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Micro-organization of Innovative Projects; Delegation and the Direction of Innovative Output

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Abstract

Delegation of autonomy to employees is an important job dimension for knowledge-intensive activities where the tasks are less routine and is scheduled and there is much room for creativity. Yet, it is not clear how delegation impacts the characteristics of innovative output especially at the project-level. In this study, we focus on innovative projects and discuss two main mechanisms that autonomy impacts the innovative output through them; the effort mechanism and the control mechanism. Using a novel and restricted dataset based on a survey of inventors, we test our theory and find that delegation in a project, increases the scientific value of the output, however its effect on the commercial value is insignificant and even negative. Discussing the reasons why companies decide to bear this cost for delegation, we show that the impact of autonomy on commercial value also depends on the fit between the employee and the assigned project.

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Abstract

Delegation of autonomy to employees is an important job dimension for knowledge-intensive activities where the tasks are less routine and is scheduled and there is much room for creativity. Yet, it is not clear how delegation impacts the characteristics of innovative output especially at the project-level. In this study, we focus on innovative projects and discuss two main mechanisms that autonomy impacts the innovative output through them; the effort mechanism and the control mechanism. Using a novel and restricted dataset based on a survey of inventors, we test our theory and find that delegation in a project, increases the scientific value of the output, however its effect on the commercial value is insignificant and even negative. Discussing the reasons why companies decide to bear this cost for delegation, we show that the impact of autonomy on commercial value also depends on the fit between the employee and the assigned project.

Introduction

Innovation is considered a key driver of firms' competitive advantage especially in knowledge-intensive contexts. The role of human capital in this process is found to be crucial (Castanias & Helfat, 1991, 2001; Gittelman & Kogut, 2003) to the extent that the effective management of key employees has been introduced as the ultimate determinant of performance (Youndt, Snell, Dean Jr. & Lepak, 1996). Thus, finding the optimal organization of innovative activities at the individual-level is critical for companies. In this paper, we focus on an important dimension in micro-organization of innovation, which is knowledge workers' level of autonomy in projects. More specifically, we investigates how delegation of autonomy to knowledge workers impacts the output in innovative projects and how the impact is related to individual and environmental characteristics. Since prior research has shown substantial variations in autonomy levels across projects in companies (Khashabi, Gambardella, & Panico, 2014), we make our analysis at the project level – rather than firm level - and study the effect of project-level autonomy on the project's output, namely on its direction and value.

Knowledge-intensive projects- unlike ordinary ones- are typically less routine and scheduled, and more based on creativity. Thus, employee autonomy within the project is an important dimension of knowledge-intensive contexts. Prior studies have highlighted that delegating to employees is associated with substantial costs for companies, e.g. losing control over the project (Aghion & Tirole, 1997; Gambardella, Panico, & Valentini, 2015) and giving rise to agency issues (Christie, Joye & Watts, 2003; Jensen & Meckling 1976; Shimizu, 2012). In spite of this, knowledge workers in practice exercise a considerable degree of autonomy (Sauermann & Stephan, 2013; Vallas & Kleinman, 2008). This is due to two main reasons: firstly because delegation improves decision efficiency (Grant, 1996; Jensen & Meckling, 1992), especially in innovative projects where employees often have higher levels of expertise over the project technicalities than the managers (Sauermann & Cohen, 2010). Secondly because autonomy is leveraged as an incentivizer for knowledge workers (Gambardella et al., 2015) especially in environments where employee motivation is a matter of concern (Khashabi et al., 2014). Considering the positive and negative impacts of autonomy, the amount of delegation becomes an important and strategic decision for companies.

Understanding more on how this decision impacts the output of the projects - contingent on individual and environmental factors- would be important for both practitioners and scholars; an issue which to the best of our knowledge has not been investigated deeply.

In this article, we discuss two main mechanisms that autonomy impacts the output through them: the effort mechanism, and the control mechanism. Since delegation is known to satisfy motivational needs (Horngren, et al. 2013; Gagne & Deci, 2005), boost creativity (Amabile, 1996) and support intrinsic motivations (Hackman & Oldham, 1980), it improves the *level* and *character* of innovative effort (Sauermann & Cohen, 2010); what we label as the *effect of autonomy via effort mechanism*. Also, since autonomy allows employees to practice their decision rights over the project, it enables them to shift the project direction to towards goals that hold greater benefits for them (e.g. scientific direction) instead of goals that company favors (e.g. commercial direction). We term this as the *effect of autonomy via control mechanism* and discuss how the interplay of these two mechanisms impact the scientific and commercial value of the innovative output.

To test the implication of the theoretical framework, we use a novel dataset which is based on a specifically designed survey of inventors of the European Patent Office (EPO). The survey collects a wide range of data related to the inventor and the inventive process of EPO patents with priority dates between 2003–2005 in twenty European countries, U.S., Japan, and Israel. This information is matched with other complementary sources such as PATSTAT, Amadeus, Orbis and Compustat to build our sample. Based on this sample, the empirical results show that delegation of autonomy to knowledge workers increases the scientific value of the output. However, the impact on the commercial value is insignificant and sometimes negative. Moreover, we find that the negative impact of autonomy on commercial value is typically associated with cases where there is a poor employee-project fit, which are typically cases where autonomy is reported to be leveraged as an instrument to strategically motivate employees (Khashabi et al., 2014).

We believe this study contributes to literature in several ways: first, we address an important issue in strategy research- i.e. performance of innovative projects- by employing a novel and unique dataset. The use of the specifically designed survey allows us to analyze our question, at the project level; to the best of our knowledge, there is no other study which has investigated the impact of autonomy on output at this level. Second, we link strategic management of key employees to the innovative output; while it is straight forward to assume that management of knowledge workers influences their innovative output, there is little integration and dialogue among the two literatures of Innovation and Strategic Human Capital. This study is an attempt to bridge between these two fields of research. Third, by introducing a micro-project level variable (autonomy), this study contributes to the line of research which investigates the determinants of value of inventions. Fourth, this paper improves our understanding on how firms organize their R&D *inside* the company; although there is a wide and established literature studying organization of R&D, its focus is almost always at *inter-firm* organization.[1] As Argyres and Silverman (2004) highlight, "*... academic research has focused on the inter-firm organization of R&D activities...almost to the exclusion of intra-firm organization*". Our study contributes to the emerging studies of *intra-firm* organization of R&D at the individual and project- level.

The remainder of this article is organized as follows. Section 2 discusses the theoretical

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[1] Few exceptions include Arora, Belenzon,& Rios (2014) and Argyres & Silverman (2004).

background, whereas the empirical setting, data, and the sample are described in section 3. Section 4 reports and discusses the main results, and section 5 concludes.

Theory

Employee autonomy and output.

As pointed in the introduction, autonomy is a crucial dimension in innovative and knowledge-intensive contexts. Therefore, the level of delegation is among the first decisions that managers make about the organization of innovative activities. Recent studies highlight that knowledge workers' autonomy level varies across R&D projects within the same company and is a project-level variable (Khashabi et al., 2014). Most R&D projects are composed of several discrete activities; for each activity, company should decide who is in charge, how to tackle a specific problem and so on (Cassiman, Di Guardo & Valentini, 2010). This is an important issue since the distribution of decision rights in a project can impact the R&D process and consequently the output of the project (Gambardella et al., 2015). In this section, we discuss two main mechanisms that this impact happens through them: *the effort mechanism* and *the control mechanism*. Below, we present each mechanism and their impact on the innovative output.

The Effort Mechanism. Individuals have a fundamental need for autonomy. Hackman & Oldham (1976) introduce autonomy as one of the five core job characteristics in their job design model that is crucial for employees. Autonomy is also mentioned among prominent factors contributing to employees' job satisfaction (Benz & Frey, 2008a & 2008b; Nguyen, Taylor & Bradley, 2003; Sousa-Poza & Sousa-Poza, 2000) which leads to higher effort and efficiency. For the case of knowledge workers, autonomy is even a more significant factor (Baylin, 1985). Empirical evidence supports the positive effect of autonomy on creativity and innovative behavior (Shalley, Zhou & Oldham, 2004). Also, Psychology literature has highlighted the importance of intrinsic motivations for employees (Amabile 1996, Ryan & Deci, 2000) which is supported by autonomy; it is discussed that employees with higher levels of knowledge enjoy the sense of independence which allows them to take credit for their decisions and assign achievements to their own (Gagne & Deci 2005, Sauermann & Cohen, 2010) which is an intrinsic motive for them.

Accordingly, it is straight forward to expect that more autonomous knowledge workers to be more motivated for their tasks. As higher motivation for a particular tasks leads to lower marginal disutility of effort, this should increase the optimal *level* of exerted effort by the knowledge worker.

In addition to this, motives also shape the *character* and of a certain quantity of effort - i.e. "*the intensity or quality of cognitive effort*" (Sauermann & Cohen, 2010). The character of effort can positively impact the extent of creativity and productivity for a given unity of effort. Therefore, when an employee has higher autonomy, the same level of exerted effort by her nay generated better/ more innovative/ higher quality output. All in all, we expect that delegation of autonomy in the projects, increases the level of effort *and* the positive effect of effort on the output of the project. This is what we label as the impact of autonomy via effort mechanism

The Control Mechanism. As discussed above, through motivational effect of delegation, and via effort, autonomy impacts innovative output of the project. However, the effect of autonomy is not bounded to the effort channel. Autonomy in projects enables knowledge workers to select tasks, approaches, challenges and directions that are of particular interest to them (see e.g. Frey & Stutzer, 2004, Gagne & Deci 2005, Hackman & Oldham 1976).

Therefore, delegating decision rights to knowledge workers can impact the project direction and consequently the project output. Below, we analyze the impact of this mechanism based on two premises: first that autonomy, when delegated will be practiced by knowledge workers to increase their utility. Second that knowledge workers have a "*taste for science*" and gain utility from working in projects more aligned with scientific directions.

It is quite established in the literature that creative individuals have peculiar motives in their job (Ederer & Manso, 2013; Stern, 2004) and non-monetary motives play a key role for them (Shalley et al., 2004). Prior studies on knowledge workers (e.g. scientists, inventors, R&D personnel) have shown that these individuals are mostly driven by motives such as scientific curiosity, intellectual challenge and visibility (Cohen & Sauermann 2007, Giuri et al. 2007, Katz, 2004). This is what Stern (2004) names as "*taste for science"* in his seminal work. The taste for science shapes the preference, approaches, and decisions of knowledge workers in their tasks. For example, it has been reported that PhD scientists and engineers tend to be engaged much in upstream research (Roach & Sauermann, 2010) and keep close ties with scientific community (Cockburn & Henderson 1998; Sauermann & Stephan, 2013). Also, survey results from industrial inventors show that motives such as intellectual challenge or satisfying scientific curiosity- rather than monetary rewards - are the main personal drivers of making inventions. Figure 1, based on PatVAL2 survey of industrial inventors shows a comparison between two motives of invention: monetary rewards vs. intellectual challenge. As it is evident, the respondents clearly report intellectual challenge a more important motive for their innovative activity. This is the essence of what we refer as scientific direction and assume that projects being aligned more with this direction would generate higher private benefits for knowledge workers. Accordingly, it is reasonable to assume that knowledge workers use their decision rights to shift the project more towards the scientific direction.

[Insert Figure 1 here]

As it is established that knowledge workers favor a scientific direction, it is also taken for granted that companies follow other goals from their activities. It is a standard assumption in Economics that increasing the profit is companies' main objective. For an innovative project, this can be achieved through directing the project towards a commercial scope, e.g. having a more market-driven target, or faster commercializing of the output. Therefore, from the company-side, commercial value is always the main goal of the project and scientific value is important only if it increases the profit. Therefore, in many instances, the objectives of the company may not be perfectly aligned with the preferences of the knowledge worker. Basic research in the industry is a classic example: both the company and the researcher *may* benefit from it, but in some occasions, the researcher may prefer to further explore and gain a better understanding of a scientific phenomenon, whereas the company prefers to move on faster to develop and commercialize the innovation. Smith and Hounshell (1985) report the case of Wallace Carothers, a science "purist" who discovered *nylon* while working for DuPont. After the invention, he was interested to conduct further research and explore the fundamental properties of nylon, while DuPont was just interested in faster developments of the fiber and moving to the commercialization phase. This divergence of interests eventually led Wallace Carothers to leave the company. This is an example where there are conflicts of interest between the knowledge worker’s preferences and the company. Therefore, delegation of autonomy can create a loss, due to the lack of control over the project by company (Aghion & Tirole, 1997), which we refer as the cost of delegation. In the following section, we discuss the effects of two mechanisms on the value of output.

Value of Innovative Output

Scientific value of the output. From the discussion above, delegating autonomy will increase the level of effort exerted by knowledge worker through leveraging her intrinsic motivation. Also, this positively shapes the character of the effort. And finally the role of autonomy in boosting the creativity is another positive factor on the scientific value. Accordingly in projects with higher levels of autonomy delegated to the employee, we expect knowledge worker to exert higher levels of effort, and achieve more productivity for a given unit of effort. Also, we expect that the creativeness to be higher for the same unit of effort. Although innovative projects are uncertain and not perfectly related to effort, however, we expect that higher autonomy on average to increase the scientific value of the project output via the effort mechanism.

Also as explained, the innovative projects typically do not have a routine and perfectly predefined arrangement. Therefore, they can be directed toward goals that hold greater interest for the company (e.g., profits) or for the employee (e.g., scientific curiosity, intellectual challenge, visibility). Thus, when more control and decision rights are delegated to the knowledge worker - as opposed to the company- we expect her to shift the direction of the project towards the scientific direction (Figure 2). When the project is more targeted towards a scientific direction, it is more likely that the output entails a higher scientific value. Accordingly, we expect higher autonomy, via the control mechanism, also to positively impact the scientific value of the project output.

Since both mechanisms predict a positive impact of delegation on the scientific value, their overall effect will enforce each other, and so we hypothesize:

H1. Higher the knowledge worker's autonomy level in a project, higher the scientific value of the project output.

[Insert Figure 2 here]

Commercial value of the output. Via the effort mechanism, we have argued that higher autonomy level will improve knowledge workers' initiative and creativity. Therefore, and regardless of the project direction, we expect the output to entail higher novelty and innovativeness when employee is more autonomous. Also, since with higher autonomy the employee has exerted higher levels of effort, it is natural to expect higher quality for the project output on average. Higher quality outputs are typically of higher commercial value (easier to commercialize, higher market success), thus via the effort channel we expect higher autonomy to generate higher commercial value (figure 2). The effect of autonomy via the effort mechanism is similar for cases of scientific and commercial value. Via this channel, the preferences of the employee aligns with the objective of the company. This is in fact the reason why companies use delegation as an incentive instrument: leveraging intrinsic motivations to benefit from employee's desired setup to achieve higher efficiency. However, there is another mechanism that moves in the opposite direction and this tradeoff defines the optimal level of employee's autonomy in the project. Output's commercial value is also impacted by the direction of the project. As our assumption with respect to autonomy is that knowledge worker will use her control to support her intrinsic motivations and preferences, we expect her to shift the direction of the project towards her preferred path (i.e. scientific direction). Since scientific direction does not necessarily coincide with the commercial direction, this on average reduces the commercial value of the output. Similar to the case of Wallace Carothers, one might think of many examples where pursuing a scientific approach may negatively impact the commercial value of the output; e.g. it is widely accepted that reputation and scientific visibility is highly valued by knowledge workers. Therefore, if they receive autonomy in release of information outside the organization, they are very likely to show off their achievements in activities such as publishing or presenting in scientific societies. However, this might hurt the commercial scope of their achievements through leak of information to competitors. Parallel to the case in our example, we expect that via control mechanism, higher autonomy leads to lower commercial value in projects (Figure 2).

In the case of commercial value, delegation of autonomy creates two forces in opposite directions: from one side, delegating more to knowledge workers creates a loss for company due to lack of control (the control mechanism) which reduces the commercial value. From the other side, autonomy creates private benefits for the worker, and leveraging their intrinsic motivations helps the company to increase the performance and creativity (the effort mechanism). Therefore, the overall effect will depend on which mechanism to be stronger and prevail over the other. The direction of the effect in reality is an empirical issue which we intend to investigate in our data, therefore we formulate two competing hypotheses:

H2a. Higher the knowledge worker's autonomy level in a project, higher the commercial value of the project output.

H2b. Higher the knowledge worker's autonomy level in a project, lower the scientific value of the project output.

Hypothesis 2a in our analysis stands for the case where the effort mechanism overcomes the control mechanism while hypothesis 2b is for the opposite case.

The Moderating Role of Employee-Project Fit

Recent studies have demonstrated that the congruence between the characteristics of employees and their project, job, team, and organization, matters for a wide variety of outcomes in companies (Kristof, 1996). Employee-project (EP) fit is related to the congruence between an employee's skills, knowledge, abilities and preferences with her project-related tasks. It is important to notice that *both* companies and employees benefit from this congruence (Werbel & DeMarie, 2005). While companies may gain higher productivity and efficiency, the employees will enjoy higher job satisfaction and motivation in good fit jobs (Holland, 1985).

[Insert Figure 3 here]

Recent studies have found that EP fit is a key determinant of delegation to knowledge workers (Khashabi et al., 2014). Based on the EP fit quality, two categories of knowledge workers receive higher levels of autonomy in projects: very high and very low EP fit cases (see figure 3). When the EP fit is high, companies delegate higher levels of autonomy to employees in order to achieve higher efficiency (Chen, Chang & Yeh, 2004; Igbaria, Greenhaus & Parasuraman, 1991). This is because in high EP fit case, employee's knowledge and experience becomes more instrumental for the project, so she can make better decisions regarding the project issue. Therefore, companies delegate more to higher fit cases for performance reasons (i.e. commercial value). However, when the EP fit is extremely low, the employee is neither productive nor motivated to work in the project. This gives rise to agency concerns especially since the output of the project is not verifiable in short-term. In these cases, companies may also delegate higher autonomy level to a low EP fit employee to motivate her and correct the agency costs by leveraging intrinsic motivation (Gambardella, et al. 2015; Khashabi et al., 2014). As a result, the employee will shift the project towards her preferred direction, be more motivated and eventually generate *an output*, which is not probably *the output* that company favors. However, if a poor EP fit case does not receive autonomy, it is very likely that she does not reach *any output* in an innovative project, since she is neither motivated nor productive. In this framework, good EP fit employees when receiving autonomy, can make better decisions for the goals of the project (i.e. increase the commercial value), while poor EP fit employees only receive autonomy for motivational purposes even outside the commercial scope of the project. Accordingly, we expect that the commercial value of projects increase when autonomy is given to a high EP fit cases- as opposed to a low EP fit cases. Therefore we hypothesize:

H3. The relation between commercial value and autonomy is positively moderated by EP fit.

Note that H3 only predicts a moderating role of EP fit on the commercial value of output –and not the scientific value. This is because the concept of EP fit is defined for the congruence between the employee and the *commercial* aspects of her project. Therefore, the notion of EP fit is almost meaningless and ineffective on the scientific value of output.

Method

Data and Sample

We use a restricted use, extensive data drawn from the PatVal-2 survey. This dataset is based on a survey of inventors for the European Patent Office (EPO) granted patents with priority dates between 2003 –2005 in twenty European countries, the U.S., Japan, and Israel. More details about the project is described in Gambardella et al. (2014). The key advantage of the survey is that it collects data about the "*the process leading to invention*", so we access the project-level information. The survey also includes a wide range of questions at the level of individual, project, company, region and technology. In the sample of our study, the survey data is merged with other data sources including Amadeus, Orbis and Compustat datasets to access complementary information about the companies. Also for some of the measures related to the scientific value of invention, the survey data is merged with PATSTAT databases by matching the inventor in the survey to its unique PATSTAT identifier. This enables the use of information in patent examiner's search report (such as number of non-patent literature references).

To address our research question, we select our sample of analysis from the inventors in PatVal-2 survey working in commercial companies at the time of invention and exclude inventions originating from universities and academic research centers. This subsample includes more than 7770 observations. However, for the majority of cases, there are numerous missing values regarding our key dependent and explanatory variables which reduce the sample size in different specifications.

Dependent Variables

Scientific value of output. We use two measures as a proxy for scientific value of the output (patents): the number of references made to the non-patent literature (typically to scientific journals) and the inventive step of the patent. The two measures are explained as follows.

a. *Number of references made to the non-patent literature* (NPL Refs) is the number of relevant scientific documents that patent examiners have listed when evaluating the patent application. The logic behind this measure is that scientific publications document the state of the art, and so, they can be used against the claims in patent application during its evaluation (Harhoff, Scherer & Vopel, 2003). For this reason, patent examiners search in the scientific literature for relevant publications and list them against the application. Accordingly, a relatively high number of references to the scientific literature may indicate strength of a patent's scientific linkage and novelty. This measure has been used in the literature as a proxy for scientific quality of patents (see e.g. Harhoff et al., 2003; Meyer, 1999). Notice that our sample is composed of successful patent applications, so while the reference has made against the application, the patent has been finally granted to the applicant. So in our case, higher number of reference to non-patent literature, shows proximity to knowledge frontier of the granted patent.

We use this measure as one of our dependent variables in testing for H1.

b. *Inventive step* is based on a question from the survey asking respondents to rate the degree inventive step for their invention according to the legal definition in the European Patent Convention. According to the European Patent Convention, inventive step means that "...*the invention, having regard to the state of the art, must not be obvious to a person skilled in the art*" (Article 56, European Patent Convention). This measure, capture mostly the innovativeness of the inventive output. The respondents could answer to this question based on a Likert scale from one ('very low') to five ('extremely high'). Although inventors may overestimate the degree of inventive step for their invention, we believe this can be considered a common bias among the individuals and will not impact the direction of the effect which we are studying. We use this construct as another dependent variable in testing for H1.

Commercial value. For this variable, we are interested to capture the component of project output, which is valuable for the company. Having inventions as the output makes it extremely difficult to calculate the value (Arora, Fosfuri & Gambardella, 2001). In this paper, as a proxy for the commercial value, we use information on whether the company has used the *patented invention commercially*, (i.e., in a product, service or in a manufacturing process) or not. We believe that this measure is able to distinguish between outputs that are in line with the objectives of the company, as opposed to the outputs which are only favored by the inventor (pure scientific patents).[2]

[2] The literature also widely uses patent citations as a proxy to calculate the financial value of the output (e.g. Gambardella, Giuri, & Luzzi, 2007; Harhoff et al., 2003). However, there this measure is also highly correlated

We build this measure based on information extracted from the survey. To make the best of the richness in data, we distinguish between three cases. First, cases where the patented output is already commercialized, second, cases where the patent is not commercialized but there is still ongoing process/ plans of commercialization, and third patented outputs which are neither commercialized nor there is any plan of commercialization associated with them. On this basis, we build a proxy for the commercial value of the output as:

zero= non-commercialized patented inventions, *one*= inventions still in the process of commercialization, and *two*= commercialized patent inventions. We use this constructs to check H2 and H3.

Independent Variables

Autonomy. By the autonomy in the project, we intend to capture the degree to which the employee is empowered with decision rights in defining her tasks.

Our constructs are based on a question from the survey asking respondents to rate their autonomy level, on a Likert scale from one ('no autonomy') to six ('very high autonomy') on the items:

(a) *'selection of your tasks or projects'*, (b) '*allocation of your working time among different tasks or projects'*, (c) '*flexibility of your working hours*'

To build our measure of employee's autonomy (AUTONOMY), we simply sum up the responses over the items above.

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with scientific value of patents. Therefore, we prefer to use commercial use of patents in this paper. However, the results of analysis with patent citation is available upon request.

Employer-project fit. The quality of fit between the employee's background, experience, and preferences with the employer's inventive project is the key dimension for our third hypothesis. To capture this concept, we need a reference point for the employee's background with respect to the inventive project. Thus we employ a question from survey, asking the inventors to consider their knowledge and experience from their prior organization and to indicate whether their experience matched the specific inventive activity leading to invention. We build this measure using a question from the survey asking inventors to which extent they agree or disagree with the following statements:

'… the combination of your previous experience with the knowledge of your new employer was instrumental in enhancing the inventive activity at the new organization.'

The responses were collected on a Likert scale from one ('fully disagree ') to six ('fully agree'). The statement captures a broad concept of PE fit. We make use of this item to build the variable FIT.

Controls

We control for a wide range of variables at the level of individual, project, company, region and technological area. At the individual level, we control for the gender, age and gross income of the employee. Moreover, we control for the inventor’s level of education and rank in the project’s structure. At the project and firm level, we control for the project size (project man-month), and firm size (measured by number of employees). Also, thanks to the information from the survey, we control for the project-level complementary assets and resources (e.g. technical instruments, complementary resources for technical success, resources for making the invention economically valuable and etc.) which improves the fit quality from the company side. These variables helps us to isolate the effects that we study from other channels impacting the value of output. Finally, due to potential role of technology-specific and geographical factors, we control for the location of the employee and technological areas.

A brief variable definition and summary of their statistics and correlations are presented in Tables 1 and 2.

[Insert Table 1 and Table 2 here]

Results

As the first step to test our theory, we focus on the determinants of scientific value of patents. According to H1, we expect that autonomy positively impacts scientific value of the patent. Therefore, we estimate the equation below:

$$\textit{Scientific value}_i = \beta_1 AUTONOMY_i + \beta_2 FIT_i + \mathbf{X}'_i\gamma + \varepsilon_i \quad (1)$$

We estimate the equation above for the scientific value of the project, generated by the employee *i,* where X in equation (1) is a vector of controls. The proper econometric model to estimate the equation (1) would depend on the dependent variable. We use consider a count model when using the number of references made to the non-patent literature as the proxy for scientific value. Also in the specifications where the inventive step is the dependent variable, we use an ordered response model to estimate the coefficients in equation (1).

Table 3, presents the results of the estimates for equations (1) where the dependent variables are the measures scientific value. As in equation (1) we include employee's autonomy and EP fit as independent variables. Also, we include a wide set of controls at the employee level (such as gender, age, education, and income) and the work/ project level (including firm and project size, resources). All specifications include geographical, technological, and firm fixed effect controls.

In columns (1) and (2) in table 3, we use number references to non patent literature as the dependent variable. Since this variable is a non-negative count, we estimate equation (1) by a negative binomial regression. Since our dependent variable is over-dispersed (mean=2.43, variance=6), the negative binomial model would be more proper than a Poisson model for our regression. Excluding the missing values, we perform our test on 404 employee-project observations.

[Insert Table 3 here]

Also, as another proxy, we use the inventive step of output as our dependent variable in columns (3) and (4). Since inventive step is reported in levels, we posit an ordered logit estimation of equation (1) and report the estimates in columns (3) and (4). For this measure, we perform our test on 2,120 employee-project observations.

The key variables of interest in table 3 is the measures of autonomy and fit. As shown in column (1), autonomy positively impacts the number of references to non-patent literature associated to the output. This implies that in projects where autonomy is higher, the output is typically closer to the knowledge boundaries and has higher scientific value. Also in column (3), AUTONOMY enters the regression with a positive and very significant coefficient. We interpret this as the positive effect of autonomy on the outputs innovativeness which is another element of scientific value for patents. All in all, the results in columns (1) and (3) in table-3 support H1, implying that delegation increases the scientific value of innovative output. This in inline with the arguments of both mechanisms of control and effort.

To compare the moderating effect of FIT, we also include an interaction term between AUTONOMY and FIT and estimate the equation below:

$$\textit{Scientific value}_i = \beta_1 AUTONOMY_i + \beta_2 FIT_i + \beta_3 AUTONOMY*FIT + \mathbf{X'}_i\boldsymbol{\gamma} + \varepsilon_i \quad (2)$$

The results of the estimation for equation (2) are reported in columns (2) and (4). We will discuss them together with the results in table 4, when testing for H3.

To test our arguments on the commercial aspects in the theory section, this time we estimate the determinants of commercial value the projects as equation below:

$$\textit{Commercial value}_i = \beta_1 AUTONOMY_i + \beta_2 FIT_i + \mathbf{X'}_i\boldsymbol{\gamma} + \varepsilon_i \quad (3)$$

Equation (3) is similar to equation (1), with the difference of having commercial value as the dependent variable. Since our measure of commercial value is reported in levels, we estimate equation (3) with an ordered logit model and report the results in table 4. The coefficients in table 4 can be reported as logs of odd ratios.

[Insert table 4 here]

In the column (1), we estimate equation (2) without including the FIT variable. In this specification, AUTONOMY while having a negative coefficient, does not exert a significant impact. Also when we include the variable FIT in column (2), still both AUTONOMY and FIT show insignificance in impacting the commercial value. The distinction in the impact of autonomy on the scientific versus commercial value is intuitive for our theory. The insignificance of autonomy in columns (1) and (2) of table 4 might be due to coexistence of two mechanism moving in the opposite directions and canceling out each other, where as these two mechanisms as aligned in table 3. Nevertheless, we cannot confirm any of the hypotheses H2a and H2b based on the results in columns (1) and (2).

To test for hypothesis 3, we include the interaction term and regress the specification in equation (4).

$$Commercial\ value_{i} = \beta_1 AUTONOMY_i + \beta_2 FIT_i + \mathbf{X'}_i\boldsymbol{\gamma} + \beta_3 AUTONOMY*FIT + \varepsilon_i \qquad (4)$$

As seen from column (3) of table 4, when having the interaction term included, both direct effects and the interaction of autonomy and fit gain significance. As H3 predicts, EP fit positively moderates the effect of autonomy on commercial value. This implies that the commercial value of the project is lower in cases where autonomy is delegated to a poor EP fits case. Also, autonomy in this specification enters with a negative and significant impact on the commercial value- which is in support of the control mechanism explanation- but when EP fit improves, delegating autonomy results in higher efficiency and wipes out this negative impact. Therefore, the results in column (3) confirm H3.

As said above, the main effect of autonomy only becomes significant when we include the interaction. This may have occurred since our moderator variable (FIT) produces a large difference in the sign and slope for AUTONOMY at different levels of the moderating variable. Therefore, when the interaction term is absent, it shows the average impact which is close to zero and insignificant; when the interaction term included, it can disentangle the effects based on the levels of moderating variable and make the direct effects significant. Also notice that as explained in the theory section, EP fit is a relevant moderator for commercial value, since it is defined for the congruence of employee with company defined project. For the scientific value, employee departs from the company-defined project, therefore, this notion becomes less meaningful. Accordingly, we do not expect to see the moderating effect for the case of scientific value of output. We check this in columns (2) and

(4) of table 3. For both proxies of scientific value of output, the interaction term between AUTONOMY and FIT is insignificant confirming our arguments.

Conclusion

The purpose of this study is to theoretically and empirically examine the questions of how does delegation of autonomy impact the innovative output? Our work develops new theoretical framework and presents empirical evidence to improve our understanding about the effects of autonomy delegation in knowledge intensive activities.

The key elements of our analysis that stand out are as follows; we develop a framework which combines the distinct effects of delegation: the effort mechanism and the control mechanism. Also by proposing EP fit as a moderator for the effect of autonomy, we link or analysis to the characteristics of the employee and the project. This work underlines the importance of fit instead of other common absolute measures such as employee's knowledge or experience. Moreover- and unlike most previous works- our theoretical framework allows us to address employee autonomy at the project-level. We find this a crucial dimension, especially with respect to increasing complexity in knowledge intensive activities which may change EP fit substantially across projects. Empirically, we expect that this lens, enables explaining variations across the project outputs and within/among firms for employees.

As the next step, we are planning to address the issue of counterfactuals to support our theory and show that e.g. what would happen to the output of a very same project/ employee with different delegation levels. To do this and complement our analysis, we have been carefully designing a survey experiment for the knowledge workers in our sample, where we manipulate key factors relevant for our theory (e.g. high/low level of autonomy). In the survey experiment, we are asking inventors to respond about their attitudes (e.g. motivation) and behaviors (e.g. their effort, choice of project direction and etc.) when they face different situations in a hypothetical situation. The survey experiment is currently at the pilot stage and we believe that matching its final results with our analysis will help us to address the issue of counterfactuals and add to the quality and contribution of our study.

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Figure 1 Monetary rewards versus intellectual challenge as the main motivation for invention (data source: PatVAl-2)

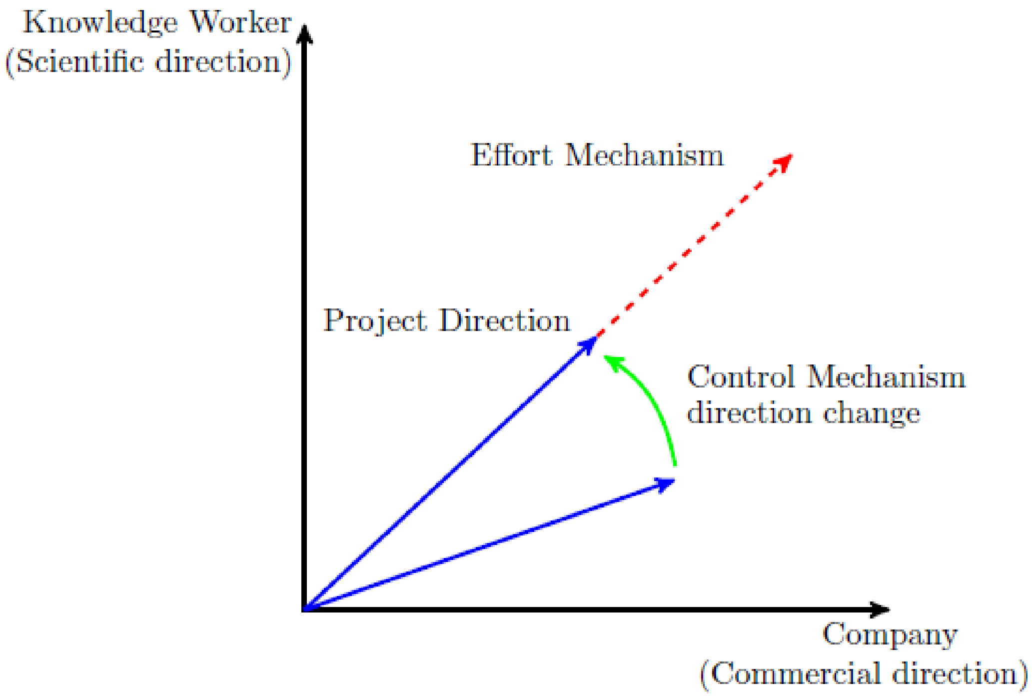

Figure 2 Innovative project and the effort and control mechanisms of autonomy

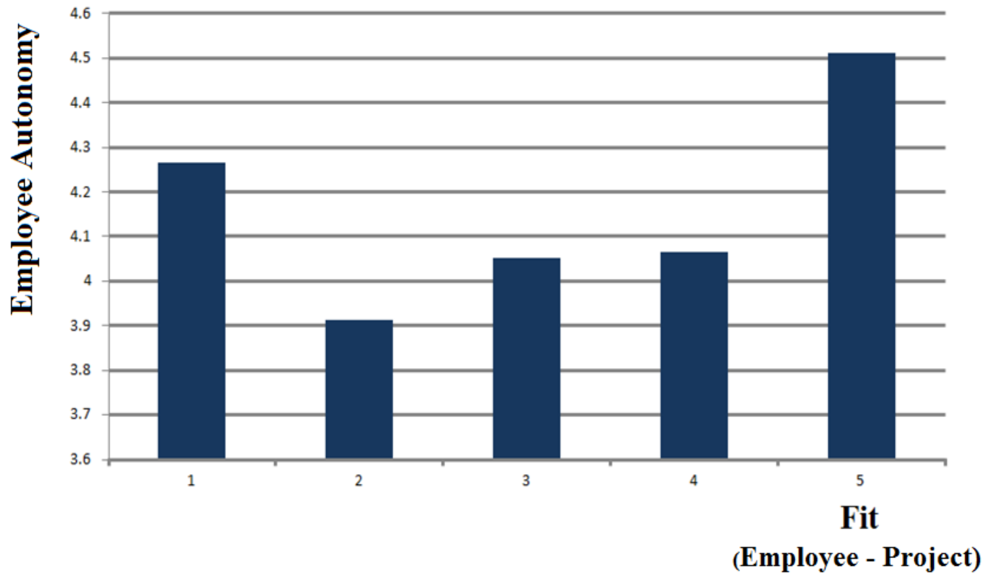

Figure 3 Mean of autonomy levels for the categories of employee-project fit in innovative projects (data source: PatVAl-2)

Table 1 Variable Definition

Variable		Definition
Commercial Value		0 for non commercialized patented inventions, 1 for inventions still in the process of commercialization, and 2 for commercialized patent inventions.
Scientific Value	NPL Refs	Number of references to non-patent literature (scientific publications)
	Inventive step	respondent's score (b/w 1-5) regarding the question on the patent's inventive step (EPC definition) in the European Patent Office application.
Autonomy	*autonomy in the selection of tasks* (AUT1)	respondent's score regarding the question on her autonomy level in *selection of tasks* (b/w 1-6)
	autonomy in time allocation among tasks (AUT2)	respondent's score regarding the question on her autonomy level in *allocation of working time among different tasks or projects* (b/w 1-6)
	autonomy in determining working time (AUT3)	respondent's score regarding the question on her autonomy level in *Flexibility of working hours* (b/w 1-6)
	broad autonomy measure (AUTONOMY)	Sum of the variables: AUT1, AUT2 & AUT3 (b/w 3-18)

Project-Employee fit (FIT)	respondent's agreement score (b/w 1-5) to the statement: "*… the combination of your previous experience with the knowledge of your new employer was instrumental in enhancing the inventive activity at the new organization.*"
GENDER	Dummy = 1 if the individual is female.
AGE	Age of the individual.
Employee's education (EDU)	Educational degree of the individual: 1= Secondary School or lower; 2= High School Diploma or equivalent; 3= Bachelor or equivalent; 4= Master or equivalent; 5= PhD or equivalent; 6= Post-doctoral degree.
Employee's gross annual income (INCOME)	Individual's approximate annual gross income in the year of the patent application: 1= Below 10,000 Euro; 2= 10,000-29,999 Euro; 3= 30,000-49,999 Euro; 4= 50,000-69,999 Euro; 5= 70,000-99,999 Euro; 6= 100,000 and more Euro
Firm size (SIZE)	Size of the employer firm: 1= 1-9 employees; 2= 10-19 employees; 3= 20-49 employees; 4= 50-99 employees; 5= 100-249 employees; 6= 250-499 employees; 7= 500-999 employees; 8= 1000-4999 employees; 9= 5000 and more employees.
Project man-month (PROJ_SIZE)	Individual's response to the question: "*How many man-months did the invention process require in total?*" 1= No research needed; 2= less than 1 man-month; 3=1-3 man-months; 4= 4-6 man-months; 5=7-12 man-months; 6=13-24 man-months; 7=25-48 man-months; 8=49-72 man-months; 9=more than 72 man-months
RANK	Individual's rank in the firm's hierarchy, based on the number of people reported to the individual at the time of invention: zero= 0 people; 1= 1-5 people; 2= 6-20; 3= 21 people and more.
Commercial Company	=1 if the respondent was working at a *private firm* at the time of invention.
Technological Class	ISI-INPI-OST Technology Classes

Project Resources (Equipment)	respondent's agreement score (b/w 1-5) to the statement: " *The organization had all the right* *instruments and technical equipment for this invention*"
Project Resources (Technical)	respondent's agreement score (b/w 1-5) to the statement: *"The organization had all the complementary resources to make the invention a technical success"*
Project Resources (Budget)	respondent's agreement score (b/w 1-5) to the statement: " *I was satisfied with the available budget for this invention*"
Project Resources (Commercial)	respondent's agreement score (b/w 1-5) to the statement:*"The organization had all the resources to turn the invention into something economically valuable"*

Table 2 Descriptive statistics and correlation matrix for the sample of analysis

	Variables	Mean	Std Dev.	Min	Max	1	2	3	4	5	6
1	**NPL Refs**	2.43	2.45	1	59	**1**					
2	**Inventive step**	3.31	0.9	1	5	0.11	**1**				
3	**COMM. Value**	1.34	0.81	0	2	-0.10	0.01	**1**			
4	**AUTONOMY**	13.47	3.28	3	18	0.13	0.14	0.01	**1**		
5	**FIT**	3.83	1.24	1	5	0.16	0.09	0.03	0.01	**1**	
6	**GENDER**	0.04	0.2	0	1	0.14	0.01	-0.10	-0.05	0.01	**1**
7	**AGE**	49.95	10.24	5	91	0.07	0.18	0.08	0.04	0.10	-0.16
8	**EDU**	3.59	1.16	1	7	0.10	0.16	-0.13	0.11	0.11	-0.09
9	**INCOME**	4.03	1.19	1	6	0.04	0.08	0.08	0.15	0.08	-0.17
10	**RANK**	0.88	0.9	0	3	0.07	0.02	0.08	0.09	0.09	-0.12
11	**SIZE**	7.01	2.56	1	10	-0.08	-0.08	-0.10	-0.23	-0.13	0.00
12	**PROJ_SIZE**	4.29	2.01	1	9	0.12	0.06	0.02	0.08	0.02	0.05
13	**Proj. Res. (Equipment)**	3.87	1.2	1	5	-0.01	-0.02	-0.03	0.06	0.00	0.06
14	**Proj. Res. (Technical)**	3.64	1.2	1	5	0.01	0.01	0.01	0.05	0.03	0.03
15	**Proj. Res. (Budget)**	3.68	1.21	1	5	-0.03	-0.02	0.04	-0.03	0.03	0.02
16	**Proj. Res. (Commercial)**	3.64	1.25	1	5	-0.08	0.00	0.14	-0.04	0.02	-0.04

	Variable	7	8	9	10	11	12	13	14	15
8	**EDU**	0.12	**1**							
9	**INCOME**	0.31	0.23	**1**						
10	**RANK**	0.16	0.12	0.28	**1**					
11	**SIZE**	-0.18	-0.04	0.01	-0.13	**1**				
12	**PROJ_SIZE**	-0.07	0.00	-0.12	0.11	-0.1	**1**			
13	**Proj. Res. (Equipment)**	-0.06	0.08	0.05	0.03	0.22	0.05	**1**		
14	**Proj. Res. (Technical)**	-0.01	0.01	0.14	0.02	0.18	0.11	0.65	**1**	
15	**Proj. Res. (Budget)**	-0.03	-0.01	0.04	-0.03	0.30	0.03	0.62	0.65	**1**
16	**Proj. Res. (Commercial)**	-0.04	-0.04	0.02	-0.03	0.25	0.04	0.44	0.48	0.60

Table 3 Estimations of determinants of scientific value of output

Dep var: *Scientific Value*	Negative Binomial		Ordered Logit	
	NPL Refs	***NPL Refs***	***Inventive Step***	***Inventive Step***
	(1)	(2)	(3)	(4)
GENDER	0.012	0.014	-0.086	-0.087
	(0.140)	(0.140)	(0.197)	(0.197)
AGE	-0.005	-0.005	0.028***	0.028***
	(0.005)	(0.005)	(0.005)	(0.005)
EDU	0.048	0.048	0.105**	0.105**
	(0.049)	(0.049)	(0.042)	(0.042)
INCOME	0.018	0.019	-0.008	-0.008
	(0.038)	(0.038)	(0.046)	(0.046)
RANK	0.030	0.029	-0.103**	-0.102**
	(0.045)	(0.045)	(0.050)	(0.050)
SIZE	-0.016	-0.016	-0.065***	-0.066***
	(0.015)	(0.016)	(0.017)	(0.017)
PROJ_SIZE	0.010	0.010	0.122***	0.122***
	(0.022)	(0.022)	(0.023)	(0.023)
Project Resources				
EQUIPMENT	-0.013	0.022	-0.024	-0.024
	(0.031)	(0.038)	(0.052)	(0.052)
TECHNICAL	-0.045*	-0.015	-0.063	-0.062
	(0.024)	(0.036)	(0.050)	(0.050)
BUDGET	0.066*	0.013	-0.065	-0.066
	(0.037)	(0.046)	(0.054)	(0.054)
COMMERCIAL	-0.037	-0.042	0.061	0.061
	(0.028)	(0.042)	(0.046)	(0.046)
AUTONOMY	0.031**	0.046	0.048***	0.070
	(0.014)	(0.036)	(0.015)	(0.048)
FIT	0.077**	0.131	0.082**	0.161
	(0.033)	(0.139)	(0.038)	(0.169)
AUTONOMY*FIT		-0.003		-0.006
		(0.008)		(0.011)
Technological class	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Observations	404	404	2,120	2,120
log likelihood	-750.038	-749.984	-2649.493	-2649.352
chi-square	160.274	164.161	186.834	186.813

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4 Ordered logit estimations of determinants of Commercial value of output

Ordered Logit Estimations	***Commercial Value* (1)**	***Commercial Value* (2)**	***Commercial Value* (3)**
GENDER	-0.545***	-0.593***	-0.585***
	(0.118)	(0.215)	(0.215)
AGE	-0.003	0.008	0.009*
	(0.003)	(0.005)	(0.005)
EDU	-0.202***	-0.225***	-0.224***
	(0.022)	(0.044)	(0.044)
INCOME	-0.015	-0.045	-0.048
	(0.024)	(0.044)	(0.044)
RANK	0.126***	0.162***	0.166***
	(0.028)	(0.053)	(0.053)
SIZE	-0.099***	-0.086***	-0.085***
	(0.010)	(0.018)	(0.018)
PROJ_SIZE	0.107***	0.124***	0.122***
	(0.012)	(0.024)	(0.024)
Project Resources:			
EQUIPMENT	-0.119***	-0.090*	-0.089*
	(0.026)	(0.048)	(0.048)
TECHNICAL	-0.017	-0.032	-0.036
	(0.025)	(0.047)	(0.048)
BUDGET	-0.009	-0.034	-0.032
	(0.030)	(0.055)	(0.055)
COMMERCIAL	0.460***	0.502***	0.507***
	(0.025)	(0.046)	(0.046)
AUTONOMY	-0.007	-0.007	-0.103**
	(0.008)	(0.015)	(0.045)
FIT		0.035	-0.316**
		(0.036)	(0.161)
AUTONOMY*FIT			0.025**
			(0.011)
Technological class	YES	YES	YES
Firm fixed effects	YES	YES	YES
Observations	7,770	2,205	2,205
log likelihood	-7236.164	-1990.975	-1988.409
chi-square	925.416	323.835	328.968

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1