



Skills or credentials? How skill specific and standardized vocational training moderates the wages of occupational mismatches

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ABSTRACT

This article examines the relationship between institutional features of vocational education and wage outcomes following occupational mismatches using a multidimensional mismatch framework. Drawing on German administrative data for early-career male VET graduates, the analysis assesses how two institutional dimensions, training standardization and skill specificity, relate to wage returns for horizontal, vertical, and full mismatches. The results show that higher standardization negatively moderates wage outcomes for horizontal and full mismatches, while greater skill specificity is linked to reduced transferability and increases wage penalties for vertical mismatches. Individuals in full mismatches experience large baseline penalties that appear less conditioned by institutional features. Horizontal mismatches do not show wage penalties when multiple mismatch dimensions are considered simultaneously. These findings suggest that distinct institutional features of the training system, credential verification and skill transferability, relate to mismatch outcomes and contribute to stratification in early-career wages.

1. Introduction

Vocational education and training (VET) systems differ in how they regulate skill acquisition, certification, and labor-market placement, thereby shaping employment opportunities and wage inequality (Abraham et al., 2018; Breen, 2005). Two institutional dimensions are particularly consequential: standardization and skill specificity. Standardization refers to the extent to which curricula and examinations follow comparable certification procedures (Allmendinger, 1989; Di Stasio et al., 2016; Woessmann, 2005), whereas skill specificity captures how narrowly training produces occupation-bound skills with limited transferability (Barbieri et al., 2018; Iversen & Soskice, 2001). Institutionalized training facilitates school-to-work transitions (Bol et al., 2019), reduces unemployment (Breen, 2005; Hanushek et al., 2017), and leads to higher initial wages (Blommaert et al., 2020; Hanushek et al., 2017), but can also reinforce occupational closure and stratification (Bol & Weeden, 2015; Iversen & Soskice, 2001; Van de Werfhorst & Mijs, 2010). In coordinated labor markets like Germany's, where training is closely tied to specific occupations, the institutional variation in training may shape VET labor-market opportunities, but their role in shaping wages for training-inadequate employment remains underexplored.

Institutional features may particularly affect occupational mismatches, where jobs differ from employees' training along one or more dimensions. Horizontal mismatches (HMM) refer to work outside one's vocational field (Robst, 2007), while vertical mismatches (VMM) indicate employment below the qualification level associated with the credential (McGuinness, 2006). About one third of workers in OECD countries are mismatched (OECD, 2023; Vandeplas et al., 2019) and typically face lower job satisfaction, psychological strain, reduced participation in further training, stigmatization, and wage penalties (e.g., Allen & Van der Velden, 2001; Somers et al., 2019; Verhaest et al., 2017; Wen et al., 2023; Damelang & Ruf, 2023). Yet the magnitude of mismatch-related wage losses varies substantially across occupations and institutional contexts (Schweri et al., 2020), suggesting that the institutional design of training shapes wage return. This motivates the central research question: How do training standardization and skill specificity moderate the relationship between occupational mismatches and wages among German VET graduates?

A growing body of research examines how VET graduates fare when their jobs deviate from their training, showing that wage penalties vary with task similarity, occupational boundaries, and skill requirements. Rohrbach-Schmidt and Tiemann (2016) show that task experience reduces subjective skills mismatch but does not eliminate formal

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mismatch wage penalties. [Kracke et al. \(2018\)](#) find that task similarity explains overqualification penalties among VET graduates, and [Eckardt \(2024\)](#) demonstrates that wage losses increase with task distance from the training field. Studies on occupational distance similarly show that transitions into more distant occupations generate larger wage penalties ([Fedorets, 2019](#); [Müller & Schweri, 2015](#)). Together, these studies underscore the importance of task structures and occupational boundaries, but they do not examine how variation within training standardization and skill specificity conditions wage penalties across horizontal, vertical, and full mismatches. This study fills this gap by showing how variation in standardization and skill specificity moderates wage losses for horizontal, vertical, and full mismatches.

This article makes two contributions. First, it advances mismatch research by jointly analyzing horizontal, vertical, and full mismatches (FMM) among VET graduates and by demonstrating that these dimensions produce distinct wage consequences that cannot be inferred from either dimension alone. This multidimensional approach avoids conflating the mechanisms of field- and level-related misalignment and reveals heterogeneity that remains hidden in studies focusing solely on overqualification. Second, it contributes to research on educational stratification by demonstrating that institutional variation in standardization and skill specificity conditions the wage effects of mismatches. By exploiting cross-occupation heterogeneity within Germany's VET system ([Stuth, 2020](#); [Vicari, 2014](#); [BIBB, 2022](#)), the analysis shows that stronger credential comparability and narrower skill profiles systematically structure the wage consequences of training-occupation misalignment, embedding mismatch penalties into broader patterns of labor-market stratification.

To investigate these institutional mechanisms, the analysis draws on the administrative Sample of Integrated Labor Biographies (SIAB 2012–2019) and examines 13,365 full-time employed male graduates of Germany's dual VET system. Germany provides an ideal context because its internationally recognized dual system tightly links apprenticeships and school-based training to occupational roles ([Wolbers, 2007](#)), while exhibiting substantial variation in standardization of curricula and examinations ([Vicari, 2014](#)) and in the specificity of occupation-bound skills ([Stuth, 2020](#)). Mismatches are identified by comparing certified training occupations with current jobs using KldB 2010 classifications ([Müller & Schweri, 2015](#)). A field-of-training fixed-effects design compares mismatched workers directly to matched peers from the same training occupation. The results show that standardization negatively moderates wage outcomes for horizontal and full mismatches, whereas skill specificity amplifies penalties for vertical mismatches. These findings suggest that wage returns vary not only by the type of occupational misalignment but also on the institutional features of training occupations, indicating that institutional variation within a single VET system is closely linked to early-career wage stratification.

2. Theoretical framework

Occupational mismatches affect wages through two mechanisms shaped by the institutional design of vocational training systems. From an occupational-closure perspective, mismatches weaken the labor-market value of vocational credentials that normally grant access to regulated and higher-paying jobs ([Acemoglu & Pischke, 2000](#); [Bol & Weeden, 2015](#); [Weeden, 2002](#)). Working below one's qualification level reduces access to these credential-restricted positions, whereas working outside the trained field undermines the credential's jurisdictional claim and erodes workers' bargaining power. From a human-capital perspective, mismatches reduce wages because workers cannot fully deploy the occupation-specific skills acquired during training when job tasks diverge from training content, lowering expected productivity and wage returns ([Hanushek et al., 2017](#); [Heijke et al., 2003](#)). Because training fields shape occupational skill profiles, specialization, and skill transferability ([Grønning et al., 2020](#)), these mechanisms manifest differently across mismatch dimensions. Yet it is unclear under which institutional

conditions these mechanisms translate into wage penalties. Their strength depends on institutional features of vocational training, particularly standardization and skill specificity, which vary substantially across German VET occupations. Standardization shapes how visible and enforceable credential–occupation boundaries are, while skill specificity determines how far training-based skills can be applied across occupational contexts. These distinct institutional channels motivate the separate theoretical treatment of standardization and skill specificity in the following sections.

2.1. Standardization and credential-based closure

Standardization strengthens the institutional authority, comparability, and jurisdictional boundaries of vocational credentials by regulating curricula, examinations, and certification procedures nationwide ([Allmendinger, 1989](#); [Di Stasio et al., 2016](#); [Weeden, 2002](#)). These arrangements transform vocational qualifications into formal closure devices: they clarify which occupations a credential grants access to, reduce employer uncertainty, and reinforce the wage-setting power attached to field-aligned credentials ([Acemoglu & Pischke, 2000](#); [Bol & Weeden, 2015](#); [Weeden, 2002](#)), especially in the early career ([Rageth & Sritharan, 2022](#)). Because standardized credentials establish clear and enforceable occupational jurisdictions, their value depends heavily on whether workers remain within the credential's recognized domain ([Montt, 2017](#)). For occupational mismatches, standardization shapes how visible and economically consequential the deviation from the credential–occupation linkage becomes.

For horizontal mismatches, working outside one's training field undermines the jurisdictional claim of the credential and reduces employers' willingness to pay for qualifications that do not correspond to the expected field ([Di Stasio et al., 2016](#); [Weeden, 2002](#)). Higher standardization increases the transparency of field-specific competence claims, making the absence of field-adequate training more salient and limiting workers' ability to invoke the credential as a bargaining resource ([Bol & Van de Werfhorst, 2013](#)). This undermines workers' ability to leverage the credential in wage bargaining and reduces access to field-specific wage premiums. Consequently, the loss of closure-based authority is sharper in highly standardized fields, which strengthens the negative association between horizontal mismatch and wages, even if horizontally mismatched workers do not always face absolute wage losses ([Schweri et al., 2020](#); [Somers et al., 2019](#)).

H1a. Standardization strengthens the negative association between horizontal mismatch and wages. ($\beta(\text{HMM} \times \text{Standardization}) < 0$)

For vertical mismatches, standardized credentials may positively moderate wage outcomes. Although overqualified workers lose the wage premium linked to the job's required qualification level, they remain within the correct occupational jurisdiction. Standardization preserves some of the credential's closure value by clearly signaling qualification hierarchies within the field, allowing overqualified workers to retain portions of the credential premium despite job-level underutilization ([Levels et al., 2014](#)). Thus, standardization should weaken the negative association between vertical mismatch and wages.

H1b. Standardization weakens the negative association between vertical mismatch and wages. ($\beta(\text{VMM} \times \text{Standardization}) > 0$)

For full mismatches, the wage outcomes may be negatively moderated by standardization, as workers leave both the field jurisdiction and the qualification hierarchy associated with the credential. Standardization heightens the visibility of this dual deviation while eliminating any remaining closure-based bargaining value tied to the credential's field. Because the positive mechanism identified for VMM (H1b) no longer applies once the field boundary is crossed, the amplified penalty associated with horizontal deviation dominates.

H1c. Standardization strengthens the negative association between

full mismatch and wages. ($\beta(\text{FMM} \times \text{Standardization}) < 0$)

2.2. Skill specificity and the transferability of occupation-specific human capital

Skill specificity moderates mismatch penalties by shaping how much of the vocational skill set remains productive when workers move into jobs that differ from their trained occupation. It captures the extent to which competencies acquired in VET are tied to narrowly defined occupational tasks and therefore have limited transferability across occupational fields (Barbieri et al., 2018; Iversen & Soskice, 2001; Shavit & Müller, 1997). From a human-capital perspective, specific skills raise productivity and ease school-to-work transitions in closely related jobs (Becker, 1967; Mincer, 1974; Bol & van de Werfhorst, 2013), but also reduce adaptability and thus earnings when workers enter occupations that do not require their specialized skills (Blommaert et al., 2020; Hanushek et al., 2017). Employers further reinforce this pattern by valuing occupation-specific skills for their immediate productivity and low training costs (Marginson, 2019; McDonald & Korber, 2023).

Because the wage effects of mismatches arise from lower expected productivity in jobs that do not utilize training-based competencies, their magnitude depends on how far these competencies can transfer. Skill specificity restricts this transferability and should therefore amplify wage penalties across all mismatch dimensions (Hanushek et al., 2017; Heijke et al., 2003; Iversen & Soskice, 2001). For horizontal mismatches, field-bound skills have limited relevance for tasks in unrelated occupational segments (Nordin et al., 2010). For vertical mismatches, high-level skills cannot be deployed in lower-qualified roles, and for full mismatches, both forms of skill loss occur simultaneously. Consequently, higher skill specificity should uniformly intensify the negative association between mismatch and wages due to limited transferability.

H2a. Skill specificity strengthens the negative association between horizontal mismatch and wages. ($\beta(\text{HMM} \times \text{Specificity}) < 0$)

H2b. Skill specificity strengthens the negative association between vertical mismatch and wages. ($\beta(\text{VMM} \times \text{Specificity}) < 0$)

H2c. Skill specificity strengthens the negative association between full mismatch and wages. ($\beta(\text{FMM} \times \text{Specificity}) < 0$)

3. Data, measurements, and methodology

3.1. Data

The analysis draws on the Sample of Integrated Labor Biographies (SIAB 7519), a 2 % random sample of German administrative records containing detailed information on employment histories, wages, occupations, and education (Frodermann et al., 2021). Individual data are linked to the Establishment History Panel (BHP; Ganzer et al., 2021), which provides establishment size, sector, and location. The SIAB is based on mandatory employer reports to the social insurance system and therefore offers highly accurate wage information. Occupations are coded using the KldB-2010 classification, which aligns with ISCO-08 and provides a five-digit structure. These detailed records enable reliable and precise identification of horizontal and vertical mismatches (Speer, 2016; Zimmermann, 2023), making the dataset well suited for studying early-career outcomes across training fields.

The sample focuses on full-time employed male graduates who completed a single dual vocational training program between 2012 and 2019, when KldB-2010 was fully implemented. Individuals with tertiary education or multiple training spells are excluded to avoid confounding from heterogeneous qualification pathways. Apprentices are identified following Fitzenberger et al. (2015), which corrects for delayed reporting of educational information. Restricting the sample to men avoids bias from unobserved working hours, and mitigates selective

part-time employment among women (Dustmann & Schönberg, 2012; Schweri et al., 2020; BIBB, 2022). The analytic sample forms an unbalanced panel of 44,039 observations from 12,339 individuals, covering up to eight years after labor-market entry, when vocational credentials are the primary signal (Gangl, 2004).

3.2. Measurements and variables

3.2.1. Measuring mismatch dimensions

Occupational mismatches are operationalized using the KldB-2010 scientific classification of occupations, which reports codes for all employment and apprenticeship spells in the administrative data. The five-digit structure distinguishes horizontal occupational fields (first four digits) and vertical requirement levels (fifth digit), enabling consistent identification of mismatch dimensions by comparing training and job occupations. Requirement levels reflect the qualification typically needed for an occupation and comprise four hierarchical categories ranging from unskilled to highly specialized tasks (Paulus & Matthes, 2013). Vocational credentials that require a minimum of two years of training correspond to the second level of skilled tasks.

A horizontal mismatch (HMM) occurs when an individual's current occupation belongs to a different horizontal field than their certified training occupation (Robst, 2007). Because horizontal mismatch depends on the definition of sufficient occupational distance (Fedorets, 2019), the analysis follows established practice for VET graduates by relying on occupational segments: 13 task-based groups that meaningfully aggregate training fields and employment occupations in the private sector¹ (Eckardt, 2024; Matthes et al., 2008; Müller & Schweri, 2015). Employees working in a different segment than their vocational training are classified as horizontally mismatched, as the skills gained during training are unlikely to be transferable to other segments. An overview of the training segments and sample shares is provided in Appendix A.1.

Vertical mismatch (VMM) captures deviations from the qualification level associated with the worker's credential. Using the KldB requirement level, workers are classified as adequately matched when employed in skilled-task occupations and as formally overeducated when employed in unskilled-task occupations (Reichelt & Vicari, 2014). Occupations requiring qualifications above skilled tasks would imply undereducation. Since undereducation is generally unrelated to negative outcomes and may indicate career progression, this group is excluded from the sample. This approach aligns with credentialism theory and employer-oriented signaling frameworks, in which the KldB requirement level objectively captures the expected qualification for each occupation.

Table 1 summarizes the four observed states: matching or adequate employment, HMM, VMM, and full mismatches (FMM). FMM denote cases in which workers are simultaneously horizontally mismatched and

Table 1
Measurement of horizontal, vertical, and full mismatches and sample shares.

Vertical dimension: requirement level	Horizontal dimension: field of occupation	
	Training Segment	Different Segment
Skilled Tasks	Matching Occupation (75.3 %)	Horizontal mismatch (HMM) (17.7 %)
	Unskilled Tasks	Full mismatch (FMM) (4.5 %)
	Vertical mismatch (VMM) (2.5 %)	

Note: N = 44,039; Individuals: 12,339; Dataset: SIAB_7519

¹ Excluding public sector and the agricultural segment due to institutional differences in wage setting, credentialization, and labor market structure.

vertically overeducated, describing individuals working in an occupational segment different from their training field and in positions with unskilled task requirements.² The distribution shows that horizontal mismatches are most common (17.7 %), while mere vertical mismatches are rare (2.5 %) and more frequently occur in combination with horizontal deviation (4.5 %). This underscores that studying a single mismatch dimension risks conflating the distinct mechanisms underlying field- and level-related misalignment.

3.2.2. Indicators for standardized and skill specific training

To capture institutional variation across vocational training occupations, the analysis employs two established indicators measuring standardization and skill specificity. The standardization indicator quantifies the degree to which vocational curricula and examination procedures are regulated uniformly at the federal or state level (Vicari, 2014). The index is derived from expert evaluations in the Federal Employment Agency's BERUFENET database, covering 100 occupational groups at the KldB-2010 3-digit level. Higher values indicate stronger extent to which curricula and final training examinations are comparable at the federal or state level. The indicator of skill specificity captures how narrowly job tasks within an occupation rely on specialized versus general competencies. It is based on German Microcensus task information and aggregated to 273 occupations at the KldB-2010 5-digit level (Stuth, 2020). Although constructed from task profiles of employed workers, the measure reflects the extent to which vocational training prepares apprentices for narrowly defined occupational activities during on-the-job training.

Both indicators are time-invariant and assigned to individuals based on their certified training occupation. For comparability, the two measures ranging from 0 to 1 and are z-standardized prior to analysis, allowing coefficients to be interpreted as the effect of a one-standard-deviation difference in standardization or specificity.³ This harmonization facilitates the interpretation of interaction effects, prevents scale differences from distorting moderator estimates, and improves comparability.⁴

3.2.3. Outcome variable: administrative log wages

The outcome variable is the daily gross wage reported in the administrative data. Because employers are legally required to submit accurate wage information for social security purposes, these records are substantially less prone to measurement error, social desirability bias, or selective nonresponse than survey-based earnings measures (Moore et al., 2000). Observations indicating marginal employment are excluded. Wages above the social-security contribution ceiling are top-coded in fewer than 0.2 % of spells. To address this censoring, the analysis applies the imputation procedure proposed by Stüber et al. (2023), which adjusts censored values while preserving the empirical wage distribution. All wages are deflated to real values and log-transformed, allowing regression coefficients to be interpreted as approximate percentage differences in earnings.

3.2.4. Control variables

The model adjusts for a range of individual- and establishment-level characteristics that may influence wages. At the individual level, it includes age and its squared term, a dummy for non-German nationality,

and school-leaving qualifications to capture baseline human capital. To account for skill accumulation and work experience, the specification incorporates overall employment tenure, establishment tenure, and occupational tenure, each grouped into deciles and squared terms. An indicator capturing whether individuals were retained by their training firm serves as a proxy for ability-based selection and employer-specific matching. At the establishment level, the model includes five categories of firm size, along with regional controls for all 16 federal states. and year fixed effects to absorb macroeconomic and cohort-specific trends. Descriptive statistics for all variables are provided in Appendix A.2.

3.3. Analytical strategy

The theory-derived estimand (Lundberg et al., 2021) is the moderating role of institutional training characteristics, i.e. standardization (H1) and skill specificity (H2), on the relationship between mismatches and wages within the same training field. Because training fields strongly shape labor-market outcomes and occupational destinations, most mismatch research compares mismatched workers to adequately matched peers from the same field (e.g., Somers et al., 2019; Bol et al., 2019; Montt, 2017). This study follows that approach by applying a field-of-training fixed-effects (FOT-FE) model, which restricts comparisons to workers from the same vocational field and therefore isolates within-field differences in mismatch returns.

The empirical model estimates the log daily wage of individual i in training field f , establishment e , occupation o , and year t . The key independent variable is a categorical indicator of mismatch status m_{it} (adequate match, HMM, VMM, FMM). Institutional characteristics I_o are captured by two time-constant, z-standardized indicators of standardization and skill specificity, assigned to each worker's training occupation (o). This specification allows the mismatch coefficients to be interpreted as wage differentials evaluated at the sample mean (Imbens & Wooldridge, 2009). The coefficients of interest are the interaction terms ($m_{it} \times I_o$), which identify how mismatch penalties vary across occupations with differing levels of standardization or specificity. The regression model is specified as follows:

$$\ln(\text{wage})_{efit} = \beta_1 m_{it} + \beta_2 I_o + \beta_3 (m_{it} \times I_o) + FOT_f + \gamma_1 X_{it} + \gamma_2 F_{et} + \gamma_3 \text{year}_t + \varepsilon_{efit}$$

Field-of-training fixed-effects (FOT_f) account for unobserved heterogeneity across the 13 training fields f and absorb all baseline wage differences associated with vocational segments (Avent-Holt et al., 2020; Rabe-Hesketh & Skrondal, 2008). The model further includes establishment-level control variables (F_{et}) and individual-level control variables (X_{it}). Year dummies capture macroeconomic and cohort-related variation (year_t), and ε_{efit} denotes the error terms. Standard errors are clustered at the occupational level of the moderator, meaning at the KldB 5-digit level for specificity and the 3-digit level for standardization (Abadie et al., 2023; Cameron & Miller, 2015).

4. Results

Table 2 reports wage estimations from field-of-training fixed-effects models with 13 training-segments, examining wage differences across mismatch dimensions and their moderation by training standardization and skill specificity. See Appendix A.3 for full regression tables. Model 1 estimates the wage effects of horizontal, vertical, and full mismatch without accounting for the institutional context as potential moderator. Vertical mismatches are associated with a statistically significant wage penalty of about 6 % relative to adequately matched workers within the same training field. Full mismatches show substantially larger penalties (around 12%), reflecting the joint disadvantages of both field and qualification misalignment. By contrast, horizontal mismatches do not

² Section B in the Appendix show occupation-training mismatch examples for each dimension.

³ Examples of standardization of occupations: low= food processors (-1.43); mid=steel smiths & planers (0.35); high= electrical engineers (1.09)

Examples of specificity of occupations: low= building services (-1.35), mid= floor layers (-0.10), high= medical assistants (1.29)

⁴ While both dimensions theoretically overlap, they measure distinct features. Empirical correlation between the two indicators is significant but negligible ($r = -0.095^{**}$).

Table 2

Wage outcomes for mismatch dimensions, standardization and specificity.

Reference group: Matched individuals	Model 1 <i>Main</i>	Model 2 <i>Standardization</i>	Model 3 <i>Specificity</i>
HMM	0.005 (0.009)	0.012 (0.010)	0.012 (0.008)
VMM	-0.059*** (0.012)	-0.053*** (0.014)	-0.047*** (0.012)
FMM	-0.122*** (0.013)	-0.109*** (0.014)	-0.121*** (0.015)
<i>Standardization</i>			
HMM x Standardization (H1a)		-0.009 (0.017)	
VMM x Standardization (H1b)		-0.029* (0.013)	
FMM x Standardization (H1c)		0.025 (0.020)	
<i>Specificity</i>			
HMM x Specificity (H2a)			0.015 (0.010)
VMM x Specificity (H2b)			-0.018# (0.011)
FMM x Specificity (H2c)			-0.045** (0.014)
Control Variables	yes	yes	yes
Segment FE	yes	yes	yes
Observations	44,039	44,039	44,039
Adjusted R2	0.469	0.471	0.471

Note: N = 44,039; Individuals: 12,339. Field-of-training fixed-effects models on 13 segment level. The dependent variable is the log daily wage and coefficients show the approximated percentage change. The reference group are matched VET from the same training segment. Significance levels: # $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses.

show a statistically significant wage penalty, indicating that working outside the training field does not entail systematic disadvantages in the absence of institutional moderators.

4.1. The moderating role of standardized training

Model 2 interacts the mismatch dimensions with the z-standardized standardization indicator (Table 2, col. 2). This section first reports the interaction coefficients, which test whether standardization changes the wage slope for mismatched workers, and then presents the combined (post-estimation) coefficients that compare mismatched to matched workers at -1 , 0 , and $+1$ SD of the moderator. Fig. 1 visualizes these predicted log-wage differences relative to matched workers, thereby summarizing how standardization moderates the wage outcomes associated with horizontal, vertical, and full mismatches.

For horizontal mismatches, the interaction with standardization is negative and statistically significant (-0.029), indicating that higher standardization is associated with a steeper HMM–wage slope. The combined coefficients of HMM and standardization at the sample mean (0 SD, Fig. 1) is statistically not significant compared to matched

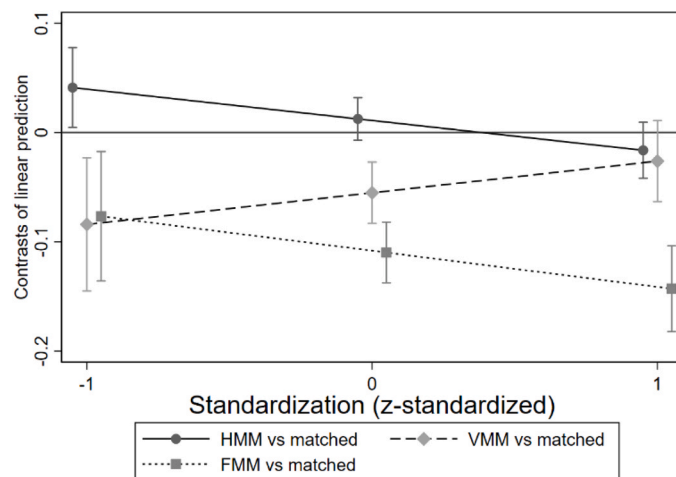


Fig. 1. Predictive margins of standardized training on wages relative to matched occupations. Displays combined log-wage coefficients of each mismatch dimension at -1 , 0 , and $+1$ SD of the z-standardized standardization index, relative to matched workers within the same training field. Detailed values in Table A.4 of appendix. N = 44,039; Individuals: 12,339. The dependent variable is the log daily wage. Confidence intervals at 95 % level.

workers from the same training field, reflecting the offsetting positive HMM main effect and negative interaction term. At -1 SD, the combined HMM coefficient is positive and significant (0.042), and negative but not statistically significant at $+1$ SD (-0.017). Thus, standardization moderates the HMM wage slope as hypothesized, but combined coefficients do not consistently indicate substantive wage penalties relative to matched workers, providing partial support for H1a.

For vertical mismatches, the interaction term is positive albeit not statistically significant, indicating no significant moderation of the VMM–wage slope. The combined coefficient at the moderator mean is negative and statistically significant (-0.053), driven by the main VMM effect. At -1 SD, the penalty is somewhat larger (-0.078), while at $+1$ SD it becomes smaller and is not statistically different from zero (-0.027). Although the difference between -1 SD and $+1$ SD is not statistically significant, the pattern suggests that VMM penalties are less pronounced in highly standardized fields. However, the results do not prove evidence supporting H1b.

For full mismatches, the interaction of standardization is negative and statistically significant (-0.044), indicating that higher standardization is associated with a negative wage slope for FMM. The combined coefficient is negative and large at the moderator mean (-0.109), and increases in magnitude from -1 SD to $+1$ SD. These findings support H1c and indicate that standardized training coincides with notably larger wage penalty associated with full mismatches. Overall, standardization shapes mismatch wage outcomes in different ways: standardization moderates wage returns for horizontal mismatches, only partially attenuates vertical mismatch wage, and amplifies penalties for full mismatches.

4.2. The moderating role of skill-specific training

Model 3 interacts the mismatch dimensions with the z-standardized indicator of skill specificity (Table 2, col. 3). Fig. 2 depicts these combined log-wage differences relative to matched workers, summarizing how skill-specific training shapes the wage consequences of horizontal, vertical, and full mismatches. Hypotheses 2a, 2b, and 2c postulate a negative moderating role of skill specific training on the relationship between wages and all mismatch dimensions, as specificity should reduce the transferability of skills to other occupational segments.

For horizontal mismatches, the interaction with skill specificity is negative and significant at the 10 % level (-0.018), indicating that higher specificity is associated with a steeper HMM–wage slope in line with H2a. The combined HMM coefficient at the moderator mean (0 SD) is small and not statistically significant, reflecting the offsetting positive

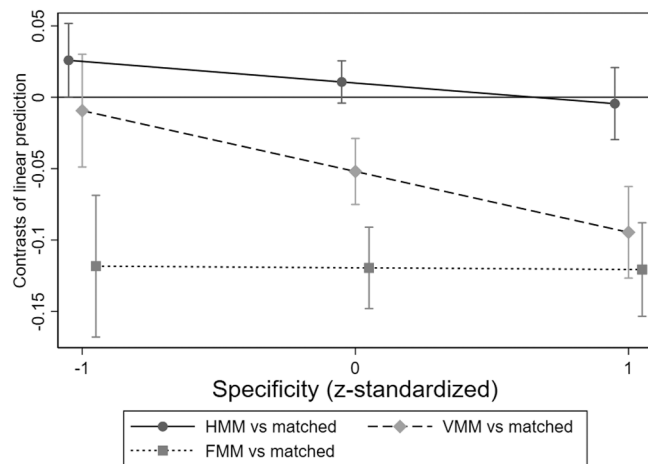


Fig. 2. Predictive margins of skill-specific training on wages relative to matched occupations. Displays combined log-wage coefficients of each mismatch dimension at -1 , 0 , and $+1$ SD of the z-standardized specificity indicator, relative to matched workers within the same training field. Detailed values in Table A.5 of appendix. $N = 44,039$; Individuals: 12,339. The dependent variable is the log daily wage. Confidence intervals at 95 % level.

(and not significant) main effect and the negative interaction. At -1 SD, the combined coefficient is positive and statistically significant (0.030), suggesting that HMM workers from generalist fields earn slightly more than matched peers. At $+1$ SD, the combined coefficient becomes negative (-0.006) but remains not statistically significant. Thus, skill specificity meaningfully moderates the HMM slope, but combined coefficients show only partial support for H2a, as wage penalties relative to matched workers are not consistently observable.

For vertical mismatches, the interaction with skill specificity is negative and statistically significant (-0.045 , Table 2), indicating that higher specificity corresponds to more negative wages for VMM workers, clearly supporting H2b. The combined coefficient at the moderator mean is -0.048 , reflecting a sizable and significant wage penalty. At -1 SD, the coefficient is near zero and statistically insignificant (-0.002), whereas at $+1$ SD it becomes large and negative (-0.093). At $+1$ SD, skill specific training partially reduces wages for vertical mismatches by 9.3 % compared to adequately matched workers from the same segment. These patterns show that VMM penalties are minimal in low-specificity fields but increase substantially in highly specific ones.

For full mismatches, the specificity interaction is small and not statistically significant (-0.003), providing no evidence for moderation postulated in H2c. The combined FMM coefficient at the moderator mean is large and negative (-0.121), driven by the main FMM effect rather than the interaction. Combined coefficients remain large and negative across -1 , 0 , and $+1$ SD, with only modest variation in magnitude. These results indicate that while full mismatches are strongly penalized and their wage disadvantage does not depend systematically on the specificity of training.

Overall, skill specificity moderates mismatch outcomes asymmetrically. It weakly and inconsistently moderates horizontal mismatch wage returns, strongly amplifies vertical mismatch penalties in line with H2b, and shows no systematic moderating effect for full mismatches. These findings partially support the human-capital argument that specific skills reduce adaptability and increase the costs of deviating from the intended occupational domain.

4.3. Addressing potential threats to identification strategy

Potential threats to identifying the moderating effects of institutional training characteristics concern limited common support and nonlinear

moderator relationships (Hainmüller et al., 2019). First, limited common support arises when standardization or specificity values are unevenly distributed between matched and mismatched workers, forcing extrapolation in the interaction model. Density plots (Figures A.3 and A.4) show generally adequate overlap for both indicators, though horizontal-mismatch models exhibit fewer observations in low-standardization occupations. To address this, additional models are estimated for samples trimmed to the min-max region of overlap between HMM and matched workers. The results yield interaction coefficients that remain negative, directionally similar, and statistically significant, indicating that the HMM moderation is not driven by extrapolation (Table A.6, A.7).

Second, nonlinearity in the moderator–wage relationship can bias the estimation of conditional (heterogeneous) effects from interaction models. Linearity diagnostics show approximately linear moderator–wage associations for HMM and VMM, but a nonlinear pattern for FMM (Fig. A.5, A.6). Models that include quadratic and cubic moderator terms reveal a modest U-shape for the FMM-standardization moderation and only statistically significant moderation of quadratic specificity on HMM-wages (Tab. A.8, A.9). These results suggest that the strongest negative moderation occurs at low-to-intermediate levels of standardization for FMM, and at high levels of specificity for HMM. Importantly, these nonlinear specifications do not alter the direction of the main interaction terms for standardization, and interactions of specificity remain stable across all higher-order models. Overall, the sensitivity analysis and are in line with H1a and H2b, supporting the results of the main analysis.

Additional robustness tests address sample composition and measurement choices. First, Table A.10 and A.11 show leave-one-segment-out estimations per moderator. The negative specificity moderation for VMM is highly stable across these models, and even HMM interactions become partially statistically significant and negative. Standardization moderation for HMM and FMM shifts modestly when excluding the food and logistics segments, indicating these segments' relevance. Tables A.12–A.14 present further sensitivity checks. Excluding occupations with legally regulated entry yields results consistent with H1a, H1c, and H2b, suggesting regulation does not drive the main findings. To address concerns about occupational-distance measures (e.g. Müller & Schweri, 2015; Fedorets, 2019), further estimations distinguish between HMM at the segment level and the 2-digit level. Specificity produces a consistently negative moderation across both distance definitions. Standardization moderates HMM wage returns negatively for distant occupations but may increase returns at intermediate distances. Overall, the associations for specificity are highly robust (H2b), whereas the role of standardization is more sensitive and partial.

5. Conclusion and discussion

This study examines how two core institutional features of vocational training systems - standardization and skill specificity - shape wage outcomes when workers are employed outside their trained occupation. By distinguishing horizontal, vertical, and full mismatches, the analysis shows that mismatch effects are not uniform but moderated by the institutional context of training. This multidimensional approach demonstrates that institutional characteristics moderate the association between mismatch and wages within training fields, advancing existing research that often focuses either on one mismatch dimension or on broad institutional comparisons.

The findings yield three main insights. First, standardized training moderates mismatch-wage relations in distinct ways across mismatch dimensions. Higher standardization negatively moderates wage returns for horizontal and full mismatches, probably since field deviations are more visible and bargaining value of credentials outside their matching occupation is reduced. In contrast, standardized credentials tend to mitigate penalties for vertical mismatch - although this moderation is

not robust across fields - probably because the credential retains closure value within the correct occupational domain. These heterogeneous patterns show that standardization does not uniformly improve labor-market outcomes but reinforces both the advantages of matching and the disadvantages of deviating from the intended field of training.

Second, the benefits of skill specificity largely accrue to workers who are well matched. Specific skills raise productivity and facilitate smooth school-to-work transitions, yet the same specialization limits adaptability when job tasks diverge from training content. As a result, skill specificity strengthens wage penalties for vertical mismatches and contributes to heterogeneous outcomes among horizontally mismatched workers. Full mismatches remain strongly penalized regardless of specificity, suggesting that once workers deviate from both occupation and skill level, specialized training offers limited protection. These results highlight the importance of considering both field and level misalignment when assessing the consequences of vocational specialization.

Third, the results emphasize the importance of disentangling mismatch dimensions, as unidentified full mismatches can bias results. Vertical mismatches are relatively rare on their own, whereas full mismatches, combining field and level misalignment, are more common and incur the largest penalties. Studies examining only one dimension risk conflating these patterns, potentially overstating or understating the role of mismatch. The results show that penalties attributed to horizontal mismatch are partially driven by workers simultaneously experiencing vertical mismatch, and that institutional moderation varies markedly across mismatch types.

These contributions should be interpreted in context by acknowledging potential limitations. First, selection into mismatch and job changes are non-random, and unobserved factors such as motivation or ability may influence both job match and wages. Unobserved heterogeneity at the individual and occupational level may influence both mismatch and wage outcomes, limiting causal interference. However, prior research (e.g., Nordin et al., 2010) suggests that including ability measures does not substantially change wage estimates. Second, the analysis covers only male graduates of dual vocational training, and results therefore apply to a comparatively institutionalized segment of the education system and may not generalize to school-based vocational paths or female employment patterns. Third, skill specificity is measured at the level of apprentice occupations, which may not fully reflect the structure of training curricula (see Muja et al., 2019). Future work should pursue causal identification and examine gendered mismatch pathways and school-based VET.

Insights from the German dual vocational training system are particularly relevant for international debates, as it represents a prototypical case of institutionalized school-to-work transitions (OECD, 2022). The German labor markets pronounced linkage between training and employment likely intensifies the moderating role of institutional features on mismatch outcomes. In more flexible or decentralized systems such as the UK or US, where occupational boundaries and training pathways are less regulated, mismatch effects may therefore be weaker or operate through different mechanisms. At the same time, Germany's strong institutionalization reduces the variance in key training characteristics, meaning that the effects observed here may represent conservative estimates relative to less regulated contexts.

The findings highlight important trade-offs in the institutional design of vocational education systems. Standardized and specific training structures increase matching efficiency, strengthen occupational closure, and raise early-career wages for well-matched workers (Bol & Weeden, 2015; Hanushek et al., 2017). Yet these same mechanisms appear to magnify wage disadvantages when workers enter mismatched jobs, particularly in more institutionalized fields. This creates a policy tension: mitigating mismatch penalties without weakening the benefits of match-specific training. As technological change and structural transformation increase the likelihood of career deviations (Acemoglu, 2002; Dengler & Matthes, 2018), maintaining adaptability within

vocational systems becomes central to preventing cumulative disadvantages for workers who do not obtain matched employment.

CRedit authorship contribution statement

Kevin Alan Franz Ruf: Writing – review & editing, Writing – original draft, Project administration, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.rssm.2026.101136](https://doi.org/10.1016/j.rssm.2026.101136).

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