

DISCUSSION PAPER SERIES

IZA DP No. 17424

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Educational Mismatch**

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ISSN: 2365-9793

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ABSTRACT

Firm Human Resource Practices and Educational Mismatch*

The paper introduces a new measure of educational mismatch at the firm level, constructed by merging firm and individual data at the sector-firm size-year level. This measure captures both the intensity of mismatch and its type – whether overeducation, undereducation, or a mix of the two. We assess the role of human resource practices in reducing the intensity of educational mismatch in Italian firms by estimating econometric models that control for a rich set of firm characteristics, as well as year and industry-region fixed effects. Firm-fixed effects and instrumental variable models complement the analysis. Findings indicate that the use of private recruitment agencies, on-the-job training, and structured supervision is associated with a reduction in mismatch intensity. The impact of other practices varies by mismatch type: higher job turnover rates correlate with lower undereducation but increased overeducation, while second-level bargaining increases undereducation and reduces overeducation.

JEL Classification: D22, D23, J24, O15

Keywords: educational mismatch, human resource practices, firm-level analysis, overeducation, undereducation

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* The authors are grateful for the feedback from participants at the TAM-WiPSS seminar and the IWPLMS and SIE conferences. They thank the *Istituto Nazionale per l'Analisi delle Politiche Pubbliche* (INAPP) for providing data from the *Rilevazione Longitudinale Imprese e Lavoro* (RIL) survey. The authors acknowledge financial support from the Department of Economics and Management, University of Trento, for the project "PROSKIM". Fabio Pieri: the topics covered in this paper are further developed in the framework of the EU - Next Generation EU / PRIN 2022 project entitled "REWIND - Resilient Enterprises and Workers: leveraging INTangibles to address Disruptions". Dr. Revathi Palat Rao has been involved in the PROSKIM project as a research assistant. The usual disclaimer applies.

1. Introduction

A persistent mismatch between the skills and qualifications required for a job and those possessed by employees can negatively affect individuals, firms, and economies (McGuinness *et al.*, 2018; Brunello and Wruuck, 2021; Cedefop, 2022). For individuals, this misalignment may lead to wage penalties, job dissatisfaction, and long-term career scarring. It may reduce firms' productivity, and at the macro level, it may hinder economic growth and competitiveness. In recent years, matching skills to jobs has become increasingly challenging due to mega-trends such as technological change (Caselli *et al.*, 2024), digital and green transitions, job automation, artificial intelligence, and demographic shifts (Brunello and Wruuck, 2021). Ongoing shocks and disruptions, such as the 2008-2009 economic crisis and the COVID-19 pandemic, have exacerbated the process (Şahin *et al.*, 2014; Cedefop, 2022).

Recent data confirm that educational mismatch is widespread in Europe, affecting around 40% of the workforce, with most being overqualified (28%) (Cedefop, 2022). This phenomenon is particularly pronounced in Italy, where 30% of workers are overeducated and 15% undereducated, and it is worsening among younger cohorts (Vera-Toscano and Meroni, 2021).

Existing research mainly focused on individual determinants and consequences, especially for overeducation (Leuven and Oosterbeek, 2011; McGuinness *et al.*, 2018). However, understanding the role of firms is essential, as they can complement public policies in reducing mismatch. Moreover, if mismatch hinders productivity, profit-maximizing firms should identify practices to mitigate it, and human resource practices (HRPs) are crucial to this end (Bloom and Van Reenen, 2007; Belfield, 2010; Bloom *et al.* 2019; Coraggio *et al.*, 2022).

This paper explores the factors influencing educational mismatch within firms, focusing on the role of human resource practices. Specifically, it investigates the role of recruitment practices (use of public and private employment services) and retaining practices (second-level wage bargaining, on-the-job training, supervisor monitoring effort, and job turnover).

The contribution of our paper is twofold. First, we develop a new measure of educational mismatch at the firm level, that can be constructed even in the absence of matched employer-employee data, by merging information from individual and firm data. This approach offers two key benefits: (i) it allows us to assess both the type of mismatch (undereducation, overeducation, or various combinations of the two), and its intensity, and (ii) it allows us to exploit the comprehensive information available in firm survey data, exploring aspects not covered by administrative sources. Second, we analyze the role of human resources practices

in determining the type and intensity of educational mismatch at the firm level – an area largely neglected in the current literature.

Our analysis relies on two different data sources for the years 2009, 2014, and 2017: the Italian Labor Force Survey (ITLFS) and Italian firm-level data from the Longitudinal Survey for Firms and Labor (*Rilevazione Longitudinale Imprese e Lavoro*, RIL). We follow a statistical approach for mismatch measurement and construct a measure of educational mismatch in each firm by comparing the expected and the observed distribution of educational levels within firms. We assess the role of human resource practices in reducing the intensity of educational mismatch in firms characterized by different types of mismatch by estimating various econometric models that control for firm characteristics, as well as years and industry-region fixed effects. We complement the analysis with firm-fixed effects and instrumental variable models to address endogeneity issues.

Results indicate that the use of private recruitment agencies for recruitment, on-the-job training, and a more structured supervision organization (i.e., a lower average span of control per supervisor) are associated with a lower intensity of mismatch. The role of other policies depends on the type of educational mismatch in the firm. A higher job turnover rate is associated with a lower intensity of undereducation, but with a higher intensity of overeducation. Conversely, second-level bargaining increases the intensity of undereducation and reduces the intensity of overeducation. The interpretation of these findings is discussed in the appropriate section.

The rest of the paper proceeds as follows. Section 2 outlines the existing literature. Section 3 describes the data and our mismatch measure and presents some descriptive evidence. Section 4 illustrates the empirical strategy. Section 5 discusses the results and Section 6 concludes.

2. Related literature

Educational mismatch refers to the misalignment between the level of education workers are endowed with and the level of education required for the job (McGuinness *et al.*, 2018; Brunello and Wruuck, 2021).² Empirical evidence indicates that this misalignment severely affects wages, workers' well-being, and productivity. Overeducated workers face a wage penalty compared to well-matched workers with the same education level, although they earn more than well-matched workers in the same occupation (Cutillo and Di Pietro, 2006; McGuinness *et al.*, 2018; Caroleo and Pastore, 2018; Gaeta *et al.*, 2023). The opposite is true for

² Instead, skill mismatch refers to the degree to which workers are endowed with skills required for their current job.

undereducated workers (Cedefop, 2012). The negative impact of overeducation on current wages also emerges from past mismatch (Guvenen *et al.*, 2020; Cedefop, 2022). Mismatch generally reduces job satisfaction and increases shirking, absenteeism, and turnover, although findings here are less consistent (Büchel, 2002; McGuinness *et al.*, 2018). It also increases gender inequalities (the gender pay gap is larger among overeducated workers; Castagnetti *et al.*, 2018), and, in the long run, it may produce a scarring effect (Guvenen *et al.*, 2020).

The effects of educational mismatch on firm productivity are ambiguous, but crucial for contextualizing the role of personnel policies in attracting and retaining the best fits. Theoretically, undereducation should reduce firm productivity, while overeducation may have two contrasting effects. On the one hand, firms may benefit from paying lower wages to overqualified workers and may even hire them deliberately. On the other hand, reduced satisfaction, increased shirking, and higher turnover could negatively affect productivity in the long run (Brunello and Wruuck, 2021). Empirical evidence suggests that undereducated workers indeed hamper firm productivity, while overeducation has a positive effect (Kampelmann and Rycx, 2012; Grunau, 2016; Bisio and Lucchese, 2023). Fanti *et al.* (2021) document that firms' ability to meet *skill* needs through new hires boosts productivity, though they do not distinguish between under and overskilling. Finally, skill mismatch and especially overskilling are costly in terms of aggregate productivity, due to inefficient resource allocation (Adalet McGowan and Andrews, 2017).

Significant attention has been paid to the role of individual determinants and institutional factors. Young workers, women, migrants, previously inactive individuals, and graduates in social sciences and humanities are more likely to be overeducated (Leuven and Oosterbeek, 2011; Adalet McGowan and Andrews, 2015; McGuinness *et al.*, 2018; Caroleo and Pastore, 2018).³ The presence of unions increases mismatch in the public sector (Belfield, 2010), whereas the relationship between temporary contracts and mismatch is mixed: some authors find that the use of temporary contracts increases overeducation (Belfield, 2010; Croce and Ghignoni, 2012), whereas others find the opposite (Maida and Tealdi, 2021).

Comparatively, less emphasis has been placed on firm characteristics and personnel policies as determinants of mismatches. Overeducation is more common for employees working in small firms or low- and medium-skilled jobs in some sectors, such as accommodation and food services, administrative services, transportation, and trade (Cedefop, 2022). Coraggio *et al.*

³ Note that differences may emerge if one focuses on skill mismatch rather than educational mismatch, and – to a smaller extent – when using different measures of educational mismatch (e.g., normative vs. statistical/empirical approach; Verhaest and Omey, 2010).

(2022) show that managerial quality, measured with a synthetic index, enhances the alignment between workers and their jobs, whereas Cedefop (2012) underlines the role of HRPs, which include recruitment and selection strategies (e.g., formal vs. informal channels; internal vs. external candidates; temporary agencies), training, performance evaluation, performance-related pay, and turnover.

Theoretically, more formal recruitment practices should reduce mismatch: the firm will properly check for the worker formal qualifications and skills (Belfield, 2010). Particularly when educational requirements are higher, firms invest more time in the recruitment process (Oyer and Schaefer, 2011), thus reducing the risk of undereducation. On the one hand, informal practices may provide better access to private information about individuals' productivity, beyond educational attainment (Pallais and Sands, 2016), leading to both over- and undereducation. On the other hand, informal channels could increase mismatch even without improving productivity, because workers may be inclined to accept a job with lower educational requirements while reducing search costs (Bentolila *et al.*, 2010). Empirical evidence on the role of recruitment channels is mixed: informal channels improve matching in the United States, while European evidence suggests the opposite (Cedefop, 2012). For example, using family networks in Italy favors overeducation (Meliciani and Radiccia, 2011), whereas hiring tests reduce this phenomenon (Belfield, 2010). Overall, mismatch is more likely to occur where screening is less intense or hiring systems are weaker (Belfield, 2010; Pelizzari, 2011).

On-the-job training is crucial for addressing skill mismatch because it can improve the skills of both undereducated and overeducated but under-skilled workers. Training may also reduce the need for overqualified workers and act as a non-monetary incentive to attract good matches. Indeed, Belfield (2010), using a subjective measure, indicates that training is associated with lower overeducation.

Performance evaluation and pay-for-performance may also help reducing skill and educational mismatch, by attracting and retaining matched workers. However, empirical evidence is scarce and ambiguous. For example, according to Belfield (2010), appraisal programs seem to reduce overeducation, but estimates are imprecise. Supervision and monitoring practices may also affect mismatch by allowing firms to identify mismatched workers and, hence, to choose whether to invest in their development or to dismiss them (Belfield, 2010; Cedefop, 2012). Indeed, these practices may help reduce information asymmetries, reallocate mismatched workers, and improve job design.

Finally, firms with higher turnover may be more prone to mismatch due to less attention in the recruitment phase and less investment in employee development, making them less

attractive. Conversely, they may be characterized by lower mismatch if they are able to let out mismatched workers and identify better fits (Cedefop, 2012). As mentioned above, existing studies suggest that overeducated workers exhibit a higher turnover rate; however, evidence regarding the effect of turnover on mismatch is scarce.

Our paper adds to this limited literature by assessing the role of various human resource practices in reducing mismatch at the firm level. Moreover, we examine how their association with mismatch varies depending on the type of mismatch.

3. Data, definitions, and descriptive analysis

3.1 Data and definitions

To construct our measure of educational mismatch, we merge information from two main sources for the years 2009, 2014, and 2017: the Italian Labor Force Survey (ITLFS) and the Longitudinal Survey for Firms and Labour (*Rilevazione Longitudinale Imprese e Lavoro*, RIL). The ITLFS is a sample household survey conducted by the Italian National Statistics Institute (Istat) which provides information on the employment circumstances of the Italian population. We use this dataset to calculate the distribution of educational levels for each occupation (as explained below).

RIL is a mandatory panel survey conducted by the *Istituto Nazionale per l'Analisi delle Politiche Pubbliche* (INAPP) on a representative sample of Italian partnerships and limited liability companies operating in the private, non-agricultural sectors. RIL provides information on a wide range of firms' observable characteristics, including size, industry, and workforce composition (in particular, the number of employees by occupation and by education, separately). We combine this information with the distribution of educational levels from the ITLFS, to construct our measure of educational mismatch.

We follow a statistical approach to mismatch measurement and propose a firm-level measure of mismatch, based on the comparison between the *expected* and *observed* distribution of employees' education in each firm. Let \widehat{sh}_{it}^e indicate the *expected* share of employees with education e for firm i in year t (whose construction is explained below), and sh_{it}^e the corresponding *observed* share. Our measure of mismatch in firm i in year t is the sum, over all educational levels, of the absolute differences between these two shares (divided by two):

$$Mismatch_{it} = \frac{\sum_e |\widehat{sh}_{it}^e - sh_{it}^e|}{2}$$

We divide this metric by a factor of two to ensure it ranges from 0 (no mismatch) to 100 (complete mismatch).

This measure can be interpreted as (a lower bound of) the share of the firm's employees who are either under- or over-educated. Suppose that a firm is expected to have 30% of employees with compulsory education, 50% with upper secondary education, and 20% with tertiary education, and that the observed shares are 20%, 60%, and 20%, respectively. Our measure of mismatch is 10, and it tells us that at least 10% of the firm's employees are mismatched (in this case, at least 10% are overeducated). By taking absolute differences, we lose information about the direction of the difference (i.e. under vs. overeducation). However, as discussed below, we can easily retrieve this information and identify various types of mismatch.

The *expected* shares (\widehat{sh}_{it}^e) are obtained in three steps. First, using ITLFS data, we calculate sh_{ot}^e , the shares of employees with education e for each occupation (o) in year t (at the sector – firm size level) in the population.⁴ Due to data limitations in RIL, we can consider only three educational levels ($e=Compulsory, Upper\ Secondary, Tertiary$)⁵ and four types of occupation ($o=Blue\ Collars, White\ Collars, Middle\ Managers, Managers$). Second, we multiply sh_{ot}^e by the number of employees that firm i (belonging to the corresponding sector and size class) reports in each occupation in year t in the RIL dataset. The result is the number of employees with a certain educational level that firm i is *expected* to have in each occupation in year t :

$$\#employees_{oit}^e = (\#employees_{oit} \cdot sh_{ot}^e)$$

Third, we calculate \widehat{sh}_{it}^e by summing $\#employees_{oit}^e$ over all occupations and divide it by the total number of employees of firm i in year t :

$$\widehat{sh}_{it}^e = \frac{\sum_o \#employees_{oit}^e}{\#employees_{it}}$$

The *observed* share of employees with educational e in firm i in year t (sh_{it}^e) is taken directly from the RIL dataset. Further details on the data and descriptive evidence on the distribution of education by occupation, firm class size, and sectors are provided in the Online Appendix A.

As mentioned above, our mismatch measure provides information about mismatch intensity at the firm level. Still, it is not informative on whether it is due to overeducation or

⁴ We consider 17 main sectors of the Italian economy and four firm size classes. The reader is referred to Online Appendix A for further details.

⁵ In Italy, compulsory education includes up to the first 2-3 years of the high school.

undereducation. However, by comparing the expected and observed shares for each educational level separately, we can identify four mutually exclusive types of mismatch:

- 1) Undereducation: firms whose observed shares of workers with compulsory (C) and upper secondary (US) education are larger than expected: $sh_{it}^C \geq \widehat{sh}_{it}^C$ and $sh_{it}^{US} \geq \widehat{sh}_{it}^{US}$ (with a strict inequality in at least one of the two conditions).
- 2) Overeducation: firms whose observed shares of workers with upper secondary and tertiary (T) education are larger than expected: $sh_{it}^{US} \geq \widehat{sh}_{it}^{US}$ and $sh_{it}^T \geq \widehat{sh}_{it}^T$ (again with a strict inequality in at least one of the two conditions).
- 3) A mix of over- and undereducation with ‘too much secondary’: firms that present a lower-than-expected share of both compulsory and tertiary educated: $sh_{it}^C \leq \widehat{sh}_{it}^C$ and $sh_{it}^T \leq \widehat{sh}_{it}^T$ (again with a strict inequality in at least one of the two conditions).
- 4) A mix of over- and undereducation with ‘too little secondary’: firms that present a higher-than-expected share of both compulsory and tertiary educated: $sh_{it}^C \geq \widehat{sh}_{it}^C$ and $sh_{it}^T \geq \widehat{sh}_{it}^T$ (again with a strict inequality in at least one of the two conditions).

Clearly, the complement to these four cases is the situation of ‘no mismatch’, when the observed shares are equal to the expected ones ($sh_{it}^C = \widehat{sh}_{it}^C$ and $sh_{it}^{US} = \widehat{sh}_{it}^{US}$ and $sh_{it}^T = \widehat{sh}_{it}^T$).

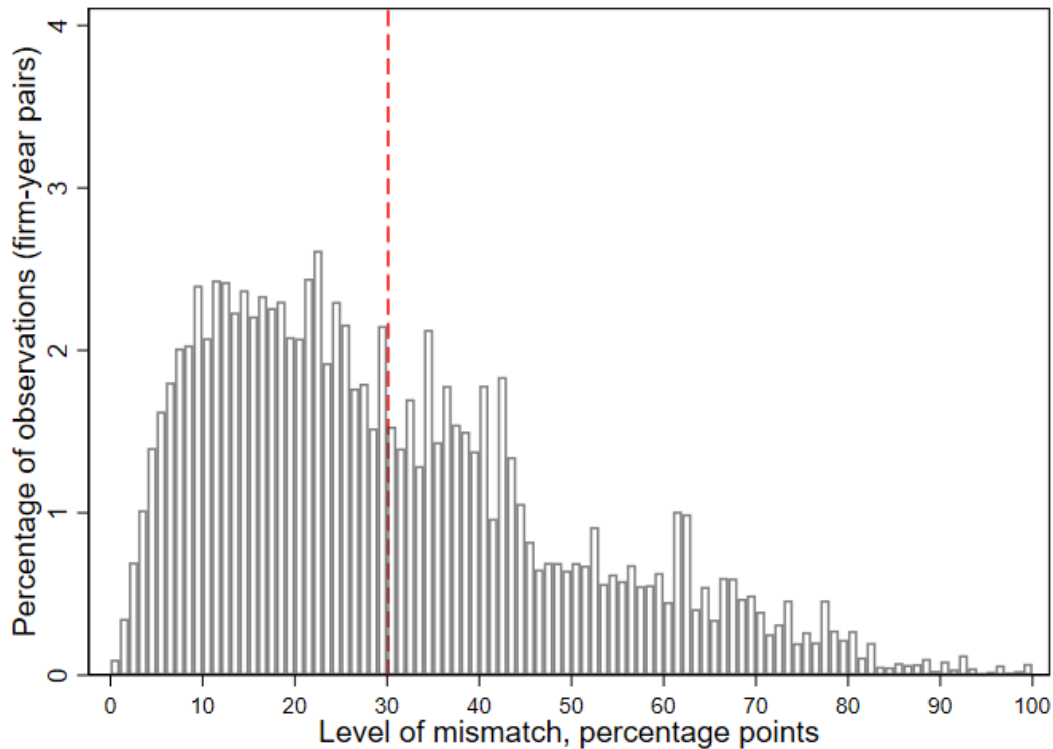
3.2 Descriptive analysis

Our empirical analysis excludes from the RIL dataset inactive firms, those that changed regional location (NUTS-2) between 2009-2017, and those in the public administration and defense sector. Furthermore, we exclude firms with no employees, missing information on employees’ educational distribution, or employment shares by education and age whose sum falls outside the 99-101 percent range. Finally, we exclude potential outliers by dropping observations for which the number of employees, sales, sales per worker, and job turnover rate are above the corresponding 99th percentile of the overall distribution. After these cleaning steps and taking into account all variables relevant for the empirical analysis, the final dataset contains 43,424 firms and 62,006 observations.⁶

Figure 1 shows the distribution of our mismatch measure in our sample. The average intensity of mismatch is slightly above 30%, but the distribution is positively skewed and presents a high degree of heterogeneity.

⁶ The RIL database, consisting of the 2010, 2015, and 2018 waves, contains 84,571 observations on 59,612 firms.

Figure 1 – Distribution of mismatch



Note: IITLFS-RIL database, 2009, 2014, 2017; the histogram refers to observations with non-missing values in all the relevant variables (N=62,006). The dashed vertical line corresponds to the mean.

Table 1 (panel (a)) shows the distribution of firms by type of mismatch and the corresponding average intensity of the latter. Firms characterized by either overeducation or ‘too much secondary’ present higher mismatch intensity than those characterized by undereducation or ‘too little secondary’ (34%-36% vs. 20%-22%). This is consistent with the evidence from individual data reported in the introduction (30% of overeducated workers and 15% of undereducated).⁷ Italy’s high overeducation rate, despite the low share of tertiary educated individuals, may result from its specialization in low-tech sectors and from the increase of low valued added service sectors (which imply a high share of routine-intensive jobs; Caroleo and Pastore, 2018; Marcolin *et al.* 2018; Basso, 2020). In terms of firms’ distribution, it is worth noting that a firm out of three is characterized by undereducation and that almost two out of five are characterized by ‘too much secondary’. These two categories account for about 70% of the observations, reflecting widespread inefficiencies in the Italian

⁷ In comparing our measure with individual-data evidence one should keep in mind that our sample of firms includes only limited liability companies and partnerships, and that our measure can be interpreted as a lower bound of mismatch at the firm level.

educational and productive system (Ghignoni and Verashchagina, 2014; Caroleo and Pastore, 2018). In contrast, only 22% of observations have an overqualified workforce.

Since a perfect match is rare (0.06% of firms), to assess the robustness of these statistics, we included in the ‘matched’ category those observations for which the mismatch intensity is below 5% (about 5% of our sample). Table 1, panel (b), shows that this change does not modify the general pattern described above. The average mismatch intensity increases by about 1pp in all other four categories, with a slightly larger reduction in the share of firms with undereducation (-2.6pp).

Table 1 – Descriptive statistics; number of observations, percentage, and level of mismatch by category

	Panel (a) – perfect match				
	(1) Obs.	(2) %	(3) Mismatch (pp), average	(4) Mismatch (pp), min.	(5) Mismatch (pp), max.
(1) Undereducation	20,908	33.72	22.14	0.50	100.00
(2) Too much secondary	23,552	37.98	36.39	0.50	100.00
(3) Matched	35	0.06	0.00	0.00	0.00
(4) Too little secondary	3,692	5.95	20.34	1.00	83.50
(5) Overeducation	13,819	22.29	34.17	0.50	100.00
Total	62,006	100.00	30.12	0.00	100.00
	Panel (b) – 5 p.p. tolerance for matched firms				
(1) Undereducation	19,294	31.12	23.70	5.50	100.00
(2) Too much secondary	22,995	37.09	37.18	5.50	100.00
(3) Matched	2,914	4.70	3.55	0.00	5.00
(4) Too little secondary	3,498	5.64	21.26	5.50	83.50
(5) Overeducation	13,305	21.46	35.36	5.50	100.00
Total	62,006	100.00	30.12	0.00	100.00

Note: ITLFS-RIL database; 2009, 2014, 2017; descriptive statistics refer to observations with non-missing values in all the relevant variables. “pp” stands for percentage points. Categories are defined, based on the statistical approach, as it follows: (1) “Undereducation”: the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) “Too much secondary”: the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) “Matched”: the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) “Too little secondary”: the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) “Overeducation”: the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one. In panel (b), category (3) “Matched” gathers also firm-year pairs for which deviations in absolute values from the expected educational shares are within 5 percentage points.

Table 2 shows the average mismatch intensity by various firm characteristics and the type of mismatch. For firm characteristics that are continuous variables, we calculated and reported

the average mismatch intensity below and above the median. The definition of the variables is provided in Table B.1. In the Online Appendix, we also examine differences in HRPs and other firm characteristics across mismatch types (Table B.2).

Focusing on HRPs, the average mismatch intensity is remarkably lower in firms that use private recruitment agencies and second-level wage bargaining (-8pp and -9pp, respectively). It is also lower, but to a lesser extent (-5pp), in firms that use public employment services and offer on-the-job training. A higher turnover rate and more subordinates per supervisor (span of control) are also associated with lower mismatch intensity (-3pp and -6pp, respectively). Generally, these effects are quite similar across mismatch types, with some exceptions. The latter include larger effects of private recruitment agencies, second-level wage bargaining, and the span of control for firms characterized by overeducation and ‘too much secondary’.

Table 2 – Mismatch intensity by firm characteristics and mismatch category

	Whole sample		Mismatch category			
			Undereducation	Too much secondary	Too little secondary	Overeducation
<i>Human resource practices (HRPs)</i>						
Use of public employment services	No	30.4	22.4	36.6	20.7	34.6
	Yes	25.8	17.6	31.5	16.3	29.4
Use of private recruitment agencies	No	31.1	22.9	37.3	21.1	35.5
	Yes	23.5	16.2	28.3	16.8	27.7
Job turnover rate	< Median	31.7	23.5	37.8	21.4	35.8
	>Median	28.6	20.7	34.7	19.6	32.8
The firm offers on-the-job training	No	32.6	24.2	39.0	22.5	37.5
	Yes	27.8	20.0	33.5	19.0	32.1
Average span of control per supervisor	< Median	33.3	24.4	40.2	22.7	37.7
	>Median	27	19.9	32.1	18.5	31.7
Second-level wage bargaining	No	31.1	22.8	37.2	21.2	35.5
	Yes	21.9	16.5	26.5	15.8	25.9
<i>Selected Workforce and CEO characteristics</i>						
No. employees	< Median	35.2	26.3	40.7	27.6	40.6
	>Median	25.2	17.9	30.5	17.4	30.4
No. layers	< Median	32.2	23.6	38.3	22.1	37.4
	>Median	24.0	17.5	28.3	17.0	28.3
Share employees with fixed-term contracts	< Median	32.4	23.9	38.4	22.5	37.2
	>Median	26.5	19.3	32.2	18.2	30.9
Share of female employees	< Median	28.4	20.7	37.0	19.2	33.2
	>Median	31.9	24.3	35.9	22.4	34.9
Union representation (RSA/RSU)	No	31.9	23.6	37.8	22.0	36.2
	Yes	23.0	16.6	28.1	16.2	28.1
CEO education: compulsory		29.2	24.1	36.4	21.5	35.4
CEO education: upper secondary		30.8	21.7	38.0	20.2	33.8
CEO education: tertiary		29.5	20.0	32.6	19.9	34.3
CEO age: 15-39 y.o.		33.3	23.9	40.2	22.8	38.0
CEO age: 40-49 y.o.		31.0	22.5	37.3	20.4	35.7
CEO age: 50-59 y.o.		30.4	22.6	36.6	20.3	33.4
CEO age: 60+ y.o.		28.5	21.1	34.4	19.9	33.2
Female CEO	No	29.6	21.7	35.9	20.1	33.7
	Yes	33.2	25.2	38.9	22.2	36.9
External (hired) CEO	No	30.3	22.3	36.7	20.5	34.6
	Yes	25.5	18.0	28.8	17.2	28.9
CEO remuneration: related to performance	No	28.3	20.2	34.3	19.1	33.2
	Yes	32.4	24.5	38.6	22.7	35.7
# Observations		62,006				
# Firms		43,424				

Note: IITLFS-RIL database; 2009, 2014, 2017. Descriptive statistics refer to observations with non-missing values in all relevant variables. Categories are defined, based on the statistical approach, as it follows: (1) “Undereducation”: the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) “Too much secondary”: the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) “Matched”: the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) “Too little secondary”: the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) “Overeducation”: the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one.

All these HRPs are likely to be correlated with firm size which, in turn, may also be correlated with the intensity of mismatch. Indeed, firms larger than the median size have a much lower mismatch intensity than others (-10pp). Similar effects can also be observed for firms with deeper hierarchies and a union representation (-8pp and -9pp). Smaller but notable effects are associated with having higher shares of fixed-term contracts (-6pp) and lower shares of female employees (-4pp). While the effect of firm size is similar across mismatch types, deeper hierarchies and union representation reduce the mismatch intensity more in firms characterized by overeducation and ‘too much secondary.’ In contrast, lower shares of female employees reduce mismatch intensity more in firms characterized by undereducation and ‘too little secondary’.

CEOs’ education is associated with the intensity of mismatch only for specific types of mismatch: CEOs with compulsory and secondary education increase the mismatch intensity in firms characterized by undereducation and ‘too much secondary’, respectively. Finally, when CEOs are older, males, externally hired and with not-for-performance remunerations, the mismatch intensity is about 4-5pp lower.

The data indicate considerable heterogeneity in the intensity and type of mismatch across sectors and regions, with evidence in line with existing findings (e.g., Cedefop, 2022). Figure B.1 shows that mismatch intensity is highest in some service sectors (more than 35% in health, education, accommodation, and other services) and lowest in mining and quarrying (23%) and some manufacturing sectors (less than 27% in chemicals, textile, and machinery). Not surprisingly, overeducation prevails in the health, education, and information sectors, whereas undereducation is more common in the mining and quarrying and industrial sectors (Figure B.2). This sectoral pattern partly explains also why the intensity of mismatch is generally lower and undereducation is more common in northern regions (Figure B.3).

As previously observed, these associations may be spurious, due to the potential correlation between various firm characteristics. In the empirical analysis, we examine which correlations remain significant once we control for all other firm characteristics and industry-region fixed effects, trying to check whether we can interpret them in causal terms.

Before examining how HRPs and other firm characteristics affect mismatch intensity, it is useful to assess whether our measure of mismatch is negatively correlated with various dimensions of firm performance, as theory would suggest (Brunello and Wruuck, 2021), in order to evaluate the effectiveness of the measure. Hence, we estimate an OLS regression, where the dependent variables include various firm performance outcomes (labor productivity, different types of investments, and export status), and the independent variables of interest are

the level and the type of mismatch, while controlling for firm size class, industry-region fixed effects, and year fixed effects. The level of mismatch is negatively and significantly associated with all dimensions of firm performance considered (Table B.3). However, in line with the literature presented earlier, firms with overeducated employees consistently outperform the others, whereas firms with undereducated workforce generally exhibit poorer performance.

4. Empirical strategy

To assess how HRPs influence mismatch at the firm level, we first estimate a pooled cross-sectional model of the intensity of mismatch $Mismatch_{it}$ as a function of relevant HRPs adopted by the firm and other firm's characteristics:

$$Mismatch_{it} = \alpha + \beta'HRP_{it} + \gamma'X_{it} + \vartheta'catmismatch_{it} + \alpha_{jr} + \tau_t + \varepsilon_{it} \quad (1)$$

where the vector HRP_{it} includes the use of public and private employment services, on-the-job training, an inverse proxy of monitoring effectiveness (span of control), the adoption of second-level wage bargaining scheme related to workers' productivity, and job turnover rate. The vector X_{it} include both workforce and CEO characteristics. $catmismatch_{it}$ is the vector of dummy variables corresponding to the type of mismatch which characterizes firm i in year t . To mitigate a possible omitted variable bias, along with several time-varying firm controls, we account for time-invariant unobserved heterogeneity at the industry-region level by including a vector of NACE 2-digit industry-region fixed effects (α_{jr}) and a vector of year fixed effects (τ_t).

The model is estimated by OLS and standard errors are clustered at the firm level to account for within-cluster correlation. β represents the coefficients of interest and can be interpreted as the relationship between the adoption of HRPs and the intensity of the mismatch, controlling for the type of mismatch prevalent in firm i in year t , as well as for other firm's characteristics and various fixed effects.

Estimates from this model cannot be interpreted in causal terms because of various potential endogeneity issues, such as unobserved heterogeneity and reverse causality. To account for the former, we present estimates from a model that substitutes industry-region fixed effects with firm-fixed effects α_i . However, due to the low number of observations per firm (1.43), the unbalanced nature of the panel, and the low within-firm variability of most HRPs over time, this approach is very demanding in our setting. Therefore, we prefer the specification that takes advantage of between-firm variability.

For other endogeneity issues (including reverse causality), we also present estimates based on an instrumental variable (IV) approach, instrumenting the vector HRP_{it} with the vector of one-wave-lagged human resource practices (HRP_{it-1}). Since a one-wave lag implies a three-year gap between the dependent variable and the lagged variable, it is quite unlikely that the latter is directly correlated with the former. Additionally, the high degree of autocorrelation in the variable of interest suggests that the lagged variable should be a valid instrument for the contemporaneous endogenous regressor.

In the last part of the empirical analysis, we explore whether the effect of HRPs on mismatch depend on the type of mismatch, as suggested by the descriptive evidence, and extend our baseline model (Eq. 1) by introducing a vector of interactions between HRP_{it} and $catmismatch_{it}$:

$$Mismatch_{it} = \alpha + \beta'HRP_{it} + \pi'HRP_{it} * catmismatch_{it} + \gamma'X_{it} + \vartheta'catmismatch_{it} + \alpha_{jr} + \tau_t + \varepsilon_{it} \quad (2)$$

We carry out the heterogeneity analysis using the OLS estimator for two reasons. First, as mentioned above, the specification with firm-fixed effects is very demanding for our dataset, and there is not enough variability to estimate interactions once we control for firm-fixed effects. Second, it is almost impossible in our setting to have appropriate instruments for both the endogenous variables and their interactions with the type of mismatch. In any case, in the Results section we will show that the signs of the IV estimates for the baseline model align with those of the OLS estimates. Thus, we can interpret results from the OLS estimators as qualitatively robust.

5. Results

5.1 Main results

Table 3 shows the coefficient of the variables of interest of Eq. (1) from the different specifications and estimation methods discussed in the previous section. In the firm-fixed effects and IV models reported in Table 3, there is a significant decrease in the number of observations and firms, because many firms have been surveyed only once across the RIL waves considered. Coefficients in the IV model are generally larger because reverse causality may bias the estimates of the coefficients of interest, β , downward.

In all models, the intensity of mismatch is negatively associated with training (in line with Belfield, 2010) and positively associated with the average number of subordinates per supervisor (span of control). Training may act as an incentive to attract good matches or enable overeducated workers to be promoted to the appropriate position. Given the fixed amount of

time a supervisor has for monitoring activities, the higher the span of control, the lower the monitoring effectiveness and the higher the possible mismatches in a firm's workforce.

The job turnover rate is negatively associated with the intensity of mismatch only in the OLS estimation, while its effects disappear in the firm-fixed effects and IV estimations. In contrast, significant effects are estimated by the IV model for the use of private recruitment agencies (negative effect) and the presence of a second-level wage bargaining scheme (positive effect). Private recruitment agencies are specialized, and therefore more effective, in selecting the right candidates, reducing mismatch. Second-level wage bargaining may provide a wage premium for mismatched workers with good skills, hence increasing mismatch. Since our dependent variable is in the range 0-100 by construction, an OLS regression is not the most appropriate one, as it assumes that the dependent variable is not bounded. A preferable alternative is the fractional probit model. Estimates from this model are reported in Table B.4 in the Online Appendix and largely confirm OLS results.⁸

Estimates for other controls are reported in Table B.5 in the Online Appendix. In terms of other firm's characteristics, the intensity of mismatch is lower in larger firms, firms with a higher number of hierarchical levels, and those with higher shares of mature workers and lower shares of female employees. Higher shares of employees with fixed-term contracts and part-time contracts increase mismatch, indicating a worse matching process in firms that use non-standard labor contracts more intensively. Firms led by a more educated CEO and whose compensation is partly a function of firm performance show higher mismatch.⁹

So far, our results indicate that an appropriate mix of HRPs, which combines the use of private recruitment agencies, the adoption of on-the-job training, and a sufficiently low number of subordinates per supervisor could reduce mismatch at the firm level. In contrast, adopting second-level wage bargaining may increase mismatch. However, before drawing general conclusions, it is necessary to assess how these effects vary across different mismatch types.

⁸ In comparing the OLS results with those of the fractional probit model, the regressors have been scaled by a factor of 1/100 because in the fractional model the outcome varies on a scale of 0-1, and marginal effects have been reported.

⁹ Additional results are reported in the Online Appendix. In Table B.6, HRPs are introduced stepwise in the OLS specification, and results are consistent. Table B.7 reports IV estimates, treating one HRP at a time as endogenous (in bold). The endogeneity test (Chi-sq. test) rejects the null hypothesis indicating a potential bias in the OLS estimates only for three HRPs (use of private recruitment agencies, the average span of control, and second-level wage bargaining). The Kleibergen-Paap Wald LM statistics also show that, in these models, instruments have a strong correlation with the respective endogenous regressor. Hence, Table 3 (col. 5) presents a unique regression, treating the use of private recruitment agencies, average span of control, and second-level wage bargaining as endogenous, while considering other HRPs as exogenous.

Table 3 – Intensity of mismatch and human resource practices

	(1) OLS	(2) OLS	(3) OLS	(4) OLS with firm FEs	(5) IV approach
<i>Human resource practices</i>					
Use of public employment services for recruitment	0.3273 (0.3243)	-0.1379 (0.3105)	-0.1398 (0.3106)	0.3707 (0.4693)	-0.3538 (0.4843)
Use of recruitment agencies	0.2140 (0.2309)	-0.3701* (0.2198)	-0.3759* (0.2200)	-0.6067 (0.4173)	-1.6296** (0.6700)
Job turnover rate	-0.0055*** (0.0020)	-0.0037* (0.0019)	-0.0037* (0.0019)	-0.0004 (0.0038)	-0.0048 (0.0032)
The firm offers on-the-job training	-0.6955*** (0.1661)	-0.9504*** (0.1583)	-0.9512*** (0.1583)	-0.6332** (0.2669)	-0.9294*** (0.2400)
Average span of control per supervisor	0.0533*** (0.0073)	0.0566*** (0.0077)	0.0567*** (0.0077)	0.0561*** (0.0206)	0.0680*** (0.0200)
Second-level wage bargaining (link to prod.)	0.3164 (0.2984)	0.4603 (0.2882)	0.4497 (0.2885)	-0.1765 (0.5336)	3.1264*** (1.0991)
<i>Type of mismatch</i>					
(2) Too much secondary		11.9118*** (0.1905)	11.9101*** (0.1905)	10.9760*** (0.3666)	11.8163*** (0.2906)
(3) Matched		-22.4107*** (1.7050)			
(4) Too little secondary		1.4291*** (0.2245)	1.4330*** (0.2245)	3.3413*** (0.4780)	1.5420*** (0.3257)
(5) Overeducation		12.8209*** (0.2375)	12.8217*** (0.2375)	11.8539*** (0.4640)	12.1570*** (0.3645)
Constant	44.3687*** (0.7524)	37.1656*** (0.7076)	37.1691*** (0.7076)	38.6868*** (1.8931)	
Firm controls	Yes	Yes	Yes	Yes	Yes
Industry-region FEs	Yes	Yes	Yes	No	Yes
Firm FEs	No	No	No	Yes	No
Year FEs	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.1897	0.2654	0.2645	0.4624	0.1494
#Observations	62006	62006	61971	33582	26806
#Firms	43424	43424	43408	15019	18986
Weak identification test: Kleibergen-Paap rk Wald F stat.					323.2770
Chi-sq. test of endogenous regressors, p-value					0.0110

Note: ITLFS-RIL database; 2009, 2014, 2017. Coefficients of industry-region FEs, firm FEs and year FEs, and firm controls are not reported to save space. Full tables are available from authors upon request. Categories are defined, based on the statistical approach, as it follows: (1) 'Undereducation': the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) 'Too much secondary': the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) 'Matched': the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) 'Too little secondary': the actual share of employees with tertiary (compulsory) education is greater or equal (greater than) the expected one; (5) 'Overeducation': the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one. In columns (3) and (4), category (1, Undereducation) is the reference (omitted) category. In columns (3) and (4), category (3), which gathers only 35 observations, is omitted from the sample. Full results for the OLS and firm FEs estimates available in Tables B.5 and B.6 and for the IV estimates in Table B.7 in the Online Appendix. Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

5.2 Heterogeneous effects of HRPs across mismatch types

According to the descriptive evidence, the relationship between HRPs and the intensity of mismatch is likely to be moderated by the type of mismatch prevalent in the firm. We examine these heterogeneous effects by introducing interactions between the HRPs variables and the type of mismatch in the OLS model. Figure 2 displays the average marginal effects of HRPs across mismatch types for all significant interactions (training, span of control, private recruitment agencies, turnover, and second-level wage bargaining). Full results are provided in Table B.8. Since using public employment services has a null effect (both on average and by mismatch type), its interactions are not included in the final model.

The effects associated with on-the-job training and the span of control maintain their sign across all mismatch types. On-the-job training reduces educational mismatch across all mismatch types (Figure 2.a), with larger marginal effects for firms characterized by overeducation and by ‘too much secondary’. Training may improve educational mismatch by enhancing the skills of overeducated individuals, which could then be promoted, and by attracting better matches among new hires. Both channels are more relevant in the context of overeducation. Conversely, the span of control increases mismatch across all categories (Figure 2.b). Lower monitoring effectiveness seems particularly detrimental for mismatch in firms characterized by undereducation, possibly because supervisors cannot fully assess their subordinates’ performance.

Using private recruitment agencies reduces mismatch only in firms characterized by overeducation and ‘too much secondary’, whereas marginal effects are not significant for other types of mismatch (Figure 2.c). Being more efficient in the recruitment process, these agencies may assess candidates’ abilities more carefully, avoiding the risk of placing too much importance to formal qualifications, which generally leads to overeducation.

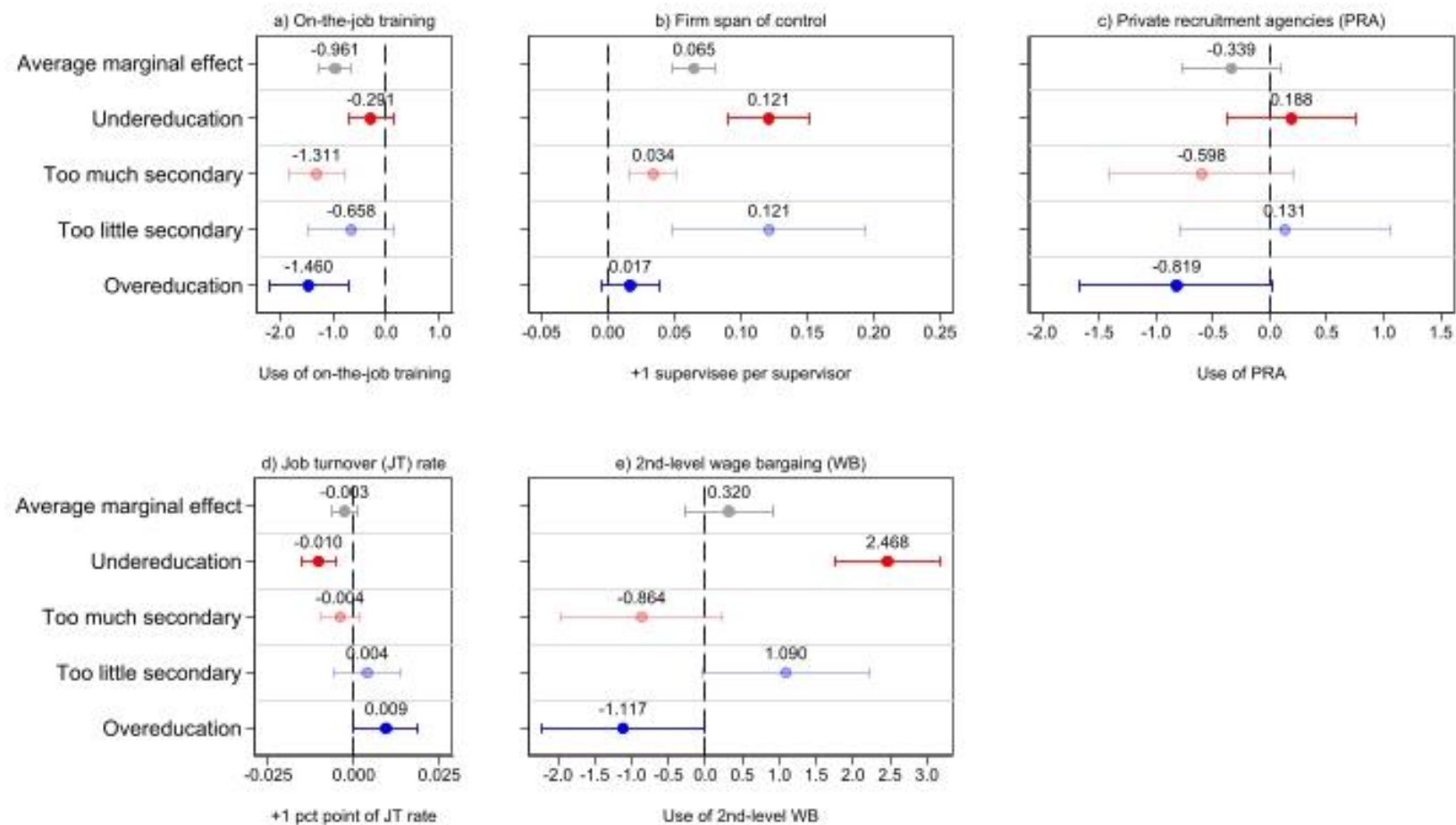
The effect of other personnel policies differs according to the mismatch type. Job turnover reduces mismatch in firms with undereducation but increases it in firms with overeducation (Figure 2.d). Since undereducation reduces firms’ productivity while overeducation increases it, firms may use firing and hiring to change their workforce composition, trying to reduce the number of undereducated workers and increase that of well-matched or overeducated ones. Furthermore, firms with higher job turnover may give more emphasis to formal qualifications in the recruitment process to reduce the costs associated with candidates’ evaluation.

In contrast, adopting second-level wage bargaining reduces mismatch in firms with overeducation, while it enhances mismatch in firms with undereducation (Figure 2.e). On the

one hand, second-level wage bargaining may increase the wage penalty of overeducated workers compared to well-matched workers with the same education level, encouraging the former to leave the company and the latter to stay. On the other hand, it may exacerbate the wage premium for undereducated workers with good skills, attracting them and favoring their permanence in the firm.

Overall, these results align with theoretical predictions (Cedefop, 2012) and the limited empirical findings (e.g., Belfield, 2010). They also highlight the importance of considering not only the level of mismatch but also its type, as the effects may differ and even go in opposite directions.

Figure 2 – The effect of various HRPs on mismatch intensity by mismatch types



Note: ITLFS-RIL database, 2009, 2014, 2017. The bars represent the 95% confidence intervals. Results based on column (8) of Table B.8 in the Online Appendix.

6. Concluding remarks

The paper complements the existing literature on educational mismatch by investigating this issue at the firm level and assessing the role that human resource practices may have in enhancing or reducing it. We develop a new measure of educational mismatch at the firm level that can be constructed even in the absence of matched employer-employee data, by merging information from individual and firm data. This measure is based on the comparison between the expected and the observed distribution of educational levels in each firm and it allows us to assess both the intensity and the type of mismatch (undereducation, overeducation, or combinations of both).

The empirical analysis is based on Italian data for the years 2009, 2014, 2017. OLS estimates are corroborated with a firm-fixed effects model and an instrumental variable approach. Our results indicate that an appropriate mix of HRPs – which combines the use of private recruitment agencies, the adoption of on-the-job training, and a sufficiently low number of subordinates per supervisor – could reduce mismatch at the firm level for all types of mismatch. Undereducation may also be reduced by higher turnover but it can be exacerbated by second-level wage bargaining. The opposite occurs for overeducation: the latter worsens with higher turnover but it is reduced by second-level wage bargaining.

These findings suggest that human resource practices play an important role in reducing educational mismatch – recently exacerbated by mega-trends, economic crises, and other shocks – and that they may represent a key complementary tool to public policies in tackling this problem.

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Appendix

Contents:

Appendix A. Data description

Appendix B. Additional Tables and Figures

Appendix A. Data description

A.1 Data sources

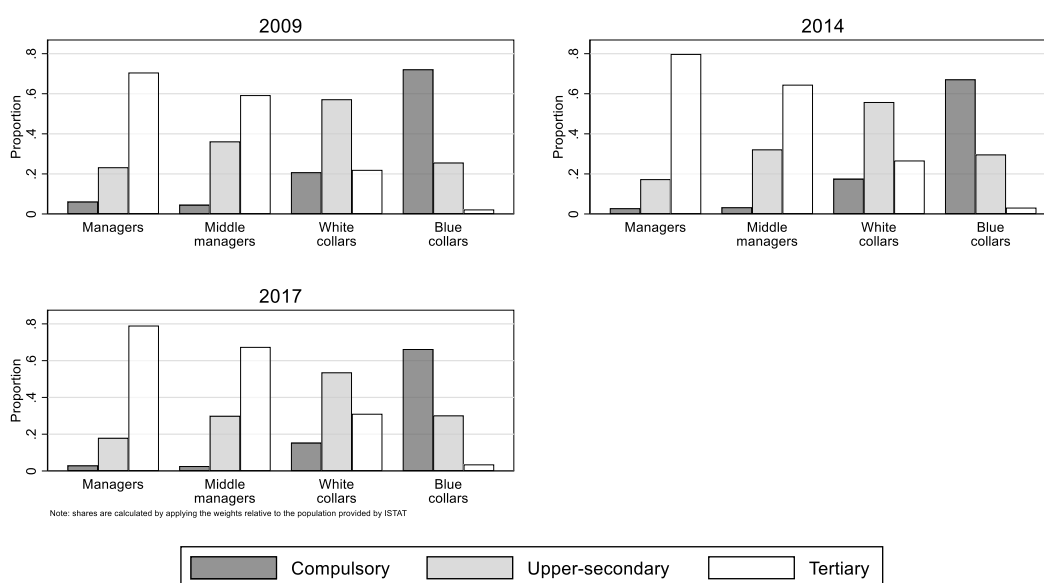
The empirical analysis of this paper is based on two data sources. The first source is the Italian Labor Force Survey (ITLFS) conducted by the Italian National Institute of Statistics (Istat) for the years 2009, 2014 and 2017. The second source is the Longitudinal Survey for Firms and Labor (*Rilevazione Longitudinale Imprese e Lavoro*, RIL) carried out by the *Istituto Nazionale per l'Analisi delle Politiche Pubbliche* (INAPP) for the years 2009, 2014 and 2017.

A.1.1 The Italian Labor Force Survey (ITLFS)

The ITLFS is conducted by the Italian National Statistics Institute (Istat) in every quarter of the year, and its reference population consists of all members of households residing in Italy.

The information in the ITLFS on individuals' current occupation and educational attainment is central to our analysis, as well as the industry and size class of the firm in which the employee works. Some descriptive statistics on the ITLFS data show how educational attainment is distributed across occupations and how heterogeneous it is across firm size classes and industries. In particular, Figure A.1 gives us the relative shares of educational attainment (compulsory, upper secondary, and tertiary) across occupations for the years 2009, 2014, and 2017, respectively.

Figure A.1 – Educational level by occupation, 2009, 2014, 2017



However, the distribution of educational attainment across occupations is uneven between micro-small and medium-large Italian firms. Figures A.2, A.3, and A.4 show the distribution of

education by occupation (managers, middle managers, white collar, and blue collar) for small (1-49 employees) and large (49+ employees) firms for the years 2009, 2014, and 2017, respectively.

Figure A.2 – Distribution of education by small and large firms, 2009

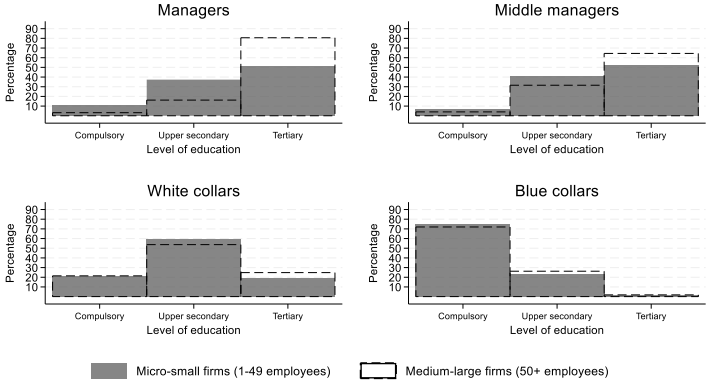


Figure A.3 – Distribution of education by small and large firms, 2014

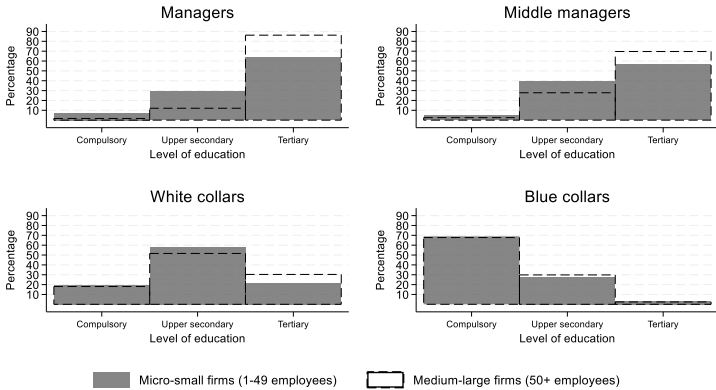
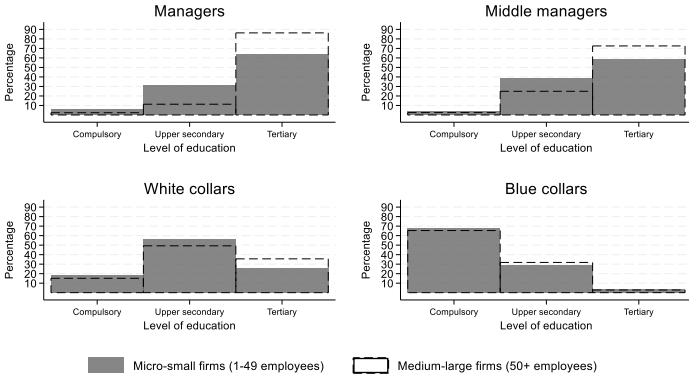


Figure A.4 – Distribution of education by small and large firms, 2017



There is also remarkable heterogeneity when looking at the distribution of educational attainment by occupation between industry and services.

Figure A.5 – Distribution of education by industry and service sectors, 2009

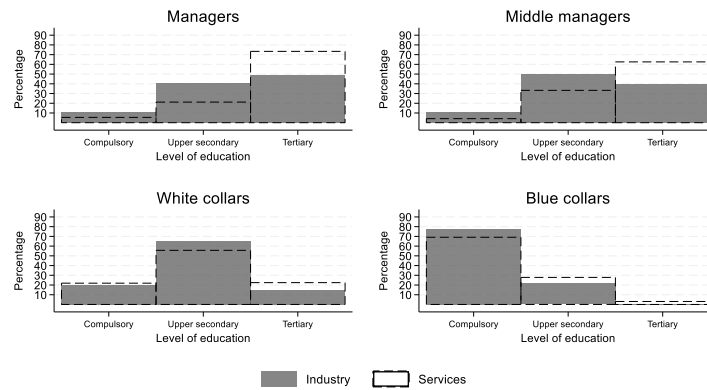


Figure A.6 – Distribution of education by industry and service sectors, 2014

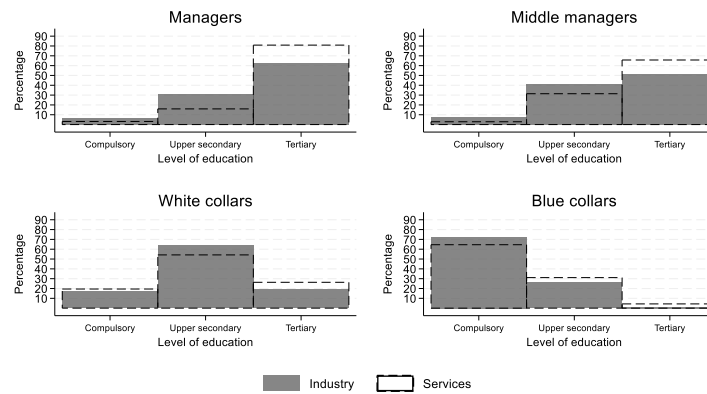
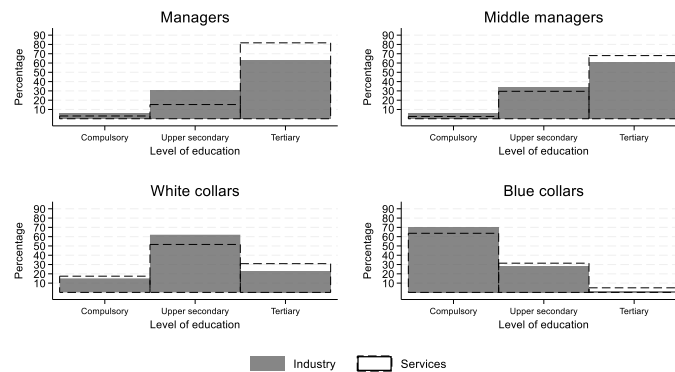


Figure A.7 – Distribution of education by industry and service sectors, 2017



Given the heterogeneity of educational attainment across occupations, firm size classes, and industries, we use the information contained in the ITLFS to calculate the annual (t) share of individuals with a certain level of education (e) in sector (j) and firm size class (s) for each of

the following occupations (o): Manager, Middle Manager, White Collar, and Blue Collar. To get enough individuals in each cell ($e \times o \times j \times s \times t$), we group the NACE 2-digit industries into 17 main sectors of the Italian economy, as shown in Table A.1, and define four firm size classes, $s = \{1 - 10, 11 - 49, 50 - 249, 250 +\}$. These shares, sh_{ot}^e , are then used in the empirical analysis to construct the expected distribution of employee education in each firm, as explained in Section 3.1 of the paper.

Table A.1 – Taxonomy of industries

	Aggregated taxonomy	Ateco 2-digit
1	Agriculture, forestry, fishing, mining, quarrying	1-9;
2	Manufacture of food beverage tobacco products	10-12;
3	Textile and wearing, wood, paper	13-18;
4	Coke, chemicals and metals	19-25;
5	Machinery and equipment	26-30;
6	Other manufacturing and repair	31-33;
7	Supply and distribution of gas, electricity, water collection, sewerage, waste collection	35-39;
8	Construction	41-43;
9	Wholesale and retail trade	45-47;
10	Accommodation and food services	55-56;
11	Transportation and storage	49-53;
12	Information and communication (included publishing, IT... 58-63)	58-63;
13	Financial and insurance	64-66;
14	Other business and professional services	68-74; 77-82;
15	Education	85;
16	Health and social work	75; 86-88;
17	Other services	90-99;
18	Public administration and defense	84

A.1.2 The RIL Survey

To examine the role of firms' human resource practices in the educational mismatch of their workforce, we use data from the RIL survey, a mandatory survey conducted by INAPP for the 2010, 2015, and 2018 waves. The information contained in RIL refers to the year prior to the publication of the wave.¹⁰ The RIL survey is conducted on a representative sample of Italian partnerships and limited liability companies of all sizes operating in the non-agricultural private sector. The aim of this survey is to collect precise information on the characteristics of the labor demand of Italian firms (i.e. number of employees, type of occupation, type of work contract, level of education of employees, etc.). In particular, we are interested in firms' human resource practices, including second-level wage bargaining, on-the-job training, the use of public employment services and recruitment agencies, supervisors' monitoring efforts, and job turnover. The RIL survey provides firm-level information on the adoption of these practices by

¹⁰ For example, the 2010 wave contains information on firms that refer to the end of 2009 and, for some variables, to the period 2007-2009. The same lag applies to the other waves.

firms. The sample of enterprises in RIL is stratified by firm size (five categories based on the number of employees: 0-4; 5-15; 16-49; 50-249; 250+), industry (ATECO 2-digit classification), and geographical area (NUTS 2 level). The inclusion (probability extraction) is proportional to the size of the enterprise (measured by the total number of employees). We use the information on the size class and industry to which a firm belongs to merge the information on the reference level of education by occupation from the ITLFS at the industry, firm size and year level with the firm-level information on human resource practices contained in the RIL. Moreover, the use of the RIL survey is particularly recommended in our case because it also contains proxies for many characteristics of a firm's workforce, management, and industrial relations that we need to control for to reduce the possibility of omitted variable bias. For example, RIL contains adequate information on the age, gender, educational level, and compensation scheme of the individual at the top of a firm's hierarchy. Table A.2 shows some basic statistics for the variables from the RIL survey.

A.1.3 The final database

After cleaning the original data sources and selecting the relevant variables, we merged the information on the reference level of education (percentages) by occupation, industry, firm size class and year with the firm-level variables from the RIL survey. We obtained a final sample of 62,006 observations and 43424 firms across 17 industries (excluding public administration and defense) for the years 2009, 2014 and 2017.

Table A.2 – Descriptive statistics; firm characteristics from the RIL survey

Variable	Definition	Mean	SD	Min	p10	p25	p50	p75	p90	Max
CEO education	CEO's level of educational attainment; share									
1. compulsory		0.209	0.407	0	0.000	0.000	0.000	0.000	1.000	1
2. upper secondary		0.510	0.500	0	0.000	0.000	1.000	1.000	1.000	1
3. tertiary		0.281	0.449	0	0.000	0.000	0.000	1.000	1.000	1
CEO age	Age category of the CEO; share									
1. 15 - 39		0.077	0.266	0	0.000	0.000	0.000	0.000	0.000	1
2. 40 - 49		0.256	0.436	0	0.000	0.000	0.000	1.000	1.000	1
3. 50 - 59		0.342	0.474	0	0.000	0.000	0.000	1.000	1.000	1
4. 60 +		0.326	0.469	0	0.000	0.000	0.000	1.000	1.000	1
Female CEO	Female CEOs; dummy	0.147	0.354	0	0.000	0.000	0.000	0.000	1.000	1
External (hired) CEO	External CEOs; dummy	0.044	0.206	0	0.000	0.000	0.000	0.000	0.000	1
CEO remuneration: related to performance	CEO remuneration related to performance; dummy	0.444	0.497	0	0.000	0.000	0.000	1.000	1.000	1
Share of employees with fixed-term contracts	Share of employees with fixed-term contracts in the firm's total employees	7.550	16.928	0	0.000	0.000	0.000	7.692	22.857	100
Share of employees with part-time contracts	Share of employees with part-time contracts in the firm's total employees	18.358	28.617	0	0.000	0.000	5.000	22.727	66.667	100
Share of female employees	Share of female employees in the firm's total employees	37.706	32.824	0	0.000	10.000	28.571	60.000	100.000	100
Share of employees 25-34 y.o.	Share of employees in age group 25- 34 years in the firm's total employees	23.644	25.032	0	0.000	0.000	18.000	33.000	56.000	100
Share of employees 35-49 y.o.	Share of employees in age group 35- 49 years in the firm's total employees	46.855	27.907	0	0.000	30.000	49.000	64.000	88.000	100
Share of employees 50+ y.o.	Share of employees in age group 50+ years in the firm's total employee	23.446	24.510	0	0.000	0.000	19.000	36.000	53.000	100
Firm size (no. employees, log)	Mean number of employees in the firm (log)	2.487	1.492	0	0.693	1.386	2.398	3.497	4.533	7
No. of layers	Number of hierarchical layers in the firm	2.010	0.905	1	1.000	1.000	2.000	2.000	3.000	4
Average span of control per supervisor	Average firm's span of control per supervisor	6.181	12.403	1	1.250	2.167	3.827	6.188	11.000	584
Job turnover rate	Firm's job turnover rate; percent	25.982	43.807	0	0.000	0.000	10.141	29.787	66.667	480
Union representation (RSA/RISU)	Firm has labor union representation; dummy	0.206	0.404	0	0.000	0.000	0.000	0.000	1.000	1
Use of public employment services for recruitment	Firm uses public employment services for recruitment; dummy	0.047	0.211	0	0.000	0.000	0.000	0.000	0.000	1
Use of recruitment agencies	Firm uses recruitment agency services; dummy	0.122	0.327	0	0.000	0.000	0.000	0.000	1.000	1
Second-level wage barg. (link to prod.)	Firms has activated a second-level bargaining scheme, linked to levels of production or productivity in the current year; dummy	0.063	0.243	0	0.000	0.000	0.000	0.000	0.000	1
The firm offers on-the-job training	Firm offers on-the-job training; dummy	0.508	0.500	0	0.000	0.000	1.000	1.000	1.000	1

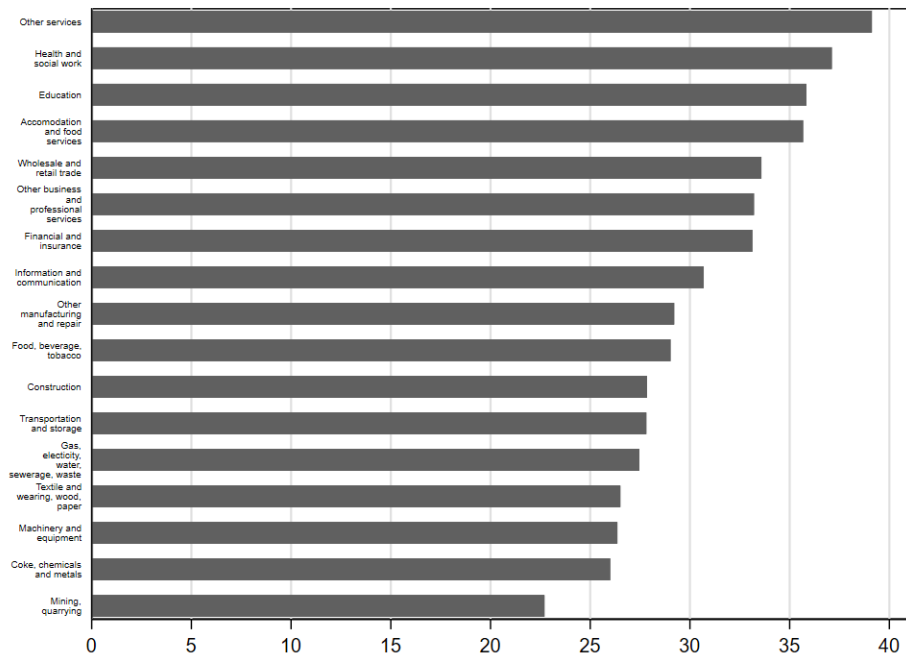
Appendix B. Additional Tables and Figures

B.1 Heterogeneity of mismatch across industries and regions

Figure B.1 shows the average mismatch intensity, across the 17 main sectors of the Italian economy. In Figure B.2 we go one step further and show the share of observations (firm-year pairs) that can be assigned to one of the five categories of mismatch we defined in Section 3.1. A relevant heterogeneity is observed in terms of both mismatch intensity and mismatch type across sectors.

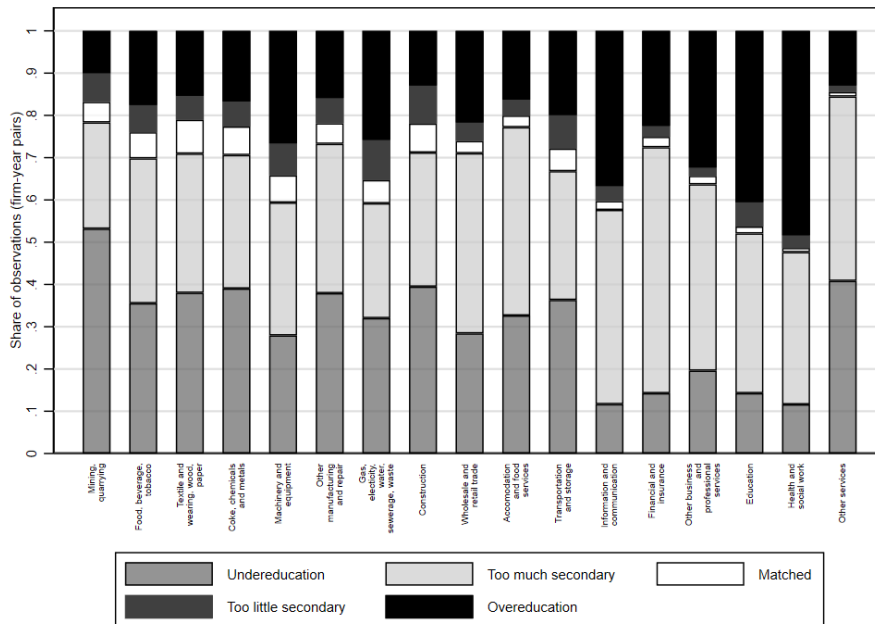
Figure B.2 shows the geographical distribution of the intensity of mismatch in the top left map and the prevalence of the different types of mismatch over the Italian territory in the other four maps. These geographical maps all refer to the year 2017, being the geographical distribution rather consistent in 2009, 2014 and 2017. Maps for 2009 and 2014 are available on request from the authors.

Figure B.1 – Average mismatch intensity by sector



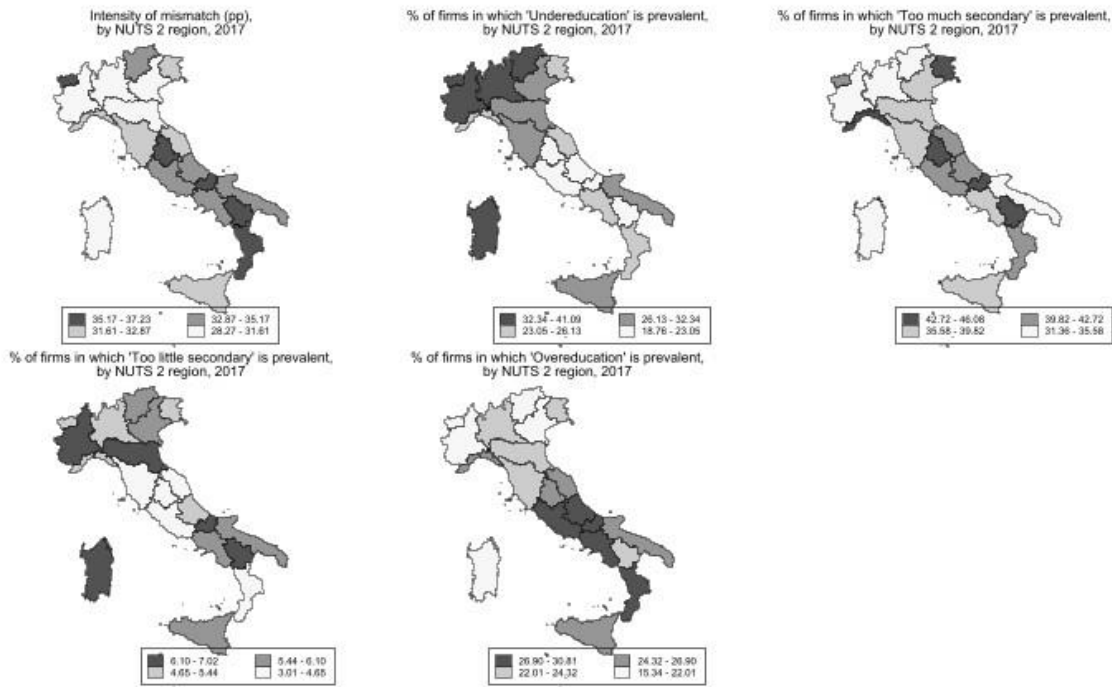
Note: ITLFS-RIL database; 2009, 2014, 2017. The bars refer to observations with non-missing values in all relevant variables (N=62,006).

Figure B.2 – Share of observations by type of mismatch and sector



Note: ITLFS-RIL database; 2009, 2014, 2017. The bars refer to observations with non-missing values in all relevant variables (N=62,006). Categories are defined, based on the statistical approach, as it follows: (1) “Undereducation”: the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) “Too much secondary”: the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) “Matched”: the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) “Too little secondary”: the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) “Overeducation”: the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one.

Figure B.3 – Average mismatch intensity and share of observations by NUTS 2 regions and type of mismatch



Note: ITLFS-RIL database; 2017. The maps refer to observations with non-missing values in all relevant variables. Since the geographic distribution has remained consistent over the years, we present only the 2017 maps here. Maps for 2009 and 2014 are available from the authors upon request. Categories are defined, based on the statistical approach, as it follows: (1) “Undereducation”: the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) “Too much secondary”: the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) “Matched”: the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) “Too little secondary”: the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) “Overeducation”: the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one.

B.2 Variables' definition and descriptive statistics

Table B.1 provides the definition of the variables, and Table B.2, panel a, provides some descriptive statistics on the use of HRPs and other firm characteristics across mismatch types.

Table B.1 – Variables' definition

Variable	Definition
<i>Human resource practices (HRPs)</i>	
Use of public employment services for recruitment	Firm uses public employment services for recruitment; dummy
Use of private recruitment agencies	Firm uses private recruitment agency services; dummy
Job turnover rate	Firm's job turnover rate: (hirings + separations)/ average number of employees between two consecutive periods; percent
On-the-job training	Firm offers on-the-job training; dummy
Average span of control per supervisor	Average firm number of supervisees in layer $l-1$ per supervisor in the adjacent non-empty superior layer (l)
Second-level wage bargaining	Firms has activated a second-level bargaining scheme, linked to levels of production or productivity in the current year; dummy
<i>Workforce characteristics</i>	
Firm size (no. employees, log)	Total number of employees in the firm (log)
No. of layers	Number of (non-empty, i.e. >0 employees) hierarchical layers in the firm, where hierarchical layers are defined as it follows: $l4$: CEO/entrepreneur; $l3$: managers; $l2$: middle managers; $l1$: white & blue collars
Share of employees with fixed-term contracts	Share of employees with fixed-term contracts in the firm's total employees
Share of employees with part-time contracts	Share of employees with part-time contracts in the firm's total employees
Share of female employees	Share of female employees in the firm's total employees
Share of employees 25-34 y.o.	Share of employees in age group 25-34 in the firm's total employees
Share of employees 35-49 y.o.	Share of employees in age group 35-49 in the firm's total employees
Share of employees 50+ y.o.	Share of employees in age group 50+ in the firm's total employees
Union representation (RSA/RSU)	Firm has labor union representation; dummy
<i>CEO characteristics</i>	
CEO education	CEO's level of educational attainment; categorical
1. compulsory	
2. upper secondary	
3. tertiary	
CEO age	Age category of the CEO; categorical
1. 15 – 39 y.o.	
2. 40 – 49 y.o.	
3. 50 – 59 y.o.	
4. 60 y.o. +	
Female CEO	Female CEO; dummy
External (hired) CEO	Externally hired CEO: the CEO is not a member of the owner's family or a former employee of the company; dummy
CEO remuneration: related to performance	CEO remuneration (partially or totally) related to firm performance; dummy

On average, firms characterized by no mismatch are more likely to adopt some HRPs compared to their counterparts: a larger share of these firms use private recruitment agencies and have a second (firm-level) wage bargaining system. They are similar to firms characterized by overeducation and ‘too little secondary’ in terms of using more public employment services and offering on-the-job training compared to firms with undereducation or ‘too much secondary’. Finally, they have fewer subordinates per supervisor (span of control) compared to firms characterized by overeducation (but similar to all other groups).

Firms characterized by no mismatch are on average larger, with deeper hierarchies, a lower proportion of part-time and female workers, and a more widespread presence of union representation. Firms characterized by undereducation have a higher share of employees above 50 years of age and are more likely to be managed by a CEO with compulsory education. In contrast, firms characterized by overeducation have a higher share of relatively young employees (aged 25-34) and are more likely to be managed by a CEO with tertiary education. No significant differences emerge in terms of CEOs’ age.

To assess the correlation of these variables with the different types of mismatch *ceteris paribus*, we estimated a multinomial logit model for the probability of belonging to the different mismatch categories. Table B.2, panel b, presents the results of this estimation, focusing on the role of HRPs. The findings align with those presented in Table B.2, panel a, although not always statistically significant.

Table B.2 – Descriptive statistics: the use of human resource practices and firm characteristics by mismatch category

Panel (a) – Average values across categories					
	(1) Undereducation	(2) Too much secondary	(3) Matched	(4) Too little secondary	(5) Overeducation
<i>Human resource practices (HRPs)</i>					
Use of public employment services	0.036	0.038	0.062	0.060	0.063
Use of private recruitment agencies	0.105	0.095	0.214	0.174	0.168
Job turnover rate	26.354	24.503	24.127	26.447	24.963
The firm offers on-the-job training	0.483	0.478	0.630	0.613	0.615
Average span of control per supervisor	5.910	6.032	6.380	5.802	7.461
Second-level wage bargaining	0.061	0.040	0.144	0.092	0.079
<i>Workforce characteristics</i>					
No. employees	36.952	29.481	66.907	45.727	52.297
No. layers	2.005	1.821	2.392	2.375	2.246
Share employees with fixed-term contracts	7.909	6.892	7.064	8.262	7.889
Share employees with part-time contracts	17.015	21.899	10.967	12.910	17.150
Share of female employees	30.826	42.896	27.896	28.569	41.485
Share of employees <25 y.o.	5.499	6.979	5.253	4.485	5.337
Share of employees 25-34 y.o.	19.143	25.125	19.865	20.203	27.336
Share of employees 35-49 y.o.	46.850	46.213	47.676	48.117	47.165
Share of employees 50+ y.o.	28.522	21.693	27.236	27.233	20.179
Union representation (RSA/RSU)	0.200	0.145	0.344	0.277	0.245
<i>CEO characteristics</i>					
CEO education: compulsory	0.320	0.180	0.226	0.192	0.097
CEO education: upper secondary	0.504	0.582	0.492	0.461	0.419
CEO education: tertiary	0.176	0.238	0.282	0.346	0.484
CEO age: 15-39 y.o.	0.072	0.076	0.053	0.070	0.069
CEO age: 40-49 y.o.	0.255	0.255	0.239	0.234	0.245
CEO age: 50-59 y.o.	0.338	0.356	0.332	0.308	0.347
CEO age: 60+ y.o.	0.336	0.312	0.376	0.387	0.340
Female CEO	0.140	0.159	0.101	0.123	0.148
External (hired) CEO	0.029	0.035	0.057	0.047	0.073
CEO remuneration: related to performance	0.455	0.485	0.381	0.360	0.398
Panel (b)					
Multinomial logit model: odds with respect to the baseline (3) Matched category					
Use of public employment services	0.9042 (0.0810)	1.0575 (0.0942)	-	1.1772 (0.1275)	1.2600** (0.1140)
Use of private recruitment agencies	0.7618*** (0.0445)	0.9144 (0.0536)	-	0.9369 (0.0678)	1.0727 (0.0642)
Job turnover rate	0.9997 (0.0006)	0.9988** (0.0006)	-	1.0001 (0.0007)	0.9997 (0.0006)
The firm offers on-the-job training	0.7851*** (0.0366)	0.8318*** (0.0389)	-	0.9647 (0.0563)	1.0196 (0.0500)
Average span of control per supervisor	1.0159*** (0.0035)	1.0144*** (0.0035)	-	0.9959 (0.0048)	1.0090*** (0.0035)
Second-level wage bargaining	0.9195 (0.0686)	0.8640* (0.0664)	-	0.7047*** (0.0667)	0.7406*** (0.0575)
Workforce and CEO characteristics				Yes	
Year, region and industry FEs				Yes	
Pseudo-R2				0.1224	
# Observations	19,294	22,995	2,914	3,498	13,305
# Firms				62,006	

Note: IITLFS-RIL database; 2009, 2014, 2017. Both descriptive statistics (Panel A) and multinomial logit estimates (Panel B) refer to observations with non-missing values in all relevant variables. Categories are defined, based on the statistical approach, as it follows: (1) “Undereducation”: the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) “Too much secondary”: the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) “Matched”: the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) “Too little secondary”: the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) “Overeducation”: the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one. Category (3), Matched, gathers also firm-year pairs for which deviations from the expected educational shares are bounded within 5 percentage points. Panel (b) shows the relative risk ratios for a one-unit change in the predictor variable obtained from estimating a multinomial logit model in which the baseline category is (3), Matched. Firm controls (Workforce and CEO characteristics), industry FEs, region FEs, and year FEs are included. Full tables available from the authors upon request. Clustered (firm) standard errors in parenthesis. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

Table B.3 – Intensity, type of mismatch and dimensions of firm performance

	(1) Sales x employee (log.)	(2) Sales x employee (log.)	(3) Dummy: R&D investments	(4) Dummy: R&D investments	(5) Dummy: investments in ICTs	(6) Dummy: investments in ICTs	(7) Dummy: investments in K	(8) Dummy: investments in K	(9) Dummy: exporter	(10) Dummy: exporter
Mismatch	-0.0006** (0.0003)	-0.0013*** (0.0003)	-0.0004*** (0.0001)	-0.0007*** (0.0001)	-0.0008*** (0.0001)	-0.0011*** (0.0001)	-0.0010*** (0.0001)	-0.0011*** (0.0001)	-0.0007*** (0.0001)	-0.0010*** (0.0001)
(1) Undereducation		-0.0326 (0.0236)		-0.0255*** (0.0068)		-0.0246*** (0.0082)		-0.0387*** (0.0092)		-0.0371*** (0.0077)
(2) Too much secondary		0.0413* (0.0250)		-0.0041 (0.0071)		0.0055 (0.0086)		-0.0143 (0.0095)		-0.0095 (0.0080)
(4) Too little secondary		0.0651** (0.0294)		0.0118 (0.0086)		0.0115 (0.0104)		0.0094 (0.0117)		0.0360*** (0.0097)
(5) Overeducation		0.1272*** (0.0262)		0.0506*** (0.0076)		0.0521*** (0.0091)		-0.0014 (0.0100)		0.0603*** (0.0084)
Constant	4.8932*** (0.0093)	4.8790*** (0.0217)	0.1197*** (0.0022)	0.1252*** (0.0063)	0.2301*** (0.0029)	0.2331*** (0.0076)	0.3516*** (0.0034)	0.3715*** (0.0085)	0.2833*** (0.0030)	0.2920*** (0.0072)
Industry-region Fes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Size class FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.1514	0.1532	0.1553	0.1618	0.1389	0.1426	0.1834	0.1844	0.3753	0.3810
#Observations	53,652	53,652	62,006	62,006	62,006	62,006	62,006	62,006	62,006	62,006
#Firms	38,343	38,343	43,424	43,424	43,424	43,424	43,424	43,424	43,424	43,424

Note: IITLFS-RIL database; 2009, 2014, 2017. Coefficients of industry-region FEs, year FEs, and firm size classes FEs are not reported to save space. Full tables are available from authors upon request. Categories are defined, based on the statistical approach, as it follows: (1) 'Undereducation': the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) 'Too much secondary': the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) 'Matched': the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) 'Too little secondary': the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) 'Overeducation': the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one. Category (3), which is the baseline (omitted) category, gathers also firm-year pairs for which deviations in absolute values from the expected educational shares are within 5 percentage points and is omitted (i.e., the baseline). Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

B.3 Robustness checks and tables not included in the main text

In this section, we report several robustness checks and complete tables that were not reported in the main text due to space limitations. Table B.4 shows a comparison of the OLS coefficients with the marginal effects obtained by estimating a fractional probit model, due to the nature of our dependent variable, the intensity of the mismatch, which is bounded by construction between 0 and 100. In comparing the OLS results with those of the fractional probit model, the regressors have been scaled by a factor of 1/100 because in the fractional model the outcome varies on a scale of 0-1. The fractional probit estimates largely confirm the OLS estimates.

Table B.4 – OLS and fractional probit model for mismatch intensity

	(1) OLS	(2) Fractional probit model (dy/dx)
Use of public employment services for recruitment	-0.1398 (0.3106)	-0.1872 (0.3212)
Use of recruitment agencies	-0.3759* (0.2200)	-0.5347** (0.2220)
Job turnover rate	-0.0037* (0.0019)	-0.0036** (0.0018)
The firm offers on-the-job training	-0.9512*** (0.1583)	-0.9495*** (0.1503)
Average span of control per supervisor	0.0567*** (0.0077)	0.0601*** (0.0072)
Second-level wage barg.	0.4497 (0.2885)	-0.1904 (0.3098)
Categories of mismatch	Yes	Yes
Firm controls	Yes	Yes
Industry-region FEs	Yes	Yes
Year FEs	Yes	Yes
Adj.R-squared	0.2645	
Pseudo-R2		0.0427
#Observations	61,971	61,971
#Firms	43,408	43,408

Note: ITLFS-RIL database; 2009, 2014, 2017. Coefficients of industry-region FEs, year FEs and firm controls are not reported to save space. In both columns category (3, Matched), which gathers only 35 observations, is omitted from the sample. Full tables are available from authors upon request. Column (1) reports the preferred OLS estimates (corresponding to col. 3 of Table B.5). Column (2) reports the marginal effects (dy/dx) for human resource practices. Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

Table B.5 shows the estimates of the coefficients of all the control variables included in the baseline linear model with and without the introduction of the categories related to the types of mismatch. The coefficient estimates of both the HRPs proxies and the firm controls are consistent across the different specifications. This is also confirmed when we introduce the HRPs proxies stepwise into the empirical model, as shown in Table B.6. Table B.7 reports IV estimates, treating one HRP at a time as endogenous (in bold). The endogeneity test (Chi-sq. test) rejects the null hypothesis indicating a potential bias in the OLS estimates only for three HRPs (use of private recruitment agencies, the average span of control, and second-level wage

bargaining). The Kleibergen-Paap Wald LM statistics also show that, in these models, instruments have a strong correlation with the respective endogenous regressor.

The coefficient estimates of the empirical model with interactions defined by Eq. (2) are presented in Table B.8.

Table B.5 – OLS estimates of mismatch intensity - various model specifications

	(1) OLS	(2) OLS	(3) OLS	(4) OLS with firm FEs
Use of public employment services for recruitment	0.3273 (0.3243)	-0.1379 (0.3105)	-0.1398 (0.3106)	0.3707 (0.4693)
Use of recruitment agencies	0.2140 (0.2309)	-0.3701* (0.2198)	-0.3759* (0.2200)	-0.6067 (0.4173)
Job turnover rate	-0.0055*** (0.0020)	-0.0037* (0.0019)	-0.0037* (0.0019)	-0.0004 (0.0038)
The firm offers on-the-job training	-0.6955*** (0.1661)	-0.9504*** (0.1583)	-0.9512*** (0.1583)	-0.6332** (0.2669)
Average span of control per supervisor	0.0533*** (0.0073)	0.0566*** (0.0077)	0.0567*** (0.0077)	0.0561*** (0.0206)
Second-level wage barg. (link to prod.)	0.3164 (0.2984)	0.4603 (0.2882)	0.4497 (0.2885)	-0.1765 (0.5336)
Firm size (no. employees, log)	-4.1271*** (0.1009)	-4.0417*** (0.0969)	-4.0454*** (0.0970)	-5.7311*** (0.4104)
No. of layers	-0.7868*** (0.1354)	-0.8220*** (0.1303)	-0.8242*** (0.1303)	-0.4196 (0.2944)
Share of employees with fixed-term contracts	0.0131** (0.0053)	0.0216*** (0.0050)	0.0215*** (0.0050)	0.0093 (0.0110)
Share of employees with part-time contracts	0.0053 (0.0033)	0.0081** (0.0032)	0.0080** (0.0032)	0.0001 (0.0070)
Share of female employees	0.0056 (0.0037)	-0.0126*** (0.0036)	-0.0126*** (0.0036)	-0.0243** (0.0118)
Share of employees 25-34 y.o.	-0.0009 (0.0072)	0.0015 (0.0067)	0.0016 (0.0067)	0.0039 (0.0126)
Share of employees 35-49 y.o.	-0.0503*** (0.0067)	-0.0300*** (0.0062)	-0.0299*** (0.0062)	-0.0060 (0.0127)
Share of employees 50+ y.o.	-0.1022*** (0.0071)	-0.0598*** (0.0066)	-0.0597*** (0.0066)	-0.0376*** (0.0140)
Union representation (RSA/RSU)	0.8147*** (0.2267)	1.0711*** (0.2143)	1.0774*** (0.2144)	-0.6673 (0.4779)
CEO education: upper secondary	2.1352*** (0.2103)	0.5040** (0.1998)	0.5056** (0.1999)	1.1901*** (0.4565)
CEO education: tertiary	3.5836*** (0.2555)	1.2286*** (0.2457)	1.2275*** (0.2459)	1.1813** (0.5963)
CEO age:40-49 y.o.	-0.4362 (0.3319)	-0.4904 (0.3150)	-0.4861 (0.3151)	0.6648 (0.6130)
CEO age:50-59 y.o.	-0.0359 (0.3269)	-0.4167 (0.3102)	-0.4132 (0.3103)	0.7513 (0.6431)
CEO age:60+ y.o.	-0.3082 (0.3320)	-0.7866** (0.3151)	-0.7850** (0.3151)	0.4803 (0.6663)
Female CEO	0.1976 (0.2274)	0.2673 (0.2174)	0.2673 (0.2175)	0.0489 (0.5490)
External (hired) CEO	0.3689 (0.3463)	-0.1644 (0.3388)	-0.1575 (0.3388)	-0.5409 (0.5492)
CEO remuneration: related to performance	0.5591*** (0.1574)	0.6762*** (0.1493)	0.6763*** (0.1494)	-0.0704 (0.2638)
(2) Too much secondary		11.9118*** (0.1905)	11.9101*** (0.1905)	10.9760*** (0.3666)
(3) Matched		-22.4107*** (1.7050)		
(4) Too little secondary		1.4291*** (0.2245)	1.4330*** (0.2245)	3.3413*** (0.4780)
(5) Overeducation		12.8209*** (0.2375)	12.8217*** (0.2375)	11.8539*** (0.4640)
Constant	44.3687*** (0.7524)	37.1656*** (0.7076)	37.1691*** (0.7076)	38.6868*** (1.8931)
Industry-region FEs	Yes	Yes	Yes	No
Firm FEs	No	No	No	Yes
Year FEs	Yes	Yes	Yes	Yes
Adj. R-squared	0.1897	0.2654	0.2645	0.4624
#Observations	62006	62006	61971	33582
#Firms	43424	43424	43408	15019

Note: IITLFS-RIL database; 2009, 2014, 2017. Coefficients of industry-region FEs, firm FEs and year FEs are not reported to save space. Full tables are available from authors upon request. Categories are defined, based on the statistical approach, as it follows: (1) 'Undereducation': the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) 'Too much secondary': the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) 'Matched': the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) 'Too little secondary': the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) 'Overeducation': the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one. In columns (2), (3) and (4), category (1, Undereducation) is omitted, i.e. the baseline. In columns (3) and (4), category (3), which gathers only 35 observations, is omitted from the sample. Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

Table B.6 – OLS estimates of mismatch intensity: Introducing HRPs stepwise

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS
Use of public employment services for recruitment		0.2520	0.2349	0.2677	0.3255	0.3260	0.3273
		(0.3230)	(0.3241)	(0.3243)	(0.3245)	(0.3243)	(0.3243)
Use of recruitment agencies			0.1186	0.1415	0.1877	0.2277	0.2140
			(0.2309)	(0.2309)	(0.2309)	(0.2309)	(0.2309)
Job turnover rate				-0.0055*** (0.0020)	-0.0054*** (0.0020)	-0.0055*** (0.0020)	-0.0055*** (0.0020)
The firm offers on-the-job training					-0.7163*** (0.1661)	-0.6914*** (0.1660)	-0.6955*** (0.1661)
Average span of control per supervisor						0.0531*** (0.0073)	0.0533*** (0.0073)
Second-level wage barg. (link to prod.)							0.3164 (0.2984)
Firm size (no. employees, log)	-3.8323*** (0.0862)	-3.8371*** (0.0865)	-3.8423*** (0.0874)	-3.8483*** (0.0874)	-3.7833*** (0.0888)	-4.1216*** (0.1006)	-4.1271*** (0.1009)
No. of layers	-1.2000*** (0.1248)	-1.2012*** (0.1248)	-1.2055*** (0.1251)	-1.2050*** (0.1251)	-1.1755*** (0.1252)	-0.7796*** (0.1351)	-0.7868*** (0.1354)
Share of employees with fixed-term contracts	0.0100** (0.0050)	0.0100** (0.0050)	0.0099** (0.0050)	0.0139*** (0.0053)	0.0134** (0.0053)	0.0131** (0.0053)	0.0131** (0.0053)
Share of employees with part-time contracts	0.0061* (0.0033)	0.0061* (0.0033)	0.0061* (0.0033)	0.0061* (0.0033)	0.0057* (0.0033)	0.0054 (0.0033)	0.0053 (0.0033)
Share of female employees	0.0065* (0.0037)	0.0064* (0.0037)	0.0064* (0.0037)	0.0065* (0.0037)	0.0063* (0.0037)	0.0056 (0.0037)	0.0056 (0.0037)
Share of employees 25-34 y.o.	0.0002 (0.0072)	0.0002 (0.0072)	0.0002 (0.0072)	-0.0009 (0.0072)	-0.0014 (0.0072)	-0.0009 (0.0072)	-0.0009 (0.0072)
Share of employees 35-49 y.o.	-0.0490*** (0.0067)	-0.0489*** (0.0067)	-0.0489*** (0.0067)	-0.0503*** (0.0067)	-0.0511*** (0.0067)	-0.0503*** (0.0067)	-0.0503*** (0.0067)
Share of employees 50+ y.o.	-0.1005*** (0.0070)	-0.1004*** (0.0070)	-0.1004*** (0.0070)	-0.1018*** (0.0071)	-0.1028*** (0.0071)	-0.1022*** (0.0071)	-0.1022*** (0.0071)
Union representation (RSA/RSU)	0.8572*** (0.2214)	0.8569*** (0.2214)	0.8521*** (0.2216)	0.8490*** (0.2216)	0.8730*** (0.2216)	0.8637*** (0.2215)	0.8147*** (0.2267)
CEO education: upper secondary	2.1218*** (0.2103)	2.1224*** (0.2103)	2.1205*** (0.2104)	2.1172*** (0.2103)	2.1310*** (0.2104)	2.1365*** (0.2103)	2.1352*** (0.2103)
CEO education: tertiary	3.5682*** (0.2552)	3.5685*** (0.2552)	3.5647*** (0.2553)	3.5583*** (0.2553)	3.5855*** (0.2553)	3.5945*** (0.2553)	3.5836*** (0.2555)
CEO age:40-49 y.o.	-0.4084 (0.3320)	-0.4075 (0.3320)	-0.4083 (0.3320)	-0.4302 (0.3321)	-0.4398 (0.3320)	-0.4326 (0.3319)	-0.4362 (0.3319)
CEO age:50-59 y.o.	0.0035 (0.3270)	0.0055 (0.3270)	0.0054 (0.3270)	-0.0260 (0.3271)	-0.0435 (0.3270)	-0.0318 (0.3269)	-0.0359 (0.3269)
CEO age:60+ y.o.	-0.2765 (0.3319)	-0.2732 (0.3319)	-0.2722 (0.3319)	-0.3106 (0.3321)	-0.3341 (0.3320)	-0.3072 (0.3320)	-0.3082 (0.3320)
Female CEO	0.1572 (0.2275)	0.1558 (0.2275)	0.1561 (0.2275)	0.1643 (0.2275)	0.1835 (0.2274)	0.1974 (0.2274)	0.1976 (0.2274)
External (hired) CEO	0.4195 (0.3451)	0.4162 (0.3452)	0.4130 (0.3451)	0.4211 (0.3451)	0.4156 (0.3449)	0.3878 (0.3457)	0.3689 (0.3463)
CEO remuneration: related to performance	0.5560*** (0.1571)	0.5562*** (0.1571)	0.5554*** (0.1571)	0.5591*** (0.1571)	0.5615*** (0.1570)	0.5679*** (0.1570)	0.5591*** (0.1574)
Constant	44.1819*** (0.7404)	44.1763*** (0.7405)	44.1882*** (0.7412)	44.4585*** (0.7483)	44.6832*** (0.7504)	44.3344*** (0.7511)	44.3687*** (0.7524)
Industry-region FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R-squared	0.1885	0.1885	0.1885	0.1886	0.1889	0.1897	0.1897
#Observations	62006	62006	62006	62006	62006	62006	62006
#Firms	43424	43424	43424	43424	43424	43424	43424

Note: ITLFS-RIL database; 2009, 2014, 2017. Coefficients of industry-region FEs, and year FEs are not reported to save space. Full tables are available from authors upon request. Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

Table B.7 – IV estimation of mismatch intensity, selected variables (HRPs); 1-wave lagged HRP as instruments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	IV GMM (end.: pub. emp. serv.)	IV GMM(end.: recr. ag.)	IV GMM(end.: job turn.)	IV GMM(end.: train.)	IV GMM (end.: sp. cont.)	IV GMM(end.: 2wagebarg.)	IV GMM (end.: recr. ag., 2wagebarg., sp. cont.)
Use of public employment services for recruitment	-0.1398	-4.9406	-0.3178	-0.3858	-0.4735	-0.4783	-0.4511	-0.3538
	(0.3106)	(4.7471)	(0.4814)	(0.4876)	(0.4871)	(0.4792)	(0.4780)	(0.4843)
Use of recruitment agencies	-0.3759*	-0.3091	-1.5507**	-0.5178	-0.5958*	-0.5495*	-0.6930**	-1.6296**
	(0.2200)	(0.4341)	(0.6574)	(0.3361)	(0.3354)	(0.3297)	(0.3344)	(0.6700)
Job turnover rate	-0.0037*	-0.0025	-0.0030	-0.0202	-0.0033	-0.0052	-0.0033	-0.0048
	(0.0019)	(0.0032)	(0.0031)	(0.0183)	(0.0031)	(0.0032)	(0.0031)	(0.0032)
The firm offers on-the-job training	-0.9512***	-0.8449***	-0.9059***	-0.9132***	-0.6314	-0.9140***	-0.9672***	-0.9294***
	(0.1583)	(0.2545)	(0.2391)	(0.2392)	(1.1462)	(0.2390)	(0.2394)	(0.2400)
Average span of control per supervisor	0.0567***	0.0390***	0.0382***	0.0391***	0.0392***	0.0665***	0.0405***	0.0680***
	(0.0077)	(0.0113)	(0.0112)	(0.0113)	(0.0113)	(0.0197)	(0.0114)	(0.0200)
Second-level wage barg. (link to prod.)	0.4497	0.9205**	1.0029**	0.8451**	0.8907**	0.8800**	3.0884***	3.1264***
	(0.2885)	(0.4146)	(0.4152)	(0.4139)	(0.4225)	(0.4153)	(1.0873)	(1.0991)
Constant	37.1691***							
	(0.7076)							
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-region FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.2645	0.1513	0.1535	0.1505	0.1537	0.1504	0.1531	0.1494
#Observations	61971	27114	27114	26840	27114	26806	27114	26806
#Firms	43408	19193	19193	19004	19193	18986	19193	18986
Underidentification test: Kleibergen-Paap rk LM stat. (p-value)		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Weak identification test: Kleibergen-Paap rk Wald F stat.		92.6155	3422.0378	9.9756	904.8001	100.0165	955.8026	323.2770
Chi-sq. test of endogenous regressors, p-value (H0: the endogenous regressors can be treated as exogenous)		0.3275	0.0745	0.3899	0.7837	0.0590	0.0211	0.0110

Note: ITLFS-RIL database; 2009, 2014, 2017. 1-wave lagged HRP are used as instruments for current HRP. Coefficients of industry-region FEs, year FEs, and firm controls are not reported to save space. Full tables are available from authors upon request. Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.

Table B.8 – OLS Estimates of mismatch intensity with interactions between HRPs and the type of mismatch

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Use of public employment services for recruitment	-0.1398 (0.3106)	0.5787 (0.4498)	-0.1208 (0.3104)	-0.1556 (0.3106)	-0.1295 (0.3106)	-0.1146 (0.3105)	-0.1329 (0.3102)	-0.1101 (0.3101)
Use of recruitment agencies	-0.3759* (0.2200)	-0.3719* (0.2200)	0.8431*** (0.2858)	-0.3719* (0.2199)	-0.3623* (0.2199)	-0.3795* (0.2199)	-0.3741* (0.2196)	0.1882 (0.2854)
Job turnover rate	-0.0037* (0.0019)	-0.0037* (0.0019)	-0.0036* (0.0019)	-0.0109*** (0.0026)	-0.0037* (0.0019)	-0.0036* (0.0019)	-0.0036* (0.0019)	-0.0104*** (0.0026)
The firm offers on-the-job training	-0.9512*** (0.1583)	-0.9509*** (0.1584)	-0.9517*** (0.1584)	-0.9529*** (0.1583)	0.0364 (0.2180)	-0.9470*** (0.1583)	-0.9587*** (0.1583)	-0.2915 (0.2196)
Average span of control per supervisor	0.0567*** (0.0077)	0.0568*** (0.0077)	0.0569*** (0.0077)	0.0567*** (0.0077)	0.0572*** (0.0077)	0.1246*** (0.0157)	0.0566*** (0.0077)	0.1211*** (0.0157)
Second-level wage barg. (link to prod.)	0.4497 (0.2885)	0.4485 (0.2884)	0.4246 (0.2882)	0.4667 (0.2883)	0.4305 (0.2881)	0.4257 (0.2889)	3.0288*** (0.3584)	2.4679*** (0.3625)
Use of public employment services for recruitment # (2) Too much secondary		-0.8677 (0.7396)						
Use of public employment services for recruitment # (4) Too little secondary		-1.1310 (0.7981)						
Use of public employment services for recruitment # (5) Overeducation		-1.1090 (0.7539)						
Use of recruitment agencies # (2) Too much secondary			-1.7929*** (0.4761)					-0.7857 (0.4875)
Use of recruitment agencies # (4) Too little secondary			-0.5160 (0.5219)					-0.0575 (0.5350)
Use of recruitment agencies # (5) Overeducation			-2.0451*** (0.4984)					-1.0074*** (0.5069)
(2) Too much secondary # Job turnover rate				0.0069* (0.0038)				0.0064* (0.0038)
(4) Too little secondary # Job turnover rate				0.0144*** (0.0053)				0.0143*** (0.0054)
(5) Overeducation # Job turnover rate				0.0206*** (0.0053)				0.0198*** (0.0053)
The firm offers on-the-job training # (2) Too much secondary					-1.5005*** (0.3191)			-1.0191*** (0.3266)
The firm offers on-the-job training # (4) Too little secondary					-0.4871 (0.4441)			-0.3667 (0.4524)
The firm offers on-the-job training # (5) Overeducation					-1.7834*** (0.4195)			-1.1689*** (0.4283)
(2) Too much secondary # Average span of control per supervisor						-0.0931*** (0.0166)		-0.0868*** (0.0166)
(4) Too little secondary # Average span of control per supervisor						0.0002 (0.0391)		0.0003 (0.0392)

continuing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
(5) Overeducation # Average span of control per supervisor						-0.1092*** (0.0183)		-0.1044*** (0.0183)
Second-level wage barg. (link to prod.) # (2) Too much secondary							-4.1526*** (0.6137)	-3.3318*** (0.6312)
Second-level wage barg. (link to prod.) # (4) Too little secondary							-1.7373*** (0.6303)	-1.3784** (0.6533)
Second-level wage barg. (link to prod.) # (5) Overeducation							-4.5495*** (0.6272)	-3.5847*** (0.6431)
(2) Too much secondary	11.9101*** (0.1905)	11.9429*** (0.1942)	12.1050*** (0.2029)	11.7267*** (0.2149)	12.6457*** (0.2550)	12.4694*** (0.2177)	12.1537*** (0.1966)	13.0422*** (0.2924)
(3) Matched								
(4) Too little secondary	1.4330*** (0.2245)	1.4854*** (0.2322)	1.4405*** (0.2507)	1.0586*** (0.2659)	1.6172*** (0.3654)	1.4466*** (0.3170)	1.5220*** (0.2392)	1.2620*** (0.4467)
(5) Overeducation	12.8217*** (0.2375)	12.8743*** (0.2442)	13.1086*** (0.2600)	12.2964*** (0.2746)	13.8045*** (0.3585)	13.5347*** (0.2712)	13.1650*** (0.2485)	14.0564*** (0.4093)
Constant	37.1691*** (0.7076)	37.1422*** (0.7079)	37.0354*** (0.7086)	37.3612*** (0.7083)	36.7115*** (0.7112)	36.8253*** (0.7098)	37.0400*** (0.7073)	36.5591*** (0.7137)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-region FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.2645	0.2645	0.2647	0.2647	0.2648	0.2654	0.2651	0.2663
#Observations	61,971	61,971	61,971	61,971	61,971	61,971	61,971	61,971
#Firms	43,408	43,408	43,408	43,408	43,408	43,408	43,408	43,408

Note: ITLFS-RIL database; 2009, 2014, 2017. Coefficients of industry-region FEs, year FEs and firm controls are not reported to save space. Full tables are available from authors upon request. Categories are defined, based on the statistical approach, as it follows: (1) 'Undereducation': the actual share of employees with compulsory (tertiary) education is greater or equal (lower or equal) to the expected one; (2) 'Too much secondary': the actual share of employees with compulsory (tertiary) education is lower than (lower or equal to) the expected one; (3) 'Matched': the actual shares of employees with compulsory, upper secondary and tertiary education is equal to the expected ones; (4) 'Too little secondary': the actual share of employees with tertiary (compulsory) education is greater or equal to (greater than) the expected one; (5) 'Overeducation': the actual share of employees with tertiary (compulsory) education is greater or equal (lower or equal) to the expected one. In all columns, category (1, Undereducation) is omitted, i.e. the baseline. In all columns, category (3, Matched), which gathers only 35 observations, is omitted from the sample. Cluster- (firm) robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *, ** and ***, respectively.