presence of zeros in counts and overdispersion in data, the Negative Binomial Regression model was again the best candidate model to answer this question.

In the calculations that led to the figures below, R&D Tax Credit Rate was used as a sole predictor. Statistical significance tests pass with *Value/DF* as close to 1.0 as possible, *AIC/BIC* and *log-likelihood* values are smaller than the ones calculated for the count models previously validated (see Table 3.5), and statistical significance for the predictor Tax credit 0 can be noticed with the p-value of 0.000 (*Sig.* column, Table 4.4). These criteria indicates a well-fitted negative binomial model.

TABLE 4.3 - Goodness of Fit for Negative Binomial Regression in RQ2

Goodness of Fit[a]

	Value	df	Value/df
Deviance	15.496	9	1.722
Scaled Deviance	15.496	9	
Pearson Chi-Square	9.151	9	1.017
Scaled Pearson Chi-Square	9.151	9	
Log Likelihood[b]	-48.497		
Akaike's Information Criterion (AIC)	102.993		
Finite Sample Corrected AIC (AICC)	105.993		
Bayesian Information Criterion (BIC)	104.448		
Consistent AIC (CAIC)	107.448		

For research question two, Tax credit 0 has the regression coefficient value (β, column *B*) corresponding to -1.994, this value is used to calculate the figures in column *Exp(B)*. The incidence rate ratio (Exponentiated β, column *Exp(B)*) in Table 4.4 corresponds to this negative value, as 0.136 is smaller than the baseline 1. The interpretation is that the incidence rate of patent families is 86.4% smaller (1 - 0.136 = 0.864, multiplied by 100% = 86.4%) in years with a tax rate of 20% than in years with tax rate of 25%.

TABLE 4.4 - p-value and Incidence Rate Ratio for RQ2

Parameter Estimates

			95% Wald Confidence Interval		Hypothesis Test				95% Wald Confidence Interval for Exp(B)	
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
(Intercept)	3.850	.3267	3.210	4.490	138.909	1	.000	47.000	24.776	89.158
[TaxCredit=0]	-1.994	.5321	-3.037	-.951	14.042	1	.000	.136	.048	.386
[TaxCredit=1]	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1[b]									
(Negative binomial)	.726	.3831	.258	2.042						

4.3.3 Inventive Performance and ICT in Ireland

Patent applications containing the first inventor residing in Ireland were filtered in the dataset and counts were used as the indicator of Irish inventive performance.

In Figure 4.5, slow growth can be seen in patent application counts with an Irish first inventor from years 2004 to 2013, with spikes in 2007 and 2008. Nevertheless, growth is not present in the years of 2014 and 2015. Possible reasons can be the time lag with the publication of a filed application in combination with the usual lag of 12 months between the filing of a domestic application (first priority filing) and foreign applications (new jurisdictions where the invention will be protected), as stated by OECD (2009).

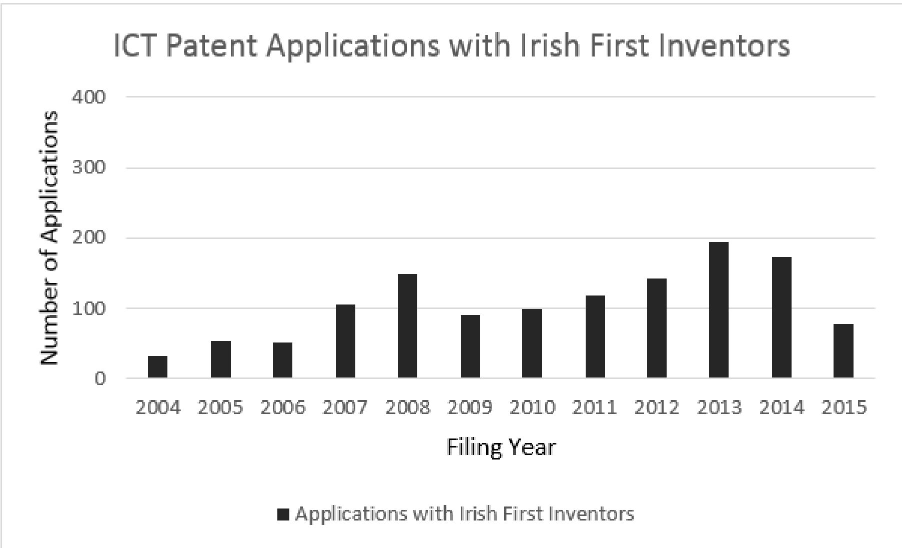

FIGURE 4.5 - ICT Patent applications with Irish first inventors from 2004-2015.

When comparing counts of all the collected ICT applications (criterion: at least one Irish inventor) with the ones containing specifically the first inventor residing in Ireland, Figure 4.6 reports that the greater part of applications had an Irish resident as the original creator for all the years, except for 2010. Although a vast number of the analysed applications revealed a mix of inventors residing in different countries, it is easy to observe that the greater number of ICT patent applications with at least one Irish inventor actually originated in Irish lands.

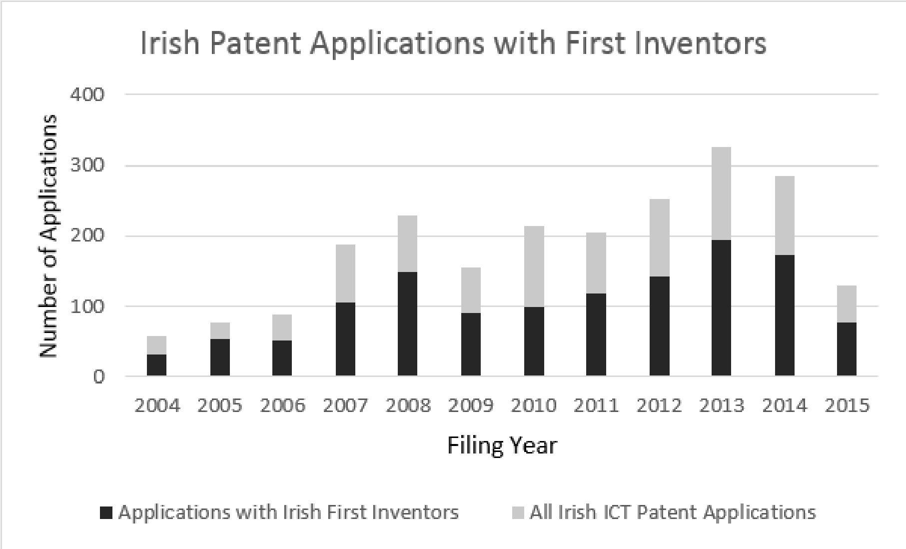

FIGURE 4.6 - ICT Patent applications with Irish first inventors in relation to all Irish ICT applications from 2004-2015.

RQ3. Did changes in the Irish R&D tax scheme culminate in an improved inventive performance for Ireland's ICT industry?

To enable the investigation of RQ3, the Negative Binomial Regression model was used for a third time with the purpose of examining if increased R&D tax benefits resulted in a higher number of ICT patents originated inside Ireland.

Statistical significance tests show a well-fitted model, as confirmed in Table 4.5. For this specific scenario, the model below is the one that presented *Value/DF* with the best approximation to 1.0. *AIC/BIC* and *log-likelihood* values are also smaller than the ones demonstrated in Table 3.6. Finally, p-value of 0.045 for the predictor Tax credit 0 demonstrate statistical significance (*Sig.* column, Table 4.6).

TABLE 4.5 - Goodness of Fit for Negative Binomial Regression in RQ3

Goodness of Fit[a]

	Value	df	Value/df
Deviance	12.374	9	1.375
Scaled Deviance	12.374	9	
Pearson Chi-Square	12.482	9	1.387
Scaled Pearson Chi-Square	12.482	9	
Log Likelihood[b]	-61.665		
Akaike's Information Criterion (AIC)	129.330		
Finite Sample Corrected AIC (AICC)	132.330		
Bayesian Information Criterion (BIC)	130.785		
Consistent AIC (CAIC)	133.785		

Table 4.6 displays the regression coefficient value (β, column *B*) of -0.494 for the predictor Tax credit 0 in comparison to Tax credit 1. The incidence rate ratio (Exponentiated β, column *Exp(B)*) value is 0.610, which means that the incidence rate of ICT patents created in Ireland is 39% smaller (1 - 0.610 = 0.39, multiplied by 100% = 39%) in years with a tax rate of 20% than in years with tax rate of 25%.

TABLE 4.6 - p-value and Incidence Rate Ratio for RQ3

Parameter Estimates

			95% Wald Confidence Interval		Hypothesis Test				95% Wald Confidence Interval for Exp(B)	
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
(Intercept)	4.851	.1576	4.542	5.160	947.363	1	.000	127.857	93.880	174.131
[TaxCredit=0]	-.494	.2462	-.977	-.012	4.029	1	.045	.610	.377	.988
[TaxCredit=1]	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1[b]									
(Negative binomial)	.166	.0707	.072	.383						

RQ3.1. Have experienced Irish inventors become more engaged with inventions from 2004 to 2015?

As a benefit, the Finance Act 2012 introduced a new section allowing companies to transfer their R&D tax relief to be credited against income tax charged from key employees who are engaged with research and development (Revenue, 2015).

This sub question goes a little bit deeper into the data analysed in RQ3 with the purpose of speculating if experienced inventors have demonstrated stronger motivation in creating a higher number of inventions over the years.

In the collected data set, it was found that only 10 individuals residing in Ireland were listed as first inventors for the threshold of at least 20 or more patents filed from 2004-2015. Together, these inventors were the creators of 424 ideas. The threshold of at least 20 applications per inventor is considered relevant enough to be visually well expressed in charts (see Figures 4.7 and 4.8).

While inspecting the period prior to the R&D benefit change in 2012, spikes in numbers of applications are displayed in the years of 2007 and 2008, where heavy inventive activity from one single individual (Sullivan, Patrick J.) can be noticed. This period is followed by three years of a drop in applications where a better dispersion of creations between inventors can be observed in 2010. From 2012 on, the number of inventions increased again and it was distributed between a broader variety of authors. Once again, there is the possibility that patents yet to be published justify the lower levels of patent applications displayed in 2015.

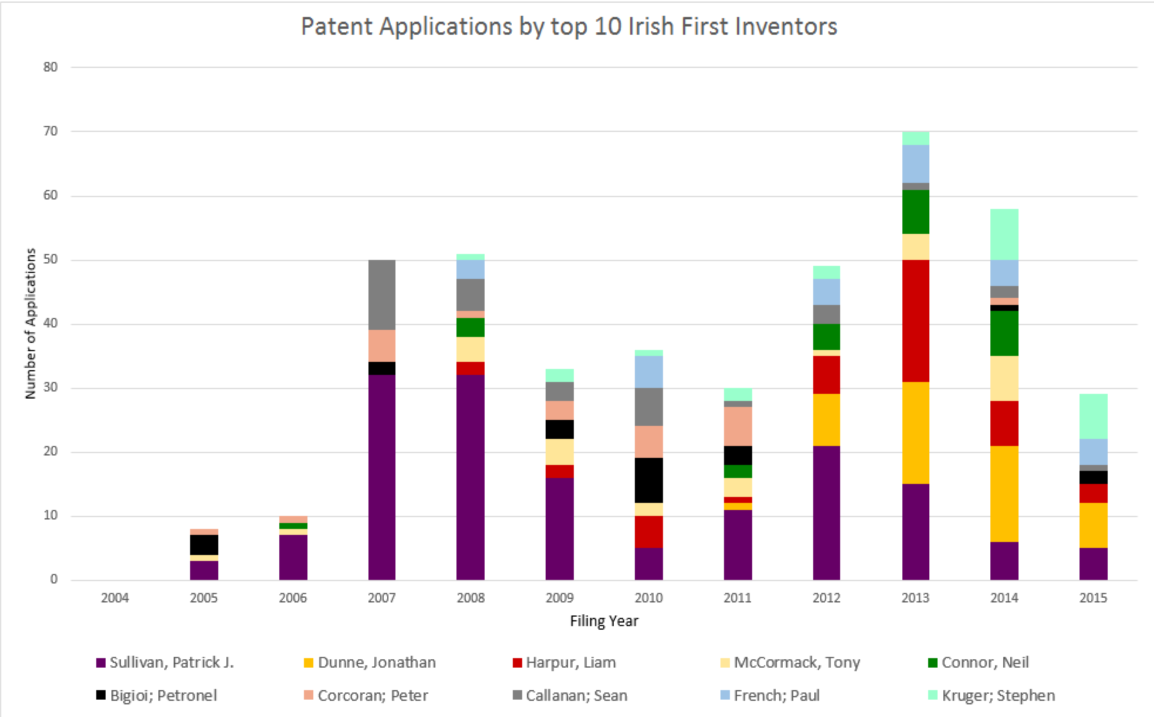

FIGURE 4.7 - ICT patent applications per year by the top 10 Irish first inventors from 2004-2015.

Although the second half of the analysed decade definitely shows more patent applications from all experienced inventors combined than the first half (Figure 4.7), when analysing the number of yearly inventions by individual master inventors (Figure 4.8), growth cannot be observed at any rate, such as linear or exponential rates. There is no evidence that shows that experienced Irish inventors as individuals became more engaged with inventions from 2004 to 2015.

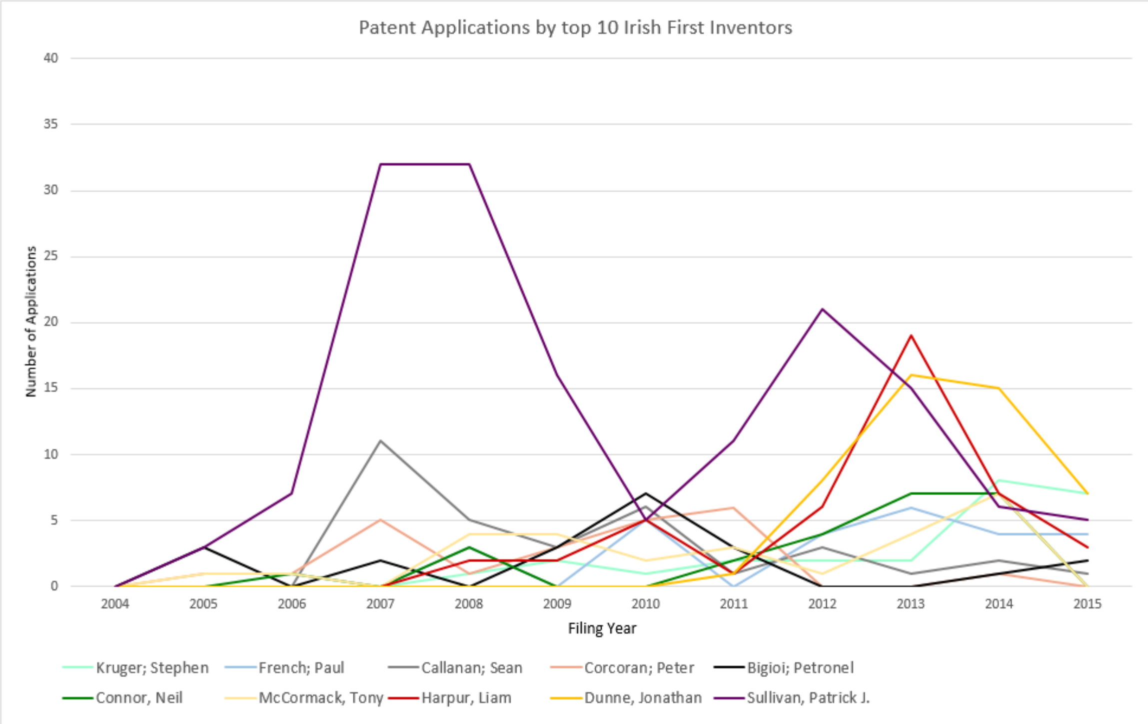

FIGURE 4.8 - ICT patent applications per Irish first inventor and per year from 2004-2015.

TABLE 4.7 - ICT patent application figures by the top 10 Irish first inventors from 2004-2015.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Sullivan, Patrick J.	0	3	7	32	32	16	5	11	21	15	6	5
Dunne, Jonathan	0	0	0	0	0	0	0	1	8	16	15	7
Harpur, Liam	0	0	0	0	2	2	5	1	6	19	7	3
McCormack, Tony	0	1	1	0	4	4	2	3	1	4	7	0
Connor, Neil	0	0	1	0	3	0	0	2	4	7	7	0
Bigioi; Petronel	0	3	0	2	0	3	7	3	0	0	1	2
Corcoran; Peter	0	1	1	5	1	3	5	6	0	0	1	0
Callanan; Sean	0	0	0	11	5	3	6	1	3	1	2	1
French; Paul	0	0	0	0	3	0	5	0	4	6	4	4
Kruger; Stephen	0	0	0	0	1	2	1	2	2	2	8	7

4.4 Summary of Findings

This chapter interpreted data with the purpose of exploring three research questions and one sub question that all focused on obtaining answers on how ICT inventions were affected from different angles in response to the increase in the Irish R&D tax credit rate from 20% to 25% incurred in 2009.

The findings for RQ1 statistically show that before the increase in tax relief rates, the incidence rate of ICT patent applications was 40% smaller. It is concluded that ICT invention production in Ireland responded positively to the improvement in the R&D tax benefit, since Irish ICT inventions nearly doubled after 2009.

RQ2 reveal the most notable finding in the study. It was found that the incidence rate of patent families was 86.4% smaller prior to the increase in R&D tax credits in 2009. Overall, approximately 36% of the Irish ICT applications to the USPTO (2004-2015) is composed of patent family members.

The findings for RQ3 showed that the incidence rate of ICT patents created inside Ireland was 39% smaller before the R&D tax credits changed from 20% to 25% in 2009. This demonstrates overall growth in ICT patents originating in Irish territory, in other words, it shows a significant improvement in the country's inventive performance.

Sub question 3.1 was answered after running a deeper analysis in the data from RQ3. The sub question investigated whether there was a higher engagement in patent creation by the top ten Irish experienced inventors after 2012, year when the Irish Government allowed corporate R&D tax relief to be transferred to key employees working with R&D. Findings disclose that the patent application numbers by all top ten inventors together increased in the years of 2012, 2013 and 2014. However, when looking at yearly invention counts by individual master inventors, there is no evidence of growth.

This research findings suggest that Irish inventive performance and invention quantity and quality reacted positively to the change in R&D tax credit rates in 2009 from 20% to 25%. Data does not show a higher engagement of experienced Irish inventors after 2012 or during the period under study.

4.5 Conclusion

This chapter graphically presents the data collected from the perspective of each research question investigated. Data for three research questions and one sub question was carefully described as a way to provide a background to the statistical analysis that followed. The significance tests and interpretation steps taken to ensure credible results during statistical analysis were also outlined.

A summary of this thesis's findings in comparison to the literature review is later discussed in section 5.3. The results found suggest that inventive performance and invention quantity and quality in Ireland responded positively to an increase in R&D tax credit rates, but trends did not show a higher engagement with patents from Irish experienced inventors over time. While most papers in the literature review found a positive relationship between innovation quantity and R&D tax schemes (Bronzini and Piselli, 2015; Ernst et al., 2014; Ernst and Spengel, 2011), a negative relationship between tax credits and innovation quality was reported by other authors (Ernst et al., 2014).

The next chapter contains the key conclusions drawn from this study's findings, at the same time that it recognizes its limitations. Opportunities for future research identified during the completion of this dissertation are also recommended.

5 Conclusions and Future Work

5.1 Introduction

This chapter concludes this dissertation by reviewing how the research questions were answered, it highlights the key findings in this thesis and it expresses how they contribute to current body of knowledge. The study limitations are presented in a later section, as well as opportunities for future work.

5.2 Answering the Research Question

The literature review shows that R&D tax schemes have a positive effect on patent quantity and negative effect on patent quality. However, the ICT sector is not the centrepiece of these papers and they focus on geographies other than Ireland. This quantitative research focuses on the analysis of ICT Irish invention production, invention value and inventive performance in response to the tax environment laid out by the Irish Government for R&D as one of the strategies for developing the continent's best research, innovation and commercialisation ecosystem.

Answers to research questions were obtained through the analysis of a patent application dataset collected from the USPTO. The dataset solely contained patents that were created by at least one Irish inventor and that are owned by ICT companies or subsidiaries based in Ireland. The full dataset was used to measure invention production. In order to measure invention value, the count of patent family IDs submitted by Irish inventors with at least two patents linked together was used. Finally, inventive performance is assessed by looking only at the patent applications where the first inventor resides in Ireland. The time frame under study starts in January 2004, when the Irish tax credit regime started favouring R&D more emphatically, and it finishes in December 2015.

Since the dependent variables (patent quantity, quality and patent quantity by Irish first inventors) consist of count data, the Negative Binomial Regression model was identified as the best statistical fit for the data under analysis. The model's data assumptions were all validated, and significance tests were executed to ensure well-fitted models. R&D tax credit rate is the independent variable examined in this study, while Base year restriction was tentatively considered as a predictor, but it was rejected after failing significance tests.

This dissertation's findings are discussed in more detail in the next section.

5.3 Research Findings

The findings of this research suggest that for the ICT sector, inventive performance and invention production and quality in Ireland responded positively to an increase in R&D tax credit rates from 20% to 25% incurred in 2009. While data trends did not show a higher engagement from experienced inventors with patents over time. Nevertheless, results must be interpreted with caution since other factors may have influenced the changes in patent indicators other than only R&D tax credit rates in isolation, as for example, other governmental R&D incentives, firms' internal policies and education on patent creation or the number of qualified ICT inventors available in the Irish market.

The RQ1 findings reveal that the ICT invention production in Ireland responded positively to the change in the R&D tax benefit. It has been statistically found that the incidence rate of ICT patent applications was 40% smaller prior to the increase in tax relief. ICT patent applications by Irish inventors nearly doubled after 2009.

This finding is consistent with research results from most studies cited in the literature review. Although different geographies and contexts were analysed, Bronzini and Piselli (2015), Ernst et al. (2014) and Ernst and Spengel (2011) also reported in their papers that more generous R&D tax credits raised patent quantity. Cappelen et al. (2011), however, have not noted any reactions in patent production in relation to the SkatteFUNN R&D Subsidy in Norway.

In this thesis, the most significant finding was uncovered by RQ2. In general, it was observed that approximately 36% of the Irish ICT applications to the USPTO (2004-2015) is composed of patents belonging to a patent family. However, prior to the increase in R&D tax credits, the incidence rate of patent families was 86.4% smaller than after the change happened in 2009.

The only paper from the literature review that investigated innovation quality found opposite results. While analysing patents of all industry sectors from twenty nine European countries filed in the EPO database, Ernst et al. (2014) detected in their data that R&D tax credits decreased patent quality.

For the period studied in this dissertation, data analysis for RQ3 exposes overall growth in ICT patents originating in Irish lands, which can be translated into an improvement in the country's inventive performance. Findings showed that the incidence rate of ICT patents created inside Ireland was 39% smaller before R&D tax credits became more plentiful in 2009.

Data from RQ3 was more deeply investigated in order to answer sub question 3.1. The sub question examined if the top ten Irish experienced inventors became more engaged with patents after 2012, the year when the Irish Government allowed corporate R&D tax relief to be passed on to key employees working with R&D. Even though not enough evidence was found to affirm that the change introduced by Finance Act 2012 could be the reason for an increase, it was found that the invention quantity levels by these ten inventors combined rose in the years of 2012, 2013 and 2014. When looking at inventors individually, however, trends do not show a higher engagement with patents over the investigated term.

During the literature review, papers that examined trends based on patent first inventors, their engagement with invention creations and ICT as the industry sector in focus have not been found, which shows that the exact same point of view investigated in RQ3 and RQ 3.1 have not been vastly explored by other scholars to date.

In summary, theoretical considerations from the literature review show that R&D tax schemes generally increase patent registrations, but there is a decrease in quality as noticed by other researchers. This dissertation finds the same regarding patent quantity, but the opposite was found concerning invention quality, since the data used showed an increase in the patent quality level.

5.4 Contribution to the Body of Knowledge

Differently from papers examined in the literature review, Ireland is the main location under analysis in this thesis and attention is aimed exclusively at the ICT sector in this territory. This perspective has not been explored before, neither was the source of secondary data collected for analysis. Instead of collecting data from the EPO, this thesis proposes to use data from the USPTO, which is the most popular patent office choice for Irish applicants in general (DJEI, 2014).

In addition, most of the studies analysed the effects of R&D tax regimes on patent quantity alone, whereas this research also takes into account patent quality or invention value and the engagement in patent creation by Irish first inventors.

In brief, this dissertation adds to the existing body of knowledge by investigating different perspectives of ICT innovation in Ireland measured with patent data from the USPTO. This study proposes to fill gaps in literature by exploring patent production, invention value and inventive performance for ICT companies in the Irish market. To date, there is limited research evidence on this topic.

The results found in this investigation provide an insight on patents for the ICT sector, an important industry for the Irish economy, as an outcome of the actions taken to establish Ireland as “The Innovation Island”. Thus, it may be of interest to the Irish government when designing tax instruments to incentivise innovation and it may be pertinent to the ICT companies based in Ireland that want to find out where they stand in relation to overall patent statistics in the same sector or to academics and researchers investigating this topic.

5.5 Limitations of the Research

This research has at least three limitations. The patent family definition that served as a basis when collecting data for RQ2 is a valid one, but it may be seen as too simplistic. The definition more frequently used in studies is the definition by the EPO esp@cenet. It only considers patents with the same Family ID and the exact same priority date as a patent family, while in this study the Family ID alone is what determines the patent family, as per one of the valid definitions presented by OECD (2009).

Secondly, due to time constraints, it was possible to achieve only a basic level of knowledge in statistics to perform calculations in chapter 4. A more proficient statistician can, perhaps, explore the same data set in deeper ways.

Lastly, it is worth mentioning a limitation of the data set collected for this thesis. Not all patent applications in the USPTO database disclosed the name of the Assignee company. In some cases, only the patent law firm that represented the assignee legally was revealed. Had there been a reliable way of tracing these law firms back to the assignee, the data set would have been more thorough.

5.6 Opportunities for Future Work

The Irish Budget 2016 announced the creation of a patent box named Knowledge Development Box (KDB). Effective from January 2016 on, this package allows companies in Ireland to earn profits, avail of low patent income taxes and tax credits from copyrighted software or patents that were created as a result of R&D activities that occurred in the State (Revenue, 2015). Future research could lead to interesting findings once the results of this recent change start reflecting patent data.

Due to time limitations, it was not possible to analyse data with the purpose of understanding if R&D benefits impacted indigenous Irish companies more strongly than multinationals based in Ireland. An investigation on this topic could give continuity to the present dissertation.

Future research can also be pursued in a more social context. During data analysis, it was noticed that the majority of the patent inventors residing in Ireland were males, with a very small female representation. This subject opens doors for interesting qualitative and quantitative studies.

5.7 Summary

Over the past decades, European authorities have been engaged in enhancing the levels of technology performance of their countries to increase economic competitivity. R&D tax incentives have played an important role as one of the tools to encourage innovation as part of this effort.

This quantitative research focused on better understanding whether the Irish R&D incentives have positively affected ICT Irish patent production, invention value and inventive performance for companies established in the state.

Findings suggest that changes to the Irish R&D tax scheme have been successful in promoting all the three aspects in the ICT sector. In other words, invention production, invention value and inventive performance all demonstrated to have a positive relationship with more generous R&D tax credit rates.

This evidence from the ICT industry in isolation may serve as a partial indication that the Economic Recovery Plan "Building Ireland's Smart Economy" has put the country in the right direction towards the goal of becoming an European innovation and commercialisation hub through a stronger R&D tax support.

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Appendices

Appendix 1 – p-values for predictor Base Year Restriction

Significance tests for Base Year Restriction showed that this predictor is not statistically significant for any of the validated models and research questions.

When the Negative Binomial Regression model is applied to answer this question considering Base Year Restriction as the only predictor, the values for AIC/BIC and log-likelihood are less than other alternative count models and the Value/DF figures are as close to 1.0 as possible. However, the predictor is not statistically significant for any of the research questions, given that $p > 0.05$ for all the ordinal variable parameters, as displayed in the *Sig.* column of Tables 6.1, 6.2 and 6.3.

Table 6.1 – p-values for predictor Base Year Restriction in RQ1

Parameter Estimates

			95% Wald Confidence Interval		Hypothesis Test				95% Wald Confidence Interval for Exp(B)	
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
(Intercept)	4.868	.3785	4.126	5.609	165.391	1	.000	130.000	61.912	272.969
[BaseYear=1]	.154	.4013	-.633	.940	.147	1	.701	1.166	.531	2.561
[BaseYear=2]	.666	.5318	-.376	1.708	1.568	1	.211	1.946	.686	5.518
[BaseYear=3]	.922	.5309	-.118	1.963	3.019	1	.082	2.515	.889	7.121
[BaseYear=4]	.781	.5314	-.260	1.823	2.163	1	.141	2.185	.771	6.190
[BaseYear=5]	0^a	.	.	.	.	.	.	1	.	.
(Scale)	1^b									
(Negative binomial)	.136	.0573	.059	.310						

Table 6.2 – p-values for predictor Base Year Restriction in RQ2

Parameter Estimates

			95% Wald Confidence Interval		Hypothesis Test				95% Wald Confidence Interval for Exp(B)	
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
(Intercept)	4.407	.9331	2.578	6.236	22.304	1	.000	82.000	13.169	510.577
[BaseYear=1]	-1.861	.9939	-3.809	.087	3.507	1	.061	.155	.022	1.091
[BaseYear=2]	-.296	1.3212	-2.885	2.294	.050	1	.823	.744	.056	9.911
[BaseYear=3]	-.202	1.3206	-2.790	2.386	.023	1	.878	.817	.061	10.874
[BaseYear=4]	-.515	1.3227	-3.107	2.078	.152	1	.697	.598	.045	7.985
[BaseYear=5]	0^a	.	.	.	.	.	.	1	.	.
(Scale)	1^b									
(Negative binomial)	.858	.4362	.317	2.324						

Table 6.3 – p-values for predictor Base Year Restriction in RQ3

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
(Intercept)	4.357	.3678	3.636	5.078	140.297	1	.000	78.000	37.932	160.392
[BaseYear=1]	.112	.3899	-.652	.876	.083	1	.774	1.119	.521	2.402
[BaseYear=2]	.606	.5145	-.402	1.615	1.388	1	.239	1.833	.669	5.026
[BaseYear=3]	.911	.5128	-.094	1.916	3.158	1	.076	2.487	.910	6.795
[BaseYear=4]	.791	.5134	-.215	1.797	2.373	1	.123	2.205	.806	6.032
[BaseYear=5]	0[a]	.	.	.	.	.	.	1	.	.
(Scale)	1[b]									
(Negative binomial)	.122	.0544	.051	.293						