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From exploration to exploitation: A pilot investigation of individual inventors in Ireland

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Abstract

Evidence for a positive relationship between investment in knowledge creation and performance is well-documented for nations (Guellec and van Pottlesberghe 2004) and for organisations (Damanpour and Evan 1984). Less well researched is the role of individuals in the innovation process specifically the knowledge generation and commercialization process. Studies incorporating individuals, have typically positioned them as a distinct tier in knowledge flows, comprising individuals, groups and organisations (Kamhawi 2010). However, implicit to these studies is the assumption that individuals are embedded in organisations.

In this paper we examine an under-researched area of knowledge creation, namely patents that are both invented and assigned to individuals. These patents tend to be excluded from studies of knowledge creation as the organisational context is ambiguous and therefore it is virtually impossible to cross-reference with other data sources on business activity and performance. Yet, as is the case in Ireland, patents created by and assigned to individuals account for a significant proportion of total patents (c. 5 per cent). This knowledge therefore represents substantial novel technology with the potential to be exploited commercially. However, in the absence of an appropriate environment for the exploitation of the technology, the return on the technology may be lost.

We adopt an explorative approach in examining the individual and organisational context of US/EU patents that were awarded to Irish individuals over the period 1976-2009. We explore the extent to which individual patents are commercialised and the various routes to commercialization taken, including intrapreneurship and licensing.

Our findings contribute to the literature on entrepreneurial learning and the relationship between exploration and exploitation both within and across organisational boundaries. Our results are of interest to policy makers in identifying the extent to which novel technology created by and assigned to individuals is, or is not, exploited and the relationship between the environment for knowledge exploration and subsequent exploitation.

Jelcodes:O31,O3

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Keywords: Patent; Independent Inventor; Exploration; Exploitation
JEL Codes: O3; O31

1. INTRODUCTION

Evidence for a positive relationship between investment in knowledge creation and performance is well-documented for nations (Guellec and van Pottlesberghe 2004) and organisations (Damanpour and Evan 1984). Less well researched is the role of individuals in the innovation process, specifically the knowledge generation and commercialization process. Independent invention is typically over-looked in the literature on innovation (Weick and Eakin 2005). Schmookler (1957, 321) states that "*Invention, defined as activity directed towards the discovery of new and useful knowledge about products and processes, is one of the most important phases of the growth of civilisation. Yet it is one of the least understood. Who engages in an inventive activity, why, when, and how?"* While there has been some effort to address this question (Astebro 1998; Parker et al. 1996; Sirilli 1987) evidence on how individuals exploit the knowledge they have created is limited.

The focus of much of the existing literature on the role of individuals in the innovation process embeds them within organisations. In most of these cases, the knowledge generated and manifest in patents is the intellectual property of the organisation employing the individual, with the patent being assigned to the organisation. Yet, for a (albeit small) proportion of patents, these are assigned to individuals with little known about why this might be the case. We therefore have limited understanding of the organisational context in which these individual-assigned patents have been created, the decision making process involved in pursuing a patent application and whether and how patents are exploited.

This paper adopts an exploratory research approach in examining inventors resident in Ireland who have been granted patents through the European Patent Office (EPO) or the United States Patent and Trademark Office (USPTO) over the period 1976-2009. Ireland provides an interesting case for the analysis, with the average annual growth rate of US patents granted from 1976 to 2009 being higher in Ireland than most countries over the period, including America and the UK. In addition, patents assigned to Irish resident individuals account for a significantly higher share of patent awards than in other countries which have experienced growth in patenting such as Singapore (Hewitt-Dundas et al 2010). For example, although the relative contribution of individuals to total patenting activity has declined over time in most countries, individuals still account for almost 1 in every 8 patent awards made in Ireland but only 1 in every 25 awards made in Singapore.

2. LITERATURE REVIEW

2.1 Introduction

This section explores the existing literature in the areas of independent inventors, knowledge exploration and knowledge exploitation. It begins with an overview of the existing literature on the demographic profile of independent inventors. A brief review of the literature on knowledge exploration of individuals is provided in section 2.3. Finally, section 2.4 discusses knowledge exploitation through the commercialisation process.

2.2 Individual Assigned Patents: Who invents?

According to Schmookler (1957: 321) invention "*is one of the most important phases of the growth of civilisation. Yet it is one of the least understood. Who engages in an inventive activity, why, when, and how?" S*tudies show that female inventors are in the minority. Kingston and Scally (2006) find that a random sample of 100 patents taken from the individual inventor category of the US-based United Inventors Association contain only five

female inventors. Further studies on U.S. independent inventors find that the majority of respondents are male: 80.9% according to Parker et al. (1996) and 82% in Weick and Eakin (2006). Astebro's (1998) study of Canadian inventors shows that 89% of respondents are male while only 2.82% of European inventors are female (Guiri et al.; 2007).

Patents are typically granted to individuals who are middle-aged; this may reflect the knowledge those individuals gathered in previous years in employment (including self-employment). This is supported by Weick and Eakin's (2006) study of U.S. independent inventors where the mean age was 50.5 years. This is quite close to the median age of 54 years of age identified by Albaum (1975). Guiri et al. (2007) find that approximately 32% of European inventors are aged between forty one and fifty.

Hisrich's (1985) study of 45 randomly selected inventors finds that the general profile of the inventor is a well-educated individual. This is supported further by Weick and Eakin (2006) who find that over half of respondents had earned at least an undergraduate college degree. Guiri et al. (2007) show that 75% of inventors have a university degree and 25% of them have a doctorate. However, it should be noted that the respondents' qualifications are not classified according to whether they are individual inventors or part of a team.

From the existing literature, it appears that the 'typical' profile of an independent inventor is a well-education, middle-aged male. This leads us to establish the following propositions which we aim to investigate in the course of this research:

- Men have a higher propensity to patent.
- Individuals who patent are more likely to be middle-aged.
- Individuals who patent have high levels of education.

2.3 Knowledge Creation: Entrepreneurial knowledge exploration

Knowledge creation is a continuous, self-transcending process through which individuals go beyond the boundary of their old self into a new self by acquiring a new context, a new view of the world and new knowledge (Nonaka et al., 2000). Knowledge is created through the interactions among individuals and between individuals and their environment.

Studies incorporating individuals, have typically positioned them as a distinct tier in knowledge flows, comprising individuals, groups and organisations (Kamhawi 2010). However, implicit to these studies is the assumption that individuals are embedded in organisations. Organisational knowledge creation is "the capability of a company as a whole to create new knowledge, disseminate it throughout the organisation and embody it in products, services and systems" (Nonaka and Takeuchi 1995: 3). Nonaka (1994) says that organisational knowledge creation is associated with the extent of social interaction between individuals that share and develop knowledge across organisational boundaries. The organisation cannot create knowledge without individuals but it provides the support needed for individuals to do so (Nonaka 1994).

Teece (1998: 62) states that knowledge assets are grounded in the experience and expertise of individuals but it is firms that provide the physical, social and resource allocation structure to enable that knowledge to be shaped into competences. The deployment of such competences shapes the competitive and commercial success of the organisation. A distinction is made by Teece (1998: 63) between the creation of new knowledge and its commercialisation. It again emphasises the role of the organisation; the creation of new knowledge can rest with the

individual, a research laboratory or a business but the commercialisation of new technology, he argues, is increasingly the domain of complex organisation. This suggests that commercialisation of individual assigned patents takes place in organisations not by the individuals themselves.

The environment in which the independent inventor operates in may also shed light on how the invention came to be. Existing studies show that a significant number (46% and 42% respectively) of independent inventors are self-employed (see Amesse et al. 1991; MacDonald 1982; 1984; in Mattes et al. 2006). For medical inventions, the workplace at the time of the invention is the source of invention for 77% of respondents (Mattes et al. 2006). The employment situation of the individual may also impact on whether or not the invention is commercialised though existing studies show divergent results. Dagenais et al. (1991) find that if the independent inventor is self-employed he is more likely to have turned the technology into an innovation. However, Mattes et al. (2006) find that a patent is more likely to become an innovation if the inventor was employed by industry at the time of the invention.

The existing literature points to the importance of both the occupational and organisational context of the independent inventor. It may seem like a contradiction to speak about the organisational context of the independent inventor but it must be recognised that unassigned patents may come from individuals who work within organisations (whether the organisation owned by the inventor or otherwise) and it therefore cannot be overlooked. The inventor's occupation is seen as the key to knowledge generation; his occupation shapes the knowledge he creates. We aim to establish whether this is the case in this research. The occupational status of the inventor, that is whether he is self-employed or employed within an organisation, may also shed some light on the knowledge exploration process. The organisation in which the inventor is working in, along with the organisational characteristics such as firm size and whether the organisation is in the private or public sector, may also influence the knowledge created by the individual. This leads to the following propositions which will be tested in this research:

- The inventor's occupation/job is the primary source of the idea behind the invention.
- Individuals who are self-employed have a higher propensity to patent.
- Individuals who work in the public sector have a higher propensity to patent.

2.4 Knowledge Exploitation: The Commercialisation Process

Little is known about how entrepreneurs and inventors find and exploit technological opportunities (Shane and Venkataraman 2000). Astebro (1999) points to an abundance of work done on the commercialisation of corporate patents but says that there is little known about the commercialisation of independent inventor patents. He finds that only 6.5% of independent inventors' inventions, of almost 1,100 responses, on average, reach the market.

The willingness to exploit an invention depends on the ability to appropriate its value (Arrow 1962 in Groves 1962). Teece (1986: 287) provides an explanation of what he means by appropriability: it "refers to the environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation". These factors relate to the ease with which an innovation can be imitated which in turn affects the appropriability of an innovation. A patent, in theory, offers perfect appropriability because it provides a monopoly of the invention for a limited period of time (Levin et al. 1987). However, in reality, appropriability is not perfect. Where the core technology can be easily imitated the commercial success of the innovation depends upon the terms and conditions

upon which the required complimentary assets are acquired (Teece 1986: 291). If these assets are owned by a third party the innovator is disadvantageously positioned relative to the owner of the complementary assets required. Thus, the inventor's ability to appropriate the returns to their inventive efforts may depend on the commercialisation method chosen.

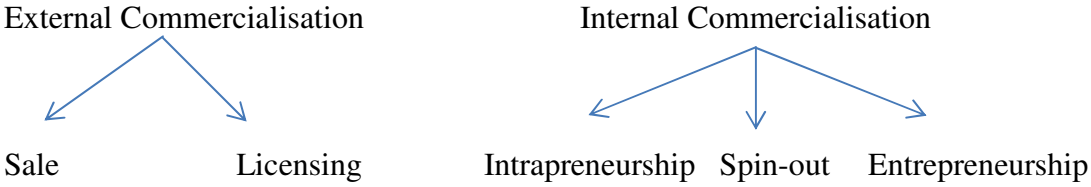
An individual may face problems when attempting to commercialise their invention. An inventor may not possess the downstream assets (e.g. production equipment) to commercialise their invention themselves (Giuri et al. 2007). Additionally, the individual may face limited funds to cover patenting and commercialisation expenses (Modlin and Glenn 2006).

There are several different modes of commercialisation (Braunerhjelm and Svensson 2010):

1. Sell the patent
2. License the patent
3. Intrapreneurship - commercialise the patent in an existing firm in which the inventor is employed.
4. Entrepreneurship
5. Spin-off - commercialise the patent in a new firm.

The methods by which inventors may choose to commercialise their inventions can be broken into two categories: internal knowledge exploitation and external knowledge exploitation. Figure one illustrates the methods of commercialisation that can be used.

Figure 1: Methods of Commercialisation



Internal knowledge exploitation occurs where the inventor chooses to commercialise their invention themselves. This can be done in a number of ways including intrapreneurship, entrepreneurship and spin-off. It also includes instances where the inventor licenses or sells the patent to their own company. External knowledge exploitation occurs where the inventor turns to the market for commercialisation purposes. This category includes the sale of the patent and licensing to a third party.

The inventor may decide to sell the patent to a third party to develop the technology behind it. The inventor typically receives a one-off payment and no longer has an ownership claim over the patent. Alternatively, the inventor may decide to license the patent. Licensing allows a company to exploit rights over a patent but may be limited as to a certain timeframe or geographical area. In return, the inventor receives royalties. Intrapreneurship is the practice of developing a new venture within an existing organisation to exploit a new opportunity (Parker, 2011). An intrapreneur is a corporate entrepreneur; it allows entrepreneurship to occur in an existing firm (Hisrich, 1990). An employee may be an intrapreneur where their invention is exploited within the company in which they are employed.

Intrapreneurship is distinct from entrepreneurship. Schumpeter (1942) recognises that entrepreneurs can exploit the technological opportunities that result from inventions by the establishment of new firms. Entrepreneurship involves the establishment of a new company outside an existing one, otherwise known as a 'start-up'. We use the term entrepreneurship to include instances where the independent inventor has commercialised their invention in an existing firm established and owned (or part-owned) by the individual through the sale or licensing of the patent to the inventor's own company. Spin-offs, also known as spin-outs,

are firms started by a former employee of an incumbent firm (Klepper, 2001; Franco and Filson, 2006). They are seen as a form of new firm formation (Koster, 2004). Spin-offs are distinct from other forms of new firm formation because the employee of the incumbent firm has previous experience in that industry; this may not be the case for the entrepreneur starting their own business (Klepper, 2001; Franco and Filson, 2006).

A patent assigned to an individual inventor does not necessarily mean that the inventor does not work within an organisation. It may be the case that the inventor did not assign the rights to the patent to the company for a particular reason (e.g. no requirement to do so). The organisational context of the individual (i.e. whether he is self-employed or working within an organisation) may impact upon the method of commercialisation chosen. Svensson (2007) finds that the majority of patents (65%) in his study on the Swedish medical and hygiene sector were commercialised in existing firms where the inventors were either employed or owners. 12% of patents were commercialised in new firms. He also finds that sole inventors report difficulty finding finance or firms that are willing to manufacture the product as the major reasons for non-commercialisation. The author points to a lack of government support in the commercialisation of patents. A study of U.S. independent inventors (Weick and Eakin, 2006) finds that the majority of inventors commercialised their inventions through a company they had started with licensing the second most popular option followed by an outright sale.

We also seek to establish whether there is a difference in the methods by which individuals exploit the knowledge they have created according to firm size (small or large) and whether he works in a public or private organisation. We aim to test the following propositions:

- Individuals in small firms have a higher propensity to commercialise their patent through entrepreneurship.
- Individuals in large firms have a higher propensity to commercialise their patent in the organisation in which they work.
- Individuals in the public sector have a higher propensity to commercialise their patent through licensing.

3. METHODOLOGY

This section outlines the methodology used in this study. The EPO and USPTO databases were searched for patents granted to individuals resident in Ireland between 1976 and 2009. This generated approximately 666 patents. Patents assigned and co-assigned to organisations are excluded from this research; it focuses on patents assigned to individuals i.e. those patents where the inventor retains ownership of their invention. Duplicate patents are also excluded from this study; thus, if, for example, an inventor had been granted a patent by the EPO in 2001 and subsequently by the USPTO in 2003 only the patent granted by the EPO is included. We felt that this eliminated double counting of the same invention from our study.

The total number of patents fell from 666 to 561 when duplicate patents were removed. Where the inventor had more than one patent from a patent office for what appeared to be the same invention (i.e. the inventions had the same title) both were included. It was felt that if the patent office granted the inventions separate patents the inventions had met the criteria of novelty and was thus included in this research. Taking all the above into account, the total number of patents granted to individuals resident in Ireland between 1976 and 2009 is 561.

While the information on patents granted is publicly available, a critical task of this research was to find the telephone numbers of the inventor listed on the patent to conduct the survey. Where there was more than one inventor per patent we sought one phone number of one of the inventors. We were not rigid in our decision as to which inventor to survey; we surveyed the inventor whose telephone number could be found.

We faced several problems in finding the inventor's telephone number. Firstly, in some cases, the inventor was still listed at an old address (and old telephone number). Of the individuals who were no longer listed at their old address we were not given any forwarding address or contact details from the new resident Secondly, there was no listed phone number for some of the inventors in our sample ("ex-directory"). Thirdly, we encountered numerous entries for several inventors within the same city or county. In this case, we rang the various telephone numbers found in an effort to track down the inventor. This was successful in a small minority of cases.
To overcome these problems, we conducted online searches to establish any business connections the inventor may have. We used a combination of the inventor's name, address on the patent application and title of invention to narrow the search criteria. We were successful in doing this for some inventors. Where this occurred we contacted the inventor via the organisation to establish their interest in participating in our survey.
We recognise that there may be sample bias as those who commercialised their inventions may be more easily found (e.g. through company name). Previous studies on independent inventors have encountered the same problems in their search for the inventor. We do not see this as a serious limitation to the value of our research.

3.1 Survey Design

A telephone survey was used to seek responses from independent inventors. In some cases, the inventor asked that the questions be emailed to them. We agreed to this request. From our initial sample of 561 patents, telephone numbers corresponding to the addresses listed on the patent application or from business addresses associated with the individual were found for 109 individuals. This corresponds to 19% of the total number of patents. Of the 109 individuals, we successfully surveyed 38 individuals (corresponding to 54 patents). The level of participation in the phone survey is set out in the appendix in table one.

To capture the necessary data, questions posed include:

- Demographic questions (age, gender and education)
- Inventor status (full-time or part-time, employment status at time of invention and organisation size, if applicable)
- Knowledge exploration (idea behind invention, sources of information used)
- Grant support received (source if applicable)
- Knowledge exploitation (commercialisation of invention and method used, if applicable)

The questions were a mix of closed and open-ended questions. Open-ended questions were used to allow the inventor to provide as much information as possible particularly in relation to knowledge exploration and exploitation. Of the 38 individuals surveyed, one individual could be described as a 'prolific' inventor in that he had ten patents (individual and collaborative). A comparison of the main results of the survey both including and excluding this individual are presented in table three of the appendix. The results are not significantly different to warrant a discussion of findings under both scenarios.

4. FINDINGS

We begin with an analysis of the total population of 561 patents granted to individuals resident in Ireland between 1976 and 2009. Of the total number of patents, 375 patents were granted by the USPTO with the remaining 186 from the EPO. 504 patents were granted to male inventors, 14 to female inventors and 41 to collaborating males and females. Thus individual female inventors account for just over 2% of our total population. This supports previous studies who find that women are significantly under-represented among patenting inventors (Astebro, 1998; Guiri et al., 2007). The majority of patents (378) belong to sole inventors; the remaining patents collaboration of between two and seven individuals. The typical size of the collaborative inventor team is two individuals (120 patents). Of the collaborative patents, the majority involve male-male collaboration (139), 41 patents involve male-female collaboration and only one involve female-female collaboration. Table one shows the percentage of patents granted by the USPTO and EPO, the percentage of male inventors and collaborative inventors, and the average number of inventors in our sample relative to the total population of 561 patents.

Table 1: Percentage of Respondents in Sample relative to Total Population

	Total Population	Sample
USPTO	67%	76%
EPO	33%	24%
Male inventors	90%	90%
Average number of inventors	1.5	1.6
Collaborative patents	33%	37%

4.1 Individual Assigned Patents: Who invents?

Our data provide a unique opportunity to answer Schmookler's (1957, 321) question: *"Who engages in an inventive activity, why, when, and how?"* Of the 38 respondents surveyed, 2 were female (5%). 91% of patents were assigned to male inventors. This supports our proposition, and previous studies, that patenting is male dominated. Individual patents account for 67% of our sample population with the remaining patents belonging to multiple inventors. Of the patents involving co-inventors, a collaborative inventor team size of two is the most common occurrence. The findings on age and education are presented on a patent basis not based on inventor numbers. This is done to reflect the fact that some individuals have more than one patent and their age and education may change over the course of their patenting life.

The average age of the independent inventor is 46 years old. There is quite a wide distribution of ages ranging from 25 to 69 with the majority of inventors in the 40-49 age category supporting the findings of Guiri et al. (2007) and lending support to our proposition that individuals who patent are more likely to be middle-aged. Inventors typically have high levels of education with 19% of our sample holding a bachelor's degree, a further 32% have a Masters and 11% have a doctorate. This implies that individuals with higher education have a higher propensity to patent.

Inventors were asked in the survey to identify their occupation. The occupation cited by the inventor shows a large degree of variety. Based on their response, we use the UK standard occupational classification (SOC) 2010 to categorise inventors' occupations. Here, we focus on inventors and not the number of patents per inventor. A review of the inventor surveys shows that none of the inventors with more than one patent surveyed had changed their occupation over the course of the patents. Of the 38 inventors surveyed, 32% fell into the 'management occupations' classification. 16% were in the category 'healthcare practitioners and technical occupations', 13% in the 'education, training, and library occupations with a further 10% in 'architecture and engineering occupations'. The remaining categories can be seen in table two in the appendix. Interestingly, the majority of the individuals who occupy the management occupation either founded or co-founded that business but didn't classify themselves as entrepreneurs; only one individual in the study stated that their occupation was an 'entrepreneur'.

Within each occupational classification, we can further explore the inventor's occupation. The most recurrent occupations include managing director of a company (13%), university lecturer (13%) and engineer (10%). Inventors were asked whether they would describe themselves as full-time or part-time inventors. The majority (81.5%) describe themselves as part-time inventors. This suggests that the capacity to generate new ideas lies outside full time research and development staff. Table two shows the percentage of patents in our sample compared to the total population categorised according to technology class.

Table 2: Respondents' patent technology class versus total population of patents

	Total Population	Sample
Electrical Engineering	14%	2%
Instruments	18%	31%
Chemicals	16%	11%
Mechanical Engineering	30%	37%
Other	15%	7%

Note: Figures don't round to 100% for total population because of missing data and rounding.

4.2 Knowledge Exploration: Where do the Ideas come from?

Necessity is the mother of invention…or is it? Inventors were asked to elaborate on the story behind their patent including where the idea for their invention came from. We deliberately left the question open-ended to elicit as much detail as we could from the inventor. It would seem that necessity is not the mother of all invention in our case. While a number of inventors chose not to respond to this question (11%), the number of inventors who said that their invention was as a result of necessity is quite low (7.4%). A number of inventors (9%) said that their invention was a result of them encountering a problem that needed a solution. However, care must be taken in interpreting this; we cannot say for definite that this is the same thing as necessity. For example, it may be because the inventor thought the existing solution was too expensive. Other reasons given include that the invention came about because the inventor saw a better way of doing something (13%), based on experience in their job (11%), the inventor was looking for a cheaper alternative (5.6%) and because of the inventor's interest or hobby (5.6%).

We sought to establish what environment independent inventors operate in; are they self-employed or in employment? Furthermore, we also asked inventors whether they work in private or public institutions and the size of the organisation (if any) in which they are employed. Our aim was to examine whether independent invention occurs within an organisational context or whether it is truly independent. This is explored on a patent not inventor basis; the rationale behind this is to reflect any change in the inventor's employment status and therefore organisational context.

70% of patents were granted to individuals who are self-employed. The requirement here is that the individual founded or co-founded the business. Many inventors classified themselves as managing directors of the organisation yet had actually founded or co-founded the business; thus they are classified as self-employed here. 24% of patents are granted to inventors who are employed within organisations. One inventor is classified as a student while two inventors chose not to respond to the question. This indicates that individuals who are self-employed have a higher propensity to patent. The majority of inventors work in private organisations (65%) with 18.5% working in the public sector. This does not support our proposition that individuals who work in the public sector have a higher propensity to patent.

For those inventors working within organisations, we classified the economic activities of those organisations based on the European Community's NACE rev. 2 classification system. Almost a third of inventors, who work within an organisation, are employed with manufacturing. Education accounts for a further 17% followed by human health and social work activities (9%). The remaining inventors are seen in small numbers in activities such as wholesale and retail trade, and professional, scientific and technical activities. Manufacturing includes a variety of activities: manufacture of plastic, manufacture of childcare products, and manufacture of medical and dental instruments and supplies.

Inventors were asked to indicate what size organisation they work in: micro (>0-9 employees), small (10-49 employees), medium (50-249 employees) or large (250+ employees) firms. The majority of inventors (33.3%) work in small firms (including those who stated they were self-employed i.e. owners of a small business). Some of the inventors who state they are self-employed do not work in organisations thus organisation size is not applicable for approximately 20% of inventors. A further 22.2% of inventors work in large organisation with 18.5% working in micro firms (the remainder did not respond to the question). Inventors were asked why, if they worked in an organisation, the patent wasn't assigned to the company. More than 50% of the inventors said that they were the owner/co-owner of the business or self-employed. Further responses given were that the inventor used his own time and resources to develop the patent, it had nothing to do with their job and that they had no requirement or wish to assign it to the company.

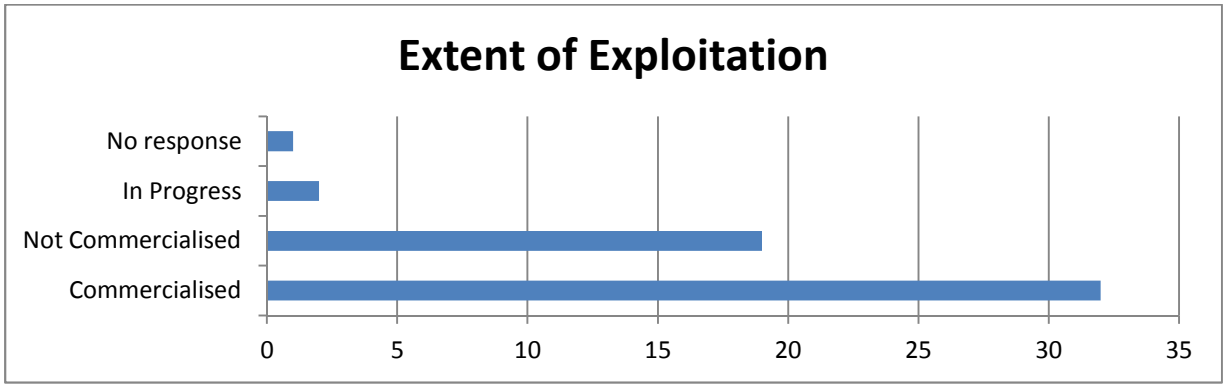
To gain an insight into how inventors use knowledge in their invention we asked them to identify any sources of information used and to explain the impetus for the patent. The majority of patents (40%) did not involve any sources of information according to the inventor. This results needs to be carefully interpreted as it involves asking inventors to retrospectively remember the sources of information used; for some inventors this involves a ten year gap or more. The result seems quite high and indicates that independent inventors may work in a 'bubble' whereby they don't interact with other individuals (or other information sources) to discuss their idea. Other sources of information include the Internet, trade shows and conferences, on the job, experts in the fields, scientific studies and existing literature and customers/potential customers. This implies that the sources of information

used in the generation of inventions (and fine-tuning of them) are very varied and that the inventor's job is not the primary source of the idea behind the invention contrary to what we expected. In fact, a substantial number of inventions arose because the inventor had an interest in the area.

4.3. Knowledge Exploration: Commercialisation of Patents

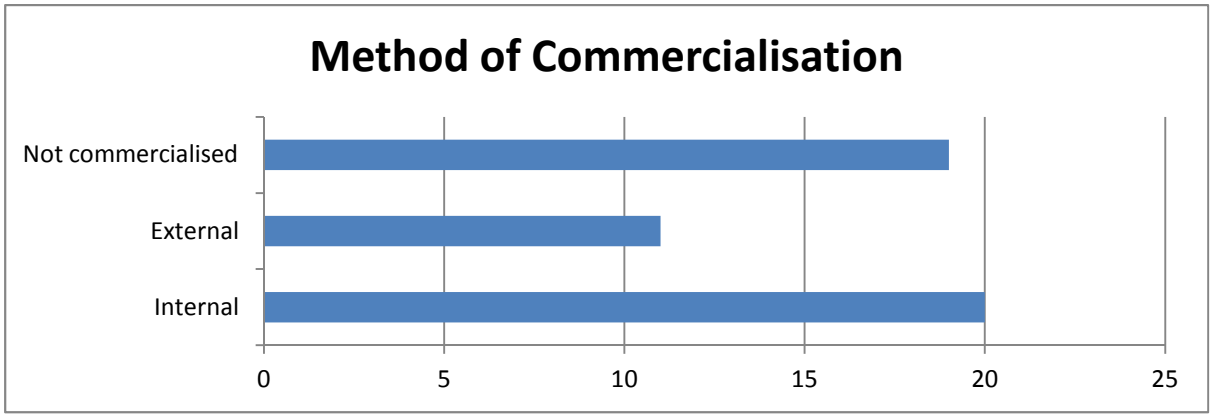
Inventions can be commercialised in a number of ways as set out previously: internal exploitation and external exploitation. Included in internal exploitation is licensing or sale of the patent to the inventor's own company while licensing or sale to a third party is included in external exploitation. Of the 54 patents in this study, 32 were commercialised (60%). This means that 19 were not commercialised with two inventions currently in the process of being commercialised. Figure two sets out the extent of knowledge exploitation.

Figure 2: Knowledge Exploitation: Extent of Patent Commercialisation



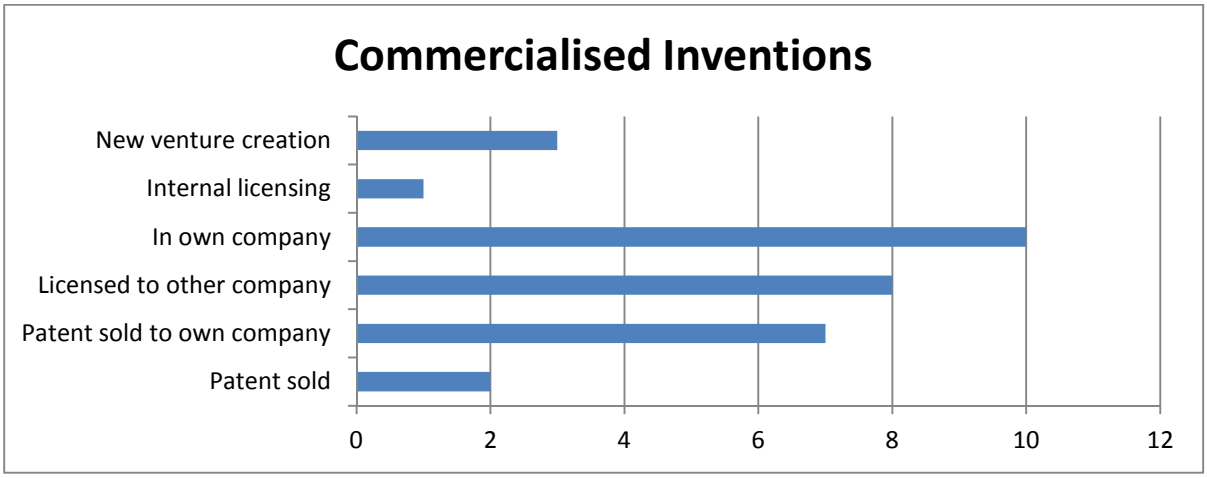
Turning to the method by which inventions were commercialised the most popular method of exploitation was internal commercialisation. It accounts for 63% of all inventions commercialised as seen in figure 3.

Figure 3: Method of Commercialisation of Inventions



We can look at this in more detail by focusing on the internal and external routes to commercialisation chosen by the independent inventor. Internal exploitation includes the sale of the patent to the inventor's own company, licensing to the inventor's own company, the establishment of a new venture by the independent inventor and within an existing firm owned by the inventor. External exploitation includes the sale of the patent to a third party and licensing to a third party. Figure 4 illustrates the internal and external methods of exploitation chosen by independent inventors.

Figure 4: Internal and External Methods of Commercialisation



57% of individuals in micro and small firms commercialised their patent internally. Only one patent was commercialised within a large firm. The remaining individuals in large firms commercialised their patents through a licensing agreement not within the organisation in which they work as previously thought. However it must be noted that these individuals are working within public organisations and thus this explains the high incidence of individuals in large firms exploiting their inventions externally. We do find support for our proposition that individuals in public sector organisations have a higher propensity to commercialise their patents through licensing; all individuals working in public sector organisations who commercialised their patents did so via licensing.

The overall view of the patent system by independent inventors surveyed is negative. Many inventors said that they wouldn't patent again; one went as far as to say that if he had his time over he would use a trademark instead. Those who had a positive experience of the patent process were those who had legal representation in the form of a patent agent. However, for many independent inventors this is an additional cost that they cannot meet.

A potential reason for the non-commercialisation of patents, from talking to inventors, is a lack of financial capital to progress from invention to commercialisation. As one inventor said "I would have needed to sink a lot of money into it, which I did not have (it had already cost me a lot to get it to the patent stage)". The cost of the patent and renewal may serve as an indirect obstacle to the exploitation of new knowledge; where the inventor feels he had already spent a substantial amount of money (and time) investing in securing the patent, he may be unable to progress it further.

Inventors were asked whether they received grant support at any stage in the development of their invention or subsequent to it. Of the 54 patents granted only 9 received some form of grant support. The type of grant support includes Enterprise Ireland (3), Invest Northern Ireland (2), City and County Enterprise Boards (2), RTI (1) and the Industrial Development Agency (1). Many inventors had quite a negative view of the support agencies in place (both financial and otherwise). A number of inventors had tried to apply for grant support but were unsuccessful in doing so. Inventors described themselves as being "very frustrated" and "feeling you're trash" when dealing with these support agencies. Others criticised them because they believed "the commercial focus in missing". One inventor went as far as to say that the fact that she was a sole inventor went against her because there's "no box to tick for sole inventor on the grant form". Of course, one must recognise that inventors may be disillusioned with the support agencies because they were refused financial support on the

grounds that their invention would not succeed when brought to market; however, the fact that a patent was secured on their invention indicates that they met the utility criteria and thus the patent office believed that the invention could succeed commercially. This is an area that warrants further research.

From an entrepreneurial perspective, only one inventor mentioned that it was their own skills, or lack thereof, that limited their ability to commercialise their invention "my biggest 'problem' I face is the marketing and sales". To overcome this perceived shortcoming, they were looking for an investor with expertise in this area to exploit their invention. Interestingly, the remaining inventors surveyed who were unsuccessful in exploiting the new knowledge they had created pointed to external factors (i.e. lack of finance) as the obstacle; the individual was not responsible. The resources available to independent inventors to exploit their invention is an area that could prove interesting in understanding the commercialisation process in more detail in future.

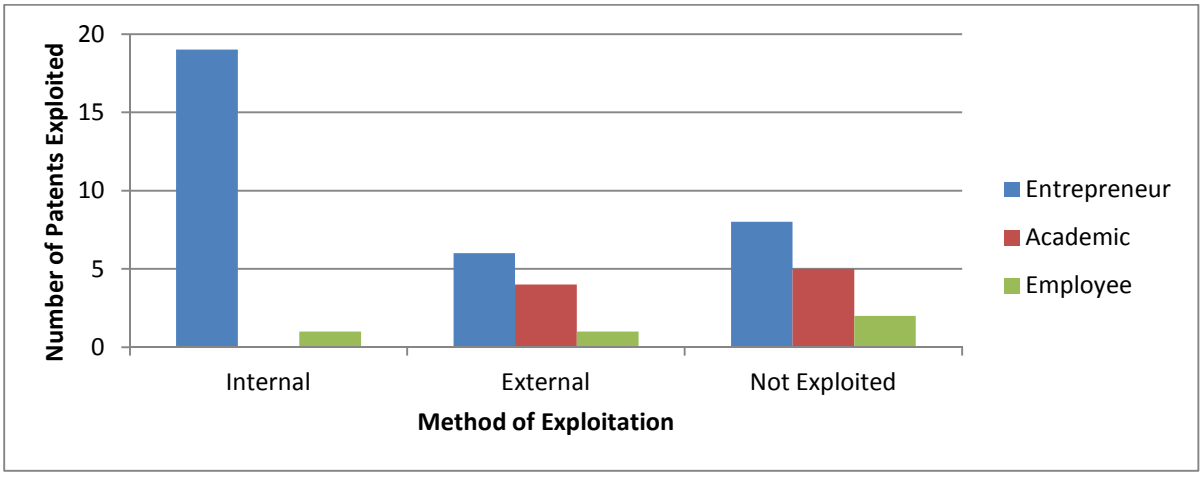
5. A TYPOLOGY OF INVENTORS

Our analysis of patents assigned to individuals suggests that their exploration and exploitation characteristics can be captured in a typology. Too often, independent inventors may be thought of as 'hobbyists' (Dahlin et al., 2004) and while there is evidence that for some obtaining a patent represents a personal pursuit this perception does not capture the diversity of contexts for individual inventors Therefore, a typology allows for a deeper understanding of the types of independent inventors that exist. The criteria for developing a typology here follows that of Amesse et al. (1991) and Meyer (2004) who sets out three criteria to classify independent inventors. This research uses two of their criteria. The first, the employment status of the inventors, looks at whether they are self-employed or employed within an organisation (private or public). The mode of utilisation of the invention is also considered; does the inventor exploit their invention themselves (by establishing a new venture or through an existing one) or do they transfer the rights (through license or sale) to a third party.

Based on the employment status of the individual, they are classified in one of three categories: entrepreneur (self-employed), academic (working within a University) or employee (working within an organisation). Several inventors are excluded from the typology. This is because they did not reveal their occupation during the interview, they do not fit into the above typology (e.g. one inventor was a student at the time of the patent grant) or they are currently in the process of exploiting their inventions and thus cannot be categorised as internal or external exploitation as that information was not given. Figure 5 presents the typology of independent inventors based on the above three categories and the methods by which they exploited their inventions.

The most frequently occurring category among the independent inventors in our sample is an entrepreneur. Entrepreneurs are self-employed individuals. While entrepreneurs exploit the highest number of patents they also represent the category with the highest number of unexploited patents as seen in Figure 5. As might be expected entrepreneurs typically exploit their inventions internally. Academics exploited their inventions externally while the two employees in our sample were split equally between internal and external exploitation.

Figure 5: A Typology of Independent Inventors



We have developed a typology of independent inventors set out in Table 3 below using the two criteria above to classify independent inventors. It looks at the context of exploration (the inventor's employment status) and the context of exploitation (how the invention was exploited). Entrepreneurs (self-employed individuals) primarily exploit their inventions internally as previously mentioned. Internal exploitation suggests entrepreneurs are pursuing IP (intellectual property) driven growth within their own companies. They are seeking to exploit their patents internally to help the business grow. Entrepreneurs who exploit their patents externally are categorised under the 'IP Sale' category. This does not just refer to the sale of the patent; it includes all forms of external exploitation. They do not exploit their inventions within their own company. This may be because they do not have the capacity to do so (e.g. a sole trader, lacking resources etc.). There is also a category titled 'Wastelands' which represents the novel technology not exploited by entrepreneurs. The reasons put forward for this include the entrepreneur's inability to find suitable partners, a lack of financial capital and the entrepreneur's own lack of necessary skills.

Table 3: A Typology of Individual Assigned Patents

		Context of Exploitation		
		Internal	**External**	**Not Exploited**
Context of Exploration	**Entrepreneur**	IP Driven Growth	IP Sale	Wastelands
	Academic	Strategic Misalignment	IP Sale	Shelf IP
	Employee	IP Driven Growth	IP Sale	Shelf IP

Of the academic inventors in the typology, Table 3 highlights that none of the patents were exploited internally. All the patents that were exploited were exploited externally. The

individual inventors in this study were employed by universities at the time the patent was granted yet the novel technology created was not assigned to the university. This suggests a strategic misalignment between the context of exploration and the context of exploitation. and implies that the intellectual property behind their invention (i.e. the patent) was shelved and, in some cases, the IP later lapsed. Further research on academic inventors may shed light on why the misalignment exists and whether any policy could be implemented to enable universities to capitalise on the new knowledge created and perhaps generate income from this.

The final category, employees, is the smallest in this study. It represents individuals employed within private sector organisations. Where the patent is exploited internally it suggests that the organisation is pursuing IP driven growth. This may mean that the employee is a corporate entrepreneur; their patent is exploited within the company in which they are employed. External exploitation represents the sale of IP while the non-exploitation of the patent is classified as shelf IP. The employee working within the organisation does not exploit the IP created through the company in which they are employed. From our research it is not possible to say what the reasons for shelving the IP created by employees is but we may surmise that it could include the organisation's unwillingness to exploit the invention or that the invention may be unrelated to the company's operations.

Applying the typology to the patents in our survey enables us to identify how the three categories of inventors exploit the novel technology they have created. For the reasons given previously several patents have been omitted from our study. Table 4 illustrates the exploration and exploitation context of the remaining 46 patents.

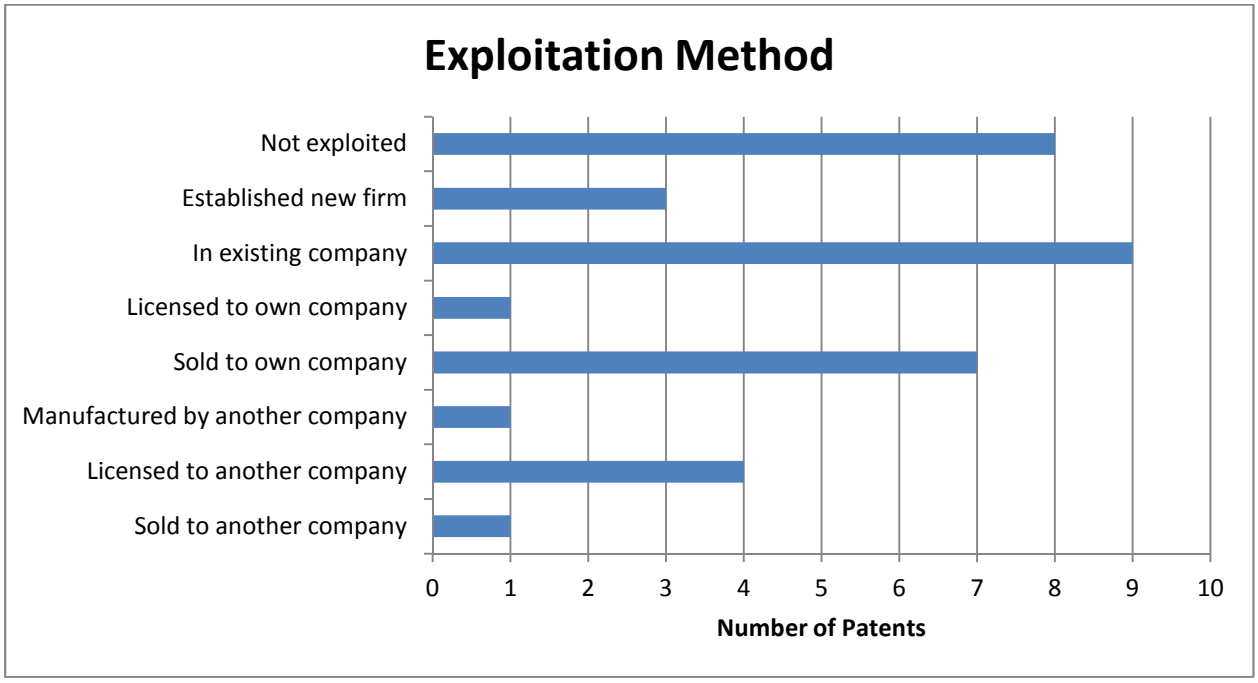
Table 4: A Typology of Individual Assigned Patents in Ireland

		Context of Exploitation		
		Internal	**External**	**Not Exploited**
Context of Exploration	**Entrepreneur**	19	6	8
	Academic	0	4	5
	Employee	1	1	2

Of the nine patents granted to academic independent inventors four were exploited while five patents were not. All academics who exploited their inventions did so externally via licensing to a third party. Four patents are assigned to employees with two exploited and the remaining two not exploited. One employee was employed in a family business at the time the patent was granted and the invention was commercialised internally in the business. The other

employee interviewed sold their patent to a third company hence it was exploited externally. The exploitation methods pursued by the largest category, the entrepreneur inventors, is set out in figure 6 below.

Figure 6: Internal and External Methods of Exploitation Chosen by Entrepreneurs



The exploitation context of entrepreneur inventors is varied. The internal exploitation methods include the sale of the patent to the inventor's own company, licensing the patent to the inventor's own company, commercialised within the inventor's own existing business or through the establishment of a new venture. The external methods used a third party to make their product (the inventor did not classify whether this was through sale or license), the sale of the patent to a third party and licensing the patent to another company.

A significant number of patents were not commercialised by inventors. They were asked why this was the case. The reasons given for this include lack of financial capital, unable to find suitable partners, wasn't worth the investment it needed and their perception that their invention was not commercially viable. This suggests that there are a number of obstacles to the exploitation of the novel technology created by independent inventors. This could prove interesting for future research in deepening our understanding of the barriers to innovation from the perspective of independent inventors.

6. CONCLUSION

Males account for the highest number of individuals resident in Ireland granted patents by the EPO and USPTO since 1976. Females are significantly under-represented accounting for just 2%. There is a high degree of collaboration among patents granted (30.7%) with the majority of collaborative patents involving an inventor team of two individuals. The patents represent a wide variety of technological classes.

Of the total number of patents granted, we surveyed 38 inventors corresponding to 54 patents. Our findings continue the pattern identified for the total population of granted patents as men

account for almost 90% of inventors surveyed. The majority (44.4%) of inventors fall into the 40-49 age category. Inventors have a high level of educational attainment with 57.8% achieving a bachelor's degree qualification or higher. Most inventors classify themselves as part-time inventors. There is a wide variety in the occupation classification of inventors surveyed including doctors, engineers, managing directors of companies and engineers. Firm size did not influence the commercialisation method in the ways in which we thought it would. Grant support was attained by a number of inventors and could be an important factor in the successful commercialisation of patents. However, a number of inventors expressed negative attitudes towards the state support agencies that are set up to encourage innovation.

Individual inventors are a heterogeneous group. The typology of independent inventors developed here shows that they typically fall into three categories: entrepreneurs, academics and employees. The majority of patents are commercialised but in a variety of ways. Entrepreneurs tend to exploit their inventions internally while academics exploit theirs externally through licensing agreements. Employees exploited their patents internally and externally. While a high number of patents are commercialised a significant number are not. Inventors cited a number of factors as obstacles to their exploitation efforts such as a lack of finance. This coincides with their view that to get to the patent stage (and maintenance of it) alone is quite expensive; moving beyond this is a step too far for many. This could be of interest to policy makers whose aim it is to promote innovation in Ireland. Entrepreneurs display the highest rate of commercialising their inventions. This suggests that entrepreneurial motivation may be important in explaining the exploitation of their inventions. While some individual inventors may be classified as 'hobbyists' the majority are not as evidenced by the high number of patents exploited. Individual inventors are a source of innovation that should not be discounted. Further research could enable us to understand the exploration – exploitation process from the perspective of the independent inventor in more detail.

References

Åstebro, T. B. & Dahlin, K. B. (2005) Opportunity knocks. *Research Policy,* Vol 34**,** pp.1404-1418.
Damanpour F and Evan, W. (1984) Organizational innovation and performance: The problem of 'Organizational Lag', Administrative Science Quarterly, Vol 29, No. 3, pp. 392-409.
Guellec, D, and van Pottelsberghe, B. (2004) From R&D to productivity growth: do the institutional settings and the source of funds matter? *Oxford Bulletin of Economics and Statistics* Vol. 66, pp.353-378.
Hewitt-Dundas, N., Singh, A., Ho, Y. & Wong, P. (2010) Knowledge Flows Of Innovation In Small Open Economies–Comparative Analysis Of Ireland And Singapore. *Institute of Small Business and Entrepreneurship*.
Hisrich, R. D. (1985) The inventor: a potential source for new products. *The Mid-Atlantic Journal of Business,* Vol. 24**,** pp. 67-80.
Hisrich, R. (1990) Entrepreneurship/Intrapreneurship. American Psychologist, 45 (2), 209-222.
Kamhawi, E. (2010) The three tiers architecture of knowledge flow and management activities, *Information and Organization*, Vol. 20, No.3-4, pp. 169-186.
Kingston, W. and K. Scally (2006) *Patents and the Measurement of International Competitiveness*, Cheltenham, Edward Elgar.
Klepper, S. (2001) Employee startups in high tech industries. *Industrial and Corporate Change*, Vol 10 pp. 639-674.
Klepper, S. & Sleeper, S. (2005) Entry by Spinoffs, *Management Science*, Vol. 51, No. 8, pp.1291-1306.
Koster, S. (2004) Spin-off firms and individual start-ups. Are they really different?, ERSA conference papers ersa04p287, European Regional Science Association.
Levin, R.C., Klevorick, A.. Nelson, R., Winter, S., Gilbert, R. and Griliches, Z. (1987) 'Appropriating the Returns from Industrial Research and Development', *Brookings Papers on Economic Activity*, Vol 3, Special Issue on Microeconomics, pp. 783-831.
Mattes, E., Stacey, M. C. & Marinova, D. (2006) Surveying inventors listed on patents to investigate determinants of innovation. *Scientometrics,* Vol. 69**,** pp. 475-498.
Meyer, M., (2004) Individual Inventors, Entrepreneurial Activity and Public Support Measures. Engineering Management Conference Proceedings 2004.
Modlin, D. & Glenn, M. (2006) International Patent Strategies for Independent Inventors. *The Journal of High Technology Law*, Vol. 6, No. 2, pp. 129-147.
Nonaka, I. (1994) A dynamic theory of organizational knowledge creation. *Organization Science***,** pp. 14-37.
Nonaka, I. & Takeuchi, H. (1995) *The Knowledge Creating Company,* Oxford University Press: New York.
O' Malley, E., Hewitt-Dundas, N. & Roper, S. 2006. An all-island system of innovation myth or reality?
Parker, R. S., Udell, G. G. & Blades, L. (1996) The new independent inventor: implications for corporate policy. Review of Business – Saint John's University, Vol. 17**,** pp. 7-11.
Parker, S. (2011) Intrapreneurship or Entrepreneurship? *Journal of Business Venturing*, Vol. 26, pp. 19-34.
Schmookler, J. (1957) Inventors past and present. *The Review of Economics and Statistics,* Vol. 39**,** pp. 321-333.
Schumpeter, J. (1942) Capitalism, Socialism and Democracy. HarperPerennial.

Sokoloff, K. 1992. Invention, Innovation, and Manufacturing Productivity Growth in the Antebellum Northeast. In Gallman and Wallis (eds). American Economic Growth and Standards of Living before the Civil War. University of Chicago Press.
Teece, D. (1986) Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy, Vol. 15, pp. 285-305.
Teece, D. (1988) Capturing Value from Knowledge Assets The New Economy, Markets for Know-How, And Intangible Assets, California Management Review, Vol. 40, No. 3, pp. 55-79.
Veer, T. & Jell, F. (2011) Patenting motives of small applicants a comparative study of single inventors, start-ups and universities. Druid Paper.
Wagner J. (2004) Are Young and Small Firms Hothouses for Nascent Entrepreneurs? *Applied Economics Quarterly,* Vol. 50, No. 4, pp. 379–391.
Weick, C. W. & Eakin, C. F. (2005) Independent inventors and innovation: An empirical study. *The International Journal of Entrepreneurship and Innovation,* Vol. 6**,** pp. 5-15.

Appendix

Table 1: Phone Survey Participation

Level of Participation	Number of Respondents
Inventor Participated	38
Message left for inventor	10
Inventor emailed	13
Inventor refused to participate	1
Inventor phone disconnected	11
Inventor moved address	3
Inventor deceased	9
Unable to contact inventor*	23
Total	108

* Inventor rang but unable to contact or leave a message (e.g. phone rang out repeatedly)

Table 2: Inventor occupational classification according to UK SOC 2010

Occupational Classification	Number of Respondents	Percentage of Respondents
Management Occupations	12	31.6
Computer and Mathematical Occupations	1	2.6
Architecture and Engineering Occupations	4	10.5
Education, Training and Library Occupations	5	13.2
Arts, Design, Entertainment, Sports and Media Occupations	2	5.3
Healthcare Practitioners and Technical Occupations	6	15.8
Construction and Extraction Occupations	3	7.9
Production Occupations	1	2.6
No response	3	7.9
Not applicable (student)	1	2.6

Table 3: A comparison of the main results including and excluding the 'prolific' inventor

	Total Population	Total Sample	Sample Excluding 1 Inventor
USPTO	65%	74%	73%
EPO	35%	26%	27%
Male inventors	90%	91%	88%
Average number of inventors	1.5	1.6	1.3
Collaborative patents	33%	37%	27%
Electrical Engineering	14%	2%	2%
Instruments	18%	31%	16%
Chemicals	16%	11%	14%
Mechanical Engineering	30%	37%	46%
Other	15%	7%	9%
Average Age	n/a	46	46
Education: Masters	n/a	32%	16%
Inventor status [f/t or p/t]	n/a	82%	84%
Occupational Classification[1]: Architecture & Engineer	n/a	11%	7%
Self-employed	n/a	33%	41%
Inventors in Private employment	n/a	57%	48%
Size of organisation: majority work in:	n/a	Small	Large
Commercialised patents[2]	n/a	63%	55%
Commercialised in company owned by inventor	n/a	32%	21%

[1] No change in management occupations or healthcare practitioners and technical occupations. Education, training and library occupations increased from 13% to 21%.
[2] Number of patents in receipt of grant support remained the same.