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The Complementary Effect of Organizational Practices and Workers' Level of Education*

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Abstract

This paper investigates how firms' productivity is affected by the relationship between organizational practices and workers' level of education. Using firm-level panel data covering the period 2002 to 2008, I estimate complementarities among workers' level of education and a large set of organizational practices aggregated into three domains: decentralization, incentive pay, and work design—where work design comprises job rotation and teamwork. I consider workers with four levels of education: no post-compulsory education, upper-secondary vocational education and training, tertiary vocational education, and tertiary academic education. The results indicate that the complementarity between education and the extent of firms' decentralization is higher for tertiary-educated workers. In contrast, the estimations reveal no complementarity between incentive pay and higher levels of workers' education. Furthermore, complementarity exists between work design and tertiary-educated workers, especially workers with a tertiary vocational education. Finally, the estimations using an aggregate measure of organization suggest complementarities across organizational practices.

JEL-Classification: J24, L23

Keywords: complementarity, education, organization, productivity

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1 Introduction

A large strand of the economic literature focuses on issues relating to organizational management, and a number of studies support the idea that organizational practices play a crucial role in determining firms' productivity (e.g., Milgrom & Roberts, 1995, Black & Lynch, 2005, Brynjolfsson & Milgrom, 2013; see also Gibbons & Roberts, 2013, for an overview on this topic). The literature also documents the beneficial effect of combining multiple organizational practices within firms. For example, Ennen & Richter (2010) suggest that complementarities occur between and among different organizational practices. Yet, surprisingly, relatively few studies examine the complementarity between different organizational practices and workers' education (Cappelli, 1996, Greenan & Mairesse, 1999, Bresnahan et al., 2002). The paucity of such research leaves unanswered the question of whether the effect of organizational practices on productivity depends on the educational composition of the workforce.

One exception is Caroli & Van Reenen (2001), who develop a model of skills-biased organizational change (SBOC). Starting with evidence that recent changes in work organization have shifted firms' strategy from mass production and bureaucratic controls toward more flexible and decentralized organization, they argue that skilled workers benefit more than other workers from those organizational changes. Specifically, they state that skilled workers are more able to analyze and synthesize new information, and that they are better at communication, more autonomous, and more likely to enjoy job enrichment. For these reasons, they conclude that skilled workers are complementary to the organizational changes that took place over the last two decades.

By analyzing specific organizational practices, three recent studies provide support for the SBOC model. For example, Bloom & Van Reenen (2011) show that decentralization is complementary to more educated workers because they are more able than lower-educated workers to process new types of knowledge in a decentralized setting. Furthermore, Kampkötter et al. (2018) suggest that organizational practices such as job rotation are especially beneficial for high-skilled workers. Finally, Bandiera et al. (2009) suggest that incentive pay tends to have stronger effects on more able workers, who generally have a higher level of education.

Despite evidence supporting the SBOC model, this stream of the empirical literature basically focuses on the percentage of tertiary-educated workers as a proxy for skilled workers. By so doing, these studies largely neglect the complex educational composition of the workforce.

Therefore, whether complementarities also exist between organizational practices and workers with a vocational education (ISCED 1997 levels 3B/3C/4B), or whether complementarities for workers with a tertiary academic education (ISCED 1997 levels 5A/6) are larger than for those with a tertiary vocational education (ISCED 1997 level 5B) remains unclear. Accounting for heterogeneity among different levels and types of education is particularly valuable for those European countries (e.g., Austria, Denmark, Germany, and Switzerland) in which the majority of the workforce has a vocational education or training (VET)[1]. Indeed, by providing both practical and theoretical skills, VET offers more than merely a middle path between high- and low-skilled workers (Hoeckel & Schwartz, 2010).

Using the educational structure of the Swiss labor force[2], this paper empirically investigates how organizational practices are complementary to workers with different levels of education in terms of affecting firms' productivity. Specifically, I subdivide workers into four levels: workers with no post-compulsory education, workers with an upper-secondary VET diploma, workers with a tertiary vocational degree, and workers with a tertiary academic degree. With respect to organization, I focus on three broad domains of organizational practices: decentralization, incentive pay, and work design (which is measured by job rotation and teamwork).

For the analysis, I rely on the KOF Innovation Survey, a paper-based survey of about 1,500 Swiss firms in each wave, closely resembling the European Community Innovation Survey. Aside from basic firm characteristics, the KOF Innovation Survey focuses on capturing firms' organizational structure and processes, thereby providing an ideal data set for analyzing the complementarities between workers' level of education and organizational practices. Specifically, the data reports information on whether certain responsibilities are held by employees or supervisors, how frequently the firm uses teamwork, and how frequently employees rotate their jobs. To assess complementarities between organizational practices and workers' levels of education I use the analytical framework of a production function at the firm level.

[1] I use the terms "upper-secondary VET" and "tertiary VET" for education programs that prepare their students for labor market entry in specific occupations. "Occupation" refers to the profession for which a young person receives training and is synonymous with vocation or trade.

[2] The Swiss education system has both an academic and a vocational track at the upper-secondary and tertiary levels. After finishing compulsory education, the vast majority of Swiss youngsters start a vocational education (either dual-VET or full-time VET-school) and receive a nationally recognized VET diploma that gives them access to vocational institutions at the tertiary level: Professional Education and Training Colleges and (Advanced) Federal Professional Education and Training Exams, as well as, in the time frame of the used sample, Universities of Applied Sciences, which are part of tertiary VET even though they deliver bachelor and master degrees. In contrast, the proportion of pupils opting for general education courses at upper-secondary level is relatively small (about 20%). See Wolter et al. (2018) for a detailed description of the Swiss education system.

In line with the predictions derived by the SBOC model, I find evidence of a complementary relationship between tertiary-educated workers and work design. Tertiary-educated workers benefit from work design more than workers with no post-compulsory education or a VET diploma, which exhibit similar complementarity. Similarly, the complementarity between decentralization and workforce education is consistent with the predictions of the SBOC model. My estimations suggest that workers with no post-compulsory education and workers with an upper-secondary VET diploma exhibit a similar degree of complementarity with decentralization, as do workers with either a tertiary vocational education or a tertiary academic education. These findings, however, show a different pattern from that suggested by the SBOC model (Caroli & Van Reenen, 2001), primarily because the complementarities I find do not increase in a linear way. While the SBOC model essentially predicts that complementarities increase with the increased education of the workforce, my findings are much more nuanced.

Furthermore, I find no evidence that a higher level of workers' education is complementary to incentive pay. My findings in this organizational domain do not fit the SBOC, because the complementarities I find do not increase in increasing the level of education, but are only larger for workers with tertiary vocational education.

Finally, this paper also contributes to the strand of the literature analyzing complementarities across organizational domains (Milgrom & Roberts, 1995, Ichniowski et al., 1997, Bresnahan et al., 2002, DeVaro & Kurtulus, 2010, Hong et al., 2016). In line with these studies, I test whether an aggregate measure based on all three organizational domains—decentralization, work design, and incentive pay—shows higher levels of complementarity than single organization domains. The results reveal an overall complementarity between all three domains and worker levels of education, a complementarity larger than the average of the three domains. This result suggests the existence of complementarity across organizational practices. This last finding is in line with the firm organization literature (e.g., Ichniowski & Shaw, 2003, Brynjolfsson & Milgrom, 2013), which suggests that firms often implement organizational practices in bundles.

The rest of the paper is organized as follows. Section 2 presents the conceptual framework of the study and derives the hypotheses. Section 3 describes the data set, and Section 4 explains the estimation strategy. Section 5 presents the results of the analysis. Section 6 concludes.

2 Organizational Practices and Hypotheses on Complementarity

A growing body of literature in organizational economics over the past three decades supports the idea that organizational capital can significantly contribute to firms' productivity (see for example Gibbons & Roberts, 2013, for an overview on this topic). However, as with other intangible assets, a general description of firms' organizational capital has not been established. One highly useful description comes from Brynjolfsson & Saunders (2009), who say that organizational capital is best understood as "the stock of intangible and non-tradable assets which conceptually have some similarities to physical assets." Different authors attempt to disentangle organizational capital into organizational practices and to classify them into distinct domains.

Black & Lynch (2005) focus on the organizational practices that have been shown to be associated with higher productivity. They divide organizational capital into three broad components: employee voice, work design, and workforce training. Employee voice is described as the organizational structures that give workers larger discretion and autonomy into the decision process. Examples of employee voice practices are suggestion box, employees' individual consultations, job enrichment schemes, employees' consultations groups, and forms of self-management. Black & Lynch (2005) describe work design as the use of production practices that allow a more flexible allocation of labor within a firm. Examples of work design practices are changes in the number of management levels within the firm or the existence and diffusion of job rotation and job share arrangements. Furthermore, they argue that also workplace training can be considered as organizational practice, given that it is the result of the joint decision of workers and firms. Training linked to the introduction of new technologies is mentioned as an example of workplace training. Finally, the authors state that incentive-based compensation—although not a type of organizational capital per se—is also an important organizational practice. Indeed, incentive-based pay schemes can compensate workers for risks taking actions aiming at improve the production process.

However, different authors provide a wider perspective on work. Besides the three organizational domains mentioned by Black & Lynch (2005), organization some other practices have been investigated by the literature. For instance, besides considering work design (e.g., work flexibility and job rotation) and the distribution of decision rights (e.g., autonomy and decentralization), Bloom & Van Reenen (2011) also mention teamwork (e.g., who works with whom) and information provision. Additionally, Gibbons & Roberts (2013) suggest that also the span of

control—that is, the number of subordinates that a manager can oversee—is a relevant domain in firms' organizational structure. Teuber et al. (2016) suggest however, that companies adapt the span of control as a reaction to institutional settings, and therefore the direct effect of this organizational practice is not clear cut. Finally, Ichniowski & Shaw (2010) stress the importance of incentive pay as an important dimension of work organization.

Only partially related to the literature on work organization, the labor economics literature suggests that labor unions are also an import work organization factor (see Freeman & Medoff, 1984). However, recent evidence provided by DiNardo & Lee (2004) suggests that unions have no effect on labor productivity.

In this paper, I take a normative approach and subdivide organizational practices into three main domains: decentralization, work design, and incentive pays. This subdivision is largely based on the structure of Black & Lynch (2005), by including work design and by considering decentralization as a broader dimension of employee voice. However, contrary to Black & Lynch (2005), I do not consider workforce training as an organizational domain given my interest in the complementary relationship between organization and education[3]. In contrast, following the comment of Shaw (2005) on Black & Lynch's article, I include incentive pay as a key measure of organizational capital.

The remainder of this section deepens the three organizational domains of decentralization, work design, and incentive pays by presenting a literature review on the relationship between these practices and workers' level of education. Building on the evidence from these three domains, I then derive my hypotheses on the complementarity between workers' education and organizational practices. Lastly, I conclude this section by discussing the implications for the complementarity between organization and workers' education.

2.1 Decentralization

One of the most studied aspects of workplace organization is decentralization, a measure of the distribution of decision rights across workers (Black & Lynch, 2005). For example, decentralization shows to what degree decision rights are delegated to the different parts of a firm, or how much control over the pace of work is delegated by the manager. The degree of decentralization represents a trade-off for firms: On one hand, decentralization reduces the costs of information

[3]Nevertheless, in the empirical specification, I control for the intensity of firms' internal training. By doing so, I take into account firms' possibility to affect workers' human capital though the provision of on-the-job training.

and communication (Bolton & Dewatripont, 1994), increases firms' speed of response to market changes (Thesmar & Thoenig, 2007), and may increase productivity through rising job satisfaction (Bloom & Van Reenen, 2011). On the other hand, decentralization may increase the risk of information duplication, makes exploiting returns to scale more difficult (Thesmar & Thoenig, 2000), and can reduce workers' efficiency if the decentralization induces rising stress (Askenazy, 2001). Finally, decentralization can also create coordination inefficiencies across different parts of the firm (Alonso et al., 2008).

The literature on the relationship between decentralization and workers' education is less extensive. From a theoretical standpoint, Bloom & Van Reenen (2011) suggest that decentralization could be complementary with workers who are more educated, because they are more able to process new types of knowledge in a decentralized setting. Furthermore, they argue that highly educated workers are more autonomous and less likely to make mistakes. For productivity, I expect that skills-intensive firms experience larger productivity growth when decentralizing.

Using early waves of the Swiss data that I use in this paper, Arvanitis & Loukis (2009) find evidence of the interaction effect between human capital and employee voice—a measure of individual job enrichment programs and decentralization. Their results suggest that, at least in Swiss firms, the combination of human capital—defined as the percentage of tertiary-educated workers—and decentralization is performance-enhancing. Arvanitis & Loukis (2009) argue that this complementary effect is economically plausible, because the existence of high-skilled workers is a precondition for an efficient application of decentralization.

Drawing on this evidence, I assume that decentralization shows complementarity with increasing levels of workers' education, and make the following hypothesis:

H1a: The complementarity between *decentralization* and workers' education in affecting firms' productivity increases with workers' level of education.

2.2 Work design

Work design describes the practices that involve changes in the occupational structure of the workplace. Specifically, according to Black & Lynch (2005), the concept of work design includes the existence and diffusion of job rotation, practices affecting the number of management levels within the firm, and the level of cross-functional co-operation.

The following three studies suggest multiple reasons for why job rotation can be beneficial for firms. Ortega (2001) argues that job rotation increases the employees' motivation and skills, and

offers managers an effective opportunity for learning about their employees. Nevertheless, firms do not adopt job rotation uniformly across all employees. Kampkötter et al. (2018) point out that job rotation is much less prevalent among high-performing workers, despite being especially beneficial for them.

Teamwork is another organizational practice with a positive impact on firms' productivity. As Arvanitis (2005) emphasizes, different forms of teamwork (e.g., project groups, quality circles, and semi-autonomous teams) have a significant positive effect on labor productivity. For the complementarity relationship with education, Arvanitis (2005) finds insignificant interaction between teamwork and the workforce level of education or exposure to continuing training. However, their analysis is based on a cross-section estimation, a method that does not take possible unobserved heterogeneity into account.

Drawing on the evidence from job rotation and teamwork, I assume that all of these organizational practices show complementarity with increasing levels of workers' education, and make the following hypothesis:

H1b: The complementarity between *work design* and workers' education in affecting firms' productivity increases with workers' level of education.

2.3 Incentive pay

Many studies shows a positive effect of incentive pay on productivity, both at the individual and group levels (see for example Lazear & Gibbs, 2014 for an overview of this subject). For individual-level incentive pay, researchers show—in addition to the pure incentive effect—an additional selection effect, which also generates higher productivity (Lazear, 2000). As the pure incentive effects are stronger for more able workers, incentive pay tends to be associated with a greater dispersion of productivity (Lazear, 2000). For example, Bandiera et al. (2009) show that, following the introduction of incentive pay, managers targeted their efforts toward high-ability workers, independently of prior social connections with the workers. Even though incentive pay programs may sometimes backfire, the literature suggests a general positive effect on productivity (e.g., Oyer et al., 2011).

When firms cannot accurately identify the contribution of each worker, group pay incentives or firm profit-sharing represent alternatives to individual pay. However, both group incentives and firm profit-sharing alternatives might face possible free-rider problems, which would eventually diminish productivity (Kamenica, 2012). Nevertheless, Ichniowski & Shaw (2003) point out

that firms can mitigate free-rider problems by combining group incentive pay with additional work innovation practices, such as work environment and managerial culture, in which peer pressure enforces incentives.

Studies on the relationship between group incentive pay and workers' education is sparse. In one of the few papers looking at the possible complementary effect between incentive pay and workers' level of education, Arvanitis & Loukis (2015) hypothesize that team compensation is more convenient for high-skilled workers than low-skilled ones. Nevertheless, their estimations on Swiss and Greek firm data do not support this hypothesis.

As the empirical literature offers mixed results, I rely on the theoretical literature, which suggests a complementary effect between incentive pay and workers' level of education. Based on this, I formulate the following hypothesis on the effect of incentive pay, both at the individual and the group levels:

H1c: The complementarity between *incentive pay* and workers' education in affecting firms' productivity increases with workers' level of education.

2.4 Complementarities between organizational practices

Milgrom & Roberts (1990), in an influential work, enhance the idea that complementarity not only refers to the relationship between two inputs but can also arise from the combination of groups of activities. Milgrom & Roberts (1995) show that the complementarity between different organizational practices is an important explanation for the persistent differences in performance across firms. Since then, several studies have explored the complementarities between different organizational practices or bundles of practices.

Ichniowski et al. (1997) analyze complementarities between workplace organizational practices in U.S. steel production, finding evidence of mutual complementarity between incentive pay, teams, flexible job assignments, and employment security. Furthermore, they suggest that, although single organizational practices have little effect on productivity, clusters of these organizational practices have clear positive effects. Bresnahan et al. (2002) conduct an analysis among 300 large U.S. firms, from both the manufacturing and service industries, and came to similar conclusions to Ichniowski et al. (1997) on complementary in workplace organization.

More recently, using data from British firms, DeVaro & Kurtulus (2010) provide evidence of a positive relationship between incentive pay and the delegation of worker authority, which they define as the amount of worker discretion over how tasks are performed. Hong et al. (2016),

using firm-level panel data on management practices in Canadian firms, show the existence of complementarities between performance-based incentives and the decentralization of decision-making authority.

All these studies stress the beneficial interplay between multiple elements within the organizational system. Similarly, one would expect that complementarities between workers' education and the organization arise among multiple organizational practices. For example, if the benefit the firm derives from simultaneously introducing incentive pay and decentralization is higher than the sum of the benefits of introducing each domain separately, then the complementary relationship between workers' education and a firm's organization is higher when the firm introduces practices in both domains. Based on this complementary relationship among organizational domains, I formulate the following hypothesis:

H2: Workers' level of education and an *index covering all organizational practices* from the domains of decentralization, work design, and incentive pay are complementary in affecting firms' productivity, and this complementary effect is larger than that of any single organizational domain.

3 Data and description of variables

The data used in this study were collected by the KOF Swiss Economic Institute through an innovation survey among Swiss firms in 2002, 2005, and 2008. The survey covers approximately 1,500 firms per wave. The response rates are around 39.6% (2002), 38.7% (2005), and 36.1% (2008). Given the relatively demanding questionnaire[4], these response rates are satisfactory. The surveys are based on stratified random samples drawn from the Swiss business census for firms with more than five employees.

The data was pooled to a data set of 3,544 observations. This data set includes all firms having information on workers' level of education and firms' organizational practices. The data set also contains information on financial variables (such as firms' total value added) and firms' basic structural characteristics.

Table 1 describes the main variables used for the empirical analysis. The descriptive statistics of all these variables are reported in Table A3 in the Appendix. To investigate the complementarity effects of organizational practices and workers' education on firms' productivity, I focus on

[4]The questionnaires are available online in all Swiss official languages (German, French, and Italian) at `https://kof.ethz.ch/en/surveys/structural-surveys/kof-innovation-survey.html`

two main sets of variables. First, I subdivide workers into four educational groups: "Lower" educated workers have no post-compulsory education, "trained" workers have an upper-secondary VET education, "advanced" workers have a tertiary vocational education, and "academic" workers have a tertiary academic education. It is noteworthy that, given the structure of the Swiss education system, only a few workers with a diploma from an upper-secondary general education as their highest degree end up in the labor force. For this reason, the survey does not explicitly ask for the share of workers with this kind of education. All four groups of workers have a minimum value of zero[5], meaning that no group of workers is employed in all firms with at least one worker. Because all labor variables enter in the estimations in logs, I add one to all variables before taking logarithms. By so doing, I avoid generating variables with negative values. This procedure is robust to different specifications[6].

Next, I construct three measures of organizational practices corresponding to the main domains identified in the literature: decentralization, work design, and incentive pay. Table A1 in the Appendix gives a detailed description of the composition of these three variables. The measure of decentralization is based on five questions that quantify the assignment of responsibility for speed of work, sequence of work, distribution of tasks, performance of tasks, and way of dealing with problems on a Likert scale ranging from 1 to 5 (1="line manager decides alone"; 5="employee decides alone"). Work design is based on the intensity of teamwork and the intensity of job rotation, both measured on a Likert scale ranging from 1 to 6 (1="not present"; 6="very common"). The extent of compensation based on individual performance, workgroup performance, or firm performance is measured on a Likert scale ranging from 1 to 5 (1="low importance"; 5="high importance").

The aggregation of the different items is confirmed by the factor analysis reported in Table A2. The rotated factor loadings suggest that the ten organizational practices reflect three distinct constructs, and that the three dimensions are internally consistent. Indeed, the practices referring to decentralization, incentive pay, and work design load into three different factors with sufficient strength.

[5]Table A3 reports the summary statistics of these variables.

[6]Estimations adding 0.1 or 10 to the labor inputs before taking the logarithm provide qualitatively similar results.

Table 1: Variables description

Dependent variable	
Firm output	
Value added	Total value added, logarithm.
Independent variables	
Capital	
Capital	Firm's total capital stock calculated based on perpetual inventory methodology
Workforce education	
Lower	Total number of untrained employees and dual VET students in a firm, logarithm.
Trained	Total number of employees in a firm with an upper secondary VET education, logarithm.
Advanced	Total number of employees in a firm with a tertiary vocational education (incl. university of applied sciences), logarithm.
Academic	Total number of employees in a firm with a conventional university (academic) tertiary education, logarithm.
Organization	
Decentralization*	Extent of decentralization of responsibilities. Mean of five variables on decentralization: (1) speed of work, (2) sequence of tasks, (3) assignment of tasks, (4) modality of the execution of tasks, and (5) problems in production.
Work Design*	Occupational structure of the workplace. Mean of three variables: (1) teamwork, (2) job rotation and, (3) number of hierarchical layers.
Incentive Pay*	Extent of compensation based on performance. Mean of three variables: (1) firm performance, (2) workgroup performance, and (3) individual performance.
Organization index	Overall measure of organizational practices. Mean of decentralization, work design, and incentive pay.
Control variables	
Intermediary goods	Purchasing costs for intermediary inputs in a firm, logarithm.
Continuing Education	Share of employees taking part in continuing training (%).
Industry dummies	Industries are grouped in 33 industries according to the NACE Rev 1.1 classification.

Notes: * See Table A1 for a detailed description of the components and measurements of the organizational variables.

To deal with differences in the Likert scales, I standardize all variables referring to the organizational practices to mean 0 and unit variance.[7] I then average the variables in each domain.[8] Furthermore, to test the hypothesis of the aggregate effect of all organizational practices (H2), I create a measure that aggregates the values of decentralization, work design, and incentive pay into a single value, which I call the "organization index".

Workers' level of education is measured at the firm level and defined according to the highest educational degree they achieved. However, firms can affect workers' human capital by providing on-the-job training. Therefore, to account for possible differences across firms in the intensity of internal training, I control for the share of employees taking part in continuing training. Finally,

[7] See Bresnahan et al. (2002) for a related procedure.

[8] Estimations based on the predicted values derived from the factor analysis provide qualitatively similar results.

I derive industry dummies from a variable, coding all firms according to their NACE 2-digit classification.

4 Empirical strategy

To assess complementarities among workers' level of education and organizational practices, I use quantitative regression analysis. Following the interaction approach (Ennen & Richter, 2010), I estimate production functions that allow me to identify complementarities among inputs.

In particular, I assume that firms' productivity is determined by the capital stock, the number of workers with different education levels, and the intensity of adoption of organizational practices. All labor and organizational inputs enter into the production function linearly and with a quadratic term, in order to account for economies of scale. Additionally, I include interaction terms between the number of workers subdivided into the four categories and the organizational practices. These interaction terms allow the identification of complementarities across organizational practices and workers' level of education.

I define the production function as follows:

$$\begin{aligned} VA_{it} = \; & \alpha + \beta \; K_{it} + \sum_{s=1}^{4} \zeta_s \; L_{s,it} + \sum_{s=1}^{4} \eta_s \; L_{s,it}^2 + \theta \; Org_{it} + \vartheta \; Org_{it}^2 \\ & + \sum_{s=1}^{4} \lambda_s \; L_{s,it} \; Org_{it} + \psi \; Training_{it} + \varphi_j + \mu_t + \epsilon_{it} \end{aligned} \tag{1}$$

where VA_{it} is the log of total value added of firm i at time t. K_{it} is the log of capital stock, while $L_{s,it}$ is the number of workers with education s in firm i at time t. Org_{it} represents intensity of organizational domain adopted by firm i at time t. $Training_{it}$ is the share of employees in firm i taking part in continuing training at time t. φ_j and μ_t introduce industry and time fixed effects, respectively. ϵ_{it} is the error term, clustered at the firm level.

In my baseline estimates, I estimate equation 1 by OLS. However, such estimations might suffer from possible bias due to time-invariant unobserved heterogeneity or from simultaneity (short-run endogeneity of firms' education-mix composition). To overcome this endogeneity issue, I follow Levinsohn & Petrin (2003) and use the control function technique to estimate production functions. This technique, which builds on the influential work of Olley & Pakes

(1996) and was further elaborated by Levinsohn & Petrin (2003), suggests that intermediate inputs (e.g., materials) can be used as a proxy for unobservable productivity shocks.

Specifically, following the control function approach I redefine the production function as:

$$VA_{it} = \alpha + \beta\ K_{it} + \sum_{s=1}^{4} \zeta_s\ L_{s,it} + \sum_{s=1}^{4} \eta_s\ L_{s,it}^2 + \theta\ Org_{it} + \vartheta\ Org_{it}^2$$
$$+ \sum_{s=1}^{4} \lambda_s\ L_{s,it}\ Org_{it} + \psi\ Training_{it} + \varpi M_{it} + \varphi_j + \mu_t + \omega_{it} + \eta_{it} \quad (2)$$

All parameters are defined as above, with the only difference being that here M_{it} represents the log of intermediate inputs. Furthermore, the error term has two components now: ω_{it} is the productivity component that is potentially endogenous, η_{it} is the part of error term that is uncorrelated to the inputs.

Furthermore, I assume that the demand for intermediate inputs M_{it}=$M(\omega_{it}, K_{it})$ depends on firms' capital, K_{it}, and the unexpected productivity shock, ω_{it}. Under the assumption that the demand function is monotonically increasing in ω_{it}, one can invert the demand function and express the unobservable productivity shock as a function of the two observed inputs, i.e. ω_{it}=$\omega_{it}(K_{it}, M_{it})$

The production function can thus be rearranged in the following way:

$$VA_{it} = \sum_{s=1}^{4} \zeta_s\ L_{s,it} + \sum_{s=1}^{4} \eta_s\ L_{s,it}^2 + \theta\ Org_{it} + \vartheta\ Org_{it}^2 + \sum_{s=1}^{4} \lambda_s\ L_{s,it}\ Org_{it}$$
$$+\psi\ Training_{it} + \phi_{it}(K_{it}, M_{it}) + \varphi_j + \mu_t + \eta_{it} \quad (3)$$

where

$$\phi_{it}(K_{it}, M_{it}) = \alpha + \beta\ K_{it} + \omega_{it}(K_{it}, M_{it})$$

As Levinsohn & Petrin (2003) suggest, using a third-order polynomial approximation[9] of K_{it} and M_{it} in place of $\phi_{it}(K_{it}, M_{it})$ allows us to estimate in the first stage the following equation:

$$VA_{it} = \delta_0 + \sum_{s=1}^{4} \zeta_s \, L_{s,it} + \sum_{s=1}^{4} \eta_s \, L_{s,it}^2 + \theta \, Org_{it} + \vartheta \, Org_{it}^2 + \sum_{s=1}^{4} \lambda_s \, L_{s,it} \, Org_{it}$$
$$+\psi \, Training_{it} + \sum_{p=0}^{3} \sum_{q=0}^{3-p} \delta_{pq} K_{it}^p M_{it}^q + \varphi_j + \mu_t + \eta_{it} \tag{4}$$

where δ_0 is not separately identified from the intercept of $\omega_{it}(K_{it}, M_{it})$. This first stage gives us estimates of $\widehat{\zeta_p}$, $\widehat{\eta_p}$, $\widehat{\theta}$, $\widehat{\vartheta}$, $\widehat{\lambda_p}$, $\widehat{\psi}$, $\widehat{\varphi_j}$, $\widehat{\mu_t}$ and $\widehat{\phi_{it}}$.

The second stage starts by computing the estimated value for ϕ_{it}:

$$\widehat{\phi_{it}} = \widehat{VA_{it}} - \sum_{s=1}^{4} \widehat{\zeta_s} \, L_{s,it} - \sum_{s=1}^{4} \widehat{\eta_s} \, L_{s,it}^2 - \widehat{\theta} \, Org_{it} - \widehat{\vartheta} \, Org_{it}^2 - \sum_{s=1}^{4} \widehat{\lambda_s} \, L_{s,it} \, Org_{it}$$
$$-\widehat{\psi} \, Training_{it} - \sum_{p=0}^{3} \sum_{q=0}^{3-p} \widehat{\delta_{pq}} K_{it}^p M_{it}^q - \widehat{\varphi_j} - \widehat{\mu_t} \tag{5}$$

By using the predicted value for $\widehat{\phi_{it}}$, one can compute for any candidate value β^* a prediction of $\omega_{it}(K_{it}, M_{it})$ for all periods t:

$\widehat{\omega_{it}} = \widehat{\phi_{it}} - \beta^* K_{it}$

and use it to predict a consistent approximation of $E[\omega_t|\omega_{t-1}]$ as follows

$$\widehat{\omega_{it}} = E[\omega_t|\omega_{t-1}] = \gamma_0 + \gamma_1 \omega_{t-1} + \gamma_2 \omega_{t-1}^2 + \gamma_3 \omega_{t-1}^3 + \xi it$$

Finally, the estimate of $\hat{\beta}$ is defined as the solution of:

$$\min_{\beta^*} \sum_t (VA_{it} - \sum_{s=1}^{4} \widehat{\zeta_{l,s}} \, L_{s,it} - \sum_{s=1}^{4} \widehat{\eta_{l,s}} \, L_{s,it}^2 + \widehat{\theta} \, Org_{it} - \widehat{\vartheta} \, Org_{it}^2 - \sum_{s=1}^{4} \widehat{\lambda_s} \, L_{s,it} \, Org_{it} - \widehat{\psi} \, Training_{it}$$
$$-\beta^* K_{it} - E[\widehat{\omega_t|\omega_{t-1}}])^2 \tag{6}$$

I construct standard errors for $\widehat{\zeta_s}$, $\widehat{\eta_s}$, $\widehat{\theta}$, $\widehat{\vartheta}$, $\widehat{\lambda_p}$, $\widehat{\psi}$, $\widehat{\varphi_j}$, $\widehat{\mu_t}$ and $\hat{\beta}$ by using a bootstrapping approach with 500 repetitions. The bootstrap procedure accounts for the panel structure of the data by applying block bootstrap clustered at firm level.

[9] Robustness checks applying fourth-, fifth-, and sixth-order polynomials provide qualitatively similar results.

I conduct all estimations of the production function with STATA (Version 16). To implement the LP procedure I rely on the *prodest* command developed by Mollisi & Rovigatti (2017).

The coefficients of interest are λ_s for each of the four educational groups s. Specifically, I identify potential complementarities between workers' level of education and organizational practices by comparing the interaction terms of the educational variables with the different measures of organization. If the coefficient of the interaction term increases with the increasing level of education, one can argue that complementarities with a given organization practice increase by increasing workers' education. In contrast, if the size of the coefficients for the four education groups are very similar, one can conclude that complementarities between education and the organizational practices do not exist.

5 Results

Table 2 reports the main results based on equation 1. Results are presented for the three organizational practices and the organization index both with OLS and with LP procedure. LP is the preferred estimation, while OLS is reported for benchmark reasons. Columns (1) and (2) present the estimations of the production functions that include work design as an organizational domain. Columns (3) and (4) present the results for decentralization, while columns (5) and (6) show the results for incentive pay. Columns (7) and (8) present the results for the organization index aggregating the three organizational domains.

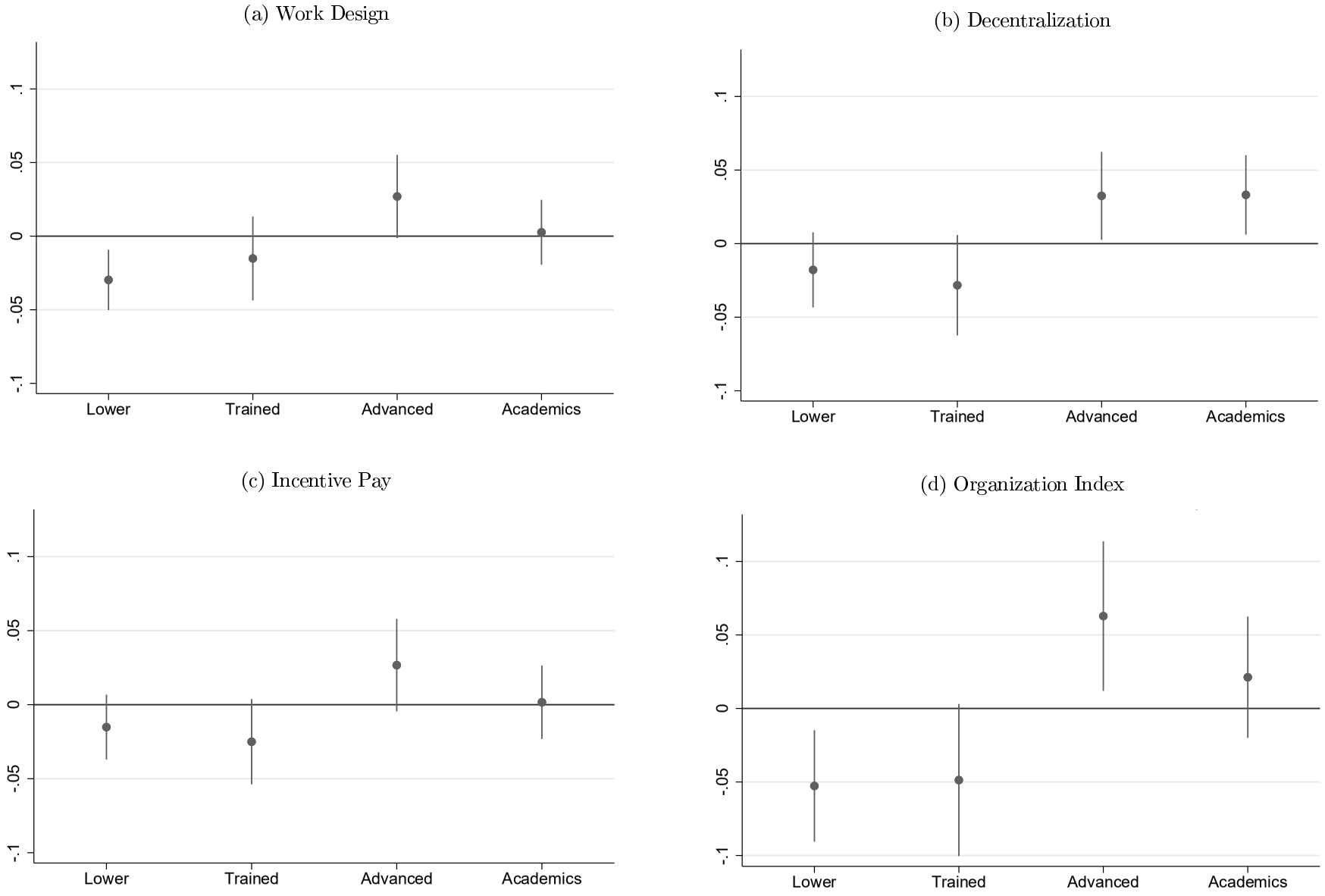
The results in the upper part of the table, detailing the contribution of workforce components in firms' total value added, are similar across estimations. When using the LP approach, which accounts for unobservable productivity shocks, the majority of the coefficients of the labor terms become smaller. The coefficients of the organizational practices suggest a large positive contribution to total value added from work design. Decentralization and incentive pay also show positive linear coefficients, even though the effects are not statistically significant. The baseline effect of incentive pay, while highly statistically significant, is smaller than those of work design or decentralization. Finally, the baseline effect of the organization index—which is an average of work design, decentralization, and incentive pay—is higher than the linear average of the three components. This finding suggests a possible complementarity across organizational domains.

Table 2: Main results

	(1) OLS	(2) LP	(3) OLS	(4) LP	(5) OLS	(6) LP	(7) OLS	(8) LP
Capital	0.0999***	0.0905***	0.102***	0.0990***	0.101***	0.103***	0.102***	0.123***
	(0.0103)	(0.00167)	(0.0103)	(0.000400)	(0.0102)	(0.000141)	(0.0102)	(0.00101)
Lower	-0.0651**	-0.0543***	-0.0643**	-0.0544***	-0.0575*	-0.0474**	-0.0624*	-0.0525***
	(0.0318)	(0.0106)	(0.0325)	(0.0199)	(0.0322)	(0.0192)	(0.0324)	(0.0204)
Trained	0.469***	0.263***	0.475***	0.261***	0.485***	0.276***	0.473***	0.260***
	(0.0493)	(0.0663)	(0.0507)	(0.0292)	(0.0504)	(0.0707)	(0.0505)	(0.0322)
Advanced	0.243***	0.114***	0.244***	0.119***	0.242***	0.114***	0.245***	0.120***
	(0.0304)	(0.0255)	(0.0309)	(0.0219)	(0.0305)	(0.0262)	(0.0309)	(0.0160)
Academic	0.0988***	0.0478*	0.0904***	0.0432**	0.0924***	0.0426***	0.0910***	0.0439***
	(0.0207)	(0.0271)	(0.0205)	(0.0172)	(0.0204)	(0.00499)	(0.0204)	(0.00601)
Lower^2	0.0370***	0.0317***	0.0372***	0.0319***	0.0358***	0.0306***	0.0370***	0.0317***
	(0.00491)	(0.000552)	(0.00496)	(0.00406)	(0.00492)	(0.00289)	(0.00494)	(0.00168)
Trained^2	-0.0124**	0.00387	-0.0133**	0.00422	-0.0149**	0.00198	-0.0128**	0.00445
	(0.00602)	(0.0106)	(0.00615)	(0.00280)	(0.00617)	(0.00942)	(0.00612)	(0.00390)
Advanced^2	-0.00735	0.00392	-0.00799	0.00296	-0.00666	0.00431	-0.00830	0.00270
	(0.00590)	(0.00625)	(0.00622)	(0.00358)	(0.00600)	(0.00525)	(0.00620)	(0.00475)
Academic^2	0.0192***	0.0233***	0.0207***	0.0236***	0.0213***	0.0250***	0.0203***	0.0232***
	(0.00542)	(0.00694)	(0.00538)	(0.00433)	(0.00533)	(0.00338)	(0.00535)	(0.00202)
Work Design	0.0861***	0.0766***						
	(0.0329)	(0.0263)						
Work Design^2	0.0000630	0.00229						
	(0.00656)	(0.00826)						
Lower * Work Design	-0.0237***	-0.0218***						
	(0.00884)	(0.00488)						
Trained * Work Design	-0.0155	-0.00854						
	(0.0127)	(0.00818)						
Advanced * Work Design	0.0250**	0.0167***						
	(0.0122)	(0.00595)						
Academic * Work Design	0.00519	0.00298						
	(0.00892)	(0.0106)						
Decentralization			0.0321	0.0333***				
			(0.0367)	(0.0118)				
Decentralization^2			-0.00938*	-0.00770**				
			(0.00529)	(0.00365)				
Lower * Decentralization			-0.0219**	-0.0108				
			(0.00940)	(0.00804)				
Trained * Decentralization			-0.00395	-0.0186***				
			(0.0123)	(0.00721)				
Advanced * Decentralization			0.0227**	0.0205**				
			(0.0109)	(0.0103)				
Academic * Decentralization			0.0135	0.0208***				
			(0.00930)	(0.00597)				
Incentive Pay					0.0418	0.0517**		
					(0.0445)	(0.0212)		
Incentive Pay^2					0.0109	0.00735**		
					(0.00762)	(0.00358)		
Lower * Incentive Pay					-0.0116	-0.0103		
					(0.00996)	(0.00837)		
Trained * Incentive Pay					-0.0184	-0.0193***		
					(0.0145)	(0.00622)		
Advanced * Incentive Pay					0.0237*	0.0196**		
					(0.0123)	(0.00773)		
Academic * Incentive Pay					0.000678	0.000502		
					(0.0104)	(0.00791)		
Organization Index							0.0441	0.0441*
							(0.0360)	(0.0242)
Organization Index^2							-0.00885	-0.00706
							(0.00542)	(0.00498)
Lower * Organization Index							-0.0252***	-0.0138***
							(0.00952)	(0.00491)
Trained * Organization Index							-0.00660	-0.0203*
							(0.0124)	(0.0110)
Advanced * Organization Index							0.0263**	0.0229***
							(0.0110)	(0.00888)
Academic * Organization Index							0.0146	0.0215***
N	3544	3544	3544	3544	3544	3544	3544	3544
Test for $\beta_{Lower*Org.} = \beta_{Trained*Org.}$	0.658	0.000318	0.321	0.600	0.733	0.535	0.311	0.663
Test for $\beta_{Lower*Org.} = \beta_{Advanced*Org.}$	0.00117	0.000113	0.00245	0.0382	0.0321	0.0348	0.000510	3.77e-08
Test for $\beta_{Lower*Org.} = \beta_{Academic*Org.}$	0.0214	0.101	0.0110	0.000000384	0.408	0.342	0.00475	1.84e-11
Test for $\beta_{Trained*Org.} = \beta_{Advanced*Org.}$	0.0648	0.0627	0.172	0.00170	0.0545	0.000000102	0.0997	0.0220
Test for $\beta_{Trained*Org.} = \beta_{Academic*Org.}$	0.182	0.509	0.289	0.000239	0.341	0.0317	0.195	0.0000274
Test for $\beta_{Advanced*Org.} = \beta_{Academic*Org.}$	0.274	0.199	0.588	0.984	0.235	0.152	0.496	0.887

Notes: Firm-level production functions estimated with OLS and Levisohn-Petrin control function approach (LP). Dependent variable is the log of total value added. Capital, Lower, Trained, Advanced, and Academic are in logs. Work Design, Decentralization, and Incentive Pay are the average of the corresponding organizational practices standardized with mean equal to 0 and standard deviation equal to 1. Estimates include time fixed effect, industry fixed effect (2-digit level), and control for the share of workers involved in continuing training. By OLS estimation, robust standard errors are reported in parentheses. By LP estimations, error terms are blockbootstrapped with 500 repetitions. * p<0.10, ** p<0.05, *** p<0.01. The bottom part of the table reports the p-values of the t-tests for pairwise equality of the interaction terms.

Figure 1: Interaction terms between workers' education and organization



Notes: The graphs report the coefficients and the corresponding 95% confidence intervals of the interaction terms between the three groups of workers and the three organization domains (a-c) as well as the organization index (d). Total value added is regressed following the Levinsohn-Petrin procedure on firm's capital stock, the linear and quadratic terms of the four labour groups, the linear and quadratic terms of organization domanins, the interaction terms between labour groups and the organization domains, the measure of firm internal training and industry dummiers at NACE 2-digit level. Error terms are blockbootstrapped with 500 repetitions. Capital and all labor inputs enter in the regression as logartims.

The interaction terms between organization and the four education groups, reported in the middle part of Table 2, allow me to test the hypotheses on complementarity. Because the comparison of these coefficients is not straightforward, Figure 1 graphically illustrates the coefficients and the corresponding 95% confidence intervals for all three organizational domains when estimated with the LP approach. Almost all coefficients are negative or close to zero. However, if one is to detect how complementarities differ with respect to workers' level of education, focusing on the difference across coefficients is informative.

Focusing on Figure 1a, which reports the coefficients of the interaction terms between work design and workers' level of education, the coefficients for Lower workers is negative, while the ones for Trained and Academic workers are not statistically different from zero. The coefficients for Lower and Trained workers are close and not statistically different from each other, as the t-tests of pairwise equality reported in the bottom part of Table 2 confirm. The coefficient for Advanced workers is positive and statistically different from the ones of Lower and Trained workers. This finding suggests that Advanced workers are more complementary to work design than Lower and Trained workers are. Taken together, the patterns of these four coefficients partially confirm H1a on the increasing complementarity between work design and workers' level of education. However, while tertiary-educated workers—in particular Advanced workers—show higher complementarity, a finding consistent with the SBOC hypothesis model, no differences are observed between Lower and Trained workers.

Figure 1b reports the coefficients of the interaction terms between decentralization and workers' level of education. The patterns reported by this figure are partially consistent with the SBOC predictions. Specifically, the coefficients of the interaction terms for Advanced and Academic workers are higher than those for Lower and Trained workers. As the t-tests reported in the bottom part of Table 2 suggest, these two pairs of coefficients are statistically different from each other. This finding means that the complementary effect between decentralization and workers' education level is observable only for tertiary-educated workers—both vocational and academic. Specifically, while the higher coefficients for Advanced and Academic workers are in line with the SBOC model, the almost equal coefficients for Lower and Trained workers do not suggest increasing complementarity from Lower to Trained workers. Thus, H1b on the complementarity between decentralization and workers' level of education is only partially supported by the estimations.

Figure 1c reports the coefficients of the interaction terms between incentive pay and workers' education. In contrast to the two previous figures, the coefficients are very similar for the four levels of education. The only exception is the coefficient for Advanced workers, which is higher than the others and statistically different from the ones of Lower and Trained workers. This figure, which highlights a similar relationship between incentive pay and workers' level of education, does not support H1c. Indeed, I do not observe any complementary effect on productivity between incentive pay and workers' education, but only a slightly higher coefficient for Advanced workers, which are more complementary to incentive pays than other workers.

Finally, Figure 1d presents the coefficients of the interaction terms between the organization index and workers' level of education. The coefficients for Lower and Trained workers are very similar, while the ones for Advanced and Academics workers are clearly larger and similar. By presenting higher complementarity for tertiary-educated workers—both vocational and academic—this measure is in line with the SBOC model. The results suggest that organizational practices affect unskilled workers and VET workers in a similar way, while both groups of tertiary-educated workers show complementarity in affecting firms' productivity. This complementary effect between tertiary-educated workers and organizational practices is larger when all the organizational domains are analyzed together. Indeed, the difference in size between the coefficients for Lower and Trained workers and the coefficients for Advanced and Academic workers is largest for the organization index. This finding indirectly confirms the existence of some complementarity between decentralization, work design, and incentive pay, thus giving partial support for H2.

6 Conclusion

This paper investigates the complementarities between organizational practices and workers' level of education. It adds to the literature on firm organization by examining workers with four different levels of education: no post-compulsory education, upper-secondary VET, tertiary vocational education, and tertiary academic education. This focus on multiple levels of education is particularly relevant, because the literature on SBOC hypothesizes that only highly educated workers are complementary to new organizational practices. In contrast, this paper provides a fine-grained view of workers' levels of education, a key aspect that is especially valuable for

countries such as Austria, Denmark, Germany, and Switzerland, where a large percentage of the workers have completed VET.

Using Swiss firm-level panel data covering the period 2002 to 2008, this paper estimates firm-level production functions including the four levels of workers' education and three organizational domains: decentralization, work design, and incentive pay. The coefficients of the interaction terms between workers' education and these three domains of organizational practices represent the paper's measure of complementarity.

The results indicate that work design is complementary to workers having tertiary education, especially tertiary vocational education. In contrast, the estimations reveal no complementarities between incentive pay and higher level of workers' education. Furthermore, the interaction effects between the extent of decentralization and workers' education indicate certain complementarities with tertiary-educated workers, both vocational and academic. Finally, the estimations using the aggregate measure of organization—which covers decentralization, work design, and incentive pay—suggest a larger complementarity between organizational practices and tertiary-educated workers. This last result suggests possible complementarities across organizational practices, a finding consistent with the literature on firms' organization.

This paper has several limitations that suggest avenues for future research. First, the estimations are based on survey data and might suffer from measurement errors as a result. The availability of administrative data would contain random and systematic measurement errors. Second, the structure of the survey does not allow me to access worker-level information, such as labor market experience or possible skills mismatch. Controlling for these characteristics would allow future research to refine the degree of complementarity. Third, this paper does not consider the role played by employers' associations in shaping the organizational structure of firms. Implications might differ across industries in which employers' associations play a leading role in firms' organization.

Finally, the question remains as to whether organizational practices have an independent effect on firms' productivity or to what extent organization is part of the transmission mechanism between technological change and firms' productivity. Indeed, a large body of literature highlights the complementarities between organization and information and communication technologies (ICT), and not considering ICT might therefore bias the effect of organizational practices upwards. Future research should therefore examine complementarities among education, organization, and ICT within the same framework.

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A Appendix

Table A1: Detailed description organizational practices

Decentralization	
Speed of work	Extent of decentralization of competencies in speed of work. Five-level ordinal variable ranging from level 1 "line manager decides alone" to level 5 "employee decides alone"
Sequence of work	Extent of decentralization of competencies in the sequence of task. Five-level ordinal variable ranging from level 1 "line manager decides alone" to level 5 "employee decides alone"
Distribution of tasks	Extent of decentralization of competencies in the assignment of tasks. Five-level ordinal variable ranging from level 1 "line manager decides alone" to level 5 "employee decides alone"
How carry out work	Extent of decentralization of competencies in the modality of the execution of tasks. Five-level ordinal variable ranging from level 1 "line manager decides alone" to level 5 "employee decides alone"
Addressing problems	Extent of decentralization of competencies in addressing problems in production. Five-level ordinal variable ranging from level 1 "line manager decides alone" to level 5 "employee decides alone"
Incentive pay	
Firm performance pay	Extent of compensation based on firm performance. Five-level ordinal variable (ranging from level 1 "low importance" to level 5 "high importance")
Workgroup performance pay	Extent of compensation based on workgroup performance. Five-level ordinal variable (ranging from level 1 "low importance" to level 5 "high importance")
Individual performance pay	Extent of compensation based on individual performance. Five-level ordinal variable (ranging from level 1 "low importance" to level 5 "high importance")
Work design	
Job rotation	Extent of job rotation. Six-level ordinal variable (ranging from level 0 "does not exist" to level 5 "very high")
Teamwork	Extent of teamwork. Six-level ordinal variable (ranging from level 0 "does not exist" to level 5 "very high")

Table A2: Factor analysis: rotated factor loading and uniqueness

	Factor 1	Factor 2	Factor 3	Uniqueness
Speed of work	**0.61**	-0.06	-0.17	0.59
Sequence of work	**0.72**	-0.02	-0.06	0.48
Distribution of tasks	**0.62**	-0.07	0.03	0.61
How to carry out work	**0.68**	0.01	-0.05	0.54
Addressing problems	**0.55**	-0.01	0.07	0.69
Firm performance pay	-0.01	**0.74**	-0.23	0.40
Workgroup performance pay	0.05	**0.77**	-0.09	0.39
Individual performance pay	-0.02	**0.66**	-0.35	0.45
Job rotation	-0.02	0.32	**0.71**	0.40
Teamwork	0.22	0.41	**0.58**	0.45
Observations	3544			

Table A3: Summary statistics

	N	Mean	SD	Min	Max
Firm output					
Total value added* (in million CHF)	3544	63.27	446.80	0.09	17589.33
Capital					
Capital* (in million CHF)	3544	1008.70	31064.76	0	1122100
Intermediary goods					
Purchasing costs for intermediary inputs (in million CHF)*	3544	78.97	708.62	0.02	32830
Workforce composition					
Lower*	3544	70.90	265.42	0	9461.6
Trained*	3544	129.77	720.00	0	26333.3
Advanced*	3544	44.98	267.99	0	11738.7
Academic*	3544	20.37	108.48	0	2670.5
Decentralization					
Speed of work**	3544	2.72	0.79	1	5
Sequence of work**	3544	2.50	0.90	1	5
Distribution of tasks**	3544	2.03	0.79	1	5
How to carry out work**	3544	2.52	0.92	1	5
Addressing problems**	3544	2.11	0.81	1	5
Incentive pay					
Firm performance pay**	3544	3.49	1.08	1	5
Workgroup performance pay**	3544	2.81	1.13	1	5
Individual performance pay**	3544	4.25	0.81	1	5
Work design					
Job rotation**	3544	1.51	1.15	1	6
Teamwork**	3544	3.25	1.69	1	6
Continuing Training					
Share of employees taking part in continued training (%)	3544	29.80	28.73	0	100

Notes: (*) This variable enters in log. (**) This variable enters standardized with mean 0 and standard deviation 1. All monetary units are expressed in nominal terms.