



WHICH INVENTORS BENEFIT FROM WORKING IN TEAMS?

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Abstract

Title

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The purpose of this dissertation is to study which inventors benefit from working in teams, taking into consideration their level of specialization and their past experience. To answer the research question, it was analyzed inventors' data collected from EPO-PastSat database from 1979 until 1999. The results show that, consistent to previous research, teams produce better inventions than lone inventors. Moreover, specialist inventors benefit from collaboration more than generalists, but only if the team have a significant number of coinventors. Lastly, the positive impact on invention quality is more relevant for experienced inventors.

Key words: *Invention, teams, specialist inventors, experienced inventors*

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1. Introduction

In the era of global markets (Swales, 2000), fast-changing environments (Tan, 1998), improvement of communication flow and rapid transfer of technology (Santos-Vijande & Álvarez-Gonzalez, 2007); markets are becoming more competitive, so companies need to focus on innovation in order to gain and keep a competitive advantage. Indeed, the innovation process plays a fundamental role in the company's success. This is important because it allows continuous improvements, the anticipation of new market tendencies, the satisfaction of customer needs (Elonnen et al., 2009) and the achievement of higher quality products or lower production costs (Castellacci et al., 2005).

For innovating, corporate inventors' knowledge, expertise and commitment are essential resources (Chen & Huang, 2009; Rotharmel & Hess, 2007). However, having such resources is not enough, it is essential to manage them effectively to guarantee the correct development and deployment of companies' innovation capabilities. Therefore, it is crucial to understand how to organize inventors in order to maximize their creativity.

In this regard, there has been a debate about whether lone inventors (Stroebe & Diehl, 1994) or teams (Singh & Fleming, 2010) produce the most valuable inventions. On the one hand, lone inventors such as Edison or Marconi had produced well known and renowned inventions. On the other hand famous inventions have been a consequence of shared know-how and experience (Dodgson, 2008), such as the Google algorithm created by Larry Page and Sergey Brin. Overall, previous researches have shown that the advantages of working in teams, in terms of average quality of inventions produced, overcome the disadvantages (Singh & Fleming, 2010).

However, we still do not know which inventors should (or should not) be allocated in teams. In other words, we still have a poor understanding of which inventors (for instance, specialists vs. with general knowledge, experienced vs. inexperienced) benefit more from working in teams.

In my first hypothesis I argue that teams produced better inventions compared to lone inventors, since the benefits of combining different knowledge areas and the interaction

between inventors are greater than the teams' inefficiencies. Moreover, to analyse if specialists benefit more than generalists from working in teams, I propose two concurrent hypothesis. On the one hand, I suggest that specialists benefit more, because in teams, it is possible to exploit the deep expertise of each inventor and have access to the necessary wide range of knowledge to produce a good invention. On the other hand, since generalists are familiar with different knowledge areas and do not suffer from coordination and communication issues, they could benefit more from working in teams. Lastly, in the third hypothesis I argue that experienced inventors benefit more than inexperienced ones from working in teams, because experienced inventors are able to overcome their major weaknesses: the lack of novelty ideas and the fear of failing. When these inventors work with more people, they are able to take more risks and in case of failure, the damage in reputation is lower.

In order to test the hypothesis, I used inventors' data collected from EPO-PatSat database from 1979 until 1999. The results demonstrate that, in fact, teams have a positive impact in the average invention quality, particularly for specialists and experienced inventors.

The structure of this thesis is as follow. Section 2 is dedicated to a literature and theory development about the advantages and disadvantages of working in a team according to inventors' individual characteristics. In section 3, it is described the sample, data, variables and empirical methodology. Then, the results and the robustness check are presented in section 4 and section 5, respectively. Finally, in section 6, it is presented the discussion of results, the implications for managers and the limitations of my thesis.

2. Literature and Theory Development

Innovating is crucial for firms' competitive advantage. It is through it that companies are allowed to offer higher quality products than their competitors, which likely implies positive financial return (Hana, 2013). However, innovating requires a careful organization of the R&D resources. In this regard, one of the most crucial decisions that companies face is not only whether to allocate inventors in team or let them work alone but also which inventors to allocate in teams.

The innovation process consists in three distinct phases and the quality of innovation performance depends on the right execution of each phase (Melero, 2012). First, there is the generation of creative ideas, which includes the problem recognition (Tesiuk et al., 1997) and the combination of information (Gopalakrishnan & Damanpour, 1997) in order to produce new and useful ideas (Amabile et al., 1996). An idea is novel when it is different from the inventor's previous work and from the audience's prior experience (Sternberg & Lubart, 1999). The next step is the selection phase, where inventors evaluate the variety of possible ideas that were generated, to make sure that the best ideas are chosen and the poor ones rejected (Chua & Iyengar, 2008; Faure, 2004; Singh & Fleming, 2010). Invention is the outcome of the two first phases, since it is the creation of a new product or process (Grant, 2010). Finally, organizations implement and commercialize the selected ideas, to transform them into innovations. (Amabile et al., 1996). It is crucial for the success of this phase that employees are motivated to execute the ideas that were previously selected (Amabile & Fisher, 2000).

Whereas the last phase (idea implementation and commercialization) usually requires the joint effort of many individuals in order to market the innovation, the first two phases of the innovation process (idea generation and selection) can be executed by individual inventors or by a team - that is, a group of inventors that works together in the same time and space, essentially sharing a common experience based on the same information (Girotra et al., 2010). Consequently, a long standing debate is whether teams or individual inventors are better off in generating and selecting ideas (Kurtzberg & Amabile, 2001).

Some scholars argue that working in team is definitely better, as it allows to combine the experiences, the expertise and manpower of multiple individuals in the achievement of a common goal (Kurtzberg & Amabile, 2001). Combination of different knowledge and expertise - which might include culturally diverse backgrounds, skills and abilities (Erdem & Pollat, 2010) - might be advantageous in both idea generation and selection.

On the one hand, in the generation phase, diversity of experience and collaboration enable more novel combinations. Teams consider in fact a broader set of perspectives, and therefore they can cross-fertilize knowledge of different individuals, combine new approaches, analyse and clarify potential applications. All of these results allow more and higher quality ideas (Basset-Jones, 2005; Singh & Fleming, 2010; Gilson & Shalley, 2004; Perry-Smith & Shalley, 2003). Furthermore, teams' working process is collaborative, which amplifies the creativity of any group member (Uzzi & Spiro, 2005). In other words, when team members share ideas, the probability that one single idea stimulates additional novel ideas increases (Paulus, 2000). On the other hand, teams can also improve the effectiveness of the selection phase. Due to members' diversity allowing a more rigorous analysis of the ideas that were generated in the first phase of the innovation process. The bigger variety of opinions permits to assess more effectively the potential problems and/or benefits of the generated ideas (Singh & Fleming, 2010).

However, working collaboratively in teams could generate some inefficiencies, especially in the idea generation phase. In particular, based on previous literature, five inefficiencies can be identified: conflicts, production blocking, evaluation apprehension, free riding and communication issues.

First, the diversity, which is so essential in innovation, can create tensions if it is not managed well (Basset-Jones, 2005). Inventors when working in groups can have divergent styles (Kurtzberg & Amabile, 2001; Pelled et al., 1999), which creates three types of conflicts: task, relationship and process conflicts. The task conflict is a results of discussions about the ideas related with the work that is being done. Moreover, there are also relationship conflicts that are a consequence of tense interpersonal interactions among team members. Process conflicts are related to the strategies, plans and division of roles and responsibilities (Jehn, 1997).

Second, the production blocking happens because, in teams, only one person can speak at a given time. Therefore, each inventor cannot verbalize his ideas when they occur; so while they are listening and understanding the colleagues, inventors might forget their ideas or even think that they are not so relevant to share with the team. Also, in teams, all inventors ought to speak the same amount of time, for everyone to have the same opportunity to express their opinions. Hence, they have less time to develop their ideas comparing to when they brainstorm alone (Stroebe & Diehl, 1994).

Third, the evaluation apprehension occurs when team members are afraid to explain their ideas in front of peers. Actually, it happens because people usually do not like to be criticised, and so it inhibits the knowledge sharing. When inventors work in a team, their evaluation is done by the teammates, thus inventors can have problems in sharing their ideas with them (Stroebe & Diehl, 1994).

Fourth, free riding is an agency cost that happens when team members do not contribute with new ideas due to three reasons. First of all, since the final outcome is a group invention, inventors may perceive that their individual contribution is negligible. Moreover, inventors feel that their contribution is less important for the invention compared to when they work individually. Lastly, inventors' personal effort is not observed, so they have less motivation to contribute properly in the innovation process (Stroebe & Diehl, 1994).

Fifth, communication issues might affect negatively the teams' work due to their difficulties in sharing effectively the knowledge and skills (Stroebe & Diehl, 1994). This could be the reason for an increase of confusion, ambiguity and complexity in the innovation process (Erdem & Pollat, 2010).

Overall, the question is whether the advantages of working in teams are greater than disadvantages. However, previous researches show that teams are better than lone inventors in the achievement of a quality invention. For instance, Singh and Fleming (2010) show that lone inventors are less likely to achieve a breakthrough and more likely to produce poor outcomes. Moreover, they demonstrate that the diversity enables more novel combinations, but it has more impact in decreasing poor outcomes than in the achievement of breakthroughs. Similarly, the

analysis of Paulus (2000) suggests that the cognitive diversity within a group is one of the most important sources of creative ideas. Moreover, Kavadias and Sommer (2008) show that in cross-functional problems, teams enable an exploitation of team members' diversity and they are capable to "build on others ideas" to generate good solutions.

Based on the previous findings, I propose the following baseline hypothesis:

H₁: Working in teams increases the average quality of inventions.

Whereas previous works clearly established that teams are better than lone inventors, it is still not clear *which individuals* might benefit more from working in teams.

For instance, some inventors are specialists, that is, experts in a specific knowledge domain, whereas other are generalists, that is, familiar with many different knowledge areas. A first set of arguments would suggest that working in teams could be particularly advantageous for specialists. Specialists have a narrower thinking and are less able to change: the restrict knowledge can result in "competency traps": any novel and valuable idea that is far from the acquired knowledge, is not taken in consideration (Taylor & Grave, 2006).

Moreover, to obtain high levels of creativity two essential factors are complementary to each other. First, inventors should have a deep knowledge, since the generation of ideas needs a strong domain expertise, in order to "push the boundaries with any nontrivial likelihood of success" (Jones, 2009; Sternberg & O'Hara, 2000). Second, at the same time, a diverse knowledge also brings benefits to the inventors' innovation performance (De Drew & West, 2011; Jones, 2009). Therefore, specialized inventors should work in teams, which allows them to exploit their deep expertise but also to have access to a wide range of knowledge (Austin, 2003; Jones, 2009).

In other words, as Smith (1776) explained, the productivity could be enhanced due to the division of labour and specialization. With the division of labour, the work is divided in simple tasks and each individual worker can be specialist in a specific phase of the working process. Indeed, the specialization allows workers to become experts in the area that each one is best. As a result, collectively, the workers are able to produce more than if each one works alone.

However, an alternate set of arguments would instead lead to the opposite conclusion. The gains from working in teams are particularly salient for generalist inventors. Generalist inventors, due to their diverse expertise, are in fact better able to mix knowledge coming from different individuals, which reduces the coordination and communication issues typical of teams (Melero, 2012).

Overall, it is not possible to say whether specialist or generalist inventors benefit more from working in teams. Hence, I formulate two concurrent hypotheses:

H_{2a}: The positive impact of working in teams on the average quality of inventions is particularly relevant for specialist inventors.

H_{2b}: The positive impact of working in teams on the average quality of inventions is particularly relevant for generalist inventors.

The benefit of working in teams can also differ for experienced vs. inexperienced inventors. In this respect, experienced inventors probably have more advantages by working in teams, as they can overcome their major weaknesses – the lack of novelty in the ideas that they produce (Conti et al., 2013). In fact, experienced inventors generate more ideas (Conti et al., 2013; Taylor & Grave, 2006), as they are able to use their developed routines and capabilities, and do not repeat past mistakes (Chua & Iyengar, 2008; Conti et al., 2013; Gino et al., 2010). However, they produce lower quality ideas, exactly because their consolidated routines cause a lower exploration of new paths. Yet, they continue using them because the sunk cost of their development is already paid. Furthermore, experienced inventors have an established reputation, so in case of failure, they suffer a bigger social penalty than inexperienced inventors. Therefore, experienced inventors are less risk takers, which can lead to less valuable ideas (Conti, 2013).

Hence, experienced inventors probably take more benefits from teamwork due to two reasons. First, the diversity of viewpoints and the interaction between team members will enable experienced inventors to have more outside-the-box approaches to develop their work. Second, working collaboratively will encourage experienced inventors to undertake riskier paths, because

the risk of failure, which can damage their previous reputation, is greatly diluted if the ideas are produced in a team.

Thereby, I formulate the following hypothesis:

H₃: The positive impact of working in teams on the average quality of inventions is particularly relevant for experienced inventors.

3. Methodology

Sample and Data

In order to test my hypothesis and understand which inventors benefit from working in teams, I used information about a random sample of 3,439 inventors having patented at the European Patent Office (EPO). Information about these inventors comes from EPO-PatSat database. I analysed the inventors, for whom I have the complete patenting histories. I used patents for measuring both my dependent (invention quality), independent (team, specialization and experience) and control variables (social diversity, dummy year and dummy technology category). The observed inventions, started in 1978, the year the EPO began to receive patent applications, and ended in 1999. In the end, the sample is composed by 32,719 patents.

Measures

The measures section describes the model variables that are used to explain the relationship between the characteristics of inventors, working in teams and invention quality. A summary of the variables description is presented in table 1.

Dependent Variable

Invention quality is defined as the number of patent citations within 5 years, received by the inventor. I used patent citations as a measure of invention quality, since patents are considered important if it is a way for further inventions (Trajtenberg, 1990). The higher the inventions' estimated economic, social and technological value is, the more the patent is cited (Harhoff et al., 1999; Singh & Fleming, 2010).

The number of citations received by a patents is related to consumer surplus (Trajtenber, 1990), renewal rates (Harhoff et al., 1999), market value of the firm (Hall et al., 2005), expert evaluation of patent value (Albert et al., 1991) and inventors' assessment of its economic value (Gambardella et al., 2008).

Independent Variable

Team measures if an invention was done individually or by a team. It is a dichotomous variable that has the value of 0, if the patent came from a single inventor or the value of 1, if it came from a team of two or more inventors (Singh & Fleming, 2010).

$Specialization_i = \sum_k \left(\frac{n_k}{n} \right)^2$, where n is the total number of patents and n_k is the number of patents in technological class k , so it measures the concentration of an inventor past stock in some technology classes before date t . The variable is 1, when the number of accumulated patents is 0 (Conti et al., 2013)

Inventors' experience is a variable that can be measured by the number of patents that each inventor had during its career (Cassiman et al., 2008).

Control variables

I included three control variables – social diversity, dummy for year and for technology category – since they are likely correlated with both dependent and independent variables.

The *social diversity* variable measures if the inventors had worked with the same or with different people during their career. The social diversity variable is a ratio of different coinventors working with the focal inventors' patents over the total number of collaborations. For example, if an inventor has patented with a total of 10 coinventors and only 5 of them are different people, the social diversity value is 0.5 (Conti et al., 2013). Indeed, when inventors work with more different people, the variable social diversity has a higher value.

The dummies *year* and *technology category* variables are taken in consideration as a control, since the time and the technological factors influence the invention process (Conti et al., 2013).

Table 1 – Description of Variables

Variable	Description
Invention Quality	Number of citation received within 5 years by the inventor. <i>Source: EPO database</i>
Team	Dummy variable. It is 1, when the number of inventors are greater than one and 0, otherwise. <i>Source: EPO database</i>
Number of Coinventors	Number of people that work with the inventor. <i>Source: EPO database</i>
Specialization	Herfindahl index of patent concentration, within the 30 ISI-INPI-OST classes, at time t. It takes a value of 1 when the number of accumulated patents is zero. <i>Source: EPO database</i>
Experience	Number of patented inventions accumulated until time t. <i>Source: EPO database</i>
Social Diversity	Number of different coinventors divided by the total number of collaborations. It takes the value of 0 when the number of patents is zero. <i>Source: EPO database</i>
Dummy Year	Dummies for 1978–1999. <i>Source: EPO database</i>
Dummy Technology Category	Dummies for ISI-INPI-OST classes. <i>Source: EPO database</i>

Empirical Strategy

In order to test the hypothesis that were previously stated, I used the Poisson Regression. I used this model, since the dependent variable – number of citations – is a count value that measures the number of citations that an inventor received within 5 years (King, 1988). The typical Poisson regression model expresses the logarithmic outcome rate as a linear function of a set of predictors. In fact, the ordinary linear regression (OLS) model will also work, but it is not so efficient, because it assumes that dependent variable values are normally distributed around the expected value and can take any value (i.e. positive, negative, integer or fractioned) (Allison, 2012).

The following models were estimated, in order to answer if teams increase the invention quality (H_1) and which inventors – specialists (H_2) and experienced (H_3) – benefit from working in teams:

$$\text{Log E (Invention Quality)} = \alpha + \beta \text{ Team} + \rho \text{ Specialization} + \delta \text{ Experience} + \mu \text{ Social Diversity} + \theta \text{ Dummy Year} + \gamma \text{ Dummy Tech} \quad (1)$$

$$\text{Log E (Invention Quality)} = \alpha + \beta \text{ Team} + \eta \text{ Team*Specialization} + \rho \text{ Specialization} + \delta \text{ Experience} + \mu \text{ Social Diversity} + \theta \text{ Dummy Year} + \gamma \text{ Dummy Tech} \quad (2)$$

$$\text{Log E (Invention Quality)} = \alpha + \beta \text{ Team} + \eta \text{ Team*Experience} + \rho \text{ Specialization} + \delta \text{ Experience} + \mu \text{ Social Diversity} + \theta \text{ Dummy Year} + \gamma \text{ Dummy Tech} \quad (3)$$

In these equations, the interactions *Specialization*Team* and *Experience*Team* measures the interaction effect of specialized or experienced inventors, respectively, in teams.

All three equations include a fixed effect per inventor. Inventor fixed effects control for any time invariant characteristics, such as innate ability. This is important because inventors' ability is probably correlated with both experience and the innovative outcome. Moreover, the standard errors are also clustered by inventor.

In order to confirm the hypothesis 1, the β of equation 1 needs to be positive and significant. Regarding, the second hypothesis, there are two concurrent hypothesis: the 2a is supported when the η of equation 2 is positive and significant; but the 2b is supported when the η is negative

and significant. Finally, the η of equation 3 needs to be positive and significant, for the third hypothesis to be supported.

4. Results

The main descriptive statistics and the correlation matrix are presented in table 2 and table 3, respectively.

Analysing the descriptive statistics, the average patent citations is 1.320. The data contains more teams than individual inventors, because in 100 inventions, 77 were done by teams. Moreover, since the average number of coinventors is 2, it is possible to conclude that, on average, teams have three inventors.

Table 2 – Descriptive Statistics

	Count	Mean	Sd	Min	Max
Invention Quality	35005	1.320	2.087	0	40
Team	35005	0.770	0.4210	0	1
Number Coinventor	35005	2.006	1.940	0	20
Specialization	35005	0.768	0.2663	0.105	1
Experience	35005	13.330	25.974	0	305
Social Diversity	35005	0.443	0.331	0	1

The correlation between the invention quality and team variable is positive. Similarly, there is a positive correlation between the number of coinventors and the invention quality. Being a specialist has a negative correlation with the invention quality, which is probably a consequence that specialists, due to their lack of diverse knowledge, produce lower quality inventions. By contrast, there is a positive relationship between inventors' experience and

invention quality. However, more robust results can be determined only with a multivariate analysis.

Table 3 – Correlation Matrix

	Invention Quality	Team	Number Coinventors	Specialist	Experience	Social Diversity
Invention Quality	1.000					
Team	0.094	1.000				
Number Coinventors	0.176	0.540	1.000			
Specialization	-0.003	-0.034	-0.028	1.000		
Experience	0.056	0.120	0.234	-0.159	1.000	
Social diversity	-0.005	0.038	-0.023	-0.238	-0.113	1.000

The results from the Poisson regressions are presented in table 4. First of all, results from the specification 1 (column 1) support hypothesis 1, according to which working in teams increases the average quality of invention. In fact, an invention done by a team, holding the other variables constant, is expected to receive 15% more citations compared with inventions done by individuals.

Considering now the direct effect of specialization and experience on the invention quality, it is possible to observe that the coefficient of the *specialization* variable is positive but not significant and the coefficient of the *experience* variable is negative and not significant. One possible explanation is that the changes in the level of specialization and experience are not directly associated with changes in the invention quality. Therefore, it is necessary to introduce an interaction variable to conclude this effect in the invention quality.

Looking at the results of column 2, the coefficient of the interaction *specialization*team* is not significant. To evaluate the effect of specialists in teams, it may be relevant to analyse the team size. Since specialists have a narrower knowledge, working with few coinventors may not be enough to achieve the advantages deriving from specialization and the division of labour among team members. Therefore, I repeated the regressions replacing *team* by *number of coinventors*, in order to take into consideration in my analysis the number of inventors in the teams. The results are described in table 5. By looking at column 2, I conclude that the hypothesis 2a - the positive impact of working in teams on the average quality invention is particularly relevant for specialist inventors – is supported. More in details, as the specialization level of the focal inventor increases by one standard deviation (0.27), the correlation between the number of coinventors and the invention quality increases by 1.95%.

Finally, the third hypothesis is also supported. For experienced inventors it is also particularly beneficial to work in teams. As the experience of the focal inventor increases by the one standard deviation, equal to 26 inventions, the correlation between working in teams and the invention quality increases by 18.25%.

Table 4 – Results: Poisson Regression

VARIABLES	Invention Quality (1)	Invention Quality (2)	Invention Quality (3)
Team	0.137*** (0.029)	0.211*** (0.079)	0.087*** (0.033)
Specialization	0.049 (0.070)	0.130 (0.105)	0.045 (0.070)
Experience	-0.002 (0.001)	-0.002 (0.001)	-0.007*** (0.002)
Team*Specialization		-0.098 (0.098)	
Team* Experience			0.007*** (0.002)
Social Diversity	-0.009 (0.035)	-0.009 (0.035)	-0.012 (0.035)
Dummy Year	Y	Y	Y
Dummy Tech. Category	Y	Y	Y
Observations	32,719	32,719	32,719
Number of inventors	3,439	3,439	3,439

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

Table 5 – Results: Poisson Regression

VARIABLES	Invention Quality (1)	Invention Quality (2)	Invention Quality (3)
Number Coinventors	0.087*** (0.008)	0.034* (0.018)	0.092*** (0.008)
Specialization	0.024 (0.069)	-0.138* (0.079)	0.026 (0.069)
Experience	-0.003* (0.002)	-0.003* (0.002)	-0.002 (0.002)
Number Coinventors* Specialialization		0.071*** (0.022)	
Number Coinventors* Experience			-0.000 (0.000)
Social Diversity	0.000 (0.036)	-0.005 (0.036)	0.004 (0.036)
Dummy Year	Y	Y	Y
Dummy Tech. Category	Y	Y	Y
Observations	32,719	32,719	32,719
Number of inventors	3,439	3,439	3,439

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5. Robustness Check

The Poisson Model restricts the variance to be equal to the mean, but if the variance exceeds the mean, the data is overdispersed. In that case, the standard errors are wrong. Therefore, as a robustness check, I replicated the previous analysis using a Negative Binomial regression, because this model can be used if data is overdispersed.

The results are presented in table 6 and 7. The coefficient of *team* in column 1 is positive and significant. An invention done by a team, holding the other variables constant, is expected to receive 10% more citations compared to inventions done by individuals. Therefore, this finding is the same to the previous analysis - teams compared to individuals produce better inventions.

Moreover, in column 2 of table 6, the coefficient of the variable *team*specialization* is negative but not significant. The reason could be the same one that was presented in Results' Section, so I replicated the analysis replacing *team* by the *number of coinventors*. The coefficient is presented in column 2 of table 7 and I conclude that, as the specialization level of the focal inventor increases by one standard deviation (0.27), the correlation between the number of coinventors and the invention quality increases by 1.16%. Hence, it is possible to confirm that an invention has a good quality when specialists work in teams with a significant number of coinventors.

Lastly, it is not possible to confirm the third hypothesis, since the coefficient *team*experience* is not significant.

Table 6 – Robustness Check: Negative Binomial Regression

VARIABLES	Invention Quality (1)	Invention Quality (2)	Invention Quality (3)
Team	0.096*** (0.023)	0.115* (0.061)	0.075*** (0.026)
Specialization	0.005 (0.042)	0.025 (0.074)	0.001 (0.042)
Experience	-0.002*** (0.000)	-0.002*** (0.000)	-0.004*** (0.001)
Team*Specialization		-0.025 (0.076)	
Team* Experience			0.002 (0.001)
Social Diversity	-0.027 (0.027)	-0.027 (0.027)	-0.028 (0.027)
Constant	-0.012 (0.087)	-0.027 (0.098)	0.013 (0.089)
Dummy Year	Y	Y	Y
Dummy Tech. Category	Y	Y	Y
Observations	32,719	32,719	32,719
Number of inventors	3,439	3,439	3,439

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7 – Robustness Check: Negative Binomial Regression

VARIABLES	Invention Quality (1)	Invention Quality (2)	Invention Quality (3)
Number Coinventors	0.065*** (0.004)	0.034*** (0.012)	0.066*** (0.005)
Specialization	-0.006 (0.042)	-0.096* (0.053)	-0.005 (0.042)
Experience	-0.003* (0.000)	-0.003*** (0.000)	-0.003*** (0.001)
Number Coinventors* Specialization		0.042*** (0.016)	
Number Coinventors* Experience			-0.000 (0.000)
Social Diversity	-0.020 (0.027)	-0.023 (0.027)	-0.020 (0.027)
Constant	-0.044 (0.086)	0.025 (0.089)	-0.049 (0.086)
Dummy Year	Y	Y	Y
Dummy Tech. Category	Y	Y	Y
Observations	32,719	32,719	32,719
Number of inventors	3,439	3,439	3,439

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6. Discussion and Conclusions

This thesis had the goal of studying which inventors benefit more from working in teams. I found that, consistent with previous research, teams compared to lone inventors produce better inventions. However, the advantages of working in teams are particularly salient for specialists and experienced inventors.

This paper contributes to past innovation literature. First, it confirms the positive effects of working in teams in the achievement of a quality invention. Previous researches have shown that teams are better than lone inventors both in the generation and selection phase of the innovation process (Singh and Fleming, 2010). Moreover, Paulus (2000) and Kavadias and Sommer (2009) analyses the positive impacts of teams' diversity in the generation of creative ideas. Furthermore, Kurtzberg and Amabile (2001) concludes that it is very important for the modern workplace that individuals work together, share ideas and be creative in team contexts.

Second, the paper gives insights about the effect of working processes in the quality of inventions. Jones (2009) shows that there is an increase in the use of teamwork overtime and at the same time, the inventors' level of specialization increases. His model also presents that there is greater teamwork in cross-sections and in areas which need deeper knowledge. Despite of Jones's conclusions that teamwork is required when the individual innovator does not have all necessary knowledge, his model does not demonstrate the effect in invention quality when a specialist works in a team.

Third, the paper focus on how individuals should be allocated inside the organizations and not how teams should be mixed, in order to produce a quality invention. For instance, Melero (2012) suggests that teams with the contribution of generalists outperform the teams composed by a diverse set of specialists. However, my findings support the opposite conclusions.

Fourth, the paper analyses the invention quality through the combined effect of inventors' individual characteristics and their work organization inside firms. Conti et al. (2012) analyse the effect of experience in the generation of breakthrough inventions. They show the inventive

outcomes of experienced and inexperienced inventors. Conversely, I analysed the inventive outcome when experienced inventors work in teams.

However, this study has some limitations. First, the dependent variable – number of patent citations – can induce to an error in the evaluation of invention quality. An invention produced by a team can have more citations just because it is done by more people and not due to its inherent quality.

Second, the use of archival data does not allow the determination of causality. Indeed, the managers' decision about the allocation of inventors in teams is not random, so it might exist an endogeneity problem. The control variables that I used, such as social diversity, try to solve this issue.

Third, in my study many important variables are not taken into consideration, for instance, the dimension of firm where inventors work, age of inventor or educational level.

Despite the limitations, this paper has relevant implications for managers. It gives insights about the best strategy for companies to create the necessary conditions to innovate. Creativity is not only dependent on inventors' individual knowledge. It is crucial that managers act as facilitators in the innovation process in order to promote the organizational conditions that are favourable for the generation of ideas by individuals or teams.

Therefore, managers should include a detailed planning of resources allocation, in particular, regarding how to integrate specialists and experienced inventors in order to exploit their intrinsic characteristics. In this respect, the thesis suggests the optimal allocation of human capital resources inside a firm.

Future research could focus on the interaction of teams with other inventors' characteristics such as their educational level, their wage or personality. Moreover, it could be interesting to evaluate the effects of organizational level characteristics in teams' effectiveness, such as the top management control, firm environment or motivation initiatives.

7. References

- Albert, M. B., F. Narin, D. Avery, P. McAllister. 1991. Direct validation of citation counts as indicators of industrially important patents. *Research Policy*, 20 251–259.
- Allison, P. D. 2012. *Logist Regression using SAS: Theory and Application*. SAS Institute Inc: North Carolina, USA.
- Amabile, T., Conti, R., Coon, H., Lazenby, J., Herron, M. 1996. *Academy of Management Journal*, 39 (5) 1154-1184.
- Amabile, T., Fisher, M.C. 2000. Stimulate Creativity by Fueling Passion. Handbook of principles of organizational behaviour.
- Austin, R.J. 2003. Transactive Memory in Organizational Groups: The Effects of Content, Consensus, Specialization, and Accuracy on Group Performance. *Journal of Applied Psychology*, 88 (5) 866-878.
- Basset-Jones, N. 2005. The Paradox of Diversity Management, Creativity and Innovation. *Diversity Management, Creativity and Innovation*, 14 (2).
- Cassiman B., Veugeler R., P. Zuniga. 2008, In search of performance effects of (in)direct industry science links, *Industrial and Corporate Change*, 17 (4) 611-646
- Castellacci, F., Grodal, S., Mendonca, S., Wibe, M. 2005. Advances and Challenges in Innovation Studies. *Journal of Economic Issues*, 39 (1) 91-121.
- Chen, C., Huang, J. 2009. Strategic human resources practices and innovation performance – The mediating role of knowledge management capacity. *Journal of Business Research*, 62 104-114.
- Chua, R.Y.J., S. Iyengar. 2008. Creativity as a matter of choice: Prior experience and task instruction as boundary conditions for the positive effect of choice on Creativity. *Journal Creative Behavior*, 42 (3)164- 180.
- Conti, R., Gambardella, A., Mariani, M. 2013. Learning to be edison? Individual experience and breakthrough inventions. *Organization Science*, forthcoming.

- Conti, R. 2013. Learning to Be Edison: Inventors, Organizations, and Breakthrough Inventions. Working Paper.
- De Drew, C.K.W., West M.A., 2001, Minority Dissent and Team Innovation: The Importance of Participation in Decision Making, *Journal of Applied Psychology*, 86 (6) 1191-1201
- Dogson, M., Gann, D., Satel, A. 2008. *The Management of Technological Innovation: Strategy and Practice*. Oxford University Press.
- Elonnen, K. H., Wikstrom, P., Jantunen, A. 2009. Linking dynamic capability portfolios and innovation outcomes. *Technovation*, 29 (11) 753–762.
- Erdem, O., Polat, S. 2010. Team analysis. *e-Journal of New World Sciences Academy*, 5 (3)
- Faure, C. 2004. Beyond Brainstorming: Effects of Different Group Procedures on Selection of Ideas and Satisfaction with the Process. *First Quarter*, 38 (1).
- Gambardella, A., D. Harhoff, B. Verspagen. 2008. The value of European patents. *European Management Review*. 5 (2) 69-84.
- Gilson, L. L., Shalley, C. E., 2004. A little creativity goes a long way: An examination of teams' engagement in creative processes. *Journal of Management*, 30 (4) 453–470.
- Gino, F., L. Argote, E. Miron-Spektor, G. Todorova. 2010. First get your feet wet: The effect of direct and indirect experience on team creativity. *Organizational Behavior and Human Decision Processes*, 111 (2) 102-115.
- Girotra, K., C. Terwiesch, K. T. Ulrich. 2010. Idea generation and the quality of the best idea. *Management Science*, 56 (4) 591 – 605.
- Gopalakrishnan, S., Damanpour, F. 1997. A review of innovation research in economics, sociology and technological management. *Omega*, 25 (1) 15-28.
- Grant, R.M. 1995. *Contemporary strategy analysis: concepts, techniques, applications*. 2nd Ed. Oxford: Blackwell.
- Hall, B., A. Jaffe, M. Trajtenberg. 2005. Market value and patent citations. *The RAND Journal of Economics*. 36 16-38.

- Hana, U. 2013. Competitive Advantage Achievement through Innovation and Knowledge. *Journal of Competitiveness*, 5 (1) 82-96.
- Harhoff, D., F. Narin, F. M. Scherer, K. Vopel. 1999. Citation frequency and the value of patented innovation. *Review of Economics and Statistics*. 81 (3) 511-515.
- Jones, B. 2009. The Burden of Knowledge and the “Death of the Renaissance Man”: Is Innovation Getting Harder? *Review of Economics Studies*, 76 283-317.
- Jehn, K.A. 1997. Qualitative Analysis of Conflict types and Dimensions in Organizational Groups. *Administrative Science Quarterly*, 42 530-557.
- Kavadias, S., S. C. Sommer. 2009. The effects of problem structure and team diversity on brainstorming effectiveness. *Management Science*, 55(12) 1899–1913.
- King, G. 2001. Statistical Models for Political Science Event Counts: Bias in Conventional Procedures and Evidence for the Exponential Poisson Regression Model. *Harvard University*
- Kurtzberg, T. R., Amabile, T. M. 2001. From Guilford to creative synergy: Opening the black box of team level creativity. *Creativity Research Journal*, 13.
- Melero, E., Palomeras, N. 2012. The Renaissance of the Renaissance Man? Specialists vs. Generalists in Teams of Inventors. Working Paper, Universidad Carlos III de Madrid.
- Paulus, P.B. 2000. Groups, Teams, and Creativity: The Creative Potential of Idea-generating Groups. *Applied Psychology: An International Review*, 49 (2) 237-262.
- Pelled, L. H., Eisenhardt, K. M., & Xin, K. R. 1999. Exploring the black box: An analysis of work group diversity, conflict, and performance. *Administrative Science Quarterly*, 44 1–28.
- Perry-Smith, J. E., & Shalley, C. E. 2003. The social side of creativity: A static and dynamic social network perspective. *Academy of Management Review*, 28 (1) 89–106.
- Rothaermel, F. T., Hess, A. M. 2007. Building Dynamic Capabilities: Innovation Driven by Individual-, Firm-, and Network-Level Effects. *Organization Science*, 18 (6) 898-921.

- Santos-Vijande, M.L., Álvarez-Gonzalez, L.I. 2007. Innovativeness and organizational innovation in total quality oriented firms: The moderating role of market turbulence. *Technovation*, 27 514-532.
- Singh, J., Fleming, L. 2010. Lone inventors as sources of breakthroughs: Myth or reality? *Management Science*, 56 (1) 41-56.
- Smith, A. [1776] 1994. *An Inquiry into the Nature and Causes of the Wealth of Nations*. Edwin Cannan (ed.). Modern Library Edition, Random House, New York.
- Sternberg, R. J., O'Hara, A. L. 2000. *Intelligence and creativity*. Handbook of intelligence, Cambridge University Press, Cambridge, UK.
- Sternberg, R.J., Lubart, T. 1999. *The concept of creativity: Prospects and Paradigms*. Handbook of Creativity, Cambridge University Press, Cambridge, UK.
- Stroebe, W., M. Diehl. 1994. Why are groups less effective than their members: On productivity losses in idea generation groups. *European Review of Social Psychology*, 5 271–303.
- Swales, S. 2000. Goals, Creativity and Achievement: Commitment in Contemporary Organizations. *Blackwell Publishers*, 9(3) 185-194.
- Taylor A., H. R. Greve. 2006. Superman or the fantastic four? Knowledge combination and experience in innovative teams. *Academic Management Journal*, 49 723–740.
- Tan, G. 1998. Managing Creativity in Organizations: A Total System Approach. *Blackwell Publishers*, 7(1) 23-31.
- Tesiuk, P. Farr, J., Klein, S. 1997. Influences of Organizational Culture and Climate on Individual Creativity. *First Quarter*, 31 (1) 27-41.
- Trajtenberg, M. 1990. A Penny for Your Quotes: Patent Citations and the Value of Innovations. *The RAND Journal of Economics*, 21 (1) 172-187.
- Uzzi, B., J. Spiro. 2005. Collaboration and creativity: The small world problem. *Journal of Sociology*, 111 447–504.