The Effect of Subcontracted Labor Mix on Financial Performance: Evidence from High-Tech Project Teams

Problem definition: We investigate the effect of using subcontracted workers together with permanent employees on long and complex project's financial performance. ***Academic/Practical relevance:*** Organizations are increasingly staffing project teams with subcontracted workers, in order to adapt to variations in demand and access specialist expertise. Despite the importance of this phenomenon, there is scant research on the effect of subcontracted workers on project performance. Investigating such an effect is important because past findings on the effects of subcontracting in retail or assembly lines cannot be simply extrapolated to the more demanding tasks associated to project environments. ***Methodology:*** We first develop a theoretical model to conceptualize how and under what conditions subcontracted workers impact project performance. We then test our hypotheses analyzing 413 projects of a European high-tech firm. ***Results:*** We find that greater use of subcontracted workers increases project profit margins. This positive effect becomes even more prominent as team size is increased. However, in projects with large scope changes, the positive effect of subcontracted workers is attenuated. Finally, we focus on the level of expertise of subcontracted workers and find that the positive effect on project performance is stronger for lower skilled subcontracted workers than for higher skilled ones. ***Managerial Implications:*** Our analysis shows that reliance on subcontracted workers in complex projects can positively impact project margins, especially for larger teams.

Keywords: Subcontracted labor mix; project performance; team size; scope change.

1. Introduction

Many firms adopt outsourcing (Polivka 1996, Bielby and Bielby 1999, Hayes et al. 2005, Sinha and Van de Ven 2005, Mishra and Sinha 2016, Tsay et al. 2018) to better match demand while keeping costs under check (Harrison and Kelley 1993, Houseman 2001, David 2005, Broschak and Davis-Blake 2006, Goyal and Netessine 2012). While outsourcing has been historically associated to transferring activities to a company, it nowadays often entails transferring work to subcontracted workers (Kalleberg 2000, Capelli and Keller 2013). In fact, according to a study from McKinsey (2016), 20% to 30% of the working-age population in the United States and Europe (up to 162 million individuals) engage in independent work. The practice of subcontracting labor is not restricted to repetitive operations where incorporating workers to deal with demand fluctuations can be relatively straightforward. It is becoming quite common in non-repetitive project-based operations too, such as new product development or professional services. In fact, global firms such as Randstad now see 46% of their IT and 20% of their engineering clients demanding subcontracted workers for their projects.

Despite the prominence of subcontracting in project teams, its effect on project performance remains understudied. Past studies in Organizational Behavior suggest that reliance on subcontracted labor produces tensions with permanent employees (von Hippel and Kalokerinos 2012) and undermines their trust in the organization (Davis-Blake et al. 2003), but does not explicitly investigate performance

effects. Conversely, research in Operations Management indicates that subcontracted labor has an inverted U-shape relation with profits and sales in retail operations (Kesavan et al. 2014), but extension of these findings to complex project settings is not warranted.

With this study, we investigate the effect of subcontracted workers on the financial performance of product development projects executed by a high-tech firm operating in space, aeronautics & vehicles, defense and healthcare equipment sectors. We use Bidwell and Briscoe (2009) definition of subcontracted workers as "workers, who provide services directly to a client firm on an explicitly short-term basis". Following Kesavan et al. (2014) we define *Subcontracted Labor Mix* as the ratio of subcontracted workers to permanent employees in a project and capture project financial performance with the final project margin (Mayer and Nickerson 2005, Di Vicenzo and Mascia 2012). We contend that subcontracted workers have a positive impact on project performance, because they have a greater incentive to exert effort in their work compared to permanent employees. This incentive to perform originates because the employer can cease the work engagement with poorly performing subcontracted workers at virtually no cost, unlike the case of permanent employees, who are protected by labor contracts (Engellandt and Riphahn 2005). We further build on this motivational mechanism to argue that subcontracted workers are more beneficial to project performance when project teams are large; attenuated when project scope changes occur; and more salient for lower skilled, easily substitutable, than for highly skilled, hard to substitute, workers.

We test these hypotheses using a unique dataset of 413 projects executed over a 10-year time span. This setting is ideal to investigate the effect of *Subcontracted Labor Mix* on project financial performance, as over 80% of projects utilize subcontracted workers together with permanent employees. Moreover, in our sample we observe sizeable across-project variations relative to the posited moderators, including project team size (interquartile range: 24 team members), magnitude of scope changes (interquartile range: 29% change in project revenues) and ratio of high vs low skilled subcontracted project team members (interquartile range: 1.5). Lastly, the data available at the research setting allowed us to investigate whether the effects we detect are driven by different mechanisms than motivation, such as lower labor costs of subcontracted team members, or access to better talent through subcontracting, as well as familiarity effects.

This study makes multiple contributions to theory and practice. First, we extend the limited empirical literature on the consequences of subcontracting on performance (Kesavan et al. 2014). We find that subcontracting workers can improve profits also in non-repetitive (i.e., project-based)

operations. In this setting, integration diseconomies from subcontracting voiced by Organizational Behavior research (Davis-Blake et al. 2003, George 2003, Engellandt and Riphahn 2005, von Hippel and Kalokerinos 2012) thus not appear to cancel out the benefits from outsourcing. Unlike Mayer and Nickerson (2005), our approach allows us to test for and quantify the effect of subcontracted workers indicating the effect they can have on project profit margin. Specifically, our results indicate that an increase of 10% in *Subcontracted Labor Mix* can increase *Project Margin* by 13.11%.

Second, by investigating the moderating effects of *Team Size* and *Scope Changes* we provide additional insights on when projects can benefit more from using subcontracted labor. Specifically, we find that subcontracting brings more prominent benefits when project team size is increased, thereby contributing to research on the effects of team size (Levine and Moreland 2006, Staats et al. 2012). Furthermore, the negative moderation effect of project scope changes suggests that the complexities associated to managing new goals and priorities reduce the beneficial effects of subcontracted labor, thus contributing to research on the effect of task changes (Huckman and Staats 2011).

Third, past research has not examined the role of skill level on the relationship between subcontracted workers and project performance. We find that the beneficial effect of subcontracted workers is stronger for lower skilled workers than for higher skilled ones. Albeit in line with our theoretical predictions, this finding downplays the idea that the benefits from outsourcing are associated with reaching skilled labor in projects (Vestring et al. 2005, Boh et al. 2007), especially when a sizeable percentage of the team is made of subcontracted workers.

All these contributions are also significant from a practical viewpoint as they indicate the need for project managers to take into account project team size, potential scope changes and the skill level of the available subcontracted workers before deciding the number of external workers they will include in their projects.

2. Theory and Hypotheses

Operations Management literature has explored the effect of using subcontracted workers on cost and performance, from various perspectives. Modeling studies focus on defining optimal labor pool size and *labor mix* (i.e., the ratio of subcontracted to permanent workers) that minimizes labor costs (Berman and Larson 1994, Milner and Pinker 2001, Pinker and Larson 2003, Bhandari et al. 2008). For example, Berman and Larson (1994) develop a probabilistic model in a postal service setting that finds the optimal pool size of temporary workers, who are called-in when a permanent worker is absent or demand shows an unexpected peak. Milner and Pinker (2001) study labor contracts between external

labor supply agencies and employers under skills and supply uncertainty of subcontracted workers. They develop two models for reaching optimal staffing policy considering a mix of both types of workers and find that when there is uncertainty about subcontracted workers' skills an optimal policy can be reached, whereas when there is uncertainty about their supply such a policy cannot be reached. Pinker and Larson (2003) develop an optimization model determining the optimal pool size of permanent and subcontracted workers, which minimizes labor and backlog costs when demand is uncertain. Bhandari et al. (2008) study labor configuration in call-centers and demonstrate that optimal labor mix increases with the opportunity cost of not serving a client. Their findings are based on the core assumption that subcontracted workers are hired only when demand peaks and are let go afterwards, while permanent workers are retained independently of their level of utilization.

Empirical studies have focused on the effect of subcontracted workers on firm performance and flexibility. Stratman et al. (2004) use data from an assembly line to study via simulation how labor mix affects line performance. They find that whereas the increasing use of subcontracted workers at the manufacturing plant achieves considerable wage cost savings, it can also adversely affect quality due to increased learning and forgetting costs arising from hiring and firing subcontracted workers. Kesavan et al. (2014) use data from a large retailer and examine how the ratio of subcontracted to permanent workers (or *labor mix*) affects store performance metrics such as revenues and profit. They find a reverse U-shaped relation between labor mix and store performance. They contend that this effect arises from the combination of nonlinear benefits and costs. Benefits of higher labor mix accrue from lower labor cost (e.g. social benefits, insurance) and flexibility in adapting to demand peaks. Costs, however, increase with labor mix due to training and coordination difficulties. While all these studies provide important insights on how using subcontracted workers impacts operational performance, they are all based on repetitive environments, (i.e., call centers, retailers or assembly lines), where workers' tasks are relatively simple and structured. It is not clear whether the same effects would be present in settings where workers need to engage in complex tasks, such as, for instance, engineering or R&D projects.

Organizational Behavior literature focuses on studying the effects of labor mix on the workers' perceptions towards the firm. This stream of literature suggests that including subcontracted workers to work groups can be detrimental for the work-place environment. For instance, George (2003) conducts a survey in three organizations (a research laboratory, a computer hardware manufacturer and a consumer product retailer) and finds that the greater the use of subcontracted workers, the lower the level of trust of the internal workers in the organization. Similarly, Davis-Blake et al. (2003), use data

from two 1991 US surveys (General Social Survey and National Organizations Survey) and find that permanent employees have lower loyalty, worse relations with their managers and higher turnover intentions when their organizations rely on subcontracted workers. Von Hippel and Kalokerinos (2012) show that if companies hire subcontracted workers for jobs of equal or higher level of seniority than permanent employees, mixing permanent and subcontracted workers could create a perception of threat for job security, decreasing the level of collaboration among workers. All these results underscore a general concern that utilizing subcontracted workers can negatively affect organizational dynamics. However, the exploration of the performance implications of labor mix by these studies remains limited.

This survey of past literature indicates that empirical research on the effect of subcontracting either does not investigate individual performance outcomes or, when it does so, it is scant and focused on repetitive operations. The applicability of this limited knowledge to project settings is problematic. Labor cost savings from subcontracting may be less significant in project settings, where highly qualified professionals are required, compared to repetitive operations. Projects require workers with high qualifications to perform complex and uncertain tasks, and these workers tend to have greater employment options and salary expectations compared to less qualified workers needed to restock shelves or assemble components. Moreover, the negative consequences of subcontracted workers on learning in repetitive environments (Stratman et al. 2004) may not be equally apparent in non-repetitive project settings. Project teams are fluid and workers are inherently subject to constant changes in the teams and the projects they work on, even when exclusively composed in permanent employees. The long duration of the projects may also ease integration of subcontracted team members, compared to more volatile repetitive settings. Consequently, staff variability induced by subcontracted workers may be less problematic. Lastly, subcontracting can provide the project with special type of expertise not internally available in the organization, thereby inducing learning benefits instead of learning costs (Vestring et al. 2005, Boh et al. 2007).

The only study that so far has investigated project performance in presence of subcontracting is Mayer and Nickerson (2005). They find that the effect of contracting difficulties (monitoring or intellectual property protection) on project margins is negative for projects with subcontracted team members, while is not significant for projects fully staffed with permanent employees. However, they neither explicitly theorize about the effect of subcontracting, nor test for it, and simply report point estimates of project margins at different levels of moderators and subcontracting. Additionally, their measure of subcontracting is dichotomous (i.e. subcontracting is 1 when there is at least one

subcontracted team member, zero otherwise)—a fact that makes it impossible to distinguish between situation where only a small vs a large fraction of team members is subcontracted. Given these two limitations, our primary goal is to more thoroughly investigate the effect of *Subcontracted Labor Mix* on project margins, complementing research from Kesavan et al. (2014). Additionally, we seek possible moderators for the effects of *Subcontracted Labor Mix* in key project features such as *Team Size* and *Scope Changes*, which may interact with the ability of the firm to integrate successfully subcontracted project team members. Furthermore, unlike previous research, we investigate the effect of the skill level of subcontracted project team members, which is arguably an important factor in project success (Boh et al. 2007). Finally, unlike previous project research (see Mayer and Nickerson 2005) we control for past employment of subcontracted workers with the focal company, which can confuse the effect of subcontracting with familiarity effects.

2.1. Subcontracted Labor Mix and Project Performance

To study the effect of subcontracted workers on project performance, it is important to establish the differences between subcontracted workers and permanent employees. Permanent employees have a work contract with the employer with no formal or implied end date. That is, the work relation between an employer and a permanent employee does not necessarily terminate when the projects to which the employee was assigned are completed. Conversely, subcontracted workers have a work contract with an employer characterized by a specific time frame or scope of work (Bidwell and Briscoe 2009, Davis-Blake et al. 2003). That is, when the contractual time expires or the contracted work is completed, the work relation between employer and employee terminates. It is though possible and actually frequent that a subcontracted worker is recruited multiple times by the employer, as the need arises.

Beyond their nominal definitions, subcontracted and permanent employees differ in their prospects to maintain a continued employment relation with a specific employer, especially in economic environments with strong employment protection laws. In such environments the cost of terminating permanent employee contract is relatively high compared to subcontracted workers (Ichino and Riphahn 2005). The ability of the employers to dismiss employees with permanent contracts can be legally limited by imposing notification requirements, severance payments, and other safeguards which often entail costly and lengthy legal proceedings (Shire et al. 2009). Furthermore, even when employment protection laws are weaker, many managers find the process of firing an employee emotionally stressful and unpleasant (Bidwell 2009, Fisher 2014, Gould 2018, Lotich 2018). Given these monetary and behavioral costs, the employer hence tends be hesitant to swiftly terminate an

employment relation when worker's performance is unsatisfactory (Bidwell 2009). Conversely, when the contract between the employer and subcontracted worker expires, the work relation automatically terminates with no cost whatsoever for the employer, unless the two parties agree on a new contract.

The difference in employment prospects between subcontracted and permanent workers has implications for the effort subcontracted workers exert in the projects they work on. If a subcontracted worker performs unsatisfactorily in a project, the employer can opt for not hiring the worker in future projects, at no cost. Conversely, if a subcontracted worker performs consistently well across multiple projects, the employer has an incentive to hire the worker again for future projects or even as a permanent employee. Future employability is an inherent concern of subcontracted workers, as they need to ensure new work engagements after the completion of each project in order to sustain themselves economically (Connelly and Gallagher 2004, Gullhaugen 2010). This argument finds ample support in empirical research on work economics. Allan and Sienko (1998) survey 149 permanent and 48 subcontracted technical and professional workers of a large US telecommunication company and find that subcontracted workers are more motivated than permanent ones. Engellandt and Riphanhn (2005) use a Swiss Labor Force longitudinal survey (1996-2001) with 15,908 respondents and find that subcontracted workers provide significantly more effort as they have 60% more probability of working unpaid overtime hours than the permanent workers. Ichino and Riphahn (2005) study 858 workers of an Italian bank who transition from a probation period to permanent contract and find that the number of days absence per week increase significantly after the transition. Similarly, Bradley et al. 2014 use longitudinal Australian database of the performance of 5,380 public sector workers from 2001 to 2004 to find that when subcontracted workers transition from subcontracted to permanent contract, they become more likely to be absent from work.

Compared to subcontracted workers, permanent workers may reduce their effort as they may take their jobs for granted or may have lost interest on them (Allan and Sienko 1998), being especially aware of the firing costs they know the employer would incur if the work relation terminates (Ichino and Riphahn 2005, Frick and Malo 2008, García Mainar et al. 2018). Additionally, the consequences of contract termination are less troublesome for permanent workers, because they can rely on a severance package and unemployment subsidies while looking for another job (Bonet et al. 2020).

We expect that the extra effort of subcontracted workers operating in project settings to benefit project performance. We capture the extent to which subcontracted workers are used in a project team with the variable *Subcontracted Labor Mix*, defined as the ratio of the number of subcontracted workers

to permanent workers within a project as in Kesavan et al. (2014). We further conceptualize project performance as the *Project Margin*, that is, the difference between final project revenues and project direct costs (i.e., variable costs plus fixed, project-linked costs), as in Mayer and Nickerson (2005) and Di Vicenzo and Mascia (2012).

Subcontracted Labor Mix can benefit project margins for multiple reasons. Heightened efforts of subcontracted workers are plausibly manifested in completion of the tasks with superior speed and quality. Reducing errors and delays pertaining to a task in turn curtails the propagation of errors and delays in subsequent and related tasks (Anderson and Parker 2013), further reducing overall project cost, and positively affecting its margin. The benefits for avoiding such chains of errors are particularly noteworthy in a high-tech setting as the one we study, where single errors or delays can propagate to affect many project activities due to high task interdependency (Hamilton 2001). In case the employer is part of a larger constellation of firms involved in the project, errors and delays can also imply legal penalties that would further detract from project margins. Finally, late completion of a project task (e.g. a component design) can lead to unexpected system integration problems which often requires time consuming efforts to be solved (Mishra and Sinha 2016).

These motivational benefits from subcontracted workers may however offset—partially or totally—by the cost of integrating these workers in project teams. Nonetheless, in settings where project teams are fluid, as the one that we study, we expect that the benefits of subcontracting dominate the costs of integrating these workers in project teams. In fact, when project teams are fluid each team is assembled ad-hoc based on specific project requirements and, upon project completion, the team is disbanded and its members are individually assigned to different projects (Huckman and Staats 2011). As these teams are not always comprised of individuals with mutually consolidated work routines, difference between subcontracted and permanent workers tends to become less salient, and with it the costs of integrating subcontracted workers to the teams. We therefore expect that:

Hypothesis 1: Subcontracted labor mix has a positive effect on project margin.

2.2. Subcontracted Labor Mix and Team Size

Next, we expect that the positive effect of *Subcontracted Labor Mix* on project margin to be positively moderated by the project's team size, for multiple reasons. First, large project teams are more vulnerable to performance disruptions than smaller ones (Huckman and Staats 2011) due to the propagation of errors and problems from one team member to the other (Sauer et al. 2007). This is because the number of linkages among team members increases at a nonlinear rate as there are (N(N-1))/2 possible linkages

in a team with N members, as observed elsewhere (Brooks 1995, Espinosa et al. 2007, Staats et al. 2012). Errors and delays from a worker hence tend to potentially affect a greater number of workers, with negative consequences for project costs and, ultimately, margins. As the heightened motivation of subcontracted workers can reduce occurrence of errors and delays, we expect that the effect of *Subcontracted Labor Mix* on project margin is stronger for projects with larger team sizes.

Moreover, when assigning internal employees to a project, each project manager attempts to get motivated and high-quality workers. However, as project team size increases reliance on internal employees forces the project manager to include workers with less desirable skills. Such limitations are less stringent when recruiting subcontracted workers, as the pool of possible workers is not constrained to company employees with unfilled hours (Brewster et al. 1994). Hence, when team size increases, a higher *Subcontracted Labor Mix* reduces the adverse selection of internal workers, with positive effects on overall team motivation and quality and, ultimately, project margins.

Last but not least, large teams present challenges regarding the motivation of team members (Staats et al. 2012, Kidwell and Bennet 1993). Specifically, large teams can create a context of social loafing and free riding, because difficulty in supervision and complexity hamper transparency and individual accountability (Latané et al. 1979, Albanese and van Fleet 1985, Karau and Williams 1993). Internal workers may take advantage of such team environment to reduce effort without being noticed, while safely maintaining their employment. This shirking possibility, with detracts from project margin, is less appealing for subcontracted workers whose interest is to signal their ability to the employer in order to secure future work contracts or a long-term employment relation. Based on the abovementioned arguments we propose that:

Hypothesis 2: Team size increases the positive effect of subcontracted labor mix on project margin.

2.3. Subcontracted Labor Mix and Scope Changes

While reliance on subcontracted workers can benefit project margin, such an effect can be hindered by the occurrence of project scope changes. We refer to project scope changes as modifications of project activities during the execution that are large enough to result in variations of the project contract value (Cheng and Carrillo 2012). Engineering projects are frequently subject to such changes in scope, which represent a major source of uncertainty (Yeo and Ning 2002). Due to the long duration and complexity of such projects, changes in the scope do not necessarily originate from poor project planning at the onset. The client may not be able to fully specify the requirements of the project in the beginning as the knowledge generated during the execution may alter the specifications (Reifer 2000) or changes in the

technologies can trigger modifications (Kulk and Verhoef 2008, Chandrasekaran et al. 2016). Although some level of scope changes is accounted for at the beginning of the project, changes in such complex systems are difficult to predict. Hence, scope changes put stress on the project, as they entail readjusting plans and reassigning tasks to team members.

When there is a scope change, it is easier to reassign tasks to internal team members than to subcontracted team members. This is so because tasks assignments to external team members are regulated by formal and project-specific contracts subject to negotiations (Cox 1997) while this is not the case for internal workers, whose activities are regulated by directives set by managers. Lengthy negotiations with subcontracted workers on contract conditions are particularly problematic when scope changes occur, because the firm is normally concerned with protecting project schedules (Peña and Valerdi 2015). Besides taking more time, negotiations with subcontracted workers also entail reduced bargaining capacity of the subcontracting firm since extant subcontracted workers are less easily substitutable than at the beginning of the project as they acquired project-specific knowledge, and substituting them would also create inefficiencies associated to the induction of new team members into an established project (van Oorschot et al. 2013).

Finally, project managers have more information on the skills and experience of the permanent employees, compared to subcontracted workers (Autor 2003), and hence can match new tasks to internal employees more swiftly and aptly than to subcontracted works in the event of a scope change. Being easier to reassign tasks to permanent than to subcontracted team members, it follows that when *Subcontracted Labor Mix* is higher reacting to project scope changes is more costly. We therefore expect that in projects with high level of scope changes the positive effect *Subcontracted Labor Mix* on financial performance of a project will be attenuated. Hence, we propose that:

Hypothesis 3: Increased number of scope changes in the project decreases the positive effect of subcontracted labor mix on project margin.

2.4. Expertise and Subcontracted Labor Mix

In order to get a more fine-grained understanding of the effect of the use of subcontracted workers on project margin, we follow past literature and investigate the effect of subcontracted workers' skill level (Barley and Kunda 2006). Comparatively "low-skilled" subcontracted workers tend to be inexperienced young professionals who use temporal work engagements as a stepping-stone towards a permanent position. Because of their low level of expertise, low-skilled workers tend to perform basic and highly structured tasks (Kunda et al. 2002, Barley and Kunda 2006), such as drafting blueprints or executing

routine engineering calculations. The supply pool for this type of workers relatively broader compared to highly skilled specialists (Houseman et al. 2003, Bidwell and Briscoe 2009). For this reason, if low-skilled workers perform unsatisfactory in a project, the employer can easily substitute them with equivalent workers for subsequent projects. Aware of their heightened substitutability, low-skilled subcontract workers are motivated to exert greater effort in the execution of project activities.

In contrast, high-skilled workers are experienced individuals who often choose not to be affiliated to any particular organization on permanent basis (Kunda et al. 2002, Barley and Kunda 2006). High-skilled subcontracted workers are hired for a project because of their specific expertise (Broschak and Davis-Blake 2006, Bidwell 2009, Kozica et al. 2014). The supply pool for this type of workers is more constrained compared to low-skilled workers. Hence, if high-skilled subcontracted workers perform unsatisfactory in a project, the employer cannot easily substitute them with other high-skilled workers for subsequent projects. Past research has also shown that subcontracted workers' commitment is decreasing as his/her qualifications are increasing (Suβ and Kleiner 2010) as high-qualified individuals tend to feel less committed to their employers due to their expertise. High-skilled subcontracted workers are therefore less motivated to exert greater effort in the execution of project activities compared to the lower-skilled subcontracted workers.

To sum up, in case of poor performance in a project, low-skilled subcontracted workers face lower chances of being hired again by the same employer compared to high-skilled, less substitutable, subcontracted workers. Aware of the different levels of substitutability subcontracted workers face depending on their level of expertise, we expect that low-skilled subcontract workers are more motivated than higher-skilled subcontracted workers to exert greater effort. We therefore propose that:
Hypothesis 4: Low-skilled subcontracted labor mix has a higher positive effect on project margin than High-skilled subcontracted labor mix.

3. Setting, Data and Variables

We test our hypotheses using a data we collected from a leading European high-tech firm. In 2017 the firm generated around 750 million revenues and employed more than 2,000 permanent and subcontracted workers. Our dataset includes all projects executed between 2006 and 2017 by the firm's Space, Aeronautics & Vehicles, Defense and Healthcare equipment departments. These projects entail a mix of engineering and prototyping/small series manufacturing activities. The projects are highly heterogeneous, for instance, one project may entail developing and building an alignment device for a

satellite antenna, while the subsequent project may be a navigation device for a rocket or design of a work system to generate carbon fiber laminates for aircraft wings.

Due to the highly heterogeneous and complex nature of the projects, the budgeting and the overall manpower requirements, such as total number of team members (i.e., permanent and subcontracted) and expertise required for the completion of certain tasks, are defined at the tendering stage of each project. The budgeting is done based on the specific client requirements. Once the project has been awarded, the project manager decides on which employees to be involved in the project, depending on the required capabilities as well as the availability of staff members, and proceeds with the recruitment of subcontracted workers depending on the established in the budgeting stage requirements in terms of number of workers and expertise level.

Even though subcontracted workers do not have a permanent contractual relationship with the company, they work full-time when hired for a specific project. To ensure their high commitment, the firm puts great care in integrating them since the beginning of the project. For instance, subcontracted workers are provided with a corporate email address and are invited to participate in project kick-off meetings. Subsequently, they join all meetings related to the tasks they perform in the project. Moreover, subcontracted workers usually work in the company premises and collaborate closely with project managers—a practice that facilitates close control and worker engagement. Once the project is completed, the company has the practice to hire again the ones that have performed well, which provides strong incentive for subcontracted workers to strive for high performance.

We assembled data for this study from three different archival sources. First, we accessed the records that the company maintained of all 413 projects initiated during the period between January 1, 2006 and November 30, 2017. For each project, the dataset includes information about the project margin, invoice variation, geographic area, project scope, project manager, etc. After removing projects with missing identifying data such as project type, activity and stage, the dataset comprises 351 observations, pertaining to projects that are executed in different geographic areas: USA and Canada, Mexico, Brazil, China; Japan and Korea, Middle East, North Africa, South Africa, Iberia, United Kingdom and Ireland, Poland, Eastern Europe, Rest of Europe and Rest of South America. From the 351 projects, 259 (or 73.79%) were finalized at the point of the data collection, while 92 (or 26.21%) were still ongoing. To perform the analysis we focus exclusively on the closed projects, therefore limiting our sample to 259 projects, to ensure that the project margin is an accurate estimator of project performance. The margin data available for the on-going projects is an estimate of the project margin

up to the date of the data collection and therefore is misleading because project performance may vary unexpectedly in the time period comprised from data collection to project termination. T-test statistics confirms that the use of subcontracted labor (subcontracted labor mix and low- and high-skill subcontracted labor mix) does not significantly differ between the closed and the ongoing projects. Similar to Staats (2012) we remove geographic areas that had only one project (a total of three projects), making our final sample equal to 256 projects. Each project is allocated into one of two categories by the company according to the final outcome: "Engineering", where only service is provided, and "Product", where physical artifacts are built as well. The sample comprises 70.31% of projects in the former category and 29.69% in the latter.

Second, we augmented the dataset by including data elaborated from monthly worker time sheets for each project. These records cover 1,027 individuals in total: 665 permanent employees and 362 subcontracted workers. Based on these records, the average duration of a project is 1.83 years whereas the average team size is 22.78 employees (18.56 permanent employees and 4.22 subcontracted workers on average). Given the nature of the work, permanent employees usually work simultaneously on several projects (average is 6.62 projects per employee). We further used this data to calculated team composition variables for each project.

The third source of data were records from the Human Resource department, which we accessed to collect information on team members, including skill level, tenure (for permanent workers) and cumulated duration of contracts with the company (for subcontracted workers). The average tenure of permanent workers in a project is 7.08 years, while the average cumulative experience in the company for subcontracted workers in a project is 1.05 years. Permanent and subcontracted workers are assigned to a specific skill level category, from 1 to 6, based on their credentials, level of seniority and expertise, where 1 indicates the highest level and 6 the lowest. In the case of the subcontracted workers, the assignment to the skill level group is based on their past experience as well as their education level (i.e., master degree, specialization, years of experience) to which the subcontracted worker also needs to agree. The assignment of the skill level is a highly systematic and valid procedure as the compensation of the workers depends on the expertise category they are assigned to. The average expertise level of permanent employees in a project is 3.54, while the average expertise level of subcontracted workers in a project is 4.90. According to our interviews, subcontracted workers assigned to category 6 are usually recent graduates and interns (40.89% of the subcontracted workers in our setting). They are therefore less experienced engineers, conducting basic drafting and technical

engineering tasks that are more structured and repetitive. The normal practice for these workers is, in case of good performance, to be offered a full-time contract after the conclusion of their internship or their subcontracting period. On the other hand, subcontracted workers from category 1 to 5 (59.11% of the subcontracted workers) are senior experts that join the project in order to perform highly specialized and complicated tasks that fit their area of expertise. These workers are not usually offered full-time contracts as they are used for a specific tasks and expertise needed for the specific project that is not available in the company, but the high performers are used for future projects if the need arises.

Finally, we conducted numerous meetings and interviews with staff members to get a better understanding of the company business environment, its project management practices and procedures, as well as how data pertaining to the three aforementioned sources was compiled.

3.1. Dependent Variable

We use project margin data computed by the corporate project control office. Project margin is calculated at the closure of the project as the difference between project contract value (invoiced to the client) and project costs. Project costs include direct project costs, as well as a fraction of general overheads that is imputed based on company-defined coefficients. Among direct project costs are manpower (both permanent and subcontracted), supplies, other subcontracted services, as well as miscellaneous R&D costs and manufacturing costs, including equipment depreciation costs. The company carefully tracked project costs, in order to keep the project earned value under check and maintain updated predictions of final project margin.

3.2. Independent Variables

Subcontracted Labor Mix. We operationalize this variable by dividing the number of subcontracted workers employed in a project by the number of total permanent workers of the project. It is defined similar to Kesavan et al. (2014) and captures the ratio of subcontracted to permanent workers for a project. We also compute an alternative measure of *Subcontracted Labor Mix* to investigate the robustness of our results to difference operationalization. Specifically, based on the monthly individual time reports for a focal project, we compute this alternative operationalization as the ratio of the hours worked by subcontracted and permanent workers.

Low- and High-skilled Subcontracted Labor Mix. In order to test Hypothesis 4, we decompose *Subcontracted Labor Mix* into *Low-skilled* and *High-skilled Subcontracted Labor Mix*. To do that we use the skill level category assigned to each engineer, as discussed in the previous general description of the setting. In order to calculate *Low-skilled Subcontracted Labor Mix* we divide all

subcontracted workers from level 6 (i.e., low-skilled workers) employed in a project by the number of permanent employees of the project. This way we capture the ratio of less experienced subcontracted workers to permanent employees. Similarly, in order to calculate *High-skilled Subcontracted Labor Mix* we divide all subcontracted workers from levels 1 or 5 employed in a project by the number of permanent employees of the project. As a robustness check we also operationalize the ratios using the number of hours instead of the number of employees, as for the *Subcontracted Labor Mix* variable.

Team Size. This variable represents the number of individuals working on a project, independent of whether they are subcontracted or permanent workers. In our sample the average team size is 22.78 employees with minimum of 1 and maximum of 171 employees. Due to the highly right skewed nature of the variable, we use the log transformation of team size in our main model. The transformation is also consistent with Tukey's (1977) ladder of powers, which reveals the most suitable transformation.

Scope Changes. We measure scope changes during the execution of a project based on variation in project invoicing amount. The total project invoicing amount is normally set with the client when signing the contract. As the project progresses, the invoicing amounts can be altered to address changes in the scope caused by external factors (e.g. obsolete component or software that needs to be replaced) of requested by the client (e.g. the client readjust product specifications such as the speed or the reach of the device). Variation in total invoicing hence is a proxy for changes in project scope. Specifically, we compute *Scope Changes* as actual invoicing minus budgeted invoicing, divided by the actual invoicing. In 79.30% of the projects in the sample there has been a change in the invoicing and a change therefore in the scope.

3.3. Control Variables

Individual Average Experience. We measure each project team member's prior experience in the company as the total number of months a team member has worked in the company prior to the focal project. To obtain the project level variable, we average across the team members. Note that the variable captures the experience of both permanent employees as well as subcontracted workers. It is also worth noting that a low number of subcontracted workers in our sample work for some months for the company and then are re-hired at a later point in time for another project. For these individuals we count only the months that they were employed by the company (i.e., excluding the months that were not working for the company).

Individual Average Expertise. We control for individual's expertise level. To measure expertise, we use the skill level categories assigned to subcontracted and full-time workers where 6 is the lowest and 1 the highest category. To obtain the project level variable, we take the average skill level of all workers in the team.

Client Familiarity. Because of the interdependent nature of engineering projects, the client and the project team interact in the creation of the project output (Larsson and Bowen 1989, Clark et al. 2013, Langer et al. 2014). By repeatedly interacting with the same client, the firm may learn the customer's requirements and improve their communication and coordination (Clark et al. 2013, Ko et al. 2005). We therefore control for client familiarity by capturing the past projects of the company with the same client. Specifically, we calculate in how many projects the company has worked with the same client up to the current project (excluding the current one).

Project Manager Role Experience. Prior literature has argued that the project manager role experience can influence the performance of the project (Huckman et al. 2009, Easton and Rosenzweig 2012, Madiedo et al 2020.). Hence we control for this variable by calculating the number of previous projects the project manager has managed (excluding the current one).

Multi-team Membership. In our setting, employees tend to work on multiple projects at the same time, which may affect their performance in the focal one (O'Leary et al. 2011, Chan 2014, Bertolotti et al. 2015). To control for multi-project membership, we take the average number of projects each team member has worked on throughout the duration of the focal project. To obtain the project level variable, we average across the team members.

Project Duration. We include a variable indicating the total duration of the project in months, to control for the size of the project. Projects with higher duration are spread across longer time periods, which may affect project margins. The duration of the project is estimated in the tendering stage with the client and is dependent on the unique specifications of the project and its tasks.

Project Complexity. We control for project complexity with two project level variables *Project Type* and *Project Department*. As previously explained, the company allocates projects into two categories based on their output: Engineering and Product. Both project types include a certain amount of engineering work in the initial stages of the project. Nevertheless, the engineering projects are considered more complex because a major part of the work is engineering. The final outcome of an engineering project is one or two prototypes of the product, such as a scanning mechanism for a satellite or a pointing mechanism for a spacecraft. In a product type projects the project consists of a less

complex initial engineering and the subsequent production of the parts. We therefore include the dummy variable *Project Type*, which is equal to one if the project is allocated into "Product" and zero otherwise. Moreover, the complexity of the projects also depends on the department in which the projects are executed, with the Space department having more engineering-heavy projects with high complexity in the requirements than other departments, for example. We therefore include dummy variables indicating the department of each project, using *Space* as our reference category (corresponding to zero values of *Aeronautics and Vehicles*, *Defense*, *Healthcare Equipment* departments).

Indicator for Start Year. To control for potential company policy changes and technological advancements we include a dummy variable indicating the year each project started.

4. Results

We first use an Ordinary Least Square model to examine our hypotheses. Since our projects have been performed in 11 different geographical areas we specify geographic area random-effects regression models, with robust standard errors clustered at the geographic area level to test our hypothesis. We use random-effects model as Hausman test fails to reject the null hypothesis that the random effects model is consistent. Our approach allows us to study the differences among the areas, while controlling for unobserved similarities of the projects within each area (Bollen and Brand 2010).

Table 1 shows descriptive statistics and correlations among our variables. We note that we do not report the real statistics of *Project Margin* because due to privacy concerns the company did not provide the actual project margins but added the constant to each project's margin. We note that the logarithmic transformation of the *Team Size* variable is reported in the table. Table 2 presents the OLS model results. In model 1, we include only the control variables. As expected, *Team Size* has a negative effect on project margin whereas *Individual Average Experience, Multi-team Membership* and *Client Familiarity* are positively associated to project margin. In model 2, we include *Subcontracted Labor Mix* and observe that it has a positive and significant at 1% coefficient, providing support for Hypothesis 1. Model 3 shows that the interaction term of *Subcontracted Labor Mix* with *Team Size* has a positive and significant at 1% coefficient, providing support for Hypothesis 2. In model 4 and 5 we add the interaction term of *Subcontracted Labor Mix* with *Scope Changes*. In model 4 we exclude the interaction term with *Team Size*, and the interaction term with *Scope Changes* is negative, but not significant. In model 5, we present both interactions together and the interaction term with *Scope*

Changes is negative and significant at 5% in accordance with Hypothesis 3, which provides support for our hypothesis. Finally, in model 6, we test Hypothesis 4. To this end, we substitute the variable *Subcontracted Labor Mix* in Model 1 with the two variables *Low-skilled Subcontracted Labor Mix* and *High-skilled Subcontracted Labor Mix*. Both variables have positive and significant at 1% coefficients. The coefficient of *Low-skilled Subcontracted Labor Mix* is higher in magnitude than the one of *High-skilled Subcontracted Labor Mix*, providing support for Hypothesis 4. A chi-square test ($\chi^2 = 4.90$, $p<0.05$) rejects the null hypothesis that the two coefficients are equal, providing further support for our hypothesis. To visualize effect sizes and interpret interaction effects we plot the predicted values for the regression models. Figures A1 and A2 of appendix examine the moderating effects of *Team Size* and *Scope Changes*.

4.1. Endogeneity Issue and Instrumental Variable Approach

The decision about the level of subcontracting for a project is not random. Unobservable factors may drive this decision and project performance, potentially biasing the estimated effects of *Subcontracted Labor Mix*. To address this potential bias, we re-test the proposed hypotheses using instrumental variable regressions and base all robustness checks and conclusions on this approach. We use different instruments for the labor mix variables. We first describe our instruments and then argue why they satisfy both the relevance and exclusion conditions.

For Hypothesis 1 we follow Nevo and Wolfram (2002) and Kesavan et al. (2014) and identify a "market-based" instrument adjusted to our setting. For instance, Kesavan et al. (2014) examined the effect of temporal labor mix on performance of stores in a state. To account for endogeneity bias, the authors used the average value of temporal labor mix of other stores in the same state. The instrument was valid since the labor cost of stores within a state would be correlated but it would not affect the performance of the focal store. Similarly, we use the average values of *Subcontracted Labor Mix* from other projects within the same department (i.e. space, aeronautics & vehicles, defense and healthcare equipment) as an instrument. We name the variable *Department Average Labor Mix*. The instrument is correlated with the endogenous variable as the requirements and supply of adequately skilled labor would be contingent on the department. For example, the space department typically feature projects with highly complex and unique engineering requirements for which internal staff or highly experienced subcontracted workers are preferred, compared to the more production focused defense department, where qualified subcontracts could be more easily identified. The instrument also meets the exclusion

restriction, because, there is no reason to expect that performance of the focal project is driven by average *Subcontracted Labor Mix* of other projects. Since healthcare equipment department has just one project in our sample, we dropped for this analysis. The rest of the departments have 120 (space), 95 (aeronautics & vehicle) and 40 (defense) projects.

When testing our second hypothesis we need a second instrument for the interaction term of *Subcontracted Labor Mix* and *Team Size*. It is worth noting that *Department Average Labor Mix x Team Size* is not a valid instrument for *Subcontracted Labor Mix x Team Size* as using it would lead to biased results (i.e., the forbidden regression), (Wooldridge 2002). Hence we come up with a second instrument for *Subcontracted Labor Mix*. Specifically, we use the average hours worked in the other projects within the same department (i.e. space, aeronautics & vehicles, defense and healthcare equipment) during the executing of the focal project and name this instrument *Department Project Workload*. This instrument is correlated with *Subcontracted Labor Mix* since while permanent employees are used for projects, tenders and research and development, subcontracted workers are used only for projects. Hence, the higher the average number of hours worked on projects, the higher the need for relying more on subcontracted workers. On the other hand, when there is low project workload, permanent employees focus on tenders and research and development and there is lower need for subcontracted workers. The instrument also meets the exclusion restriction, because the allocation of hours to other projects than the focal one does not logically have a direct effect on the performance of the focal project. Hence, for the second hypothesis we use the interaction term *Department Project Workload x Team Size* as instrument for *Subcontracted Labor Mix x Team Size*.

A third instrument is needed when testing both Hypotheses 2 and 3 in the same model, because multiplying one of the previously defined instruments (i.e., *Department Labor Mix* or *Department Project Workload*) with *Scope Changes* would lead again to inconsistent estimators. We address this problem by applying the following procedure recommended by Wooldridge (2002). We first run the first stage of the model regressing *Subcontracted Labor Mix* on *Department Average Labor Mix* and *Department Project Workload x Team Size* including all control variables and fixed effects. We then take the linear prediction from that model, multiply it with *Scope Changes* and use it as an instrument for *Subcontracted Labor Mix x Scope Changes*. We can thus create a valid instrument in order to test our third hypothesis.

Finally, Hypothesis 4 presents two endogenous variables (*Low* and *High-skilled Subcontracted Labor Mix*), which require two different instruments. Following the approach used to instrument

Subcontracted Labor Mix, we calculate the two variables *Department Average Low-skilled Labor Mix* and *Department Average High-skilled Labor Mix*. They capture the average values of *Low Subcontracted Labor Mix* and *High Subcontracted Labor Mix* from other projects than the focal one within the same department of the focal project. We expect them to be valid instruments for the same reasons previously discussed for *Department Subcontracted Labor Mix*.

To check the validity of the instruments we look at the overall R squared of the first stages, which are all above 80%, and the Wald Chi square statistics, which are all significant at 1% and very high, indicating high values of F-statistics too (well above the common threshold of ten) confirming that all our instruments are indeed not weak as suggested by Stock and Yogo (2005). Tables A1 and A2 of the appendix present the results of the first stage models for the four hypotheses, where the dependent variables are *Subcontracted Labor Mix, Low-* and *High-Subcontracted Labor Mix* as well as the two interaction terms. It is worth noting that many coefficients of the control variables are close to zero as they have too high values compared to the labor mixes.

Table 3 presents the results for the second stage of the proposed instrumental variable analysis. In model 1, *Subcontracted Labor Mix* is positive and significant at 1%, providing full support for Hypothesis 1. An increase of one standard deviation in *Subcontracted Labor Mix* increases *Project Margin* by 2.76%. In model 2 we add the interaction term with *Team Size*. The interaction term has a positive and significant at 1% coefficient, providing full support for Hypothesis 2. In model 3 we add the interaction of *Subcontracted Labor Mix* and *Scope Changes* and observe that it has a negative and partial significant at 10% coefficient providing partial support for our third hypothesis. In model 4 we include both interaction terms *Subcontracted Labor Mix x Team Size* and *Subcontracted Labor Mix x Scope Changes* and get full support for Hypotheses 2 and 3 as the coefficient of the latter interaction term is positive and significant at 1% and the coefficient of the latter interaction term is negative and significant at 1%. Finally, in model 5, we test the fourth hypothesis. Both *Low-skilled Subcontracted Labor Mix* and *High-skilled Subcontracted Labor Mix* have positive and significant at 1% coefficients. The coefficient of *Low-skilled Subcontracted Labor Mix* is also higher in magnitude than the one of *High-skilled Subcontracted Labor Mix*, providing full support for Hypothesis 4. A chi-square test ($\chi^2 = 18.27$, $p<0.01$) rejects the null hypothesis that the two coefficients are equal, providing further support for our hypothesis. An increase of one standard deviation in *Low-skilled Subcontracted Labor Mix*

increases project margin by 2.20%, whereas such an increase in *High-skilled Subcontracted Labor Mix* increases project margin by 1.64%.

5. Robustness Checks

5.1. Alternative operationalization of model variables

As previously observed, an alternative way to operationalize the extent to which a project relies on subcontracted workers is to compute a ratio of the hours worked by subcontracted workers over the hours worked by permanent employees. Compared to the measure we used as per Kesavan et al. (2014), this measure aims to capture the amount of work executed by subcontracted workers relative to permanent employees, instead of the number of subcontracted workers vs permanent employees. We hence create new measures for both *Subcontracted Labor Mix* as well as for *Low-skilled* and *High-skilled Subcontracted Labor Mix*. Regression results provide full support for all of the four hypotheses (see Table A3 of appendix), lending further credibility to our results.

We further check the robustness of our results for Hypothesis 4 by providing an alternative operationalization of *Low-skilled* and *High-skilled Subcontracted Labor Mix*. Specifically, we calculated the two ratios considering subcontracted workers from category 5 and 6 to be low-skilled and from 1 to 4 to be high-skilled (instead of considering only category 6 as low skilled workers). The results of our fourth hypothesis are supported again (see Appendix, Table A4).

A potential concern with our analysis could be driven by the log transformation of the team size variable, which corrects for team size skewedness. This transformation implies an assumption in the functional form on how team size directly and interactively affects project margins, which may influence our results. We therefore re-run regression models without log-transformation of the team size variable, and again find full support for the four hypotheses (see Appendix, Table A5).

Lastly, we did not log-transform experience-related variables in the model (i.e., *Client Familiarity*, *Individual Average Experience*, *Individual Average Expertise* and *Project Manager Role Experience*), while past research often used log-log models to estimate learning effects (Argote 1999, Cameron and Trivedi 2005, Cleves et al. 2010). While our choice was based on Tuckey (1977), we nevertheless applied logarithmic transformations to both experience-related variables and the dependent variable. Also, in this case we found full support for the four hypotheses (see Appendix, Table A6).

5.2. Alternative model specifications

While we find support for a linear relationship between *Subcontracted Labor Mix* and *Project Margin*, there is a chance that this relationship is non-linear (Kesavan et al. 2014). Specifically, one can expect that the marginal effect of using subcontracted workers might decrease or even turn negative beyond a specific value of *Subcontracted Labor Mix*. We therefore repeat the analysis for Hypothesis 1 after including the square term of *Subcontracted Labor Mix*, and for Hypothesis 4 after including the square terms of both *Low-skilled* and *High-skilled Subcontracted Labor Mix*. In all cases, we do not find evidence for a significant diminishing effect. Hence, it seems that in our sample there are no projects with a *Subcontracted Labor Mix* large enough to negatively affect *Project Margin*.

Next we investigate the robustness of the geographic area random-effects specification of our model. The projects in our setting are conducted in different geographic areas but are from the same company, therefore the random effects specification allows us to capture the unobserved characteristics of the different geographic areas, while not eliminating the common characteristics of the projects derived from being performed by the same company. Nevertheless, we repeat the analysis using geographic area fixed effects in order to confirm the robustness of the findings. The results provide full support for the four hypotheses (see Appendix, Table A7).

Furthermore, we check the robustness of the results including the on-going projects. As these projects have not been terminated at the time of the data collection, we do not have the final project margin available. However, the company provided the on-going margin for these projects. Our results again provide full support for all the hypotheses (see Appendix, Table A8).

Finally, we check if the results are driven by overfitting due to the limited sample size. In general, overfitting happens when a model includes too many parameters compared to the number of observations, a fact that can lead to wrong inferences (Freedman 2009). In order to mitigate this concern, we reevaluate support for the hypotheses using simpler regression models, obtained by dropping the insignificant continuous control variable (Aggarwal et al. 2015). More specifically, we drop *Individual Average Experience* from models 2 of Table 3. We get full support for all our hypotheses according to Table A9 of the appendix.

5.3. Additional Specification of Instrumental Variable Approach

A potential concern is that team size is not exogenous to our model as companies do not determine the size of the team randomly. In order to address this concern, we use additional instruments to confirm the robustness of our team size interaction hypothesis. We estimate two additional instruments, one for

Team Size and one for its interaction with *Subcontracted Labor Mix*. More specifically, similarly to our instrument of *Subcontracted Labor Mix* for Hypothesis 1, we estimate *Activity Average Team Size* by calculating the average team size of projects within the same activity as the focal project, excluding the focal one. We use this instrument for Hypotheses 1, 3 and 4 and the main effect of *Team Size* in Hypothesis 2. For the interaction term of the second hypothesis we instrument *Team Size* with the linear prediction of the first stage of the later model and interact it with the *Project Workload* instrument for *Subcontracted Labor Mix* to maintain the consistency with the main analysis presented in Table 3. The results provide full support for the four hypotheses (see Appendix, Table A10).

5.4. Alternative Explanations

The main mechanism we invoke to explain the effect of *Subcontracted Labor Mix* on project margin is higher motivation for subcontracted workers vis-à-vis permanent employee. This effect is largely supported by previous research (Allan and Sienko 1998, Engellandt and Riphanhn 2005, Ichino and Riphahn 2005, Bradley et al. 2014), consistent with the observed moderating effects and reflected in the views of managers and workers at the research site. However, data about workers' effort by project was not available at the research site, making it impossible to empirically pinpoint the mechanisms underlying Hypothesis 1. We hence check if the findings could be driven by alternative explanations to the one we provide.

To begin with, *Subcontracted Labor Mix* may positively affect project margin because of possible labor cost savings from the use of subcontracted workers compared to permanent employees. Managers at the research site reported that these costs are similar within each worker category skill level, but that hourly rates used for project accounting are loaded with a higher overhead for permanent employees than for subcontracted workers. To investigate if the results are independent from savings in hourly labor costs we re-run the regression models using an alternative dependent variable, *Margin Variation*. This variable is the difference between actual and expected (i.e. budget) project margin, divided by expected project margin. Project margin estimations are done before project kick-off, when hours for different skill categories and for subcontracted vs internal team members are budgeted. Project margin is hence not affected by hourly cost differentials. Yet, since estimated activity durations include safety buffers, a greater productivity of subcontracted team members would increase actual project margin, compared to the expected one. We repeat the analysis with the alternative dependent variable and find full support for our hypotheses (Table A11 of the appendix).

Subcontracted workers may also positively affect project margin because, by means of subcontracting, the employer can select specialists that possess the right expertise for the project (Boh et al. 2007). Project managers at the research site admitted that this could be the case at times, but also pointed out that, in general, subcontracting was pursued to overcome capacity limitations and test new talent before recruiting. This observation is consistent with the results for the test of Hypotheses 4, which indicates that low-skilled subcontracted workers have a stronger impact on project margin than high-skilled subcontracted workers. If subcontracting was benefiting projects due to inclusion of highly talented team members, the effect of high skilled subcontracted workers would have been stronger.

A third possible mechanisms through which *Subcontracted Labor Mix* may also affect project margin is through familiarity of subcontracted workers with permanent employees included in the project team. It may be that when *Subcontracted Labor Mix* is higher, familiarity among team members can be comparatively lower, thereby undermining project margins (Reagans et al. 2005, Huckman et al. 2009, Staats 2012, Avgerinos and Gokpinar 2017). To rule out this alternative mechanisms through which *Subcontracted Labor Mix* could impact project margin we create the variable *Average Team Familiarity*. We include the variable *Average Team Familiarity* in the regression model, calculated as in Reagans et al (2005), Huckman and Staats (2011), Staats (2012) and Avgerinos and Gokpinar (2017). Regression results do not change upon introducing this variable (see Appendix, Table A12). Nevertheless, to more precisely disentangle the effect of subcontracting project team members from their familiarity with permanent employees, we finally calculate the variable *Average Subcontracted Team Members Familiarity*, which captures the average familiarity among subcontracted and permanent team members. Also, in this case the statistical conclusions from the regression model do not change (see Appendix, Table A13). This follows our expectation too as higher subcontractor labor mix does not necessarily entail lower team familiarity: The two concepts are distinct and impact project performance through different mechanisms.

6. Conclusions and Discussion

Organizations increasingly staff project teams with both permanent and subcontracted workers to nimbly adapt to demand variation or access expertise not internally available (Cappelli and Sherer 1991, Cappelli 2000, Kalleberg 2000). Despite the importance of this phenomenon, empirical research has largely neglected the study of the impact of subcontracting team members on project performance. Instead, research on the effects of subcontracted workers has focused on repetitive operational environments such as retail or manufacturing assembly operations. Overlooking project operations is

problematic, because past findings on the effects of subcontracting in retail or assembly lines cannot be simply extrapolated to the more demanding tasks associated to project environments. With this paper, we attempt to address this research gap. To this end, we investigate the effects of subcontracted workers on project performance, considering possible contingency factors that intervene in this relation. We discuss hereafter the theoretical and practical implications of the findings from this research.

With this study, we extend the limited research on the financial consequences of subcontracted labor. We detect a positive and linear effect of *Subcontracted Labor Mix* on project margins, which increase by 175% as team composition moves from 0% to 60% of subcontracted workers (90^{th} percentile of *Subcontracted Labor Mix* variable). While it is plausible that at higher levels of subcontracting—unobserved in our sample—such effect would become marginally decreasing, our data point towards a linear association between subcontracted labor mix and project margin, in contrast to Kesavan et al. (2014) who detect a reverse U-shaped relation. This result downplays concerns for organizational tensions associated to subcontracting voiced by research in organizational behavior (George 2003, Davis-Blake 2003, von Hippel and Kalokerinos 2012). Our analyses also suggest that cost or talent differentials between subcontracted workers and permanent employees do not explain this finding. In fact, both field interviews and empirical research in subcontracting (Allan and Sienko 1998, Engellandt and Riphanhn 2005, Bradley et al. 2014) point towards heightened worker motivation as the underlying performance-improving mechanism. Overall, our results challenge the view that the advantages of subcontracting are restricted to volume flexibility and access to specialized labor. In reality, subcontracting also warrants motivational advantages that may not be offset by integration costs, at least in project-based operational environment where fluid working relations are customary.

A further counter-intuitive contribution of this study is that the benefits of subcontracted workers are stronger for less skilled workers than for more skilled ones. This finding is in line with the proposed motivational mechanism underlying the positive effect of subcontracting (Engellandt and Riphahn 2005). That is, less experienced, lower skilled workers are more likely to exert an extra effort during the project, being aware that they are more easily substitutable in case of unsatisfactory performance. As one informant put it: "The juniors are super motivated. For those of higher categories it is different […] because they have been working for many years and may question whether they really want to stay in the company or not, so they may not be as motivated." Managers at the site also agreed that subcontracting helps tapping talent not available internally (Bidwell and Briscoe 2009), but they

see this benefit as limited to specific individuals, and pointed out that reliance on this strategy is not necessarily reflected in the amount of subcontracting, as captured by *Subcontracted Labor Mix*.

The results of this study also address Mayer and Nickerson (2005) call for research investigating when projects can benefit more from using subcontracted labor. Specifically, we find that the positive effect of subcontracted workers is more prominent within larger project teams. This result complements the literature on the effect of team size on team performance, suggesting that the motivation, communication and conflict problems associated to large teams (Hackman 2002, Levine and Moreland 1998, Steiner 1972) can be mitigated by relying on subcontracted team members. Furthermore, occurrence of unexpected scope changes in a project tends to lessen the positive effect of *Subcontracted Labor Mix* on project margin. This result contributes to past research on task changes in project settings (Huckman and Staats 2011) suggesting that scope changes may induce unexpected costs of integrating subcontracted team members, which offsets the benefits of subcontracted workers.

In contrast to increased team size, occurrence of unexpected scope changes in a project tends to lessen the positive effect of *Subcontracted Labor Mix* on project margin. This result contributes to past research on task changes in project settings (Huckman and Staats 2011) suggesting that scope changes may induce unexpected costs of integrating subcontracted team members, which offsets the motivational benefits of subcontracted workers. If we consider project scope changes as a specific manifestation of project complexity, this result is consistent with the finding that complex projects benefit less from collaboration with external constituents (Novak and Eppinger 2001).

Our findings also provide important insights for managers. Regression results suggest that projects managers can increase their project margin if they use subcontracted workers when necessary. Specifically, an increase of 10% in subcontracted labor mix can increase project margin in our setting by 13.11%. Managers at the research site were surprised to learn about this finding. They considered subcontracting as a necessity and consolidated practice, but were not aware of the benefits of *Subcontracted Labor Mix* on project margin and the vast majority of project managers are concerned for the cost of integrating subcontracted workers, which drives to rely on this resource less that it would be financially optimal.

As in all empirical studies, ours comes with boundaries of validity and empirical limitations. First, our sample comes from a company that operates in a highly protective labor environment, with high cost of termination of full-time contracts. Generalizability of findings to countries characterized by less protective labor laws is not warranted and should be object of future replication studies. Second,

project-level data about worker motivation was not available, making it impossible to empirically investigate the postulated mechanisms through which subcontracted workers increase projects profitability. We nevertheless notice that both the literature and field interviews support the existence of a motivational effect of subcontracting, and that we could rule out competitive explanation by means of multiple analyses. Third, data about project schedule deviations was not available. It would be certainly of interest to study the effect of *Subcontracted Labor Mix* on schedule deviations. However, our model captures this effect because, as observed by multiple informants, schedule deviations automatically increase cost and ultimately reduce project margin. Fourth, multiple variables in our model capture different facets of project complexity, including project type, department, and team size, project duration as well as scope changes. Nevertheless, other unobservable dimensions of complexity could drive both project performance and subcontracting. We downplay this concern by using an instrumental variable approach but acknowledge as desirable that future research on the effect of subcontracting project team members would capture other dimensions of project complexity. Fifth, our interviews suggest that workers with lower expertise perform less complex tasks compared to their higher expertise colleagues, which may have an impact on the project margin. Even though our data lacks detailed information on the specific tasks performed by the workers, we aim at addressing this concern by first controlling for the average expertise level of the team members and second utilizing the instrumental variable approach. Sixth, our setting does not allow us to control for project worker, manager and client fixed effects due to the high number of different project managers (106 in our sample) and clients (88) and the small number of observations we have. We partially address this limitation by controlling for project manager role experience (i.e. number of past projects as project manager) and client familiarity (i.e. number of past projects with the same client). Moreover, we have limited information about project team members' background. Specifically, we do not have information about their employment history outside of the company. Future work could integrate this information to extend knowledge about how subcontracted project team members' individual characteristics affect project performance. Finally, we cannot study project profit margin in the different stages of the project. Our interviewees stated that the company aims at maintaining the team as stable as possible throughout the project to avoid incurring inefficiencies due to integrating and training new to the project employees. However, future work may supplement our study by studying the effect of changes in subcontracted labor mix throughout the project execution in response to increasing or decreasing project margins.

Answering the call to advance theories at the boundary of operations and human resource management (Boudreau et al. 2003) our study highlights the importance of subcontracted labor on project performance. Our results suggest that reliance on subcontracted workers within project teams positively affects project's financial performance, in particular when comparatively lower skilled workers are contracted. Additionally, we find this effect to be stronger for large project teams, and for projects that do not undergo sizeable scope changes. Overall, we extend past operations management research on the effects of subcontracting to project-based operations, and downplay the concern voiced by Organizational Behavior research about the downside of subcontracting.

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Table 1: Summary Statistics and Correlation Table of Dependent, Independent and Control Variables of Interest (n=256)

Variable		*Mean*	*S.D.*	*Min*	*Max*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	*Profit Margin*	-13.78	271.20	-4066.49	105.03	1.00														
2	*Subcontracted Labor Mix*	0.23	0.29	0	2	0.03	1.00													
3	*Low-skilled Subcontracted Labor Mix*	0.10	0.16	0	1	0.03	0.74**	1.00												
4	*High-skilled Subcontracted Labor Mix*	0.13	0.20	0	2	0.02	0.84**	0.25**	1.00											
5	*Team Size*	2.67	0.94	0	5.14	-0.18**	0.16*	0.20**	0.07	1.00										
6	*Scope Changes*	0.27	0.65	-0.99	3.65	0.09	-0.03	-0.03	-0.02	0.13*	1.00									
7	*Individual Average Experience*	72.86	55.29	0.67	343.5	0.02	-0.24**	-0.18**	-0.20**	-0.05	0.13*	1.00								
8	*Individual Average Expertise*	3.66	0.75	1	5.71	-0.02	0.47**	0.55**	0.24**	0.30**	-0.06	-0.39**	1.00							
9	*Client Familiarity*	6.78	8.53	1	39	0.07	0.38**	0.44**	0.18**	0.11+	-0.01	-0.07	0.30**	1.00						
10	*Project Manager Role Experience*	2.84	2.40	1	13	-0.03	0.15*	0.25**	0.01	0.06	0.00	0.02	0.19**	0.31**	1.00					
11	*Multi-team Membership*	6.62	3.12	1.28	19.67	0.06	-0.21**	-0.09	-0.23**	-0.16**	-0.00	-0.14*	-0.01	-0.18**	0.18**	1.00				
12	*Project Duration*	21.96	18.39	2	101	-0.04	0.02	0.03	0.01	0.69**	0.24**	0.11+	0.04	-0.04	-0.04	-0.01	1.00			
13	*Project Type*	0.30	0.46	0	1	0.06	-0.16**	-0.18**	-0.09	0.07	-0.02	-0.12+	-0.14*	-0.01	-0.08	0.12+	0.14*	1.00		
14	*Aeronautics and Vehicles*	0.37	0.48	0	1	0.06	0.37**	0.34**	0.26**	-0.05	0.17**	-0.20**	0.46**	0.26**	0.20**	-0.17**	-0.18**	-0.41**	1.00	
15	*Defense*	0.16	0.36	0	1	-0.19**	-0.02	-0.08	0.04	0.13*	-0.13*	0.15*	0.00	-0.20**	-0.25**	-0.15*	0.17**	0.17**	-0.33**	1.00
16	*Healthcare Equipment*	0.01	0.06	0	1	0.01	-0.04	-0.01	-0.04	0.01	-0.03	-0.02	0.01	-0.04	0.00	-0.00	-0.03	-0.04	-0.05	-0.03

+,* and ** denote significance at 10%, 5% and 1% levels respectively

Note that the descriptive statistics of the log transformation of the *Team Size* variable has been shown.

Table 2: Regression of Subcontracted Labor Mix on Profit Margin

	(1)	(2)	(3)	(4)	(5)	(6)
Subcontracted Labor Mix		108.274**	-85.427**	107.479**	-132.970**	
		(30.658)	(15.533)	(29.181)	(37.381)	
Low-skilled Subcontracted Labor Mix						136.655**
						(40.962)
High-skilled Subcontracted Labor Mix						95.670**
						(27.230)
Subcontracted Labor Mix x Team Size			83.093**		102.370**	
			(20.767)		(29.357)	
Subcontracted Labor Mix x Scope Changes				-32.242	-105.705*	
				(33.051)	(50.233)	
Team Size	-93.665**	-93.149**	-115.854**	-92.099**	-117.680**	-93.769**
	(31.587)	(30.910)	(41.762)	(29.368)	(41.918)	(31.530)
Scope Changes	25.288**	27.064**	28.119**	32.977**	47.750**	27.217**
	(6.313)	(6.559)	(6.493)	(4.551)	(7.746)	(6.438)
Individual Average Experience	0.217**	0.279**	0.283**	0.283**	0.295**	0.276**
	(0.073)	(0.083)	(0.063)	(0.089)	(0.073)	(0.073)
Individual Average Expertise	38.298**	26.507**	30.992**	27.266**	34.519**	24.457**
	(13.846)	(9.047)	(10.757)	(10.006)	(13.306)	(8.268)
Client Familiarity	2.426*	1.505	0.590	1.616	0.742	1.358
	(1.160)	(0.994)	(0.657)	(1.145)	(0.830)	(0.962)
Project Manager Role Experience	-14.504	-16.162	-17.783	-16.247	-18.439	-16.388
	(10.014)	(10.345)	(11.061)	(10.506)	(11.620)	(10.289)
Multi-team Membership	4.585**	6.463**	6.061**	6.673**	6.656**	6.277**
	(1.222)	(1.710)	(1.519)	(1.920)	(1.812)	(1.669)
Project Duration	2.658*	2.568*	2.648*	2.551*	2.614*	2.582*
	(1.096)	(1.048)	(1.151)	(1.020)	(1.110)	(1.069)
Project Type	62.578	67.794	72.230	67.888	73.569	68.723
	(53.199)	(57.491)	(58.441)	(57.882)	(59.666)	(57.898)
Constant	13.331	21.287	63.703+	14.600	51.618+	29.625
	(17.110)	(17.766)	(34.359)	(13.411)	(26.509)	(20.126)
Observations (N)	256	256	256	256	256	256
Start Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Project Department FE	Yes	Yes	Yes	Yes	Yes	Yes
Overall R^2	0.1276	0.1351	0.1426	0.1354	0.1452	0.1354

Models are OLS random-effects models with robust standard errors, clustered on Geographic area.
+, * and ** denote significance at 10%, 5% and 1% levels respectively.

Table 3: IV Regression of Subcontracted Labor Mix on Profit Margin

	(1)	(2)	(3)	(4)	(5)
Subcontracted Labor Mix	131.142**	-1,816.195**	127.904**	-2,186.916**	
	(19.860)	(564.320)	(18.239)	(664.892)	
Low-skilled Subcontracted Labor Mix					189.917**
					(31.245)
High-skilled Subcontracted Labor Mix					113.281**
					(16.597)
Subcontracted Labor Mix x Team Size		930.072**		1,020.843**	
		(284.528)		(306.730)	
Subcontracted Labor Mix x Scope Changes			-15.740+	-878.070**	
			(8.546)	(237.756)	
Team Size	-93.039**	-346.132**	-92.541**	-343.006**	-94.166**
	(13.279)	(127.953)	(11.338)	(121.277)	(12.808)
Scope Changes	27.439**	42.870**	30.279**	202.807**	27.826**
	(5.201)	(5.694)	(4.919)	(53.906)	(5.740)
Individual Average Experience	0.292**	0.461	0.292**	0.484*	0.289**
	(0.072)	(0.348)	(0.084)	(0.239)	(0.070)
Individual Average Expertise	24.017**	50.172**	24.698**	90.700**	19.573**
	(3.795)	(8.613)	(4.179)	(22.864)	(3.256)
Client Familiarity	1.310*	-10.803*	1.388*	-7.609**	0.987*
	(0.615)	(4.269)	(0.549)	(2.599)	(0.452)
Project Manager Role Experience	-16.512**	-38.035**	-16.510**	-40.030*	-17.022**
	(5.488)	(13.903)	(4.888)	(16.441)	(4.923)
Multi-team Membership	6.860**	6.192**	6.913**	9.079**	6.607**
	(1.123)	(1.631)	(1.497)	(2.306)	(1.299)
Project Duration	2.548**	3.265**	2.543**	3.029**	2.572**
	(0.571)	(1.137)	(0.514)	(0.920)	(0.467)
Project Type	68.895*	129.189*	68.804*	129.983*	70.884*
	(32.349)	(57.424)	(30.262)	(60.440)	(32.072)
Constant	22.967*	513.961*	19.493	368.068+	38.932**
	(11.598)	(261.124)	(13.736)	(193.293)	(12.726)
Observations (N)	255	255	255	255	255
Start Year FE	Yes	Yes	Yes	Yes	Yes
Project Department FE	Yes	Yes	Yes	Yes	Yes
Overall R^2	0.1347	0.0485	0.1350	0.0512	0.1347
Wald ch2 (Pr>chi2)	<0.001	<0.001	<0.001	<0.001	<0.001

Models are 2SLS random-effects models with bootstrap standard errors.
+, * and ** denote significance at 10%, 5% and 1% levels respectively.