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Meta-analysis and report on skill shortages in EU countries

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Summary

Deliverable D2.1 provides a systematic evidence synthesis on the definition, measurement, drivers and policy responses to labour and skill shortages and skill mismatches in the European Union. It is designed to complement the skill mismatch modelling and scenario analysis undertaken by Marois et al. (2025) by providing an evidence-based assessment of the mechanisms that shape labour market imbalances. While the modelling framework captures demographic, migration, and human capital drivers of future labour market imbalances, it does not incorporate endogenous wage responses. This deliverable, therefore, complements the modelling of skills mismatches by synthesising the evidence on wage adjustment, alongside immigration and automation, and assessing their interactions and effectiveness in addressing labour and skill shortages across the European Union. The common search focused on academic literature published between 2004 and 2024. The AI-assisted methodology, described in section 2, retrieved 8,423 records from Web of Science, Scopus and EBSCOhost; 6,124 records remained after duplicate removal and 497 were retained for human review after AI-assisted attribute screening. Research-question-specific eligibility checks then produced smaller analytical corpora. Because the studies differ substantially in concepts, outcomes, methods and units of analysis, the deliverable uses structured narrative and mechanism-based synthesis rather than pooling effect sizes.

RQ1 asks how skill shortages and mismatches can be systematically defined and measured across EU countries. The synthesis in Section 3 shows that labour shortage, skill shortage, recruitment difficulty, skill gap and skill mismatch should not be used interchangeably. A genuine shortage refers to insufficient supply at prevailing wages and working conditions, whereas unfilled vacancies or long vacancy duration may also reflect unattractive jobs, search frictions or temporary adjustment. Skill mismatch covers vertical, horizontal and skills-based discrepancies. No single indicator is sufficient. Diagnosis requires triangulation of vacancy, wage, employer-survey, administrative and worker-job matching measures.

RQ2 examines the primary drivers of skills shortages and mismatches in the EU. The synthesis in section 4 identifies mutually reinforcing drivers: technological and green transformation, demographic change, education-labour market misalignment, regional restructuring, migration, occupational segmentation and underuse of human capital. Educational expansion has raised qualification levels without ensuring proportional diffusion of foundational or job-relevant skills; overeducation is therefore not a general cause of shortages.

RQ3 investigates how raising wages compares with recruitment of foreign workers in mitigating skill shortages. Existing literature finds stronger direct evidence for foreign recruitment than for wage increases as an evaluated intervention, but migration is not a substitute for adequate pay, job quality, recognition and integration (Section 5).

RQ4 explores how upskilling the local workforce and automation compare with reliance on migrant labour recruitment. Academic literature rejects a universal ranking, highlights complementarity and points to the importance of temporal aspects: migration is relatively fast, upskilling builds longer-run resilience, and automation is most feasible for codifiable tasks where firms have capital, complementary skills and organisational readiness.

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1. Introduction

Labour shortages, skill shortages, and skill mismatches are pressing issues in the European Union's labour market, affecting economic productivity, social cohesion, and individual career development. Addressing these challenges is crucial for policymakers, educators, and employers to enhance workforce development and support economic growth. Labour shortages occur when the demand for specific skills or occupations exceeds the available supply of workers willing to work under required conditions (location of job, wage, etc.), leading to unmet needs and potential economic stagnation. Therefore, employers' requirements and the working conditions they offer play a crucial role in shaping labour shortages: the available supply of workers with required skills and qualifications is only one side of the equation. Skill mismatches arise when there is a discrepancy between the skills workers possess and those required by their jobs, resulting in either over-skilling or under-skilling. These mismatches can lead to decreased job satisfaction, reduced productivity, and inefficiencies in the labour market and resources spent on education and skilling of workers whose potential is not fully utilised.

The first objective of this meta-analysis is to synthesise the different operationalisations of skill shortages and mismatches, together with the indicators and proxy measures used in the academic literature, drawing on peer-reviewed studies indexed in Web of Science, Scopus and EbscoHost. This involves assessing definitions and measurements across different sectors and occupations and identifying gaps and potential to further standardise the use and measurement of skill shortages and mismatches to ensure consistency and comparability in data collection and analysis. By doing so, this study aims to clarify dilemmas related to the relationships between sectors, occupations, and skills, which are often inconsistently reported or misunderstood in public statistics (Rafferty, 2020; Brunello, 2021). The analysis incorporates definitions and conceptual frameworks from leading organizations such as CEDEFOP, ILO, OECD, and EURES to provide a comprehensive understanding of these terms and their applications (CEDEFOP, 2024; ILO, 2024; Rafferty, 2020).

Skill mismatches occur when there is a misalignment between the skills workers have and the skills needed for their jobs. This can be categorized into over-skilling, where workers possess higher skills than required for their job roles, and under-skilling, where workers lack the necessary skills to perform their job effectively. The International Labour Organization (ILO) defines skill mismatch as a situation where the demand and supply of skills at a specific wage do not match. This broad definition highlights the complexities involved in accurately measuring and addressing skill mismatches (ILO, 2024).

Empirical evidence indicates significant disparities in the incidence of labour shortages and skill mismatches across Europe. For instance, the CEDEFOP report emphasizes the multifaceted nature of labour shortages, noting that foundational skills such as functional literacy are often lacking among job seekers, leading to widespread mismatches (CEDEFOP, 2024). The ILO report highlights that the definitions and measures of skill mismatches vary, with some reports focusing on unemployment-to-vacancy ratios, while others emphasize job mismatch based on qualifications and job requirements (ILO, 2024).

Second, this meta-analysis aims to synthesize the existing knowledge regarding the drivers of labour shortages and skill mismatches in Europe, drawing from a range of empirical studies and theoretical frameworks. The primary objectives are to identify the underlying causes of these phenomena. Labour shortages are defined as situations where employers are unable to fill vacancies

due to a lack of suitable candidates. This can be driven by various factors, including demographic shifts, evolving skill requirements, and geographic mobility constraints.

Demographic changes fundamentally alter the balance between labour supply and labour demand. A shrinking workforce reduces the availability of workers at a time when demand for labour remains strong in many sectors, increasing the likelihood of labour shortages and skill mismatches. Although labour shortages are shaped by multiple factors - including business cycles, working conditions, technological change, and institutional arrangements - population ageing is one of the most significant long-term structural drivers. Skill shortages are often measured by the vacancy rate, which is the proportion of total job vacancies to the total demand for labour (CEDEFOP, 2024). Structural labour shortages, however, should not be conflated with hiring difficulties which may have numerous underlying causes.

Current policy debates and the academic literature broadly identify three principal adjustment mechanisms addressing imbalances between the available labour supply and the labour demand. The first is international migration, which supplements domestic labour supply by attracting workers from abroad and can alleviate shortages relatively rapidly where local labour is insufficient. The second is investment in the domestic workforce through education, lifelong learning, and upskilling or reskilling policies, enabling workers to adapt to changing labour market requirements and technological transformation. The third is automation, including robotics and artificial intelligence, which can partially substitute for labour or enhance worker productivity by reallocating tasks between humans and machines (Acemoglu & Restrepo, 2019). Each mechanism addresses demographic pressures through a distinct economic channel and differs substantially in its speed of adjustment, implementation costs, institutional requirements, and long-run implications.

The methodological approach for this meta-analysis follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)¹ guidelines, ensuring a rigorous and transparent review process. The selected studies include both quantitative and qualitative research, encompassing a variety of data sources and analytical methods. The inclusion criteria focus on empirical research published in peer-reviewed journals, official reports from international organizations, and significant grey literature that addresses labour shortages and skill mismatches in the European context (Sam, Naicker, & Rajkoomar, 2020; Brunello, 2021).

Addressing labour shortages and skill mismatches is crucial for the sustainable development of Europe's labour markets. This meta-analysis seeks to bridge the gap between research and practice by providing a comprehensive overview of existing knowledge, identifying gaps in the literature, and proposing future research and data collection directions. The goal is to contribute to a more efficient and equitable labour market that benefits both employers and workers (CEDEFOP, 2024; ILO, 2024; Sam, Naicker, & Rajkoomar, 2020).

¹ The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is an evidence-based set of items designed to help authors report systematic reviews and meta-analyses. PRISMA focuses on improving the transparency and quality of reporting by providing a 27-item checklist and a flow diagram to ensure clarity in the presentation of the methodology, findings, and conclusions. It is primarily used for reviews evaluating the effects of interventions, aiming to reduce the risk of bias and enhance the reproducibility of the research. By following PRISMA guidelines, researchers can offer a comprehensive and systematic summary of the evidence, ensuring that key information is consistently and adequately reported.

This meta-analysis addresses the complex and multidimensional phenomenon of skill shortages within the European Union by systematically investigating four key thematic areas.

First, it examines the definition and measurement of skill shortages and mismatches (RQ1), asking how they are conceptualized in academic literature and by authoritative international organisations (sections 3.2 and 3.3), and identifying which data, indicators and metrics are used to quantify shortages and mismatches across economic sectors and timeframes (Section 3.4).

Second, it explores the drivers and dynamics underlying these shortages and mismatches (RQ2) across sectors and EU countries (Section 4.2). We have particularly focused on macrostructural drivers such as structural demographic shifts due to ageing of European populations and the resulting workforce shrinkage (Section 4.3) and the possible mismatch between educational attainment and actual skill acquisition, raising the question of whether overeducation contributes to persistent shortages (Section 4.4).

Third, the analysis considers recruitment models (RQ3), comparing the effectiveness of economic incentives (e.g., raising wages) with the recruitment of foreign labour as strategies to mitigate shortages (Section 5).

Fourth, it investigates alternatives to migrant labour (RQ4), assessing the trade-offs between investing in local workforce upskilling or automation, and exploring the feasibility and policy conditions necessary for automation in sectors heavily reliant on migrant labour (Section 6).

Collectively, these research questions, presented in a nutshell in Box 1, build a comprehensive understanding of how skill shortages and mismatches are framed, produced, and addressed across Europe, and to support the development of evidence-based responses, including through tools such as the Link4Skills AI-assisted policy decision dashboard.

BOX 1 - RESEARCH QUESTIONS

RQ 1 Definition and Measurement

- a) How can skill shortages be systematically defined and measured across EU member states and regions?
- b) What are the indicators and metrics to quantify skill shortages in economy sectors and timeframe?

RQ 2 Drivers and Dynamics

- a) What are the primary causes of skill shortages in the EU, and how do they vary by sector and region?
- b) How do the ageing population and shrinking workforce contribute to skill mismatches in the EU?
- c) Is educational expansion coupled with skills diffusion/improvement in (foundational/cognitive) skills? – Alternatively, this can be also phrased as Is overeducation a reason for skill shortages in Europe?

RQ 3 Recruitment Models

How do economic incentives for raising wages compare with recruitment of foreign workers in mitigating skill shortages?

RQ 4 Alternatives to Migrant Labor

What are the trade-offs between upskilling the local workforce and automation versus reliance on migrant labour?

The structure of this report is designed to address systematically the research questions on skill shortages and mismatches in the EU while remaining aligned with the broader objectives of the Link4Skills project. This introduction to the rationale and objectives of the study is followed by the methodology (Section 2). The retrieval of the literature corpus follows the methodology piloted in the deliverable 2.3 "Meta-analysis on AI, Automation, Skills and Migration". The methodology section describes the common literature search and screening methodology, combining systematic review procedures with AI-assisted classification and data extraction, combined with human-in-the-loop verification. The four analytical sections then address the research questions in sequence. Section 3 examines the operationalisation, definition, and measurement of skill shortages and skill mismatches (RQ1). Section 4 analyses their drivers and dynamics, including sectoral and regional variation, demographic change, educational expansion, and the underutilisation of human capital (RQ2). Section 5 evaluates recruitment strategies, with particular attention to wage incentives and the recruitment of foreign workers (RQ3). Section 6 examines migrant labour, domestic upskilling, and automation as alternative or complementary labour-market adjustment mechanisms and discusses the conditions affecting their feasibility (RQ4). Finally, Section 7 synthesises the main findings and presents implications for policy and future research. References provided within the analytical chapters document the evidence used in each part of the review.

2. Methodology

The meta-analysis has been conducted by combining traditional and AI-assisted methods to provide a comprehensive review of skill shortages in Europe. Our approach starts by clearly defining the objective and providing background context, explaining the necessity of integrating these two methodologies. Below, we outline our search strategy, detailing the databases on which data extraction was performed. We define the inclusion and exclusion criteria for selecting relevant studies, ensuring a robust and comprehensive data set.

Our data extraction process involved automated extraction using AI tools to enhance accuracy and efficiency. We assess the quality of the studies using established tools like PRISMA and AI algorithms to ensure consistency and reliability. The AI-assisted analysis involves employing natural language processing, and automated data extraction tools to complement the traditional analysis. Our approach follows the extraction methodology employed by Sowa, K., Przegalinska, A., Bezat-Jarzebowska A., Grabowska, I. (2024) for the Deliverable D2.3 which focused more specifically on the AI, automation and migration.

To ensure both comprehensive coverage and efficiency in identifying relevant literature for this meta-analysis, a structured, multistage search and screening protocol was developed and executed. The strategy incorporated both traditional systematic review principles and large language model (LLM)-assisted classification, applied across all four research question domains. This included creation of custom GPT agent for the retrieval of the initial literature corpus according to the inclusion and exclusion criteria specified by the research team to create search strings for the extraction from selected databases.

2.1. Unified search strategy

A unified Boolean search syntax was used across three primary academic databases: Web of Science, Scopus, and EBSCOhost. This approach maximized recall while minimizing redundancies. Synonyms were systematically included for key concepts such as *skill shortages*, *economic impacts*, *skill levels*, *responses*, and *EU-focused geography*. The search was limited to peer-reviewed articles, proceedings papers, and book chapters in English published between 2004 and 2024.

- Web of Science: 1,697 records
- Scopus: 4,975 records
- EBSCOhost: 1,751 records
- Total retrieved: 8,423
- Post-duplicate removal: 6,124

The final extraction prompt is presented for transparency in Appendix 1.

Additional manual searches were conducted within RQ1 and RQ4 through platforms such as Google Scholar, Semantic Scholar, and ScienceDirect to identify grey literature (such as report by international organisations) or missed articles.

2.2. Multi-level screening protocol

The screening process was conducted in four levels, combining automated classification by GPT-4o with human-in-the-loop verification to ensure transparency and reliability.

Level 1: Thematic and Relevance Classification via LLM

A prompt refined through calibration with 30 human-coded abstracts was used to classify papers based on thematic relevance. The GPT-4o model was run three times per abstract, and a majority decision rule was applied. This stage excluded 2,746 papers, retaining 3,378.

- 1.1 Thematic Fit: Defined using a strict rule-based checklist.
- 1.2 RQ Matching: Abstracts were tagged with one or more research questions; unmatched abstracts were retained for further assessment (488 cases).

Level 2: LLM-Assisted Attribute Extraction

A series of extraction tasks were conducted to identify studies fitting key scoping parameters using classification prompt (Appendix 2):

- 2.1 Geography: Only studies explicitly mentioning EU countries were retained.
– Excluded: 2,827 papers
- 2.2 Time Period: Only studies referencing 2004–2024 were retained.
– Excluded: 54 papers
- 2.3 Method & Industry Tags: Used for descriptive analysis, not exclusion.

Remaining papers: 497

Level 3: RQ-Specific Filters

Further refinement was done for each RQ using RQ mapping prompt (Appendix 3):

- RQ1 (Definition & Measurement): No additional filtering
- RQ2 (Drivers & Dynamics):
– Required tags: *quantitative, causal, macro or mixed scope*
– Resulted in two sets:
 - Strict filter: 3 papers
 - Expanded (manual causal review): 85 papers
- RQ3 (Recruitment Models):
– Required: *macro/mixed scope* → 19 papers
- RQ4 (Alternatives to Migrant Labour):
– No additional filtering → 19 papers

Note: Overlapping classifications across RQs were allowed and tracked separately to avoid overcounting.

Level 4: Human Review and Final Inclusion

A final manual review was conducted on all retained articles (n=497), with 5% of prior LLM decisions randomly spot-checked during earlier phases to validate alignment with inclusion criteria. Discrepant or ambiguous cases were resolved by consensus among the research team.

2.3. Summary of screening results

- Initial corpus (post-duplicate): 6,124
- Articles retained after automated attribute filtering for human review: 497
- Distribution by research question:
 - RQ1: 64
 - RQ2: 98
 - RQ3: 19
 - RQ4: 19
 - None matched: 57

Next, abstracts of 57 papers which were not matched to any RQ were screened by the research team and either classified into an appropriate RQ or excluded from the dataset. Duplicated entries were removed².

Finally, the cleaned corpus of research papers for analysis by research question counted:

- RQ1: 61
- RQ2: 103
- RQ3: 20
- RQ4: 29

Note: Some articles were assigned to more than one RQ category.

Respective research teams further checked and verified the content of this literature corpus when performing the analysis. The respective chapters of this report dedicated to each research question further explain human checking and selection of the final set of papers for each analysis. This included human verification of the classification assigned by the AI agent to the retrieved papers and removing duplicates. Each respective analytical section (3-6) further specifies the criteria and selection of the papers included in the actual synthesis.

² Interestingly, the duplicates occurred because papers with identical doi had titles ending with full stop "." in one database and without "." in another – AI treated them as separate entries, but the prompts consistently allocated them the same RQ.

3. Operationalisations of key concepts and measurement of skill shortages and mismatches

3.1. Selection of papers for the synthesis

The first research question (RQ1) of our meta-analysis focused on the definitions and measurement of skill shortages in the academic literature. To address this question, we instructed the prompt to extract the primary operational definition and, alongside it, alternative verbatim examples of how these concepts are used. The initial literature corpus included 61 papers (58 full texts and 3 abstracts for papers where full texts were not available for download). We systematically extracted relevant information from all 61 papers using an AI assistant and prompted it to extract verbatim information classified into the following categories:

- Definition or closest operational definition of skills shortage or skill mismatch: If no primary definition could be identified, the prompt was instructed to return a verbatim quote of the closest operational definition and complement it with any alternates.
- Methodological approach and research method used in the analysis
- Data sources
- Metrics and indicators of skills shortage or mismatches shortage/mismatches
- Economic scope (microeconomic/macroeconomic)
- Sector or Industry
- Geographic scope
- Time period of the study

In the next step, the research team performed human screening and verification of the extracted information. First, we assessed whether the conceptual, operational, or alternative definitions extracted by the prompt provided sufficient information. Human screening revealed that 10 research papers did not provide any conceptual or closest operational definition, and these papers were excluded from further analysis. Rather than analysing skill mismatches or shortages, these concepts were used only for reference and contextual framing of the actual study. This reveals that skill shortages are sometimes referred to as matter-of-fact objective phenomena rather than concepts that are critically addressed and investigated. This is partly related to the way some academic abstracts are written. The AI-assisted screening identified terms used to support the broader context and relevance of the study, although the actual analytical focus of the retrieved papers was much narrower or did not analyse labour and skill mismatched but rather curricula, school to work transitions of graduates from specific fields or institutions. This points to the limitations of AI-assisted literature screening at the time of this study.

Next, we screened information regarding the economic scope and measurement approaches among the remaining 51 papers. Human checking and verification proved essential, as the AI prompt did not always assign accurate classification. This was particularly true for the economic scope, but also quantitative and causal nature of the study was often misclassified. We excluded 20 papers with a microeconomic, firm-level focus because our interest was in a macroeconomic perspective on skill shortages in the overall economy or in specific sectors. We also excluded the three studies for which only abstracts were available, as insufficient information could be obtained from abstracts alone. Additional 11 papers were excluded because they either did not use quantitative measurement;

focused on curriculum analysis rather than labour market skill mismatches; or had a very restricted scope with respect to specific occupations, skills or institution rather than having broader industry or sectoral scope (e.g., specific on job skill for medical staff in specific hospitals, specific skill among ICT specialists, green transition experts, or studies conducted within firms or educational institutions).

The above-mentioned human checking and selection steps yielded a **final corpus consisting of 17 research papers** and book chapters published during the decade 2014-2024. These studies included explicit operational definitions of skill shortages and/or mismatches, adopted a macroeconomic perspective, and provided explicit measurements and metrics of shortages and mismatches.

Most studies focused on specific country-context or occupations. Among 17 papers, eight can be classified as *comparative studies*. Among the eight comparative studies, seven were cross-country comparative studies with EU scope and provided an economy-wide perspective on skill shortages and mismatches across occupational groups (Livanos & Núñez (2017); Flisi et al. (2017); Sparreboom & Tarvid (2016); McGuinness, Pouliakas & Redmond (2018); Hatos (2015); Grigorescu et al. (2022); Kostis et al. (2022)). One study was cross-country comparative study but not comparative across occupations or industry, as it focused on the ICT sector and digital occupations (Aksenova et al., 2024). In addition to EU/Europe-wide comparative analyses, Maer Matei (2014) focused on managers and professionals in Italy and Spain.

Among the *eight single-country studies*, four were comparative across occupational groups or sectors of the economy and can be considered macro-level studies (Maier et al. (2017), Bischof (2021), Bischof (2024) for Germany; Tijdens et al. (2018) for Czechia), while four were rather meso-level studies that focused on specific occupational groups or industries in Germany, Poland, Malta, and Italy. More specifically, Iftikhar and Zaharieva (2019) focused on manufacturing and services sectors in Germany; Pater et al. (2022) on ICT occupations in Poland; Axisa and Borg (2024) on construction professionals in Malta; and Nuccio and Mogno (2023) on creative industries and ICT in Italy. In sum, Germany represents the most researched country context, while single-country studies tend to focus on specific occupations and industries, resulting in a fragmented evidence base rather than providing material for systematic comparisons across industries. Moreover, we do not expect that conceptual definitions of skill shortages and mismatches would be sector or industry-specific, rather that different skill dimensions would be analysed.

The chapter is organised into sections and we first summarise and discuss the concepts of skill shortage, followed by a separate section on skills mismatch and outline how both can be systematically defined and differentiated. To place our findings into perspective, the definitions extracted from the retrieved research papers are complemented by definitions from authoritative organisations (ILO, OECD) and from other relevant research papers not identified through our AI-assisted methodology and therefore not included in our corpus. Next, we outline the most used datasets, indicators, and metrics for measuring skill mismatches and skill shortages. Rather than discussing each paper separately, we focus on the use and evolution of these concepts and their measurement approaches. Given the sparse data and limited sectoral coverage, we do not provide systematic assessment of skill shortages and mismatches by sectors and industries.

3.2. The concept of skill shortages

The terminology and use of the concepts of *shortage* and *mismatch* have evolved over time, gradually distinguishing between broad umbrella concepts and terms referring to specific types of labour market imbalances. Although the terms "labour shortage" and "skills shortage" are widely used in policy and public debate, there is no universally accepted definition. The labour economics literature consistently argues that these concepts are inherently ambiguous.

In comparison to skill shortages, the concept of skill mismatch is more frequently defined and analysed in the academic literature published from 2010 until 2024. Within the literature reviewed, all 17 reviewed papers provided some form of operational definition of occupational or skill mismatch, whereas only seven papers provided an explicit or implicit operational definition of skill shortage (Table 3.1).

Conceptually, labour or skill shortages point to a specific imbalance between labour supply and labour demand when the employers are unable to recruit labour into specific jobs or fill vacancies requiring specific skills. Within the academic literature reviewed, skill shortage is most commonly defined in broad terms as the *supply-demand gap*. This is also the most common explicit definition in our academic literature corpus (Table 3.1). In this interpretation, the inability to fill vacancies reflects a gap between the skills demanded by employers and those available in the labour market.

Table 3.1 Operational definitions of skill shortage in the peer-reviewed literature corpus

Paper	Extracted verbatim definition	Definition
Aksenova et al. 2024	"gap between the demand and supply of digital specialists" in the EU labour market"	gap between supply and demand
Hatos 2015	"Skills scarcity or abundance – when the offer (or request) for a given skill exceed[s] the request (or offer)."	gap between supply and demand
Nuccio et al. 2023	"skill shortages between labor demand and supply in the industry"	gap between supply and demand
Grigorescu et al. 2022	"skill gaps... driven by changes in technologies, working methods and practices, products and services"	skill gap
Livanos et al. 2017	"difficulties in filling vacancies of skilled labor."	difficulty to hire
McGuinness et al 2018	"unfilled or hard-to-fill vacancies... due to a lack of suitably qualified candidates"	difficulty to hire
Ifthikar et al. 2019	"the average vacancy duration increased... reflecting a rising shortage of the workforce."	average vacancy duration

Definitions developed by international organisations have followed a related but distinct trajectory, reflecting their primary objective of labour market monitoring and policy design. While academic research has focused mainly on conceptual distinctions between shortages, mismatches, and labour market frictions, international organisations have developed operational definitions designed to support measurement, forecasting, and policy intervention. More recently used definitions of the OECD^[1] and CEDEFOP^[2] adopted definitions of skill shortage that reflects that they arise in the context of prevailing wages and working conditions, moving away from labour supply–demand imbalances. The ILO definition^[3] focuses on the availability of workers with required skills, although it does not explicitly incorporate labour market conditions such as prevailing wages and employment conditions into the definition. These differences show that, despite increasing agreement

on the concept of skill shortages, international organisations still differ in how they define, measure, and interpret labour market imbalances.

Skill shortages arise when employers are unable to recruit staff with the required skills in the accessible labour market and at the ongoing rate of pay (Quintini, 2011) and long-term structural shortages are not typical (Brunello and Wruuck 2021). From the standing point of economic theory, labour and skill shortage indicates a labour market disequilibrium. Strictly speaking, a genuine skill or labour shortage should point to a situation of genuine lack of workers with a given skillset. However, recruitment difficulties may arise from a range of factors—including wages, working conditions, limited workers' mobility, recruitment practices, and changing skill requirements—rather than from an absolute scarcity of workers or skills and can rather be a sign of temporary adjustments in fast expanding sectors (Healy et al 2012). Early academic literature already raised that that skill shortages should not be equated with employers' recruitment problems (Shah and Burke 2005) and the terminology should distinguish genuine skill shortages—where there is an insufficient supply of suitably qualified workers at prevailing wages and working conditions—from hiring or recruitment difficulties, which may instead result from unattractive wages, poor working conditions, geographic constraints, or inefficient recruitment practices. Our literature corpus demonstrates that the distinction is not consistently maintained. Several studies continue to use the term *skill shortage* or *labour shortage* to describe observable recruitment outcomes, such as unfilled vacancies, difficulties recruiting qualified workers, or increasing vacancy duration (e.g., Livanos et al., 2017; McGuinness et al., 2018; Ifthikar et al., 2019). This reflects the continuing conceptual overlap between skill shortages, labour market tightness, and recruitment difficulties.

The empirical identification of skill shortages is challenging because observed recruitment outcomes do not necessarily indicate a genuine shortage of workers. A genuine labour shortage is a labour market disequilibrium—insufficient labour supply at prevailing wages and working conditions. Many empirical studies instead measure employer-reported hiring difficulties or vacancy duration, which are *indicators* that may reflect shortages but may equally arise from unattractive wages, working conditions, search frictions, or temporary adjustment. The distinction between genuine, temporary and persistent structural shortages is not consistently maintained and consistently use concept that differentiate between these. Moreover, several studies continue to use the term *skill shortage* or *labour shortage* to describe observable recruitment outcomes. Therefore, a terminology should ideally distinguish between persistent structural labour shortages (a persistent excess demand for labour that exists at prevailing wages and working conditions and cannot readily be eliminated through normal market adjustment) and temporary recruitment difficulties. This distinction is essential for understanding the nature of the underlying labour market imbalance and to identify the most suitable responses depending on specific drivers (further analyses in Section 4.3 and 4.4 of this meta-analysis).

A practical implication of this synthesis is that the terminology should distinguish explicitly between:

1. **Persistent structural labour/skill shortages** that indicate a persistent excess demand for labour or a specific skill that exists at prevailing wages and working conditions and cannot readily be eliminated through normal market adjustment; and
2. **Temporary or cyclical recruitment difficulties** — hiring frictions arising from wage levels, working conditions, geographic or mobility constraints, rapid penetration of technological innovations or short-run demand surges, which are expected to alleviate as wages, temporary

pressures induced by technological change and hiring practices adjust towards new labour market equilibrium.

Only the first category should be treated as a genuine skill shortage in the strict economic sense; the second should be reported as "recruitment difficulty" or "labour market tightness." Maintaining this distinction is essential not only for conceptual clarity but for policy design: structural shortages justify supply-side interventions (education, training, targeted migration), while cyclical recruitment difficulties are more appropriately addressed through wage, working-condition, and labour-mobility channels rather than skills policy per se.

3.3. The concept of skill mismatches

Skill mismatch is a broad concept, which refers to different types of structural imbalances between the labour supply and labour demand requirements. At the macro level, skill mismatch refers to the gap between the (aggregate) supply and demand for skills, typically with reference to a specific geographical unit (region, country or country group), and to the fact that observed matches between available workers and available jobs offered by firms in terms of skills and/or qualifications are sub-optimal (Brunello and Wruuck 2021). At the micro level, skill mismatch occurs when workers have a level of skills that is different from what is required for their job. (ibid) Skill mismatch has over time evolved into an umbrella term referring to different types of discrepancies between labour supply and labour demand.

The broad scope of skill mismatch concepts is reflected in the summary of definitions across the literature corpus presented in Table 3.2. 16 out of 17 research papers in our literature corpus explicitly defined the concept or provided a concrete operational definition of the mismatches analysed in the study. In general, skill mismatch refers to discrepancy between the requirements or expectations on the side of the labour demand and actual skills, qualifications or education of labour supply (workers or/and job seekers).

Table 3.2 Concepts and operational definitions of skill mismatches in the literature corpus

Authors	Concept	Extracted definition
Bischof 2021	horizontal skill mismatch	the actual skills of employees do not match the skills required for their job
Grigorescu et al. 2022	horizontal skill mismatch	when the level or type of skills available does not correspond to existing needs... consisting of a surplus or a lack of knowledge and competencies
Axisa et al 2024	horizontal skill mismatch	migrant workers engaged in jobs that do not match their training and skills set
Hatos 2015	horizontal skill mismatch	type/scope of training/skills inappropriate for the workplace
Vera-Toscano 2017	occupational mismatch	discrepancy between workers' competencies and job requirements, operationalised as overeducation and overskilling (upward mismatch).
McGuinness et al 2018	skill gaps	[when] the employer believes that workers do not possess the adequate competencies
Kostis et al. 2022	skill mismatch	gaps as missing skills versus job/course requirements

Maer Matei 2014	skill mismatch	whether workers have the actual skills needed to carry out successfully the tasks required by their current job; tested vs, perceived
Hatos 2015	skill mismatch	Skills mismatch is a generic term that refers to various types of imbalances between skills and competences offered and those required in the labour market.
McGuinness et al 2018	skill mismatch	Skills mismatch... can relate to many forms of labour market friction, including vertical mismatch, skill gaps, skill shortages
Nuccio et al 2023	skill mismatch	mismatch between unemployed workers' skills and companies' needs
Ifthikar et al. 2019	skill underutilisation	"productive capacities of immigrant workers are underutilized" (discussed in the counterfactual on equal employment opportunities)
Hatos 2015	Skills scarcity or abundance	when the offer (or request) for a given skill exceed[s] the request (or offer)
Pater et al 2022	vertical (occupational) mismatch	a difference between the educational profiles of job seekers, and those of workers sought by employers. structures of labour supply and demand differ according to a specific variable; for example, occupation or skill.
Aksenova et al 2024	vertical skill mismatch	lack/excess of qualifications
Tijdens et al. 2018	(vertical) skill mismatch	skill mismatch refers to the mismatch between a worker's educational and vocational attainments and the requirements of the job.
Sparreboom et al. 2016	vertical skill mismatch	over/undereducation: Overeducation ... means having more/less education than required by the job
Hatos 2015	vertical skill mismatch	training/qualification level lower or higher than requested
Livanos et al 2017	Over/underskilling	Underskilling/overskilling: situation where workers' skills are lower/higher than the required by their job
McGuinness et al 2018	Over/underskilling	[worker] possesses more skills than their current job requires; underskilling... current skills do not meet the demands of the job.
Bischof 2024	Over/underskilling	underskilled, matched or overskilled in foundational skills (reading and mathematics)

Note: Papers that contain definitions of multiple concepts are listed multiple times in this table.

Some definitions of skill mismatch in our literature are intentionally broad and introduced as an umbrella term and are complemented by a more specific definitions of different types of mismatches. Hatos (2015) and McGuinness et al. (2018) define skill mismatch as an umbrella term and complemented by additional concepts that were introduced to more specially identify specific type of skill mismatches. Studies in our literature corpus most frequently differentiate and subsequently analyse either horizontal or vertical mismatch. Hatos (2015) provides comprehensive overview of the concepts and clearly delineates them from one another.

Conceptual ambiguity is partly related to the varied use and meaning of the term *skills* itself, which may refer to formal education, qualifications, job-specific skills and competencies, or foundational cognitive skills. The fact that some analyses look at mismatches across multiple dimensions of human capital (education-occupation-skills) contributes to the inconsistent use of

mismatch terminology across studies focusing on different dimensions of mismatch. At the same time, the need to clearly define which type of imbalance and which dimension of skills are being analysed has led to the introduction of additional terminology, further increasing the plurality of concepts used in the academic literature.

Vertical mismatch is generally the most clearly defined concept. Educational attainment is often used as proxy measure of skills in absence of directly assessed measures of skills. Consequently, the concepts of *overeducation* and *undereducation* are commonly used to describe vertical mismatch. The increasing availability of direct skill assessments, particularly through the OECD's Programme for the International Assessment of Adult Competencies (PIAAC) and national skills surveys, has enabled researchers to distinguish more clearly between *over-skilling* and *under-skilling*, on the one hand, and *overeducation* and *undereducation*, on the other. The concepts of over-skilling and under-skilling are applied both to objectively assessed cognitive skills (e.g. literacy and numeracy) (Bischof, 2024) and to workers' self-assessments of their skills relative to job requirements (e.g. Livanos et al., 2017), reflecting the multidimensional nature of skills.

The concept of skill gaps by Guinness et al. (2018) puts emphasis on the relevance of employer's perceptions and brings in the importance of perception gaps in the discourse on skills mismatches. In fact, micro level analyses on skill mismatches rely on surveys that either poll the perceptions of employers or the perceptions of workers and elicit their self-reported assessment on how well their skill correspond or lack to their job requirements. To reflect the supply side of skills, additional concept such as skill scarcity and skill abundance were introduced (Hatos 2015), turning the perspective from employer's requirements to the capital of (potential) workers.

The concepts of skill shortages, skill gaps, and skill mismatches have evolved considerably over the past two decades, reflecting a shift from a narrow focus on labour supply towards a broader understanding of the relationship between workers' skills and labour market demand. Academic scholarship as well as terminology used by authoritative institutions such as ILO, OECD and CEDEFOP, has progressively broadened the conceptualisation of labour market imbalances beyond shortages in labour supply. The notion of *skill gaps* emerged primarily as an employer- or enterprise-level construct, describing situations in which employees do not possess the competencies required to perform their current roles to the expected standard. Unlike skill shortages, which concern the availability of suitably qualified workers in the external labour market, skill gaps relate to deficiencies within the existing workforce and are therefore typically addressed through training and workforce development interventions. ILO uses the term skill gaps in the meaning of the extent to which workers lack the skills necessary to perform their current job (ILO 2019, p.10).

International organisations, including Cedefop, the OECD, and the ILO, have advanced the overarching concept of *skill mismatch* to capture the diverse forms of misalignment between the skills supplied by individuals and those demanded by jobs or the wider economy. Within this framework, skill shortages constitute only one dimension of mismatch, alongside vertical mismatch (over- and under-education or over- and under-skilling), horizontal mismatch (field-of-study mismatch), skill surpluses, and skill obsolescence. This evolution reflects a transition from viewing labour market imbalances primarily as quantitative deficits in labour supply towards recognising the multidimensional nature of the alignment between workers' knowledge, skills, qualifications, and occupational requirements, with each form of mismatch implying distinct measurement approaches and policy responses.

The literature review indicates that conceptual ambiguity arises less from disagreement about the underlying phenomena than from the inconsistent use of overlapping terminology across different levels of analysis. *Skill mismatch* is not a single, well-defined concept. It is an umbrella term encompassing different types of mismatches (education, qualifications, field of study, skills, competencies, cognitive skills), measured in different ways and at different analytical levels (overall economy, sectors and industries, firms and workers). A more coherent conceptualisation would distinguish concepts according to their analytical level and the specific phenomenon and skill dimension under investigation, such as structural labour market mismatch, overeducation, overkilling and self-assessed skill gaps.

To conclude, the conceptual ambiguity identified in the corpus is largely terminological rather than substantive. Authors are not in disagreement about the underlying phenomena; rather, overlapping terms are applied inconsistently across different levels of analysis (macro/micro), different reference points (education vs. tested skill vs. self-assessed skill), and different sub-types (horizontal vs. vertical). Review studies of Hatos (2015), McGuinness et al. (2018) and Brunello and Wruuck (2021) explicitly differentiate between mismatch as the umbrella term from its constituent sub-concepts that clearly delineate specific types of misalignments. Their taxonomies are a useful reference point for standardising terminology in this meta-analysis.

A practical implication for this meta-analysis is that "skill mismatch" should not be used as a synonym for any one of its sub-types. Consistent with the ILO/OECD/CEDEFOP framework, we recommend nesting terminology as follows: **skill mismatch** as the umbrella term for any misalignment between labour supply and demand; and, within it, distinguishing **skill shortage** (external labour-market scarcity of a skill, addressed in Section 3.2), **skill surplus** (excess supply), **vertical mismatch** (over/undereducation or over/under-skilling), **horizontal mismatch** (field-of-study misalignment), **skill gaps** (internal workforce deficiency relative to current job requirements, addressed through training), and **skill obsolescence** (skill decay over time, often technology-driven). Each sub-type implies a different measurement strategy.

3.4. Metrics and indicators used to measure skill mismatches and skill shortages

Skills mismatches and skill gaps can be approached from either demand (understanding the needs of employers) or supply side perspectives (understanding the assessment of skills of the workers themselves). Such assessments require surveys that either ask for the assessments or test actual skills. Studies included in our corpus rely on surveys, administrative labour market data and digital data. Surveys are the most commonly used data to study skill mismatches, followed by mixed methods designs combining surveys with eliciting structured information from employers, workers and/or stakeholders. Comparative analyses use PIAAC surveys of adult skills, European Skills and Jobs Survey (ESJS), country-specific surveys such as German micro census, German socio-economic panel, German National education panel study (NEPS), Cedefop's surveys, European Social Surveys, in many instances complemented by contextual data sources from ILO, OECD, Eurostat, large databases such as O-NET.

Mismatch analyses require data for the labour supply and demand, and this naturally leads to the need for combination of various data sources, data types and research instruments. Besides typical survey analyses, some more innovative research designs combine web-scraped data for either demand (job offers, vacancies) or supply (CVs) with survey data for the other dimension, i.e. analyses web-

scraped job offers with survey of corresponding group of professionals (for example Pater et al. 2022) _Surveys for specific sectors also used analyses of web-scraped CVs, aggregate vacancy data and big data analyses of job offers. One of typical mixed designs combined vacancy data – web-scraped or aggregate data from employment agencies/services – with employer surveys.

Importantly, there is a clear relationship between how skill shortages or skill mismatches are defined, the data sources used, and the indicators selected. Most studies distinguish between worker-job mismatches (micro level), labour market shortages (macro level), or demand-supply imbalances using administrative, survey, or big-data sources.

Table 3.3 Data types and their typical use

Data source type	Studies	Typical purpose
Large international skills surveys	PIAAC, ESJS, ESS	Measure individual skills, qualifications, education mismatch and overskilling/underskilling
National longitudinal surveys	NEPS, GSOEP, German Microcensus	Link worker skills with occupations, wages and employment outcomes
Administrative labour market data	Public Employment Services, Federal Employment Agency, Eurostat, OECD	Measure labour shortages, vacancies, employment trends and demand-supply imbalances
Employer surveys and professional questionnaires	Malta climate adaptation study, employer surveys,	Capture perceived skill gaps, recruitment difficulties and preparedness
Big data / digital sources	Online job advertisements, LinkedIn profiles, CV databases, ESCO, Skills-OVATE	Measure real-time demand for skills, semantic matching and emerging skill needs

Table 3.4 illustrates typical data and indicators used to study different types of labour and skill mismatches and shortages (recruitment difficulties) It is apparent that large surveys are typical sources used to investigate and quantify vertical mismatches (over/undereducation; over/underqualification, overskilling/underskilling) using normative mismatch classifications and self-assessed measures. Most commonly used indicators compare education/qualifications/skills possessed to those required by the job occupied, such as survey-weighted shares of matched and mismatched workers, various ratios and indices, including vacancy rates, vacancy durations, share of hard to fill vacancies, are used to investigate and quantify labour shortages. These tend to be constructed by combining contextual datasets such as vacancy databases and administrative labour market data with employer surveys. Because labour supply and labor demand are often collected in different datasets, mismatch indices, scarcity ratios and demand-supply ratios often combine vacancy databases of web-scraped vacancy and CV datasets with surveys or other contextual databased and indicators from authoritative providers (O-Net, OECD, ILO, OECD, Eurostat indicators). Mixed-method designs are used to investigate emerging gaps. Semantic or AI-based matching of CVs, job advertisements and LinkedIn data used to study skill overlap scores and similarity scores in specific sectors or skills, such as digital specialists and ICT.

Table 3.4 Data sources and indicators measuring specific types of skill mismatches

Definition category	Typical data sources	Indicators used
Worker-job skill mismatch (skills possessed vs. skills required)	PIAAC, NEPS, ESJS, ESS, worker surveys	Under-/overskilling, matched workers, proficiency scores, self-assessed mismatch, objective (normative) mismatch classifications, job satisfaction, wage effects
Vertical mismatch	PIAAC, ESS, NEPS, ESJS, national surveys	Overeducation, undereducation, qualification mismatch, education required vs. attained
Horizontal mismatch	ESJS, national surveys, employer surveys	Field-of-study mismatch, occupational mismatch, discipline-job correspondence
Labour shortages / recruitment difficulties	Employer surveys, labour market statistics, vacancy databases, administrative labour market data	Vacancy duration, hard-to-fill vacancies, recruitment difficulties, shortage indices, vacancy rates
Demand-supply imbalance	Online job advertisements, CV databases, administrative labour market data, Eurostat, OECD	Demand-supply ratios, mismatch indices, scarcity ratios, skills demand by occupation
Skills gaps / emerging skills	Professional surveys, focus groups, interviews	Perceived preparedness, training adequacy, missing competencies, digital skills gaps
Semantic or AI-based skill matching	CVs, job advertisements, ESCO ontology, LinkedIn profiles	Skill overlap scores, cosine similarity, suitability scores, skill frequencies

The measurement of vertical mismatch is relatively straightforward, and internationally comparative surveys provide sufficient data (PIAAC, ESS, labour force surveys) for international and temporal comparisons. Comparative analysis of 26 European countries by Sparreboom & Tarvid (2016) revealed that overeducation increased in many European countries following the financial crisis, particularly where labour demand shifted away from middle-skilled occupations. Countries with greater job polarisation tend to experience higher levels of vertical mismatch. Focusing on underskilling and using self-reported data (ESJS), the analysis of 28 EU countries identified that younger workers, workers rapidly changing occupations and workers with limited life-long learning are more at risk of underskilling (Livanos and Núñez 2017).

The empirical evidence on **horizontal skill mismatch** remains relatively limited in comparison to studies of vertical mismatch (overeducation and overskilling). The only study providing direct worker-level estimates is Bischof (2021) for Germany, showing that approximately one in five workers perceive themselves as skill mismatched, although objective assessments identify fewer mismatches and reveal substantial disagreement between perceived and measured mismatch. At the European level, Flisi et al. (2017) demonstrate that horizontal and vertical mismatch represent distinct latent dimensions of labour market mismatch and that their incidence varies considerably across countries

depending on the measurement approach. Using PIAAC data, the authors examined 20 different indicators of educational and skill mismatch. Horizontal mismatch was represented through skill mismatch based on the relationship between workers' skills and the skills actually used at work ("engagement"), rather than simply educational attainment. Principal Component Analysis showed that educational mismatch and skill mismatch capture different dimensions of labour market mismatch. Rather than reporting a single prevalence rate, the study argues that mismatch is inherently multidimensional and cannot be captured by a single indicator. Methodological studies (Kostis et al., 2022; Nuccio & Mogno, 2023) further illustrate how ESCO-based semantic matching and machine-learning techniques can identify discrepancies between workers' skills and occupational requirements, representing a shift towards dynamic, skills-based measurement of horizontal mismatch rather than traditional education–occupation comparisons.

The multidimensionality of skills translates into the definitions and measurement of labour market and skills mismatches. It is not surprising that no single measure adequately captures skills mismatch. Review studies (McGuinness et al. 2018, Maer Matei 2014) recommend combining several educational and survey indicators when analysing labour market mismatch. As subjective and objective measures produce different estimates of the mismatches, and their combination allows for more holistic evaluation because they reflect different dimensions of mismatch. Conceptual review paper by Maer Matei (2014) provides practical guidance in that regard and summarises the indirect (proxy) indicators that have been used in the literature to measure occupational and skills mismatches. Each proxy measure listed in the table below captures only one dimension of mismatch and therefore no single indicator provides a complete measure of occupational mismatch.

Table 3.5 Proxy-indicators for skill mismatches according to Maer Matei (2014)

Proxy indicator	Measure	Interpretation
Education–job comparison (vertical mismatch)	Compares an individual's educational attainment with the education required for the job.	Identifies overeducation and undereducation. This is the most widely used proxy.
Field of education versus occupation (horizontal mismatch)	Compares the field of study or training with the occupation performed.	Indicates whether workers are employed outside their area of qualification.
Qualification mismatch	Difference between qualifications held and qualifications required by employers.	Measures the alignment between formal credentials and job requirements.
Hard-to-fill vacancies	Employers report recruitment difficulties, missing competencies or hard-to-fill vacancies.	Used as an indirect indicator of skill shortages or skill gaps, although the paper notes these may also reflect wage or working-condition issues.
Education level of employed versus unemployed workers	Compares unemployment rates across educational groups.	Used to infer whether certain qualification levels are in surplus or shortage.

Duncan & Duncan Dissimilarity Index	Compares the distribution of unemployment across education levels.	Higher values indicate greater structural mismatch between education supply and labour market demand.
Employment and unemployment rates by education level	Labour market outcomes for different education groups.	Used as macro-level evidence of mismatch or imbalance

Recent research shifts towards more complex objective measures of skills mismatch. Study of Bischof (2024) recommends a mixed approach combining objective tested skill scores with job requirement information. Rather than relying on self-reported assessment, the study recommends combining competency tests (NEPS, PIAAC) to eliminate subjective reporting bias and occupational requirements according to ISCO categories to identify well matched workers. By establishing a requirement range of competences (mean+1 standard deviation) provides a statistical measure of underskilled and overskilled workers within occupation groups. Applying this approach across multiple skill domains (functional literacy, numeracy, problem solving, digital skills) enable to construct a multidimensional mismatch classification as workers can be well-matched, underskilled or overskilled in different domains. The study recommends mixed measures as the most reliable approach for future research. mixed approach provides the best balance between theoretical validity and empirical performance because it uses tested measure of worker's competences rather than education as proxy and derives job requirements from empirical labour market data rather than relying entirely on subjective assessments.

In addressing our research question on the indicators and metrics used to quantify skill shortages and mismatches, the review highlights the need to distinguish between measures of labour market imbalance and measures of worker–job alignment. Indicators of labour market tightness and excess demand for specific skills or occupations, including vacancy rates, hard-to-fill vacancies, vacancy duration, recruitment difficulties, and wage pressures, provide signals of potential skill shortages rather than direct measures of labour shortages. In contrast, skill mismatches are quantified through worker–job comparison measures that assess discrepancies between individuals' education, qualifications, or skills and the requirements of their jobs. The literature consistently concludes that neither skill shortages nor skill mismatches can be adequately captured by a single indicator and recommends combining complementary objective and subjective measures to distinguish genuine labour market shortages from different forms of worker–job mismatch.

To conclude, measurement of skill mismatches ranges from simple indicators such as shares of workers with level of education or qualification (not) corresponding to those required by their current occupation, to indices that attempt to combine several indicators across different dimensions of skills or across different types of labour market imbalance. Important, however, is the distinction between subjective (self-reported) and objective (tested) measurement of skills. Indicators split between an objective, anchored in externally verifiable data (educational attainment, directly tested competencies such as PIAAC literacy and numeracy scores, vacancy counts, wages), and a subjective axis, anchored in perception (employer-reported hiring difficulty or skill gaps, worker self-assessed over-/under-skilling). The two do not always converge, as workers can be matched on educational attainment or qualification but self-report as under- or overskilled. Soft skills and competencies are particularly difficult to measure using objective indicators and constitute a separate outside of this review.

3.5. Key findings

- **Skill shortages and skill mismatches are conceptually distinct phenomena and should not be used interchangeably.** A genuine skill shortage represents a labour market disequilibrium, where the supply of workers with a particular skill is insufficient at prevailing wages and working conditions. In contrast, many empirical studies rely on employer-reported hiring difficulties, which may also reflect wage-setting, recruitment practices, job quality, or geographic mismatch rather than an actual shortage of skills.
- **Skill mismatch is best understood as an umbrella concept encompassing several analytically distinct forms of mismatch.** The literature identifies multiple dimensions, including vertical mismatch (over-/undereducation and over-/underskilling), horizontal mismatch (field-of-study mismatch), skill gaps, skill shortages, skill surpluses, and skill obsolescence. These concepts describe different labour market phenomena and operate at different analytical levels.
- **The observed conceptual ambiguity is primarily a classification and terminology problem rather than a disagreement about underlying labour market mechanisms.** The multidimensional nature of skills—from educational attainment and formal qualifications to cognitive, functional and job-specific competencies—has generated a proliferation of overlapping concepts and labels. Greater conceptual consistency can be achieved by explicitly specifying the analytical level (macro labour market, sector, firm or individual worker), the skill dimension under investigation (education, qualification, competence or self-assessed skills), and the specific subtype of mismatch being analysed.
- **A hierarchical terminology provides a more coherent conceptual framework.** Consistent with the ILO/OECD/CEDEFOP framework, *skill mismatch* should be reserved as the overarching concept describing any misalignment between the supply of and demand for skills. Within this framework, researchers should distinguish between skill shortages, skill surpluses, vertical mismatch, horizontal mismatch, skill gaps and skill obsolescence, rather than using *skill mismatch* as a synonym for any one of these concepts.
- **Measurement approaches capture different dimensions of mismatch and should not be treated as interchangeable.** The literature distinguishes between objective measures, such as educational attainment, qualifications and direct assessments of competencies, and subjective measures based on employer or worker self-assessments. These approaches frequently produce different empirical results because they measure different underlying constructs.
- **Direct assessments of skills have substantially improved the measurement of mismatch but have not resolved conceptual inconsistency.** The introduction of large-scale assessments such as OECD's PIAAC has enabled researchers to distinguish qualification-based mismatch (e.g. overeducation) from competency-based mismatch (e.g. overskilling), overcoming an important limitation of earlier studies that relied solely on educational attainment as a proxy for skills.
- **Shortages and mismatches cannot currently be summarised by a single composite indicator.** Indicators of labour shortages (e.g. vacancy rates, vacancy duration or employer-reported hiring difficulties) are derived from labour market demand, whereas mismatch indicators (e.g. overeducation, skill gaps or overskilling) are constructed from worker-level characteristics and

worker-job relationships. Because these indicators originate from different data sources, represent different analytical levels and capture different mechanisms, disaggregated indicators remain both conceptually clearer and empirically more interpretable than a single composite measure.

- **The choice of measurement has direct implications for policy interpretation.** Different forms of mismatch require different policy responses: labour shortages call for interventions affecting labour supply and demand, skill gaps are primarily addressed through education and workplace training, while skill obsolescence requires lifelong learning and skills renewal. Consequently, empirical studies should always report the analytical level, the skill dimension, the specific mismatch subtype and the measurement approach employed.

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4. Drivers and dynamics of skill shortages and mismatches

This chapter examines why skill shortages and skill mismatches emerge in the EU and why they differ across sectors, regions and groups of workers. The analysis treats shortages not as a simple lack of educated labour, but as the result of several overlapping processes: technological and green transformation, demographic change, regional restructuring, education-labour market misalignment, migration, occupational segmentation and the underuse of available human capital.

The chapter is organised around three research questions. RQ2a identifies the main causes of skill shortages and shows how they vary by sector and region. RQ2b focuses on ageing and workforce shrinkage, analysing how demographic change affects the effective supply, use and retention of skills. RQ2c extends the discussion to educational expansion, skills diffusion and overeducation, asking whether higher levels of formal education translate into better skills and better matching in the labour market.

The evidence is synthesised through a mechanism-based approach. Rather than presenting paper-by-paper summaries, the chapter groups studies by the principal mechanisms through which shortages and mismatches arise and by their relevance to RQ2a, RQ2b and RQ2c.

4.1. Selection of the studies

For RQ2, the screening focused on papers dealing with the drivers and dynamics of skill shortages and skill mismatches. The initial set included 98 papers potentially relevant to this part of the review. After human screening, 40 papers were excluded because they did not provide a direct answer to the questions formulated under RQ2. Most excluded papers dealt with narrowly defined curriculum development, firm- or worker-level training needs, specific educational initiatives, recruitment practices, individual wellbeing, job-entry mismatch, or reskilling and upskilling processes more relevant to later research questions. Other papers were excluded because they addressed skills in a very specific occupational or educational setting without linking them to broader labour-market shortages or mismatch mechanisms.

The remaining 58 papers were retained for further assessment. For these papers, we systematically extracted information on the main driver or mechanism of skill shortage or mismatch, the sectoral or occupational context, territorial scope, methodological approach, level of analysis, and the type of evidence provided. Each paper was then assessed against the specific wording of RQ2a, RQ2b and RQ2c. The aim was not to include all papers that used the general vocabulary of skills, mismatch or shortage, but only those that provided evidence relevant to the particular research question.

For RQ2a, papers were selected when they explained the causes or mechanisms of skill shortages and mismatches and allowed these mechanisms to be linked to specific sectors, regions, occupations or labour-market contexts. 34 papers were selected for this part of the analysis. Papers were not included in RQ2a when they only described curriculum design, individual training needs, firm-specific skill gaps, recruitment preferences or general education initiatives without addressing shortages as a broader labour-market phenomenon.

For RQ2b, papers were selected only when ageing, workforce shrinkage, late-career employment, retention, demographic decline or replacement constraints were linked to skill mismatch mechanisms. 10 papers were selected for this part of the analysis. Many papers retained in the broader RQ2 screening did not address ageing or workforce shrinkage directly; these were therefore excluded from the RQ2b synthesis, even when they were relevant for RQ2a or RQ2c.

For RQ2c, the selection focuses on papers addressing educational expansion, skills diffusion, foundational and cognitive skills, overeducation, overskilling and the underutilisation of human capital. This part of the review examines whether the expansion of formal education is accompanied by improvement in skills and better labour-market matching, or whether higher educational attainment may coexist with persistent mismatch between qualifications, skills and job requirements. For RQ2c, 31 papers were selected for the synthesis.

4.2. Causes of skill shortages and mismatches across sectors and regions

The reviewed literature, covering 34 core articles on European labour markets, shows that skill shortages in Europe are not simply the result of an insufficient number of educated workers. They emerge from a more complex set of mechanisms: technological change, green transformation, demographic pressures, education-labour market misalignment, weak retention in shortage occupations, regional economic specialisation, migration, gender and ethnic segmentation, and the uneven capacity of sectors and regions to absorb, develop and retain skills. Thus, the evidence points less to a general “lack of skills” and more to a fragmented European skills landscape in which shortages are sector-specific, regionally embedded and institutionally mediated.

The classification should not be read as fully exclusive, since several papers address more than one mechanism. Its purpose is to identify the dominant causal channel in each contribution and to organise the evidence in a way that is analytically useful for RQ2a.

The first group covers technological, digital, AI, Industry 4.0 and green-transition drivers of skill shortages. These papers show that shortages are strongly connected with changes in the content of work, especially in ICT-intensive, manufacturing, STEM, process-industry, construction and green-energy sectors. The transition towards Open Building Manufacturing in construction requires new forms of collaboration, new production-related competences and stronger links between industry and academia (Sharp and Goulding, 2009). In the European process industry, the development of industrial symbiosis, energy efficiency, circular economy models and digital technologies generates new cross-sectoral skill needs in steel, ceramics, water, cement, chemicals and minerals (Akyazi et al., 2023). Similar pressures are visible in STEM-related occupations and employer expectations in Slovenia and Norway, where companies increasingly require broader 21st-century competences beyond narrow technical expertise (Abina et al., 2024).

The digital transformation of higher education and labour markets is also reflected in evidence on the response of higher education institutions to digitalisation and smart specialisation in the EU (Noja et al., 2024), the uneven integration of AI training into Bulgarian higher education programmes (Simeonov et al., 2024), and the territorial differentiation of digital and AI skills gaps across small and large European living areas (Pham et al., 2024). In green maritime energy, skills gaps are linked to the

development of offshore wind, wave and tidal sectors, where human capital, regulatory conditions and supply-chain capabilities jointly affect sectoral growth (Combe, 2014). Manufacturing evidence points in the same direction: the move towards Factories of the Future creates demand for ICT-based production skills, STEM competences and new forms of workforce preparation (Skevi et al., 2014). The German evidence further shows that skill shortages can directly weaken innovation capacity, including through the cancellation or abandonment of innovation projects (Horbach and Rammer, 2022). Finally, the “war for talent” in high-tech and knowledge-intensive sectors demonstrates that inward FDI and innovation-oriented regional strategies may intensify competition for scarce skilled labour, especially where local talent pools are limited (Becker et al., 2020).

Table 4.1 Technological, digital, AI, Industry 4.0 and green-transition drivers

Author and year	Territorial scope	Methods used	Drivers / causes
Sharp and Goulding (2009)	United Kingdom; construction sector	Attitudinal questionnaire survey within an EC-funded research project	Construction skill gaps; Open Building Manufacturing; fragmented industry; need for industry–academia collaboration; new production paradigm
Akyazi et al. (2023)	European process industry; steel, ceramics, water, cement, chemicals, minerals	Identification of skills requirements and job profiles; mapping to ESCO; sectoral skills analysis	Industrial symbiosis; energy efficiency; circular economy; digitalisation; green transition; Industry 4.0; new job profiles
Abina et al. (2024)	Slovenia and Norway; STEM-related companies	Analysis of international competency frameworks; questionnaire survey among company HR managers	STEM skill needs; 21st-century competencies; employability skills; technological change; HEI–employer alignment
Noja et al. (2024)	European Union, with empirical focus including ICT employers and HEIs	Desk research; qualitative interviews with ICT employers, HEI representatives and policymakers; bibliometric analysis; Escalator methodology	Digital transformation; ICT skills; smart specialisation; HEI response to digitalisation; employer–university coordination
Simeonov et al. (2024)	Bulgaria; higher education institutions	Curriculum review of 163 bachelor’s and 239 master’s programmes across 28 HEIs	AI skills gap; uneven AI curriculum integration; concentration of AI courses in computer science; weak AI exposure in other technical fields
Pham et al. (2024)	Eight EU countries; small and large living areas	Survey dataset of 4,006 respondents; bivariate analysis	Digital and AI skills gaps; territorial digital divide; small-community constraints; education, age and gender differences
Combe (2014)	Scotland; green maritime energy industry	Sectoral analysis; supply-chain and regulatory framework analysis; questionnaire surveys on innovation and human capital	Renewable energy transition; offshore wind, wave and tidal sectors; skills gaps; regulatory barriers; economic uncertainty
Skevi et al. (2014)	European and global manufacturing; Factories of the Future	Literature review; analysis of industrial stakeholder surveys within the ManuSkills project	Manufacturing skills gap; ICT-based production; STEM shortages; ageing workforce; weak workforce planning; education gap

Horbach and Rammer (2022)	Germany; innovative firms	Panel data from German Innovation Survey; instrumental-variable probit estimation	Skills shortage as barrier to innovation; unfilled vacancies; intermediate and high-skilled labour; abandoned innovation projects
Becker et al. (2020)	Europe; high-tech and knowledge-intensive sectors	Empirical and policy-oriented analysis of inward FDI and skilled labour markets	War for talent; high-tech FDI; skilled labour scarcity; wage bidding; regional competition for talent; innovation-driven labour demand

The second group concerns education–labour market mismatch, curriculum adaptation and graduate pathways. These papers show that shortages may arise not because education systems produce too few graduates in general, but because the competences supplied by education and training institutions do not correspond sufficiently to employer demand, or because graduates do not enter, remain in, or become effectively matched with shortage occupations.

In Slovenia, a data-driven comparison of academic offerings and labour-market requirements points to gaps between university curricula and the skills sought in business and economy occupations (Andonovikj et al., 2024). In Northern Portugal, employers report a temporal mismatch between firms’ need for stable, long-term employment relationships and graduates’ preference for mobility, flexibility and job-hopping (Vasconcelos et al., 2020). The Irish computing case shows that shortages may persist despite higher education capacity when student perceptions, preferences and enrolment choices limit the domestic supply of computing graduates (Stephens et al., 2007). The transferability of foreign higher education is another source of mismatch, as shown in the case of Norwegians educated abroad and their subsequent labour-market outcomes (Wiers-Jenssen and Try, 2005).

At the local level, Italian evidence from Perugia points to graduate overeducation and weak university-to-work matching, showing that local labour markets may not absorb graduate skills effectively (Marelli et al., 2014). The UK STEM evidence is particularly important because it challenges a simple supply-side interpretation of shortages: producing STEM graduates does not automatically guarantee a sufficient supply of highly skilled STEM workers, since many STEM graduates do not enter or remain in highly skilled STEM occupations (Smith and White, 2022). At doctoral level, regional and national labour markets may fail to absorb PhD holders into jobs that use their qualifications and skills fully, as shown for Catalonia and Italy (Germain-Alamartine, 2019; Castellano et al., 2017). Broader European evidence on young people confirms that weak school-to-work transitions, insufficient employer–education links and vertical or horizontal mismatch remain important channels through which education systems and labour markets fail to connect effectively (Hatos, 2015).

Table 4.2 Education-labour-market mismatch, curriculum adaptation and graduate pathways

Author and year	Territorial scope	Methods used	Drivers / causes
Andonovikj et al. (2024)	Slovenia; business and economy education	Data-driven comparison of curricula and labour-market demand using LLaMA-2-7B-chat and multilingual Sentence Transformer	Curriculum mismatch; employer-demand misalignment; academic offerings vs job-market requirements; competency gaps

Vasconcelos et al. (2020)	Northern Portugal; local companies and HE graduates	Interviews with 20 employers	Temporal mismatch; graduate job-hopping; flexible work preferences; employers' need for long-term commitment
Stephens et al. (2007)	Ireland; computing higher education and ICT labour market	Labour-market and higher-education policy analysis	Computing graduate shortage; student perceptions; weak enrolment response; manpower planning limits; reliance on immigrants
Wiers-Jenssen and Try (2005)	Norway; graduates educated abroad	Graduate labour-market outcome analysis	Transferability of foreign education; international qualifications; domestic labour-market recognition; mobility-related mismatch
Marelli et al. (2014)	Italy; province of Perugia and University of Perugia graduates	Matched administrative data from university and public job centres	Graduate overeducation; local labour-market absorption; university-to-work transition; local mismatch
Smith and White (2022)	United Kingdom; STEM graduates	Longitudinal analysis using the 1970 British Cohort Study	STEM pipeline leakage; weak retention in STEM occupations; early career entry; movement out of highly skilled STEM jobs
Germain-Alamartine (2019)	Catalonia, Spain; doctoral labour market	Descriptive analysis of regional data on doctorate holders	Doctoral mismatch; non-academic labour-market absorption; overeducation; weak valorisation of doctoral skills
Castellano et al. (2017)	Italy; PhD holders	Logit models; log-earnings equations; Oaxaca–Blinder decomposition	PhD overeducation; overskilling; wage penalties; insufficient absorptive capacity of research-intensive jobs
Hatos (2015)	European level; young people	Secondary analysis of international databases and policy indicators	School-to-work mismatch; weak employer–education links; vertical and horizontal mismatch; over- and under-education

The third group captures regional, spatial and post-transition restructuring drivers. These papers are important because they show that skill shortages are not only national phenomena; they are embedded in specific regional labour markets and historical development paths. Regional labour markets differ in their sectoral structure, employer base, institutional density, urbanisation level, labour mobility and attractiveness to workers.

The comparative study of 18 European regions demonstrates that regional demand-side factors explain both skill shortages and skill surplus. Shortages appear not only in dynamic urban economies, but also in peripheral or specialised regions where dominant sectors require specific skills or suffer from low attractiveness among young workers (Capsada-Munsech and Valiente, 2020). The CENTROPE study similarly shows that mismatch in Central Europe has both a skill and a regional dimension, reflecting heterogeneity across Austria, Czechia, Hungary and Slovakia and pointing to the role of imperfect spatial mobility (Kouba and Rozmahel, 2013).

In post-transition economies, shortages are shaped by the incomplete adjustment of skills to new private-sector, service-oriented, ICT-intensive and innovation-driven activities. Evidence from Central and Eastern Europe shows that perceived skill shortages are particularly relevant for larger and innovative firms and are negatively associated with productivity (Botrić et al., 2022). Comparative evidence for Bulgaria, Romania and Serbia shows that youth unemployment coexists with skill mismatch, partly because young people often lack applied, digital and transversal competences required by employers (Vutsova and Arabadzhieva, 2022). More generally, the Central European transition experience shows that skill shortages can constrain labour reallocation and convergence towards EU-15 employment structures, especially where low-skilled workers remain weakly integrated into expanding sectors (Brixiova et al., 2009).

Table 4.3 Regional, spatial and post-transition restructuring drivers

Author and year	Territorial scope	Methods used	Drivers / causes
Capsada-Munsech and Valiente (2020)	18 regions in nine European countries	Quantitative and qualitative data from EU Horizon 2020 project; desk review; 81 semi-structured interviews; grey-literature review	Regional skill ecosystems; sub-national variation; regional demand-side factors; high- and low-skill equilibria; youth mismatch
Kouba and Rozmahel (2015)	CENTROPE region: Austria, Czechia, Hungary, Slovakia	Labour Market Monitoring Tool; regional and occupational mismatch analysis	Regional mismatch; skill mismatch; cross-border labour-market heterogeneity; imperfect mobility
Botrić et al. (2022)	Central and Eastern European post-transition economies	Firm-level analysis; new indicator of perceived skill shortages; econometric modelling	Post-transition skill shortages; innovation; firm size; productivity effects; technological intensity; labour mobility
Vutsova and Arabadzhieva (2022)	Bulgaria, Romania and Serbia	Comparative analysis using Eurostat data, scientific literature and policy reports	Youth unemployment; skills mismatch; emigration of young people; soft skills; labour-market entry barriers
Brixiova et al. (2009)	Central Europe: Czech Republic, Hungary, Poland, Slovakia	Theoretical model of labour reallocation with transaction costs; policy simulation of training subsidies and tax financing	Transition restructuring; low employment of unskilled workers; skill shortages as barrier to labour reallocation; training incentives

The fourth group covers migration, cross-border mobility, posting, brain drain and job-attractiveness mechanisms. These papers show that shortages are not always caused by an absolute lack of qualified workers. They may also reflect wages, working conditions, occupational image, career prospects, migration incentives and the ability of sectors and regions to retain workers.

The Belgian evidence on posting shows that firms use posted workers in sectors such as construction, transport, meat processing, cleaning and food partly because local recruitment is difficult in jobs perceived as unattractive, demanding or insufficiently rewarding (Lens et al., 2022). In Poland's medical sector, potential brain drain is linked to poor financial and professional development prospects for doctors and dentists at home, suggesting that shortages may be intensified when skilled workers see better career opportunities abroad (Krajewski-Siuda et al., 2008). At the same time, migration may help receiving labour markets adjust to shortages. EU-level evidence shows that immigrants may respond more flexibly than natives to labour shortages across countries, industries and skill groups,

making migration a potential adjustment mechanism in segmented European labour markets (Guzi et al., 2018). Swiss evidence on the liberalisation of access for European cross-border workers shows that greater availability of foreign labour benefited skill-intensive firms, especially those that had previously reported skill shortages (Beerli et al., 2021). However, migration may also be associated with mismatch: immigrants in the EU are more likely than natives to experience vertical and horizontal mismatch, particularly when their human capital was acquired outside the EU and is less transferable or less recognised in host-country labour markets (Nieto et al., 2015).

Table 4.4 Migration, cross-border mobility, posting, brain drain and job-attractiveness mechanisms

Author and year	Territorial scope	Methods used	Drivers / causes
Guzi et al. (2018)	EU labour markets	EU-LFS and EU-SILC data; analysis of residual wage premia across country-industry-skill cells	Immigration as labour-market adjustment; migrant responsiveness to shortages; institutional and policy contexts
Beerli et al. (2021)	Switzerland; regions near EU borders	Difference-in-differences analysis of free movement reform; employer survey; business census; innovation surveys	Cross-border workers; easing labour supply constraints; skill-intensive firms; productivity and innovation effects
Lens et al. (2022)	Belgium; sectors using posted workers	Qualitative interviews with sector representatives and firms; triangulation with quantitative and secondary data	Posting of workers; manpower shortages; cost and flexibility motives; unattractive jobs; construction, meat, transport, cleaning
Krajewski-Siuda et al. (2008)	Poland; medical and dentistry students	Questionnaire survey of 367 students; binary and multivariate logistic regression	Medical brain drain; poor wages; weak professional development; dissatisfaction with domestic labour-market options
Nieto et al. (2015)	European Union; immigrants and natives	Adult Education Survey microdata; probit models; Yun decomposition	Immigrant skill mismatch; vertical and horizontal mismatch; limited transferability of non-EU human capital; recognition barriers

The last group concerns structural labour-market change and the underutilisation of available human capital. These papers show that skill shortages coexist with broader changes in occupational demand, educational expansion and persistent segmentation of labour-market opportunities. Job polarisation changes the structure of demand by increasing the relative importance of high- and low-skill jobs while reducing some medium-skill occupations, thereby reshaping the forms of overeducation and undereducation observed across Europe (Sparreboom and Tarvid, 2016). Educational expansion may also produce different mismatch outcomes depending on national institutional settings and labour-demand structures, as illustrated by the contrast between the United Kingdom and West Germany (Wiedner, 2024). At the same time, shortages may be reinforced when existing labour reserves are not effectively mobilised. Ethnic minorities may remain weakly connected to sustainable employment and shortage occupations when activation policies prioritise rapid job

placement over skill development (Peijen and Wilthagen, 2025). Gender segregation similarly narrows the effective recruitment pool for STEM, technical and apprenticeship-based occupations, as shown in the Italian and Scottish evidence (Berra and Cavaletto, 2020; Campbell et al., 2005). This group therefore highlights a macroeconomic mechanism of inefficient human-capital allocation, so shortages may arise not only because skills are absent, but because existing skills and potential workers are unevenly channelled, recognised and used across the labour market.

Table 4.5 Structural labour-market change and underutilisation of human capital

Author and year	Territorial scope	Methods used	Drivers / causes
Sparreboom and Tarvid (2016)	European countries	Macro-level job polarisation index and skills mismatch index; system of equations; micro-level multilevel mixed-effects logistic models	Job polarisation; changing occupational structure; growth of high- and low-skill jobs; decline of some medium-skill jobs; overeducation; undereducation; crisis-related mismatch
Wiedner (2024)	United Kingdom and West Germany, 1984–2017	Long-term trend analysis of self-assessed overqualification and underqualification	Educational expansion; overexpansion of education in the UK; partial under expansion in West Germany; institutional differences in qualification mismatch
Peijen and Wilthagen (2025)	Netherlands; ethnic minorities	Quasi-experimental comparison of employer-based programme and generic work-first support; long-term employment outcomes	Ethnic minority disadvantage; weak activation of vulnerable groups; insufficient skill investment in generic work-first policies; vocational skills; sustainable employment; underused labour reserves
Berra and Cavaletto (2020)	Italy; Piedmont Region	Action research project; institutional and school-work network; survey of 572 high-school students; orientation and firm-based interventions	STEM gender gap; gender stereotypes; weak school-to-work orientation; female underrepresentation in technical-scientific tracks; restricted future supply of STEM skills
Campbell et al. (2005)	Scotland; Modern Apprenticeship system	Policy and labour-market analysis of apprenticeship participation and occupational segregation	Gender segregation in apprenticeships; restricted recruitment pool; inefficient use of human capital; gendered access to shortage occupations; reinforcement of labour-market segmentation

4.3. Ageing, workforce shrinkage and skill mismatch

The following section synthesises the evidence from the reviewed papers in relation to RQ2b. Rather than treating ageing and workforce shrinkage as purely demographic variables, the analysis

approaches them as mechanisms that reshape the availability, use and allocation of skills across labour markets. The evidence is organised around four interrelated mechanisms: the employability and retention of older workers, the firm-level consequences of shrinking labour supply, territorial and technological disparities, and institutional filters affecting the conversion of human capital into shortage-relevant skills.

Ageing and workforce shrinkage contribute to skill mismatch in the EU not only through a numerical reduction in labour supply, but through a more complex transformation of the relationship between skills, work organisation and institutional access to employment. The reviewed evidence suggests that the ageing workforce should be understood as an issue of *effective skill availability*. Older workers may formally remain in the labour force, but their contribution to easing shortages depends on whether their skills are still aligned with changing job requirements, whether they have access to training and development, and whether workplaces are organised in ways that support retention. In this respect, mismatch emerges when older workers' skills are either insufficiently renewed, over-stretched in relation to job demands, or underused because of age-related barriers in hiring, training and promotion. The evidence on older workers' skill utilisation shows that ageing does not simply imply lower productivity or lower skill levels; rather, it changes the way skills are deployed at work. Older workers may have lower measured skills on average but can also use their available skills more intensively, which indicates that mismatch is partly a problem of skill use, not only skill possession (Bönisch et al., 2019). Re-employment evidence further shows that, once older workers become unemployed, they face weaker chances of returning to wage employment and a higher risk of exit or downward mobility. This means that ageing can deepen mismatch because experienced workers are not necessarily reabsorbed into jobs where their skills remain useful (Öylü et al., 2024). Health and job-resource conditions are also central: where older workers lack social support, recognition, autonomy combined with support, promotion prospects and development opportunities, their continued participation becomes more fragile, reducing the effective supply of experienced labour (Gut et al., 2024).

Shrinking labour supply creates a different but closely related mechanism. Demographic change reduces the inflow of younger workers at the same time as firms' demand for specialised and combined skill sets is increasing. This produces mismatch when vacancies cannot be filled with workers who are not only available, but also qualified, willing and able to perform the required tasks under existing labour-market conditions. The firm-level evidence is particularly important here because it shows that demographic pressure becomes economically visible through unfilled or delayed vacancies, especially for skill groups needed in innovation processes. In ageing economies, shortages of specialised labour do not simply slow recruitment; they may alter firms' technological and organisational trajectories. Innovation-oriented firms require combinations of academic, vocational, technical and practical skills, and when these combinations are unavailable, firms may abandon or cancel innovation projects. The mechanism is therefore cumulative: demographic decline narrows the future skill pipeline, technological change raises the complexity of demand, and firms experience mismatch as a direct constraint on innovation, productivity and structural transformation (Horbach & Rammer, 2022).

Spatial and technological mismatch adds a territorial dimension to RQ2b. Ageing and shrinking do not affect all European regions in the same way. Smaller and peripheral living areas may combine population decline, ageing, weaker infrastructure, lower access to learning resources and lower digital readiness. In such contexts, demographic change interacts with digital transformation: the regions that need new digital and AI-related competences may also be those with fewer

institutional and infrastructural capacities to produce them. The mismatch is therefore not only between workers and jobs, but also between regional development needs and regional skill ecosystems. Digital and AI skills become increasingly necessary for work, public services and social participation, while residents of smaller living areas face weaker access to broadband, financial resources, educational opportunities and targeted support. This makes ageing and shrinking regions more vulnerable to cumulative disadvantage, because the same places that experience demographic weakening may also lag behind in the skills required for the AI-enabled economy (Pham et al., 2024).

Institutional filters explain why demographic pressure does not automatically translate into uniform skill shortages across the EU. Education systems, migration regimes, occupational segregation and career pathways shape whether existing human capital is converted into skills that are actually relevant for shortage occupations. **Education systems** can reproduce mismatch when tracking or vocational pathways create persistent gaps in core skills such as numeracy, especially where vocational graduates are insufficiently upskilled for changing labour-market requirements (Kim, 2023). The STEM evidence similarly shows that increasing the number of graduates is not enough if graduates do not enter, remain in, or return to high-skilled STEM jobs over the life course; shortage-relevant skills may exist in the population but fail to be retained in the occupations where they are needed (Smith & White, 2022). **Migration** may partly compensate for demographic decline by reallocating labour across countries, sectors and skill groups, but it can also redistribute shortages within Europe. Migrant mobility can help receiving labour markets adjust to shortages, while sending countries may lose scarce professionals, especially in sectors such as healthcare where ageing populations increase demand (Guzi et al., 2018; Krajewski-Siuda et al., 2008). **Occupational segregation** works in a similar way - when training and apprenticeships channel women and men into different occupations, the potential pool of recruits is artificially restricted, which can intensify shortages in sectors already affected by demographic decline (Campbell et al., 2005).

Table 4.6 Mechanisms linking ageing and workforce shrinkage to skill mismatch in the EU

Group	Mechanism	Articles
A. Direct ageing-workforce mechanisms	Older workers' skill use, employability, health and retention shape the effective supply of skills, not only the numerical size of the labour force.	Bönisch et al. (2019); Öylü et al. (2025); Gut et al. (2024)
B. Shrinking labour supply and firm-level consequences	Demographic decline reduces the inflow of young workers and intensifies shortages of specialised labour, especially where firms need specific combinations of vocational, technical and innovation-related skills.	Horbach & Rammer (2022)
C. Spatial and technological mismatch	Shrinking and ageing regions face weaker digital and AI readiness, poorer infrastructure and more limited access to learning resources, which may deepen territorial skill mismatches.	Pham et al. (2024)
D. Institutional filters: education, migration and segmentation	Education systems, migration flows, occupational segregation and STEM career leakage determine whether existing human capital is converted into shortage-relevant skills.	Kim (2023); Smith & White (2022); Guzi et al. (2018); Krajewski-Siuda et al. (2008); Campbell et al. (2005)

The reviewed papers suggest that ageing and workforce shrinkage contribute to skill mismatches through the weakening of labour-market renewal, the uneven retention and re-employment of older workers, the territorial concentration of digital and AI skill gaps, and the institutional filtering of human capital through education, migration and segmentation. The core issue is not simply that Europe has fewer workers, but that the available and potential workforce is not always positioned, trained, retained or mobilised in ways that correspond to changing labour-market demand. For policy, this implies that demographic responses cannot be limited to increasing labour-force participation. They require age-inclusive lifelong learning, better workplace resources for older workers, stronger re-employment pathways, territorial investment in digital and AI skills, and institutional reforms that reduce avoidable losses of human capital through tracking, occupational segregation, STEM leakage and unmanaged brain drain.

4.4. Educational expansion, skills diffusion and overeducation

The reviewed literature, covering 31 articles, does not support the assumption that educational expansion automatically produces a proportional improvement or diffusion of foundational and cognitive skills. The expansion of secondary and tertiary education has increased the formal qualification level of the European workforce, but qualifications remain an incomplete measure of what workers know, what they are able to do and how their competencies are used at work. Workers with similar educational attainment may differ substantially in literacy, numeracy, problem-solving, digital proficiency, occupation-specific knowledge and transferable skills.

Higher educational attainment may therefore coexist with overeducation, overskilling, underskilling and employer-reported shortages. These phenomena are not mutually exclusive because qualifications, skills and employment opportunities are distributed unevenly across educational fields, occupations, sectors, regions and population groups. The evidence also indicates that overeducation is not, in itself, a general cause of skill shortages. It may signal genuine underutilisation of human capital, but it may also reflect credential inflation, differences in educational quality, limited transferability of qualifications, weak labour-market demand or the use of education as a signal of trainability.

The evidence is organised around five mechanisms. The classification is based on the dominant contribution of each paper, although several studies address more than one dimension of the relationship between educational expansion, skills and labour-market mismatch.

Educational expansion and foundational/cognitive skills

Educational expansion does not ensure that foundational and cognitive skills improve at the same rate as formal attainment. The relationship depends on the institutional organisation and quality of education, the differentiation of academic and vocational pathways, social background and opportunities to maintain skills after leaving education. Evidence on numeracy shows that formally comparable educational tracks can generate different skill outcomes across countries. In more stratified systems, educational pathways may preserve inequalities in cognitive proficiency and in the everyday use of skills (Kim, 2023).

The labour-market effects of expansion are equally dependent on the structure of demand. The United Kingdom and West Germany illustrate that a similar long-term increase in educational participation may result in overexpansion in one setting and continuing shortages within parts of the

qualification structure in another (Wiedner, 2024). Occupational restructuring also changes the capacity of labour markets to absorb educated workers. Where the growth of graduate supply is not matched by the development of suitable occupations, overeducation increases; where high-skill demand grows faster than supply, underqualification and recruitment difficulties persist (Sparreboom and Tarvid, 2016). Among young workers, these processes are reinforced by weak school-to-work links, limited work experience and adverse economic conditions (Hatos, 2015). Educational expansion should therefore be evaluated not only through enrolment and graduation rates, but also through learning outcomes and the occupational demand for the skills acquired.

Table 4.7 Educational expansion and foundational/cognitive skills

Author and year	Territorial scope	Methods used	Main findings / mechanisms
Kim (2023)	Austria, Germany, United Kingdom and United States	Comparative analysis using PIAAC data; analysis of the relationship between social origin, educational track and numeracy acquisition	Educational expansion does not ensure an equal diffusion of foundational skills; vocational pathways produce different numeracy outcomes across education systems; educational stratification may reproduce social inequalities in skill acquisition and use
Wiedner (2024)	United Kingdom and West Germany, 1984–2017	Long-term trend analysis of self-assessed overqualification and underqualification	Educational expansion produced overexpansion in the United Kingdom and partial underexpansion in West Germany; labour-market absorption depends on national institutions and qualification demand
Sparreboom and Tarvid (2016)	European countries	Macro-level job polarisation index and skills mismatch index; system of equations; micro-level multilevel mixed-effects logistic models	Job polarisation changes the occupational demand for qualifications and skills; growth in high- and low-skill jobs and decline in parts of medium-skill employment affect overeducation and undereducation; crisis conditions intensify mismatch
Hatos (2015)	European countries; young people	Secondary analysis of European labour-market indicators and research on school-to-work transitions and mismatch	Expansion of tertiary education may increase overeducation where suitable employment does not grow correspondingly; weak employer–education links and difficult labour-market entry reinforce mismatch

Qualification mismatch versus skills mismatch

Qualification mismatch and skills mismatch overlap only partially. Formal education indicates the level and field of completed study but does not directly measure the competencies possessed by workers or required in their jobs. A worker may have more education than is formally required without

possessing surplus skills, while another may hold an appropriate qualification but lack specific competencies or be unable to use existing capabilities fully.

Cross-country evidence confirms that educational mismatches provide only an approximate indication of how knowledge and skills are used at work (Allen and De Weert, 2007). Cognitive skills contribute to labour-market outcomes independently of years of education, and their returns are higher when combined with education that is relevant to the job (Mateos Romero et al., 2017). This makes it necessary to distinguish apparent overeducation from genuine overeducation. The former concerns excess formal qualifications without corresponding overskilling; the latter combines qualification mismatch with the underuse of actual skills. Wage losses are largest where both forms of mismatch occur together (Cultrera et al., 2022).

The distinction remains important at the highest levels of education. Doctorate holders may work in positions that do not formally require a PhD while still using advanced analytical, research or problem-solving competencies. Others experience both overeducation and overskilling, particularly where non-academic labour markets have limited capacity to absorb research skills (Castellano et al., 2017). The scale of overeducation cannot therefore be treated as a direct measure of unused human capital.

Table 4.8 Qualification mismatch versus skills mismatch

Author and year	Territorial scope	Methods used	Main findings / mechanisms
Allen and De Weert (2007)	Five European countries	Cross-country graduate survey; analysis of educational level, field of study and competence use at work	Educational mismatch and skills mismatch overlap only partially; formal education-job correspondence does not guarantee that acquired skills match those required at work
Mateos Romero et al. (2017)	13 European countries	PIAAC data; wage equations including years of education, numeracy proficiency and mismatch measures	Education and cognitive skills independently affect wages; educational and skills mismatches are distinct; the returns to education rise with cognitive proficiency
Cultrera et al. (2022)	28 European countries	CEDEFOP European Skills and Jobs Survey; wage equations and instrumental-variable estimation	Apparent overeducation should be distinguished from genuine overeducation; the largest wage penalty occurs when workers are both overeducated and overskilled
Castellano et al. (2017)	Italy; PhD holders	Logit models; log-earnings equations; Oaxaca–Blinder decomposition	Overeducation and overskilling among doctorate holders have different determinants and wage effects; formal doctoral mismatch does not necessarily

			indicate the non-use of advanced skills
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Labour-market absorption and underutilisation of highly educated workers

The production of graduates does not ensure their entry into jobs that correspond to their education. Matching depends on field-of-study choices, local labour demand, economic conditions at graduation, occupational mobility and the capacity of sectors to retain qualified workers.

The Irish computing case shows that shortages may persist despite the institutional capacity to educate more graduates when students do not select the relevant programmes (Stephens et al., 2007). Local labour markets may also be unable to provide sufficient graduate-level employment, resulting in uneven matching across fields and regions (Marelli et al., 2014). Adverse conditions at labour-market entry compound this problem. Graduates entering employment during a recession are more likely to accept jobs in industries that do not value their field-specific skills, and the consequences may persist through later careers (Liu et al., 2016).

Sectoral shortages may reflect leakage rather than insufficient educational output. In the UK, many STEM graduates never enter highly skilled STEM occupations or leave them during their working lives, weakening the connection between graduate numbers and the effective supply of STEM labour (Smith and White, 2022). A similar issue occurs at doctoral level: regions may retain PhD holders without providing enough positions that formally require or fully use their advanced qualifications (Germain-Alamartine, 2019). Comparative evidence on graduate transitions further shows that educational attainment produces different outcomes depending on national institutions, degree level, cohort, job security and the duration of transition into stable employment (Symeonaki et al., 2021).

Overeducation within this group is primarily an indicator of insufficient absorption or poor allocation. It may contribute indirectly to shortages if qualified workers remain outside shortage occupations, lose skills through non-use or leave sectors offering weak career prospects.

Table 4.9 Labour-market absorption and underutilisation of highly educated workers

Author and year	Territorial scope	Methods used	Main findings / mechanisms
Stephens et al. (2007)	Ireland; computing higher education and ICT labour market	Higher-education and labour-market policy analysis	Computing shortages persisted despite available educational capacity because student preferences constrained enrolment; immigration partly compensated for the insufficient domestic supply
Marelli et al. (2014)	Italy; province of Perugia and University of Perugia graduates	Matched administrative data from the university and public employment centres	Graduate matching depends on field of study and local labour-market structure; regional economies may be unable to absorb the skills produced by universities
Liu et al. (2016)	Norway; university graduates	Longitudinal administrative data; analysis of cyclical skill	Graduating during a recession increases the probability of entering industries that do not value field-specific skills; initial

		mismatch and career outcomes	mismatch has persistent effects on earnings and careers
Smith and White (2022)	United Kingdom; STEM graduates	Longitudinal analysis using the 1970 British Cohort Study	STEM shortages coexist with a substantial graduate supply because many graduates do not enter or remain in highly skilled STEM employment
Germain-Alamartine (2019)	Catalonia, Spain; doctorate holders	Descriptive analysis of regional data on doctoral education and employment	High regional retention of doctorate holders coexists with widespread employment in positions that do not formally require a doctorate
Symeonaki et al. (2021)	Eight European countries; recent graduates	Cross-national analysis using the EUROGRADUATE Pilot Survey	Graduate transitions differ across countries, cohorts and degree levels; educational attainment improves average employment prospects but does not guarantee stable or well-matched work

Regional, sectoral and institutional variation

Educational expansion takes place within heterogeneous regional economies and sectoral labour markets. The same stock of qualifications may be excessive relative to demand in one locality and insufficient in another. Regional industrial structure, firm innovation, labour-market concentration, mobility and the responsiveness of education and training institutions determine whether skills are productively absorbed.

Regional skill ecosystems can contain high-skill growth, low-skill employment and sector-specific shortages at the same time. National education systems therefore generate different mismatch outcomes across regions because the availability and quality of jobs vary locally (Capsada-Munsech and Valiente, 2020). Labour-market concentration also shapes employer behaviour: firms may demand higher education as a signal of trainability while providing job-specific training internally, weakening the direct link between educational requirements and the existing content of workers' skills (Colombo and Marcato, 2023).

Technological and organisational change further increases demand for combinations of technical, cognitive and social competencies. STEM employers seek adaptability, innovation, complex problem-solving and the ability to manage uncertainty alongside specialised knowledge (Abina et al., 2024). Digital transformation similarly requires universities to update curricula, strengthen employer cooperation and respond to regional smart-specialisation needs (Noja et al., 2024). Static, discipline-based programmes are poorly suited to a labour market in which future skills are dynamic, interdisciplinary and continuously revised (Caratozzolo et al., 2023). Digital and AI skills are also distributed unevenly between metropolitan and smaller living areas, showing that national educational progress does not remove territorial disparities in skill access and use (Pham et al., 2024).

The experience of post-transition economies demonstrates that a relatively educated workforce may still be poorly aligned with changing demand. Economic restructuring has shifted employment towards private services, ICT, innovative firms and more adaptable skill combinations. Larger and innovative firms are especially likely to report recruitment problems, and shortages can

restrict productivity and innovation (Brixiova et al., 2009; Botrić et al., 2022; Horbach and Rammer, 2022). Youth unemployment may therefore coexist with hard-to-fill vacancies when qualifications do not include the practical, digital and transversal skills expected by employers or when young workers migrate to more attractive labour markets (Vutsova and Arabadzhieva, 2022).

This evidence indicates that apparent contradictions between educational surplus and skill shortage are often generated by the territorial and sectoral specificity of demand rather than by the aggregate quantity of education.

Table 4.10 Regional, sectoral and institutional variation

Author and year	Territorial scope	Methods used	Main findings / mechanisms
Colombo and Marcato (2023)	Italy; local labour markets	Online job-vacancy data for 2013–2018; regression analysis; instrumental-variable approach	Employers in concentrated labour markets demand higher education together with social and learning skills; education may function as a signal of trainability rather than existing job-specific knowledge
Abina et al. (2024)	Slovenia and Norway; STEM-related companies	Analysis of international competency frameworks; questionnaire survey among company HR managers	Employers require adaptability, innovation, uncertainty management and process-management competencies in addition to specialised STEM knowledge
Capsada-Munsech and Valiente (2020)	18 regions in nine European countries	Quantitative and qualitative evidence from an EU Horizon 2020 project; interviews and comparative regional analysis	Regional demand conditions mediate national skill-formation outcomes; skill surpluses and shortages may coexist within the same institutional system
Noja et al. (2024)	European Union	Desk research; qualitative interviews with employers, HEI representatives and policymakers; bibliometric analysis	Higher education institutions can reduce digital gaps, but adjustment requires coordination with employers, regional smart-specialisation strategies and curriculum renewal
Pham et al. (2024)	Eight EU countries; small and large living areas	Survey of 4,006 respondents; bivariate analysis	Digital skills are unevenly distributed territorially; residents of smaller areas report weaker digital proficiency despite broader educational expansion
Caratozzolo et al. (2023)	Higher-education and Industry 4.0 context	Development of a dynamic future-skills taxonomy based on occupational and competency frameworks	Static curricula do not adequately respond to changing demand for digital, cognitive, social and interdisciplinary skills; lifelong and experiential

			learning become increasingly important
Botrić et al. (2022)	Central and Eastern European post-transition economies	Firm-level analysis; indicator of perceived shortages; econometric modelling	Large and innovative firms are more likely to report shortages; educational expansion has not eliminated gaps between available human capital and specialised employer demand
Horbach and Rammer (2022)	Germany; innovative firms	Panel data from the German Innovation Survey; instrumental-variable probit estimation	Shortages of specialised labour may lead firms to delay or abandon innovation projects; general educational attainment does not prevent specific recruitment constraints
Vutsova and Arabadzhieva (2022)	Bulgaria, Romania and Serbia	Comparative analysis using Eurostat data, academic literature and policy reports	Youth unemployment coexists with demand for applied, digital and transversal skills; migration and weak transitions reduce the effective supply of young workers
Brixiova et al. (2009)	Czech Republic, Hungary, Poland and Slovakia	Theoretical model of labour reallocation with transaction costs; simulations of training and tax policies	Economic restructuring changed the composition of required skills; inherited formal education did not prevent shortages in new private-sector and service activities

Migration, recognition and transferability of human capital

Migration exposes the limitations of treating qualifications as directly transferable measures of skills. Education acquired abroad may contain valuable human capital, yet its labour-market value depends on recognition, language proficiency, country-specific knowledge, professional regulation and employers' familiarity with foreign institutions.

Graduates educated abroad may face higher initial risks of unemployment and overqualification even when their international education later produces wage or career advantages (Wiers-Jenssen and Try, 2005). The disadvantage is greater among non-Western immigrants and cannot be explained solely by the country in which education was completed, pointing to the interaction of transferability problems and discrimination (Støren and Wiers-Jenssen, 2010). Immigrants from outside the EU are also more exposed to vertical and horizontal mismatch because both the level and field of their education may be valued less in destination labour markets (Nieto et al., 2015).

The distinction between formal qualifications and measured skills is particularly important in this context. Immigrants may be more frequently overeducated without being more frequently overskilled. Their higher qualifications may compensate for weaker destination-country language proficiency, limited institutional knowledge or differences in educational quality (Prokic-Breuer and

McManus, 2016). Italian evidence shows that migrants may even be overqualified and underskilled in host-country literacy at the same time (Bonacci and Mineo, 2018). Conversely, qualified immigrants may possess relevant productive capacities that remain unused because their probability of obtaining appropriate employment is lower than that of comparable native workers (Iftikhar and Zaharieva, 2016).

Mismatch also affects the capacity of receiving countries to retain migrant human capital. Settlement decisions are embedded in broader processes of integration, discrimination and access to stable employment, although mismatch alone does not fully explain migrants' intentions to remain in the destination country (Shelest-Szumilas and Wozniak, 2024).

Immigrant overeducation should consequently not be interpreted as straightforward evidence of a surplus of skills. It may indicate imperfect portability, recognition barriers, unequal employment opportunities or a temporary deficit in host-country-specific competencies.

Table 4.11 Migration, recognition and transferability of human capital

Author and year	Territorial scope	Methods used	Main findings / mechanisms
Wiers-Jenssen and Try (2005)	Norway; graduates educated domestically and abroad	Analysis of employment probability, mismatch and wages	Foreign education may generate valuable competencies but also creates initial recognition and matching difficulties
Støren and Wiers-Jenssen (2010)	Norway; graduates differentiated by diploma origin and immigrant background	Multinomial logistic regression	Foreign diplomas increase unemployment and overqualification risks; non-Western immigrants face an additional disadvantage regardless of where they studied
Prokic-Breuer and McManus (2016)	13 Western European countries	PIAAC data; direct cognitive-skill measures and occupational requirements	Immigrants are more frequently overeducated but not more frequently overskilled; much immigrant overeducation is apparent and reflects language, educational quality and limited transferability
Bonacci and Mineo (2018)	Italy; migrant and native workers	PIAAC data; comparison of qualifications, literacy proficiency and job requirements	Migrants may be overqualified and simultaneously underskilled in host-country literacy; qualifications and destination-country competencies capture different dimensions of human capital
Nieto et al. (2015)	European Union; immigrants and natives	Adult Education Survey; probit models; Yun decomposition	Immigrants, particularly those from outside the EU, experience more vertical and horizontal mismatch because foreign human capital is imperfectly transferable and less strongly valued
Iftikhar and Zaharieva (2016)	Germany; native and immigrant workers	Calibrated search-and-matching general-equilibrium model	High-skilled immigrant capacities are underutilised because immigrants have lower

			employment probabilities; more equal employment opportunities would improve labour-market allocation
Shelest-Szumilas and Wozniak (2024)	Poland; Ukrainian economic migrants and war refugees	Survey-based structural analysis of mismatch, discrimination, integration and settlement intentions	The retention and use of migrant skills depend on integration, discrimination and access to stable employment; mismatch is embedded in wider settlement processes

The reviewed evidence indicates that educational expansion in Europe has increased formal qualification levels but has not produced an equivalent or uniformly distributed improvement in foundational, cognitive and job-relevant skills. Qualifications and actual competencies remain distinct dimensions of human capital, while their labour-market value depends on the quality and structure of education, occupational demand, regional and sectoral conditions, career transitions and the recognition of skills acquired abroad. Overeducation is therefore not a general cause of skill shortages. It may reflect genuine underutilisation when workers possess competencies that are not required or used in their jobs, but it may also arise from credential inflation, limited local demand, imperfect transferability of qualifications or the use of education as a signal of trainability. Skill shortages can consequently coexist with a substantial supply of highly educated workers when qualifications and skills are located in different sectors or regions, when graduates do not enter or remain in shortage occupations, or when migrant competencies are not fully recognised. The central problem is thus not simply the quantity of education, but the alignment between skill formation, the changing content of labour demand and the institutional capacity to recognise, allocate, retain and productively use existing human capital.

4.5. Key findings

- Skill shortages and skill mismatches in the EU arise from interacting technological, demographic, educational, regional and institutional mechanisms rather than from a general lack of educated workers.
- Technological, digital and green transformations generate new and often hybrid skill requirements, particularly in ICT, STEM, manufacturing, construction, process industries and renewable energy.
- Shortages vary substantially across sectors and regions because labour demand, economic specialisation, mobility, job attractiveness and the capacity to develop and retain skills are unevenly distributed.
- Population ageing and workforce shrinkage affect the effective supply of skills through the retention, re-employment, training and skill use of older workers, as well as through weaker labour-market renewal.
- Educational expansion does not automatically produce a proportional diffusion of foundational, cognitive and job-relevant skills; qualifications and actual competencies therefore need to be analysed separately.
- Overeducation is not a general cause of skill shortages. It may instead reflect insufficient labour-market absorption, credential inflation, poor allocation of human capital or limited transferability and recognition of qualifications.

- Migration can alleviate shortages by reallocating labour, but its contribution depends on recognition, integration and retention, while unmanaged mobility may deepen mismatch or redistribute shortages through brain drain.
- Effective policy responses require coordinated measures addressing skill formation, lifelong learning, job quality, regional skill ecosystems, labour mobility, recognition of qualifications and the fuller use of existing human capital.

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5. Wage incentives and foreign recruitment as responses to skill shortages

5.1. Introduction

Building on Chapter 4, which identified the main demographic, structural and institutional drivers of skill shortages and mismatches, this chapter examines two immediate employer and policy responses: wage incentives and the recruitment of foreign workers. It addresses Research Question 3:

How do economic incentives for raising wages compare with recruitment of foreign workers in mitigating skill shortages?

The motivation for this question is that persistent shortages are often interpreted as an imbalance between labour demand and labour supply. Employers and policymakers typically respond through two broad channels. The first is to increase wages or other forms of compensation in order to attract and retain workers. The second is to expand the available labour supply by recruiting workers from abroad, either through firm-level international hiring or through policy changes that reduce barriers to migration and employment.

The evidence base screened for RQ3 includes peer-reviewed journal articles, book chapters, working papers, sector-focused analyses, policy-oriented studies and descriptive accounts. These sources differ substantially in purpose, design and evidential strength. A small subset evaluates clearly defined migration or recruitment interventions and links them to measurable labour-market or firm-level outcomes. A larger group provides qualitative or descriptive evidence on international recruitment practices, mobility channels, sectoral dynamics and the constraints involved in deploying and retaining foreign workers. Additional studies contribute background evidence on migration incentives, wage premia, qualification recognition, integration barriers and the wider labour-market effects of immigration.

To ensure relevance to RQ3, the screening prioritised studies that explicitly address labour or skill shortages and examine either wage-based incentives or foreign-worker recruitment as a response. Preference was given to studies that connect these responses to outcomes consistent with shortage mitigation, including vacancy filling, hard-to-fill positions, recruitment and retention outcomes, time to hire, or the easing of firm-level constraints associated with shortages. Where direct comparisons between wage incentives and foreign recruitment were not available, studies were retained for partial inclusion when they provided evidence on one strategy in a documented shortage context and offered insights relevant to the implied trade-off, such as wage effects associated with foreign recruitment or the sustainability of recruitment through retention.

Because few studies compare wage increases and foreign recruitment within the same empirical design, the synthesis combines evidence in three layers. First, core evidence comes from studies that evaluate foreign-recruitment interventions or changes in access to migrant labour and link them to outcomes plausibly related to shortage mitigation. Second, partially included studies provide insight into how foreign recruitment operates in practice, including employer strategies, sectoral variation and retention. Third, background studies are used to interpret mechanisms and boundary

conditions, including how workers respond to wage signals, how integration and recognition barriers affect the effective use of foreign labour, and how institutional settings shape labour-supply responses.

The resulting evidence base is asymmetric. It contains stronger direct evidence on foreign recruitment and changes in access to migrant labour than on wage increases as a deliberate shortage-mitigation intervention. The chapter therefore does not present a balanced causal comparison. Instead, it assesses what the literature can credibly establish about the likely effectiveness, speed, institutional conditions and trade-offs associated with both strategies. This evidential structure is summarised in Table 5.1.

Table 5.1 Overview of the RQ3 evidence base

Evidence dimension	Description	Implication for the synthesis
Research question	How do economic incentives for raising wages compare with recruitment of foreign workers in mitigating skill shortages?	The analysis compares two potential adjustment channels: improving compensation and expanding labour supply through international recruitment.
Types of sources screened	Peer-reviewed journal articles, book chapters, working papers, sector-focused studies, policy-oriented analyses and descriptive accounts	The evidence base is heterogeneous in purpose, method and analytical strength.
Core causal evidence	One quasi-experimental study evaluating expanded access to EU cross-border workers: Beerli et al. (2021)	Provides the strongest evidence that foreign-worker access can relax staffing constraints and improve firm outcomes.
Partially included evidence	Studies of employer recruitment practices, skilled mobility, health-worker recruitment, migrant retention and construction-sector labour sourcing	Explains how foreign recruitment is implemented and which conditions affect its feasibility and sustainability.
Background evidence	Studies of migration incentives, wage premia, integration, credential recognition, mobility frameworks and broader immigration effects	Supports interpretation of mechanisms and boundary conditions but does not directly evaluate shortage-mitigation strategies.
Direct evidence on wage raising	No selected study directly evaluates a wage increase as an intervention and measures vacancy filling, hiring speed, retention or shortage reduction	The effectiveness of wage raising cannot be estimated or directly compared with foreign recruitment from the selected corpus.
Direct head-to-head comparisons	None	Conclusions must be based on an asymmetric evidence base rather than a causal comparison of the two strategies.
Overall evidential balance	Stronger evidence on foreign recruitment and migration-access channels than on deliberate wage-raising interventions	Foreign recruitment has clearer demonstrated short-run effects, but this does not establish that it is generally superior to wage improvement.

Source: Authors' synthesis of the RQ3 literature corpus.

5.2. Selection and classification of studies

For RQ3, the screening aimed to isolate evidence on recruitment strategies used to mitigate skill shortages, specifically the trade-off between raising wages as an economic incentive and recruiting foreign workers. Papers were categorised as included in the core analysis when they evaluated a concrete foreign recruitment or access intervention and linked it to outcomes relevant to shortage

mitigation. Papers were categorised as partially included when they clearly addressed skill shortages and discussed foreign recruitment as a response but did not provide outcome based evaluation or did not engage with wage raising as a competing strategy. Papers were excluded from the core analysis and treated as background when they contributed useful context, mechanisms, or constraints around migration, mobility, or integration but did not examine wage incentives or foreign recruitment as an intervention tied to shortage mitigation outcomes. Finally, papers were excluded entirely when they did not inform recruitment strategies for shortages at all.

Table 5.2 Evidence classification and inclusion logic for RQ3

Evidence category	Inclusion criterion	Studies or types of studies	Contribution to RQ3	Main limitation
Core analysis	Evaluates a concrete foreign-recruitment or labour-access intervention and links it to shortage-relevant outcomes	Beerli et al. (2021)	Provides causal evidence on changes in foreign employment, firm performance, innovation and native-worker outcomes following expanded access to cross-border labour	Does not evaluate wage raising as a deliberate competing intervention
Partially included: employer practice	Examines foreign recruitment as a response to recognised talent shortages	Boege and Blomme (2013)	Shows how German and Dutch multinationals use international recruitment and which organisational investments are required	Does not measure vacancy filling, time to hire or shortage reduction
Partially included: sector evidence	Examines international recruitment in a sector facing staffing shortages	Lozano, Meardi and Martín Artiles (2015); Clarke (2006)	Provides evidence from health and construction on the speed, practical use and risks of importing labour	Mainly qualitative or descriptive; no direct strategy comparison
Partially included: mobility policy	Connects skilled mobility channels with the objective of addressing EU skill shortages	Chanda and Mukherjee (2014)	Identifies visa, work-permit and mobility arrangements that enable international recruitment	Does not evaluate measurable shortage outcomes
Partially included: retention	Examines whether recruited labour migrants intend to remain	Ette, Heß and Sauer (2016)	Shows that long-term shortage mitigation depends on retention, language, family conditions and legal security	Measures settlement intentions rather than vacancies or shortage reduction
Background: migration response	Analyses whether migrants respond to wage premia or shortage signals	Guzi, Kahanec and Mýtna Kureková (2018)	Supports the mechanism that mobile workers may respond more strongly to shortage-related wage signals	Does not evaluate recruitment or wage raising as an intervention
Background: integration and recognition	Examines barriers affecting the labour-market use of migrants' skills	van Riemsdijk (2023); Ramos, Matano and Nieto (2015);	Identifies credential, employer, recognition and integration constraints	Does not directly measure shortage mitigation

		Gatteschi et al. (2012)		
Background: institutional and sector context	Describes mobility systems, migration drivers or recruitment practices	Lucas and Martin (2010); Gruber et al. (2020); Hibbert (2006); Green (2024)	Clarifies enabling institutions, sector pressures and practical recruitment behaviour	Descriptive or contextual evidence only
Excluded entirely	Does not inform wage incentives or foreign recruitment as responses to shortages	Bárcena Martín, Budría and Moro Egido (2012); Bjørnstad and Skjerpen (2006)	None for RQ3	Focuses on skill mismatch, wage inequality, trade or unemployment rather than recruitment strategies

Note: “Partially included” studies inform particular mechanisms or contexts but do not provide a direct outcome-based comparison of wage incentives and foreign recruitment.

5.3. Background mechanisms and institutional conditions

Wages are the ‘price signal’, but the supply response differs by group and context. Several papers frame shortages as creating upward wage pressure because firms may need to raise pay to attract scarce workers. But the responsiveness of labour supply to wages varies across occupations, sectors, and institutions; and wage-based signals can widen wage differentials. A key ‘bridge’ insight is that immigrants may respond more strongly to shortage signals (wage premia) than natives because some mobility costs are already sunk. Guzi, Kahanec & Mýtna Kureková (2018) operationalise shortage with unexplained wage premia and study whether immigrants reallocate more toward those shortage cells across EU labour markets. Implication for RQ3: wage increases can help, but the effective ‘recruitment elasticity’ may be higher for mobile groups (including immigrants), meaning wage signals and foreign recruitment interact rather than being clean substitutes.

Foreign-worker recruitment can relieve constraint quickly, and can raise (not only lower) native high-skill wages. The strongest quasi-experimental evidence among the set of articles is Beerli et al. on Switzerland: abolishing restrictions on EU cross-border workers is a clear foreign-labour access intervention, and the analysis ties effects to firms that reported skill shortages pre-reform. It also documents wage outcomes (e.g., positive effects for highly educated natives) alongside firm performance changes. Implication for RQ3: foreign recruitment isn’t only a ‘cheap labour’ channel; it can operate through complementarities (and productivity/innovation responses), which can support high-skill wages rather than depress them.

Sector case evidence shows ‘importing labour’ is often used when training/wage reforms are slow or contested. In UK construction, Clarke (2006) argues that shortage responses often emphasised importing skilled labour (including East European workers) rather than fixing training/regulation and ‘valuing labour’, with discussion of wage-setting and labour process implications. A trade/industry

example (Hibbert, 2006) similarly describes firms recruiting engineers from abroad due to shortages, noting overseas hires are paid ‘the going rate’ (useful context, not evaluation). Implication for RQ3: employers may pick foreign recruitment because it’s faster/operationally feasible, even when wage/conditions are part of the underlying problem, so policy design matters.

Health workforce: international recruitment is used as a ‘short-term fix’, with ethical/planning risks. Lozano, Meardi & Martín-Artiles (2015) describe UK health-sector experience where international recruitment expanded in the early 2000s, and is characterised as short-term in workforce planning discussions, with later shifts toward self-sufficiency and ethical concerns. They also note a ‘two-tier’ dynamic where foreign doctors may not be visibly disadvantaged in wages but can face worse hours/segmentation. Implication for RQ3: foreign recruitment can mitigate shortages, but may create long-run dependence, segmentation, and ethical issues, so it’s not a pure substitute for improving domestic pay/conditions.

Policies that ‘enable’ foreign hiring matter, but integration barriers limit effectiveness. Several background items are about enabling conditions rather than direct comparisons:

- Integration policies can improve immigrants’ labour market outcomes (wage gaps/returns), which affects how effective foreign recruitment is in practice.
- Refugee/credential/recognition barriers constrain how quickly high-skilled migrants can be deployed to shortage occupations.
- Mobility/visa channels (e.g., Blue Card regimes, short-term mobility) are described as mechanisms to address shortages, but typically without outcome evaluation.

Implication for RQ3: if integration/recognition is slow, raising wages may outperform foreign recruitment in the short run simply because foreign supply can’t be activated quickly, even if recruitment policy exists on paper.

Bottom line answer to RQ3 from the background set:

- Raising wages is the canonical market response to shortages and creates the signal that draws labour in, but the supply response depends on institutions and who can move.
- Recruiting foreign workers can be an effective and rapid pressure valve-sometimes with positive wage effects for high-skilled natives-when restrictions are eased and when matching/integration works.
- In practice, sectors sometimes rely on foreign recruitment as an ‘operational shortcut’ when wage/conditions/training reforms are slow, but this can create planning and fairness risks (notably in health).

5.4. Comparative assessment between recruitment of foreign workers and rising wages in addressing skill shortages

Across the studies, the evidence is substantially stronger on recruitment of foreign workers than on wage increases as a deliberate shortage-mitigation intervention. Only one study in the core set directly evaluates a policy change that expanded access to foreign workers and links it to shortage-relevant outcomes (Beerli et al., 2021). The other selected studies provide complementary, mostly qualitative or descriptive evidence about how foreign recruitment operates in shortage contexts, what constraints shape its effectiveness, and what affects retention. None of the selected studies directly tests raising

wages as the main intervention to fill shortage vacancies or reduce shortage indicators, and none provides a head-to-head causal comparison of wage increases versus foreign recruitment on vacancy filling or shortage reduction outcomes.

Recruitment of foreign workers: effectiveness and mechanisms

High-quality causal evidence (Switzerland) is offered by Beerli et al. (2021) who analyse the removal of restrictions on employing EU cross-border workers in Switzerland, exploiting the fact that the liberalisation affected regions closer to the border earlier and more strongly. Their core findings are directly relevant to shortage mitigation. First, greater availability of cross-border workers increased foreign employment substantially, and the reform's effects were mainly driven by firms that had reported skill shortages prior to the reform. Second, the reform increased the size, productivity, and innovation performance of skill-intensive incumbent firms and attracted new firms. These firm-side responses are important for interpreting mitigation: the study suggests that expanding access to foreign workers relaxes binding staffing constraints, enabling expansion and reorganisation rather than merely reallocating a fixed number of jobs.

A key point for the wage-versus-recruitment comparison is that opening access to foreign workers did not produce average wage declines for natives in exposed areas; instead, wages of highly educated natives increased. The paper provides evidence on the adjustment channel: natives moved up the management ladder. The probability that a highly educated native held a top-tier management position rose by about 18 percent relative to the pre-reform average, and the wage effect for highly educated natives in the most exposed areas is about 0.045 log points (roughly 4.5 percent). They also show that a meaningful share of this wage growth is associated with movement into higher management ranks. In short, the best causal evidence in your set indicates that foreign recruitment access can mitigate shortage-related constraints while being compatible with wage growth for highly educated natives, because firms expand and natives shift into complementary tasks.

Complementary evidence (how recruitment is used in practice) is conducted by Boege and Blomme (2013) who provide qualitative evidence from interviews with senior managers in German and Dutch multinationals. All interviewed managers recognised a shortage of highly skilled professionals and described employer strategies that include diversifying the workforce and hiring international highly skilled professionals, with Indian professionals viewed as potential candidates for talent vacancies. The study is useful for showing the employer logic behind foreign recruitment in shortage contexts and the organisational investments required for it to work (for example cross-cultural and integration training). It does not quantify vacancy filling or shortage reduction, but it supports the interpretation that, for some firms, foreign recruitment is a practical response when local supply is perceived as insufficient.

Chanda and Mukherjee (2014) add a policy-channel perspective. They explicitly frame EU high-skill shortages as a driver of initiatives aimed at facilitating skilled migration and discuss EU-level instruments such as the Blue Card and Schengen arrangements as mechanisms to improve mobility. They also note political economy constraints: implementation delays are linked to protests and fears of increased unemployment, even as long-term shortages of high-skilled employees are recognised. This matters for effectiveness because it highlights that 'recruit foreign workers' is not only an employer choice but also depends on administrative capacity, legal frameworks, and public acceptance.

Sector-specific evidence (health) is conducted by Lozano et al. (2015) who examine international recruitment of health workers, comparing the UK experience and emerging dynamics in Spain. They report that Spain addressed an emerging shortage of health workers through foreign professionals in the 2000s and conclude that entry of international health workers alleviated shortages in the short term. They also document risks that affect medium- and long-run performance: occupational segregation, career uncertainty, and de-skilling linked to credential recognition obstacle. For RQ3, this is crucial because it shows that foreign recruitment can provide relatively fast shortage relief, but if the institutional environment does not support proper skills utilisation and progression, the system may trade short-term vacancy coverage for longer-term problems in workforce quality, retention, and equity.

Economic incentives for raising wages

Within the selected core and partially included studies, there is no direct evaluation of wage-raising policies as a shortage-mitigation strategy (for example, a study that raises wages in shortage occupations and measures changes in vacancies, hiring speed, retention, or shortage indicators). As a result, the wage incentive side cannot be meta-analysed in the usual effect-size sense from this set.

Indirect wage-related insights that still inform the comparison. Even without direct wage-intervention studies, the selected papers offer three insights relevant to the wage-versus-recruitment comparison. First, Beerli et al. (2021) show that expanding access to foreign workers can coincide with wage increases for highly educated natives and occupational upgrading. This weakens a common assumption behind the comparison that foreign recruitment necessarily substitutes for wage adjustments. In at least this context, foreign recruitment access enabled expansion and complementarity rather than wage suppression.

Second, Lozano et al. (2015) identify financial motives as central for some groups' mobility decisions, especially nurses, for whom the main motivation tends to be financial. This implies that pay and broader employment conditions remain critical levers for attracting and retaining staff even when the system relies on foreign recruitment. In practice, wages are part of the recruitment system for migrants too, not a separate alternative.

Third, Ette et al. (2016) show why raising wages alone may not secure long-term shortage mitigation when the strategy relies on internationally recruited labour. They reject a simple neo-classical expectation that better economic integration leads to longer intended stays: the most economically successful migrants in their data show the lowest propensity to permanently settle. Instead, language skills, family context, and a transparent legal pathway toward permanent status are decisive for settlement intentions. They explicitly caution that concentrating on working conditions alone is not going to foster retention. This does not mean wages do not matter, it means wages are not sufficient for retention-based shortage mitigation, especially for mobile, high-skill creative class workers who have outside options.

Comparative assessment

Table 5.3 brings together the main comparative findings on wage incentives and the recruitment of foreign workers as responses to skill shortages. The comparison is necessarily asymmetric because the selected evidence base contains no direct evaluation of wage increases as a shortage-mitigation intervention, while it includes one strong quasi-experimental study and several qualitative and sector-specific studies on foreign recruitment. The table therefore does not rank the two strategies in a definitive way. Instead, it compares their principal mechanisms, likely speed of response, effects on

firms and workers, institutional requirements, retention conditions and associated risks. The synthesis shows that wage incentives and foreign recruitment are not simple substitutes: higher pay may attract both domestic and foreign workers, while access to foreign labour may relieve staffing constraints, support firm expansion and complement native workers. At the same time, the effectiveness of both strategies depends on broader institutional conditions, including wage-setting arrangements, legal access, qualification recognition, integration support and job quality.

Table 5.3 Comparative assessment of wage incentives and foreign recruitment

Assessment dimension	Raising wages and improving compensation	Recruiting foreign workers	Interpretation based on the selected evidence
Primary mechanism	Increases the attractiveness of jobs and signals scarcity to potential workers	Expands the available labour supply by drawing workers from outside the domestic labour market	The mechanisms can interact higher wages may attract both domestic and foreign workers.
Direct evidence in the corpus	No direct evaluation of a wage-raising intervention	One strong quasi-experimental evaluation, supported by qualitative and sector evidence	The evidence base is substantially stronger for foreign recruitment.
Speed of response	Potentially rapid where workers are available and responsive to pay, but not tested directly in the selected studies	Can increase effective labour supply relatively quickly where legal and administrative channels permit	Foreign recruitment has stronger demonstrated short-run effects in the selected corpus.
Effect on vacancy and staffing constraints	Not directly measured	Expanded access to cross-border workers increased foreign employment and relaxed staffing constraints in shortage-affected firms	The evidence supports foreign recruitment as a means of easing binding staffing constraints.
Effect on firms	Higher labour costs may encourage retention, participation, training or productivity adjustment, but these effects are not evaluated in the corpus	Associated with firm expansion, productivity, innovation and entry in the Swiss study	Foreign recruitment may expand productive capacity rather than merely redistribute existing jobs.
Effect on native wages	Expected to improve pay in shortage occupations, but not directly evaluated	No average native-wage decline in the strongest study; wages of highly educated natives increased	Foreign recruitment does not necessarily suppress native wages where complementarity and firm expansion dominate.
Effect on occupational mobility	Higher pay may attract workers into shortage occupations, but evidence is indirect	Highly educated native workers moved into higher management positions following expanded foreign-worker access	Task complementarity and occupational upgrading may mediate wage effects.
Retention	Better pay may support retention, although wage effects are not quantified	Retention also depends on language, family circumstances, legal security and career prospects	Wages are important but insufficient for durable shortage mitigation.

Institutional requirements	Wage-setting capacity, employer willingness, collective bargaining and appropriate working conditions	Visa and mobility channels, administrative capacity, recognition systems, integration support and public acceptance	Neither strategy operates independently of labour-market institutions.
Principal risks	Wage increases alone may not resolve geographic, occupational or non-wage barriers; they may also widen wage differentials	Segmentation, de-skilling, dependence on foreign supply, ethical recruitment concerns and weak retention	Strategy effectiveness must be assessed together with job quality and institutional design.
Overall assessment	A theoretically central market response, but insufficiently evaluated in the selected evidence base	Better-supported as a rapid shortage response, although long-term effectiveness is conditional	The corpus does not justify a universal ranking of the two strategies.

Source: Authors' comparative synthesis.

5.4.1. Key limitation for the comparison

Because none of the selected core studies evaluates wage increases as an intervention to fill shortage vacancies, the selected literature does not enable a direct quantitative comparison of raise wages versus recruit foreign workers on vacancy filling, time-to-hire, or measured shortage reduction. What it does support is a more nuanced conclusion that foreign recruitment can be an effective shortage-mitigation tool and can even coexist with rising wages, but it is not a complete substitute for wage and job-quality incentives, and its sustainability depends heavily on institutional and integration conditions.

5.5. Overall answer to RQ3 based on the selected studies

In this evidence set, recruitment of foreign workers has clearer and stronger support as a shortage-mitigation strategy than wage-raising incentives, primarily because the wage-raising strategy is not directly evaluated in the selected studies. The strongest causal study shows that liberalising access to foreign cross-border workers increased foreign employment and improved shortage-relevant firm outcomes (growth, productivity, innovation), with effects concentrated in firms that reported skill shortages. Importantly, this foreign recruitment access was compatible with wage increases for highly educated natives through occupational upgrading and firm expansion, suggesting that foreign recruitment can relax constraints without necessarily depressing wages.

The partially included studies indicate that foreign recruitment is widely used in shortage contexts, but its effectiveness depends on implementation capacity (visa and mobility regimes), organisational investments (integration and cross-cultural practices), and system design (credential recognition and career pathways). Retention evidence shows that long-run mitigation through foreign recruitment is not guaranteed by pay or economic success alone, also language, family, and legal security are pivotal. Table 5.4 summarises the overall answer to Research Question 3 by bringing together the main conclusions, the strength of the supporting evidence and the principal qualifications that limit interpretation. The table reflects the asymmetry of the selected literature: evidence on foreign recruitment is more direct and methodologically stronger than evidence on wage increases, while no study provides a balanced head-to-head causal comparison of the two strategies. The findings therefore support a cautious conclusion. Foreign recruitment can relieve staffing constraints relatively quickly in some settings, but its effectiveness depends on legal access, recognition, integration and

retention. Wage increases remain an important labour-market mechanism, yet their direct effects on shortage reduction are insufficiently evaluated in the selected corpus. Taken together, the evidence suggests that the two approaches should be understood as potentially complementary rather than mutually exclusive responses.

Table 5.4 Summary answer to Research Question 3

Question component	Evidence-based conclusion	Strength of evidence	Qualification
Can wage increases mitigate skill shortages?	Wage increases are a central market response because they improve job attractiveness and transmit scarcity signals.	Limited and indirect in the selected corpus	No included study directly evaluates a wage increase and measures vacancy filling, recruitment speed, retention or shortage reduction.
Can foreign recruitment mitigate skill shortages?	Yes. Expanded access to foreign workers can increase effective labour supply and relieve constraints in shortage-affected firms.	Moderate, with one strong quasi-experimental study and supporting qualitative and sector evidence	The evidence is concentrated in particular countries, sectors and institutional settings.
Which strategy acts more quickly?	Foreign recruitment has demonstrated clear short-run effects where legal and administrative channels function effectively.	Moderate for foreign recruitment; insufficient for wage raising	Slow recognition, visa processing or integration can substantially reduce this advantage.
Does foreign recruitment reduce native wages?	Not necessarily. In the strongest study, native wages did not fall on average and wages of highly educated natives increased.	Strong within the specific Swiss setting	Results may differ where migrants substitute for rather than complement domestic workers.
Are wage incentives and foreign recruitment substitutes?	They should not be treated as clean substitutes. Pay influences both domestic and foreign recruitment, while foreign labour may complement domestic workers.	Supported by indirect and mechanism-based evidence	The interaction has not been tested through a direct head-to-head research design.
Is foreign recruitment sufficient for long-term mitigation?	No. Sustainable effects depend on retention, recognition, language, legal security, integration, job quality and career progression.	Consistent qualitative and descriptive evidence	Recruitment without supportive institutions may provide only temporary vacancy coverage.
Is raising wages sufficient?	No firm conclusion can be drawn from the selected studies, but the evidence indicates that non-wage barriers and institutional conditions also matter.	Indirect evidence	The absence of evaluated wage interventions is a major research gap.
Overall answer to RQ3	Foreign recruitment has stronger demonstrated short-run shortage-mitigation effects in the selected evidence base. However, the literature does not support a universal conclusion that it is	Moderate for foreign recruitment; low for comparative ranking	Conclusions are constrained by the asymmetry of the evidence and the

	more effective than raising wages. The two strategies interact and should usually be combined with adequate pay, good working conditions, recognition, integration and workforce-development policies.		absence of direct causal comparisons.
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Source: Authors' synthesis.

5.6. Key findings

- The evidence base for Research Question 3 is substantially stronger on foreign-worker recruitment than on wage increases as a deliberate strategy for mitigating skill shortages.
- Only one study in the core evidence set provides strong quasi-experimental evidence on expanded access to foreign workers, while the remaining studies are mainly qualitative, descriptive or focused on specific sectors and institutional settings.
- The strongest causal evidence indicates that easing access to cross-border workers can increase foreign employment and relieve staffing constraints, particularly in firms that had already reported skill shortages.
- In the Swiss case examined by Beerli et al. (2021), expanded access to foreign labour was associated with firm growth, higher productivity, stronger innovation performance and the entry of new firms in skill-intensive activities.
- Foreign recruitment did not lead to average wage declines for native workers in the strongest study. Wages of highly educated native workers increased, partly because they moved into higher-level management positions.
- These findings suggest that foreign recruitment does not necessarily substitute for domestic labour. Where foreign and native workers perform complementary tasks, recruitment from abroad can support firm expansion, occupational upgrading and wage growth.
- Sector evidence, particularly from health care and construction, shows that employers often use foreign recruitment as a relatively rapid response when domestic training, wage reform or improvements in working conditions are slower or more difficult to implement.
- Foreign recruitment can alleviate shortages in the short term, but it may also create risks of occupational segregation, de-skilling, career uncertainty, dependence on international labour supply and ethical concerns in sectors such as health care.
- The effectiveness of foreign recruitment depends on enabling institutions, including visa and mobility arrangements, qualification recognition, administrative capacity, language support, integration measures and transparent pathways to secure residence.
- Retention cannot be secured through wages and working conditions alone. Family circumstances, language proficiency, legal security, opportunities for career progression and wider social integration are also important for whether recruited workers remain.
- Wages remain a central labour-market signal and may attract both domestic and foreign workers to shortage occupations. However, the responsiveness of labour supply to higher pay differs across occupations, sectors and worker groups.
- The selected literature does not directly evaluate wage increases as an intervention and does not measure their effect on vacancy filling, hiring speed, retention or shortage reduction. It therefore does not permit a reliable causal comparison between wage raising and foreign recruitment.

- Wage incentives and foreign recruitment should not be treated as simple alternatives. Pay and working conditions influence the attraction and retention of foreign workers, while access to foreign labour may complement domestic workers and support wage growth.
- The main conclusion is that foreign recruitment has clearer demonstrated short-term effects in the available evidence, but the literature does not support a universal claim that it is more effective than raising wages.
- Sustainable responses to skill shortages are most likely to combine adequate wages, good working conditions, foreign recruitment where appropriate, domestic training, qualification recognition, integration support and long-term workforce planning.

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6. Alternatives to migrant labour: trade-offs and feasibility

This section addresses RQ4 What are the trade-offs between upskilling the local workforce and automation versus reliance on migrant labour?

Migration, human-capital investment, and automation frequently interact and may either complement or substitute for one another depending on labour market conditions, sectoral characteristics, and the nature of technological change. Greater availability of migrant labour may reduce incentives for firms to automate certain production processes, while labour scarcity itself may accelerate technological adoption. Similarly, investments in workforce skills may enhance the productivity gains from automation while reducing dependence on migrant labour in some occupations. Understanding these interactions has therefore become increasingly important for both researchers and policymakers seeking sustainable responses to demographic decline.

Despite a rapidly expanding literature on migration, workforce development, and automation, these three adjustment mechanisms have largely evolved as separate research agendas. Consequently, relatively limited attention has been devoted to systematically comparing their respective economic functions, identifying the conditions under which they complement or substitute for one another, and evaluating the trade-offs associated with alternative policy choices. In this context, trade-offs refer to situations in which strengthening one adjustment mechanism involves economic costs, implementation constraints, or reduced reliance on alternative mechanisms. These trade-offs may arise because migration, workforce development, and automation differ in their speed of adjustment, fiscal and institutional requirements, distributional consequences, and long-term effects on productivity, labour market flexibility, and social sustainability.

Against this background, this systematic literature review synthesises the existing evidence on the trade-offs between three principal responses to demographic-induced labour shortages: reliance on migrant labour, investment in the upskilling and reskilling of the domestic workforce, and automation. Rather than seeking to identify a universally optimal strategy, the review examines the conditions under which these mechanisms act as substitutes or complements, the economic costs and benefits associated with each approach, and the circumstances under which different policy combinations are likely to be most effective. By integrating evidence across these traditionally separate strands of literature, the review aims to provide a comprehensive understanding of their relative strengths, limitations, complementarities, and policy implications for maintaining labour market resilience and long-term economic competitiveness in ageing European economies.

The next section reviews the selected studies and presents the analytical strategy used to categorise the literature according to its contribution to the research question. This categorisation is then applied to distinguish between direct empirical evidence and contextual or conceptual studies. The subsequent section synthesises and discusses the main findings of the reviewed literature. Building on this synthesis, we develop a comparative framework and a contingency framework for analysing the respective roles of migration, upskilling, and automation as labour market adjustment mechanisms. The final section concludes by summarising the principal findings, discussing their policy implications, acknowledging the study's limitations, and outlining directions for future research.

6.1. Selection and organisation of relevant studies

Selection of relevant studies

To structure the analysis, this study distinguishes three primary adjustment mechanisms through which economies respond to labour and skill shortages: upskilling of the domestic workforce, automation of production processes, and reliance on migrant labour (table 1). These dimensions capture the main channels identified in the literature and provide a common analytical framework for comparing their respective roles, constraints, and trade-offs. While analytically separable, these mechanisms are not mutually exclusive; rather, they often operate jointly, reflecting different temporal, institutional, and sectoral conditions under which labour markets adjust to structural imbalances.

Table 6.1 Analytical Dimensions of the Trade-Off Framework

Dimension	Core Mechanism	Time Horizon	Key Constraint
Upskilling - Human capital development of local population through training, education, reskilling	Human capital formation	Long-term	Institutional capacity
Automation - The adoption of technologies that perform, augment, or reallocate tasks previously undertaken by human labour.	Task automation and augmentation	Medium-term	Capital and skills
Migrant labour - Hiring external workers, often foreign-born, to fill skill or labour gaps	External labour supply	Short-term	Integration capacity

In total, 28 papers were retrieved through the AI-assisted literature-screening process. This corpus included peer-reviewed articles, book chapters, proceedings papers, and conference contributions. Two studies were subsequently excluded from the final sample. The first one was removed due to redundancy, as it duplicated another included study. The second study was excluded because the full text was not accessible; relying solely on the abstract and introduction risked incomplete or biased interpretation. As a result, the final analysis is based on 26 studies.

None of the selected studies directly addresses the specific research question of this review, namely the trade-offs between migrant labour, automation, and upskilling as alternative responses to labour and skill shortages. Instead, the existing literature is fragmented, with most studies examining only one adjustment mechanism in isolation and only a small number considering interactions between multiple mechanisms. Furthermore, the evidence base is heterogeneous. Some studies provide direct empirical evidence on labour market outcomes using quantitative or causal research designs, whereas others offer conceptual frameworks, policy discussions, case studies, or contextual insights into the implementation of individual adjustment strategies. Consequently, the present review distinguishes between core empirical evidence, which directly informs the research question, and contextual or conceptual studies, which contribute to understanding the institutional conditions, implementation challenges, and broader policy context surrounding each adjustment mechanism.

Table 6.2 Analytical Categorization of the Literature by Primary Analytical Focus

Category	Selected literature
Migration-focused (5)	Ratna (2016) ; Ramos et al. (2015) ; Guzi et al. (2018) ; Green (2024) ; Ette et al. (2016)
Upskilling-focused (13)	Moeller & Sitzmann (2012) ; Yamin & Katt (2022) ; Bhatt (2024) ; Mystakidis et al. (2017) ; Mukhuty et al. (2022) ; Kolding et al. (2018) ; Braun et al. (2023) ; Aspøy (2020) ; Araújo et al. (2019) ; Gatteschi et al. (2012) ; Sulz & Bleicher (2023) ; Georgiou et al. (2024) ; Büscher et al. (2022)
Automation-focused (6)	Schroeder et al. (2024) ; Mehdiyev et al. (2021) ; Braun & Kropp (2023) ; McGuinness et al. (2023) ; MacKinnon et al. (2017) ; Lanz et al. (2021)
Cross-cutting / Mixed (2)	Beerli et al. (2021) ; Iftikhar & Zaharieva (2019)

Strategy for organising the literature

Given the heterogeneous nature of the retrieved literature, the reviewed studies are organised according to their contribution to answering the research question rather than by publication type or methodological design. Specifically, the synthesis distinguishes between direct empirical evidence, which explicitly informs the trade-offs between migrant labour, upskilling, and automation, and contextual or conceptual evidence, which provides theoretical, institutional, technological, or policy background necessary for interpreting these trade-offs but does not evaluate them directly.

This distinction reflects the fact that the existing literature is fragmented. While a number of studies empirically examine individual adjustment mechanisms or their labour market consequences, very few directly compare migration, automation, and upskilling as alternative responses to labour and skill shortages. Consequently, greater analytical weight is assigned to studies that provide direct evidence on labour market outcomes, whereas contextual and conceptual studies are used primarily to explain implementation conditions, institutional constraints, and broader mechanisms through which these adjustment strategies operate.

6.2. Review of selected literature

The reviewed literature does not directly examine the trade-offs between migrant labour, workforce upskilling, and automation as alternative responses to labour and skill shortages. Instead, it consists of studies investigating one or, less frequently, two of these adjustment mechanisms from different disciplinary and methodological perspectives. That is why, the evidence is fragmented, with relatively few studies explicitly analysing how these mechanisms interact or under which conditions they substitute for or complement one another. Nevertheless, taken together, the literature provides sufficient evidence to identify several recurring themes relevant to the present research question.

A first body of literature examines migration as a mechanism for alleviating labour and skill shortages. The strongest empirical evidence consistently indicates that migrant labour can relax labour market constraints without generating substantial adverse effects on native employment or wages. Studies of labour-market reforms, migrant integration, and labour mobility suggest that immigration can improve labour allocation, increase firm productivity, and facilitate occupational upgrading among native workers, particularly where migrants complement rather than substitute for domestic labour (Beerli et al., 2021; Ratna, 2016; Guzi et al., 2018). At the same time, the effectiveness of migration depends heavily on institutional conditions. Research shows that immigrants frequently experience lower returns to education, skill mismatch, and barriers to labour market integration, while the long-term contribution of migration depends on successful settlement, qualification recognition, and retention (Ramos et al., 2015; Ette et al., 2016). Collectively, these studies suggest that migration provides a

rapid mechanism for expanding labour supply, but its effectiveness is contingent upon institutions capable of utilising migrant human capital efficiently.

A second and larger body of literature focuses on workforce upskilling and reskilling. Despite considerable variation in research design and sectoral focus, these studies converge on a common conclusion: developing domestic human capital requires substantial institutional investment, organisational commitment, and time. Research on lifelong learning systems, online education, workplace training, and Industry 4.0 initiatives consistently emphasises that successful upskilling depends on coordinated educational infrastructure, employer participation, digital learning environments, and continuous skill development rather than isolated training programmes (Moeller & Sitzmann, 2012; Mystakidis et al., 2017; Yamin & Katt, 2022; MacKinnon et al., 2017; Braun et al., 2023). Complementary conceptual and review studies further argue that technological transformation increases the importance of organisational learning, reskilling, and human-resource strategies capable of supporting continuous adaptation (Bhatt, 2024; Mukhuty et al., 2022). At the firm level, employers frequently prefer retraining existing employees because it is less costly than external recruitment and contributes to workforce retention, although such investments remain constrained by financial costs, coordination problems, and uncertainty regarding employee retention (Kolding et al., 2018; Araújo et al., 2019). Importantly, the literature also cautions against treating upskilling as a universal solution. Evidence from low-wage sectors demonstrates that training alone does not necessarily improve job quality or fundamentally alter production systems when broader organisational and institutional conditions remain unchanged (Aspøy, 2020).

The third strand of literature considers automation and digital technologies as responses to labour scarcity. Across diverse sectors - including manufacturing, horticulture, software development, and public administration - the reviewed studies consistently identify labour shortages as an important incentive for technological adoption (Schroeder et al., 2024; Sulz & Bleicher, 2023; Mehdiyev et al., 2021; Braun & Kropp, 2023). However, the evidence also demonstrates that automation rarely constitutes a complete substitute for human labour. Instead, technological adoption frequently increases demand for complementary skills, organisational adaptation, and workforce learning. Studies examining robotics, artificial intelligence, low-code technologies, and Industry 4.0 initiatives therefore portray automation as closely intertwined with workforce development rather than independent of it (Lanz et al., 2021; McGuinness et al., 2023; Büscher et al., 2022). Taken all into consideration, this body of literature indicates that automation is constrained not only by technological feasibility but also by firms' financial resources, digital capabilities, and the availability of complementary human capital.

A small number of studies adopt broader or cross-cutting perspectives that extend beyond a single adjustment mechanism. Beerli et al. (2021) and Iftikhar and Zaharieva (2019) are particularly important because they provide the closest available evidence to the central research question by examining how immigration interacts with labour market adjustment, productivity, occupational allocation, and welfare outcomes. Although neither study directly compares migration, automation, and upskilling within a unified analytical framework, both demonstrate that labour market adjustment is inherently multidimensional and cannot be understood through a single policy instrument. Similarly, Green (2024) situates labour shortages within broader structural processes - including demographic ageing, technological change, and economic restructuring - and argues that governments increasingly rely on combinations of migration policy, workforce development, and technological upgrading rather than isolated interventions.

Several additional studies contribute important contextual evidence by examining the institutional conditions that influence the effectiveness of adjustment mechanisms. Research on labour market forecasting systems highlights the importance of accurately identifying emerging skill shortages before designing migration or training policies (Georgiou et al., 2024), while work on qualification comparability demonstrates that improving the transparency and recognition of occupational skills can enhance both domestic workforce development and the productive utilisation of migrant labour (Gatteschi et al., 2012). Although these studies do not directly evaluate labour market outcomes, they clarify the informational and institutional capacities necessary for migration, automation, and upskilling to operate effectively.

Overall, the reviewed literature reveals a common pattern despite its fragmentation. Rather than identifying a universally superior response to labour shortages, the evidence consistently suggests that migration, workforce upskilling, and automation operate through distinct but interconnected adjustment channels. Migration provides relatively rapid labour supply adjustment but depends on successful integration and skill utilisation. Upskilling strengthens domestic human capital but requires sustained institutional investment and long implementation periods. Automation can improve productivity and reduce dependence on scarce labour in suitable tasks, yet its adoption depends on complementary skills, organisational capabilities, and financial resources. Accordingly, the literature increasingly points towards complementarity rather than simple substitution between these adjustment mechanisms, thereby motivating the comparative synthesis developed in the following sections.

6.3. Categorisation of studies by their contribution to the research question

The 26 selected studies are divided into two broad groups: direct empirical evidence and contextual or conceptual evidence.

Direct empirical evidence – this group of the literature provide direct empirical evidence relevant to the research question. These include causal evaluations, econometric analyses, structural modelling, surveys, and qualitative studies that examine labour market outcomes associated with migration, automation, or workforce upskilling. Particular emphasis is placed on studies that explicitly analyse interactions between these adjustment mechanisms or generate evidence that informs their comparative advantages, limitations, complementarities, or trade-offs.

Contextual and conceptual evidence - this subsection consists of studies whose primary contribution is conceptual, technological, institutional, or policy-oriented. Although these studies do not directly evaluate the trade-offs between migrant labour, automation, and upskilling, they provide important context for interpreting the empirical evidence. In particular, they identify implementation challenges, institutional requirements, technological constraints, educational infrastructure, and organisational conditions that influence the feasibility and effectiveness of each adjustment mechanism. These studies therefore complement, rather than substitute for, the direct empirical evidence presented in the preceding subsection.

Table 6.3 Classification of selected studies by type of contribution to the research question

Evidence category	Number of studies
Direct empirical evidence	11
Contextual or conceptual evidence	15
Total	26

Direct empirical evidence

Eleven studies are classified as direct empirical evidence. These studies receive greater analytical weight in the synthesis because they examine labour market, firm-level, worker-level, or welfare outcomes that directly inform the relative advantages, limitations, complementarities, or distributional consequences of the three adjustment mechanisms.

Table 6.4 Direct empirical evidence included in the review

Primary contribution	Selected studies
Cross-cutting or mixed evidence	Beerli et al. (2021); Iftikhar and Zaharieva (2019)
Migration-related evidence	Ramos et al. (2015); Guzi et al. (2018); Ette et al. (2016)
Upskilling-related evidence	Kolding et al. (2018); Aspøy (2020); Araújo et al. (2019)
Automation-related evidence	Schroeder et al. (2024); McGuinness et al. (2023); Büscher et al. (2022)

Cross-cutting or mixed evidence

Beerli et al. (2021) and Iftikhar and Zaharieva (2019) are placed first because they provide the closest available evidence to the central research question. Beerli et al. examine how an expansion in access to migrant labour affects native workers, firms, productivity, occupational allocation, and capital investment. Their findings directly inform whether migrant labour substitutes for or complements domestic human capital and firm-level technological adjustment. Iftikhar and Zaharieva analyse the aggregate and distributional consequences of immigration within a model incorporating labour market frictions and skill mismatch. The study therefore informs both the benefits of migration and the continuing need for domestic skill formation and technological adaptation. Although neither study compares all three mechanisms experimentally, both examine interactions extending beyond a single adjustment channel.

Migration-related evidence

Ramos et al. (2015), Guzi et al. (2018), and Ette et al. (2016) are included as direct migration evidence because they empirically examine conditions that determine whether migrant labour can function effectively as a response to labour and skill shortages. Ramos et al. analyse the utilisation and returns to migrant human capital, demonstrating the importance of integration policies and skill transferability. Guzi et al. examine whether migrants respond more flexibly than native workers to shortage signals across European labour markets. Ette et al. analyse the factors influencing migrants' long-term settlement intentions, which directly affect whether migration provides temporary relief or a durable contribution to labour supply. Together, these studies identify integration, mobility, skill recognition, and retention as central constraints on the migration mechanism.

Upskilling-related evidence

Kolding et al. (2018), Aspøy (2020), and Araújo et al. (2019) are categorised as direct evidence on upskilling because they empirically examine how firms or labour markets use training to respond to skill problems and what limits its effectiveness. Kolding et al. show how firms facing digital skill shortages combine recruitment, retention, and internal reskilling, thereby providing evidence on the relative costs of internal and external skill acquisition. Araújo et al. similarly examine employers' decisions between training existing employees and obtaining skills externally, while identifying financial, coordination, and retention constraints. Aspøy provides evidence that formal upskilling does not necessarily improve job quality or alter work organisation, demonstrating that the effectiveness of training depends on wider institutional and production conditions.

Automation-related evidence

Schroeder et al. (2024), McGuinness et al. (2023), and Büscher et al. (2022) are classified as direct automation evidence because they empirically examine technology as a response to labour scarcity or analyse its consequences for skill demand and workers. Schroeder et al. investigate whether managers and employees perceive automation as a feasible response to personnel shortages in horticulture and identify capital costs and task characteristics as important constraints. Büscher et al. analyse whether low-code technologies can reduce reliance on scarce programming skills, providing evidence of partial technological substitution alongside continuing demand for advanced expertise. McGuinness et al. examine how skills-displacing technological change affects task complexity, upskilling, and job insecurity, showing that automation frequently restructures skill requirements rather than eliminating the need for human-capital investment.

Contextual or conceptual evidence

The remaining 15 studies are classified as contextual or conceptual evidence. These studies are retained because they clarify the institutional, educational, organisational, policy, or technological conditions under which migration, upskilling, and automation operate. However, they are assigned less weight when drawing conclusions about the comparative effectiveness or labour market consequences of the three mechanisms because they do not directly estimate these trade-offs.

Table 6.5 Contextual and conceptual studies included in the review

Primary contextual contribution	Selected studies
Migration and structural labour market context	Ratna (2016); Green (2024)
Upskilling and skills-system context	Moeller and Sitzmann (2012); Yamin and Katt (2022); Bhatt (2024); Mystakidis et al. (2017); Mukhuty et al. (2022); Braun et al. (2023); MacKinnon et al. (2017); Georgiou et al. (2024); Gatteschi et al. (2012)
Automation and technological implementation context	Sulz and Bleicher (2023); Mehdiyev et al. (2021); Braun and Kropp (2023); Lanz et al. (2021)

Migration and structural labour market context

Ratna (2016) and Green (2024) are included as contextual rather than direct evidence because their principal contributions are synthetic and conceptual. Ratna reviews theoretical arguments and existing evidence concerning immigration's effects on host economies, while Green situates migration within the broader structural drivers of labour and skill shortages, including demographic change, economic restructuring, and technological innovation. Both studies help establish why migration is considered

an adjustment mechanism, but neither provides new empirical evidence directly comparing migration with upskilling or automation.

Upskilling and skills-system context

Moeller and Sitzmann (2012), Yamin and Katt (2022), Mystakidis et al. (2017), Braun et al. (2023), and MacKinnon et al. (2017) describe or evaluate particular educational and workplace-learning models. They demonstrate that upskilling requires suitable curricula, digital infrastructure, pedagogical design, workplace integration, and cooperation between firms and educational institutions. Their relevance lies primarily in explaining the institutional and organisational requirements of domestic skill formation rather than its comparative labour market effectiveness.

Bhatt (2024) and Mukhuty et al. (2022) provide conceptual and review-based accounts of organisational adaptation, reskilling, and human-resource practices under technological change. They support the proposition that automation requires complementary organisational and human-capital investments, but they do not directly estimate labour market outcomes or compare alternative shortage responses.

Georgiou et al. (2024) and Gatteschi et al. (2012) contribute institutional and informational context. Georgiou et al. describe an infrastructure for identifying and forecasting skill mismatches, while Gatteschi et al. examine the comparability of occupational and educational qualifications. These systems may improve the design of upskilling policies and the utilisation of migrant skills, but the studies do not evaluate whether such mechanisms outperform alternative adjustment strategies.

Automation and technological implementation context

Sulz and Bleicher (2023), Mehdiyev et al. (2021), Braun and Kropp (2023), and Lanz et al. (2021) are included as contextual evidence on automation. Sulz and Bleicher demonstrate the technical feasibility of a specific industrial automation application, while Mehdiyev et al. present potential uses of explainable AI in public administration. Lanz et al. describe the institutional and skills infrastructure required for small and medium-sized firms to adopt robotics, and Braun and Kropp analyse how digitalisation is framed in construction and architectural discourse. These studies clarify technological feasibility, adoption barriers, complementary skill requirements, and policy narratives, but they do not directly measure whether automation reduces labour shortages or substitutes for migration and domestic training.

This distinction does not imply that contextual or conceptual studies are of lower scholarly quality. Rather, it reflects their degree of relevance to the specific research question. Conclusions concerning the economic effects and trade-offs among migration, upskilling, and automation are therefore based primarily on the 11 studies classified as direct empirical evidence. The remaining 15 studies are used to interpret these findings by identifying the institutional capacities, implementation barriers, and technological or organisational conditions that shape the feasibility of each adjustment mechanism.

6.4. Feasibility and constraints of automation

The reviewed evidence suggests that the effectiveness of automation depends less on the availability of technology itself than on the characteristics of production processes, workforce capabilities, and the institutional environment in which firms operate. Automation appears most feasible where tasks are routine, standardized, repetitive, or technically codifiable, allowing digital technologies, robotics,

or AI systems to substitute for specific human activities with relatively limited organisational disruption. Evidence from horticulture (Schroeder et al., 2024), software development (Büscher et al., 2022), manufacturing (Lanz et al., 2021), and public administration (Mehdiyev et al., 2021) illustrates that automation is particularly attractive when firms face persistent labour shortages in tasks that can be formalised and supported by available technologies.

By contrast, the reviewed studies also indicate that automation becomes considerably less feasible where production relies on complex problem-solving, interpersonal interaction, tacit knowledge, or occupation-specific expertise. Even in technologically advanced sectors, automation rarely eliminates the need for skilled workers. Instead, it frequently changes the composition of work by automating some tasks while increasing demand for complementary human capabilities. As demonstrated by McGuinness et al. (2023), technological change is commonly associated with greater task complexity and additional upskilling requirements rather than complete labour substitution. Similarly, Büscher et al. (2022) find that low-code technologies can reduce demand for routine programming tasks but remain insufficient for complex software development, where specialised expertise continues to be essential.

The literature further suggests that firms' incentives to automate are shaped by economic as well as technological considerations. Persistent labour shortages, rising labour costs, recruitment difficulties, expected productivity gains, and improvements in working conditions all increase the attractiveness of automation. At the same time, high capital costs, uncertainty regarding investment returns, implementation complexity, and shortages of complementary digital skills frequently constrain adoption. Consequently, labour scarcity alone does not automatically result in greater automation; firms must also possess the financial resources, technological capabilities, and skilled workforce required to implement and operate new technologies effectively.

From a policy perspective, the reviewed studies consistently indicate that automation cannot be promoted through technology policy alone. Successful adoption depends on complementary investments in digital infrastructure, workforce upskilling, innovation support, and mechanisms that facilitate technology diffusion, particularly among small and medium-sized enterprises. Digital Innovation Hubs (Lanz et al., 2021), lifelong learning systems (MacKinnon et al., 2017; Mukhuty et al., 2022), and targeted support for digital capability development emerge as important enabling conditions. These findings reinforce the broader conclusion of this review that automation should not be viewed as an independent substitute for migrant labour or domestic upskilling, but rather as one component of a broader adjustment strategy whose effectiveness depends on complementary human capital and institutional capacity.

6.5. Evidence synthesis and discussion

This systematic review examines the trade-offs between upskilling the local workforce and automation versus reliance on migrant labour in the context of labour and skill shortages. Across 26 studies included in the final sample, one general conclusion is that the evidence does not support a simple substitution or linear cost/benefit logic in which policy makers or firms can choose one strategy and dispense with the others. Rather, the evidence from the literature corpus demonstrates that migrant labour, automation, and upskilling are best understood as distinct but interconnected channels through which labour markets adjust to demographic pressure, technological change, and persistent skill mismatch.

First, the evidence indicates that migrant labour can generate clear economic gains, especially when labour shortages are immediate and concentrated in specialized or hard-to-fill roles. The strongest evidence in the review points to positive or at least non-negative labour market effects of immigration on natives under such conditions. Beerli et al. (2021) show that easing access to migrant labour in Switzerland did not reduce native employment or wages; instead, highly educated natives experienced wage gains, partly because migrant inflows relaxed bottlenecks and enabled firms to expand, innovate, and reorganize production. Similarly, Ratna's (2016) review and Guzi et al.'s (2018) findings indicate that migrants often complement native workers and can respond flexibly to shortage occupations. Iftikhar and Zaharieva (2019) also suggest that immigration can improve aggregate welfare under labour market frictions, even if the gains are unevenly distributed. Overall, this body of evidence implies that migration is often the fastest adjustment mechanism when shortages are binding and firms cannot wait for slower domestic responses.

The evidence also indicates that migration is not a frictionless or universally sufficient solution. Its effectiveness depends heavily on whether migrants' skills are recognized, transferable, and actually used in productive roles. Ramos et al. (2015), show that immigrant workers often receive lower returns to education, while Ette et al. (2016) demonstrate that long-term contribution depends on successful integration and settlement. Gatteschi et al. (2012) further underline that the value of migration as a response to shortages depends on the comparability and recognition of qualifications across systems.

In this sense, migrant labour cannot simply be treated as a ready-made substitute for domestic skill formation. If institutional systems fail to absorb and utilize migrant human capital, migration may relieve vacancy pressure in the short run while leaving deeper problems of mismatch unresolved. The trade-off, therefore, lies between rapid labour supply adjustment and the institutional effort required to make that adjustment productive and durable, rather than between migrants and locals.

A second major conclusion is that upskilling remains indispensable but is slow, resource-intensive, and often conditional on organizational change. Many of the studies in the review do not measure labour market outcomes directly, but they converge on a common point: building skills domestically requires significant infrastructure, coordination, and time. Moeller and Sitzmann (2012), Mystakidis et al. (2017), MacKinnon et al. (2017), Braun et al. (2023), and Mukhuty et al. (2022) all, in different ways, show that effective reskilling depends on institutions, curriculum design, firm participation, workplace learning systems, and sustained investment. Araújo et al. (2019) and Kolding et al. (2018) add an important firm-level perspective: employers often prefer internal training, especially where retention is valuable, but training is costly, risky, and not easily scaled. This means that upskilling, rather than serving as a low-cost alternative to migration, constitutes a long-horizon strategy whose returns depend on coordination between firms, education providers, and the state.

Moreover, the literature reviewed here warns against an overly optimistic view of upskilling. Upskilling does not automatically transform jobs, wages, or labour demand. Aspøy's (2020) study is particularly important in this regard: in low-wage, price-competitive sectors, additional certification did not substantially improve job quality because the structure of work itself remained unchanged. This is a crucial corrective to policy narratives that treat training as a universal remedy. Upskilling can raise human capital, but where production models are organized around low cost, standardized tasks, and weak worker bargaining power, training alone may do little. The real trade-off, then, is not simply between training and migration, but between investing in skills and reforming the organizational and institutional structures that determine whether those skills can actually be rewarded and used.

Third, the systematic review indicates that automation is best understood as a partial and uneven substitute, rather than a general solution to labour scarcity. Several studies indicate that automation is frequently adopted precisely because labour shortages are difficult to fill, as in horticulture, manufacturing, software development, and public administration. Yet the results also show that automation rarely eliminates the human-capital problem; it often reshapes it. McGuinness et al. (2023) demonstrate that technologically exposed workers are more likely to experience upskilling and higher task complexity, even as insecurity rises. Lanz et al. (2021) and Mukhuty et al. (2022) similarly suggest that automation depends on complementary capabilities inside firms, meaning that technology adoption itself requires learning, adaptation, and new skills. Büscher et al. (2022) provide one of the clearest examples of limited substitution: low-code systems can reduce dependence on scarce programming skills for simpler tasks, but they cannot replace highly skilled labour for complex functions. In short, automation may reduce demand for some scarce labour, but it also creates new demand for complementary capabilities.

This implies that the trade-off between automation and migrant labour is also conditional. In some sectors, especially where tasks are routine, physically demanding, or standardizable, automation may reduce dependence on external labour supply. In others, especially knowledge-intensive sectors, automation appears more as a complement to skilled labour than as its replacement. Beerli et al. (2021) indirectly support this point by showing that migrant inflows can coexist with productivity-enhancing firm upgrading. Schroeder et al. (2024) likewise indicate that managers and workers often perceive automation as a response to shortages rather than as a pure displacement device. Therefore, the relevant question is not whether automation replaces migration, but which types of labour shortages are technically substitutable, and which still require human input that must come either from domestic training or from migration.

A fourth conclusion concerns distributional consequences. Even where migration or automation improves aggregate productivity, the gains are not equally shared. Iftikhar and Zaharieva (2019) show that immigration can produce welfare gains overall while imposing losses on some low-skill groups in manufacturing. McGuinness et al. (2023) indicate that technology-related upgrading opportunities are also unevenly distributed and tend to favour more skilled workers. The central problem is not only how to fill shortages efficiently, but also how the gains and losses of each adjustment strategy are distributed across workers, sectors, and regions. Migration may help firms and consumers while leaving some local workers exposed; automation may raise productivity while increasing insecurity; upskilling may disproportionately benefit workers and firms already in stronger positions.

Another critical point is that the review highlights a gap in the literature. Most studies analyse migration, automation, or upskilling in isolation, with limited empirical work directly comparing their relative effectiveness or interaction. As a result, the existing evidence base is fragmented. Future research should move beyond single-mechanism analysis and develop integrated empirical frameworks that capture how this adjustment channels interact across sectors, skill groups, and institutional contexts.

6.6. Comparative and contingency framework of labour market adjustment

Comparative framework of labour market adjustment mechanisms

The framework proposed here reveals that the relationship between migration, upskilling, and automation is more appropriately understood as a multidimensional policy space than as a binary choice among competing alternatives. Although each mechanism addresses labour and skill shortages, they do so through fundamentally different economic channels, implying that their relative desirability depends on the specific characteristics of the labour shortage, institutional environment, and production system.

Across the reviewed studies, five dimensions consistently emerge as shaping the trade-offs between adjustment mechanisms: speed of adjustment, implementation requirements, resource intensity, sustainability, and distributional consequences. These dimensions provide an analytical framework for comparing policy options beyond their immediate capacity to alleviate labour shortages.

First, the mechanisms differ substantially in their speed of adjustment. Migration generally provides the fastest response by immediately expanding available labour supply, whereas domestic upskilling requires substantial time for education, training, and skill acquisition. Automation typically occupies an intermediate position. While technological solutions may eventually reduce dependence on scarce labour, their implementation requires planning, investment, organisational adaptation, and complementary workforce capabilities.

Second, the reviewed evidence highlights important differences in implementation requirements. Migration depends primarily on immigration policy, qualification recognition, and successful labour market integration. Upskilling requires sustained investment in educational institutions, lifelong learning systems, employer participation, and coordination between labour market actors. Automation depends on firms' technological capabilities, access to capital, digital infrastructure, and the availability of complementary skills necessary to implement and maintain new technologies.

Third, the mechanisms involve distinct forms of resource intensity. Migration primarily requires institutional capacity for recruitment and integration. Upskilling demands long-term investment in human capital and educational systems. Automation requires substantial financial investment in physical and digital capital, together with organisational restructuring and technological expertise.

Fourth, the reviewed studies point to differences in long-term sustainability. Migration provides rapid adjustment but may remain vulnerable to political constraints, integration challenges, and changing migration flows. Upskilling strengthens domestic human capital and therefore contributes to long-run labour market resilience, although its benefits materialise gradually. Automation can generate persistent productivity gains, but only where technological adoption remains economically feasible and supported by complementary skills and organisational capabilities.

Finally, the reviewed studies consistently indicate that all three mechanisms generate distributional consequences. Migration may produce aggregate productivity gains while affecting workers differently depending on occupation and skill level. Upskilling may disproportionately benefit workers and firms already possessing stronger learning capacities. Automation may increase productivity while simultaneously altering occupational structures and creating unequal adjustment costs across workers and sectors.

Collectively, these dimensions imply that the relevant policy question is not which adjustment mechanism is universally superior, but which combination of mechanisms provides the most appropriate response under different labour market conditions. The evidence therefore supports understanding migration, upskilling, and automation as complementary components of a broader labour market adjustment strategy rather than mutually exclusive policy alternatives.

Table 6.6 A comparative framework for analysing labour market adjustment mechanisms

Dimension	Migration	Upskilling	Automation
Primary adjustment channel	Expands labour supply	Expands domestic human capital	Increases productivity through task automation
Speed of adjustment	High	Low	Medium
Main investment	Integration capacity	Education and training	Capital and digital technology
Main constraint	Integration and recognition	Time and institutional capacity	Capital and complementary skills
Long-run sustainability	Medium	High	Medium-High
Distributional risks	Integration, wage heterogeneity	Unequal access to training	Job restructuring and skill polarization

* Indicative synthesis based on reviewed evidence

A contingency framework for labour market adjustment

A second synthesis emerging from the reviewed evidence is that the effectiveness of each adjustment mechanism depends fundamentally on the characteristics of the labour shortage being addressed. Building on the reviewed evidence, this review proposes a contingency framework in which migration, upskilling, and automation become more or less appropriate under different economic conditions.

Migration appears most effective where labour shortages are immediate, severe, and concentrated in occupations requiring skills that cannot be developed domestically within the required time horizon. In such circumstances, expanding labour supply provides rapid adjustment while allowing firms to maintain production and economic activity.

Upskilling becomes increasingly advantageous where labour shortages reflect persistent structural transformation rather than temporary recruitment difficulties. Building domestic human capital requires longer implementation periods but offers greater resilience by expanding the productive capacity of the local workforce and improving its adaptability to future technological and economic change.

Automation emerges as the preferred adjustment mechanism where shortages are concentrated in routine, repetitive, or technically codifiable tasks and where firms possess sufficient financial resources and complementary organisational capabilities to adopt new technologies.

However, the reviewed evidence consistently indicates that automation is least effective where production relies on tacit knowledge, interpersonal interaction, creativity, or complex problem-solving, emphasising that technological adoption frequently complements rather than replaces investments in human capital.

Consequently, the reviewed literature does not support a universal ranking of the three mechanisms. Instead, it indicates that their effectiveness depends on the interaction between the nature of labour shortages, sectoral production characteristics, institutional capacity, and firms' technological readiness.

6.7. Key findings and implications

To sum up, this review examines the trade-offs between three principal responses to demographic-induced labour and skill shortages: migrant labour, domestic upskilling, and automation. Taken together, the evidence indicates that the central policy challenge is not choosing among three mutually exclusive alternatives but understanding how adjustment mechanisms that differ systematically in their speed of response, implementation requirements, institutional dependence, and long-term sustainability can be combined to address labour market imbalances. Consequently, the review finds little support for the notion that any single mechanism constitutes a universally optimal response to demographic change.

A central contribution of this review is to demonstrate that the trade-offs between migration, upskilling, and automation are inherently contingent rather than universal. Their relative effectiveness depends on the nature of labour shortages, sectoral production characteristics, firms' technological capabilities, institutional capacity, and the time horizon over which adjustment is pursued. Migration provides the most immediate expansion of labour supply but depends on successful integration, skill recognition, and political acceptability. Upskilling strengthens the adaptive capacity of the domestic workforce and offers the greatest long-term resilience yet requires substantial investment and time before benefits materialise. Automation can reduce dependence on scarce labour in routine and technically codifiable tasks while increasing productivity, but its effectiveness depends on capital availability, complementary skills, and organisational readiness. Rather than representing competing solutions, these mechanisms frequently complement one another by addressing different dimensions of labour market adjustment.

From a policy perspective, the findings indicate that successful responses to demographic ageing and shrinking workforce require coordinated rather than isolated interventions. Migration can alleviate immediate labour shortages, automation can improve productivity and reduce dependence on scarce labour in suitable tasks, and upskilling can strengthen the long-term adaptability of the domestic workforce. However, the effectiveness of each mechanism ultimately depends on complementary institutions, including education and lifelong learning systems, innovation and technology-support policies, and labour market institutions capable of integrating migrant workers and facilitating technological transition. Accordingly, the principal policy trade-off is not between migration, automation, and upskilling themselves, but between balancing short-term labour market responsiveness with the long-term development of productive and resilient labour market institutions.

The findings should also be interpreted in light of several limitations. The existing evidence remains fragmented, with relatively few studies directly comparing adjustment mechanisms within a common analytical framework. Much of the literature continues to examine migration, automation,

and workforce development as separate research agendas, limiting opportunities for direct comparison. Future research would therefore benefit from integrated empirical analyses that simultaneously evaluate these mechanisms across different sectors, occupations, and demographic contexts. Such work would provide a stronger evidence base for understanding not only whether individual adjustment mechanisms are effective, but also under what conditions their interactions produce the greatest economic and social benefits.

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7. Conclusions

7.1. Summary of findings

This deliverable provides a systematic synthesis of the literature on the definition, measurement, drivers and possible responses to labour and skill shortages and skill mismatches in the European Union. The findings demonstrate that these phenomena are multidimensional and cannot be adequately understood through a single definition, indicator or policy response.

The analysis conducted under RQ1 shows that labour shortages, skill shortages, recruitment difficulties, skill gaps and skill mismatches should not be treated as interchangeable concepts. A genuine labour or skill shortage refers to an insufficient supply of workers with the required skills at prevailing wages and working conditions. By contrast, unfilled vacancies, long vacancy durations or employer-reported recruitment difficulties may also result from unattractive pay, poor working conditions, geographical constraints, ineffective recruitment practices or temporary adjustment processes. Skill mismatch is a broader concept covering discrepancies between workers' education, qualifications or skills and job requirements, including vertical mismatch, horizontal mismatch, over- and underkilling, and skill gaps within the existing workforce.

No single indicator provides a complete or unambiguous measure of shortages or mismatches. Vacancy rates, hard-to-fill vacancies and vacancy duration may indicate labour-market tightness but do not in themselves prove the existence of a structural skill shortage. Similarly, educational attainment is only an imperfect proxy for actual skills. Reliable diagnosis therefore requires the combination of different sources and measures, including administrative labour-market data, employer and worker surveys, direct skill assessments, wage indicators, occupational information and data on working conditions.

The evidence reviewed under RQ2 indicates that shortages and mismatches arise from the interaction of several mechanisms rather than from a general lack of educated workers. The principal drivers include technological and green transformation, demographic ageing and workforce shrinkage, education–labour-market misalignment, regional restructuring, occupational and social segmentation, migration and the underutilisation of existing human capital. Their relative importance varies substantially across sectors, occupations and regions.

Ageing and workforce decline affect not only the numerical availability of labour but also the effective supply and use of skills. The retention, re-employment and continued development of older workers depend on access to training, workplace organisation, health, job quality and age-inclusive employment practices. At the same time, demographic pressures are particularly significant in regions and sectors that combine population decline with limited educational, technological or institutional capacity.

Educational expansion has increased formal qualification levels but has not necessarily produced a proportional improvement or diffusion of foundational, cognitive and job-relevant skills. Overeducation is therefore not a general cause of skill shortages. It may reflect the underutilisation of human capital, but it may also result from credential inflation, insufficient regional demand, weak school-to-work transitions, limited transferability of qualifications or differences between formal education and actual competencies. Skill shortages can consequently coexist with a substantial supply

of highly educated workers when their skills are located in different sectors or regions, are not recognised, or are not used productively.

The evidence for RQ3 is considerably stronger for foreign recruitment than for wage increases as a deliberately evaluated shortage-mitigation intervention. The available studies show that access to foreign labour can rapidly ease binding recruitment constraints and support firm growth, productivity and innovation. However, this should not be interpreted as evidence that foreign recruitment is inherently superior to wage adjustment. The imbalance largely reflects a lack of studies directly evaluating the effects of wage increases on vacancy filling, recruitment time or retention.

Foreign recruitment is not a substitute for adequate wages, job quality and domestic workforce development. Its effectiveness depends on migration and mobility rules, recognition of qualifications, language acquisition, labour-market integration, career opportunities, family circumstances and the possibility of long-term settlement. Where these conditions are absent, migration may provide only temporary relief or lead to the underutilisation of migrant skills.

RQ4 similarly does not support a universal ranking of migration, upskilling and automation. The three mechanisms address labour-market imbalances through different channels and over different time horizons. Migration can expand labour supply relatively quickly. Upskilling and reskilling strengthen domestic human capital and long-term adaptability but require sustained investment and institutional coordination. Automation may substitute for labour in routine, repetitive and technically codifiable tasks, but it is less applicable where work depends on interpersonal interaction, tacit knowledge, creativity or complex problem-solving.

Automation also rarely eliminates the need for skills. Instead, it often changes task structures and creates demand for complementary technical, digital and organisational capabilities. Its feasibility therefore depends not only on the availability of technology but also on access to capital, firms' organisational readiness, digital infrastructure and the availability of workers able to implement, maintain and work alongside new technologies.

Overall, the findings indicate that migration, upskilling and automation are more often complementary than mutually exclusive. Effective responses to shortages require combinations of instruments adapted to the specific mechanism, sector, occupation, region and time horizon involved.

7.2. Implications for policy and research

The principal policy implication is that the underlying mechanism should be diagnosed before a policy response is selected. Recruitment difficulties should not automatically be classified as evidence of structural labour or skill shortages. Policymakers should first assess whether vacancies persist at prevailing wages and working conditions and whether the problem results from insufficient skills, unattractive employment, geographical mismatch, weak mobility, poor matching, limited recognition of qualifications or temporary changes in demand.

Policy responses should therefore be differentiated. Wage and job-quality improvements are particularly relevant where shortages are associated with low pay, difficult working conditions, limited career prospects or high employee turnover. Education and training policies are appropriate where shortages reflect persistent changes in job requirements, but they should be linked to employer

demand, work organisation and realistic career pathways. Migration can provide faster adjustment where appropriately skilled workers are not available domestically, but it requires effective recognition, integration and retention policies. Automation should be supported where tasks are technically suitable and where firms possess or can develop the required complementary capabilities.

The findings also support stronger coordination between education, labour-market, migration, regional-development and innovation policies. Increasing graduate numbers alone will not resolve shortages when graduates do not enter or remain in shortage occupations, when regional economies cannot absorb their skills, or when employers do not offer conditions that support retention. Lifelong learning should therefore be integrated with employment and innovation strategies rather than treated as a stand-alone educational intervention.

Regional and sectoral differentiation is essential. National averages may conceal the coexistence of shortages and surpluses across local labour markets, sectors and occupational groups. Monitoring systems should therefore distinguish country, regional, sectoral and occupational levels and identify whether observed imbalances are temporary or persistent.

Future research should develop more integrated empirical designs comparing alternative responses to shortages within a common framework. In particular, more evidence is needed on the effects of wage and job-quality interventions on recruitment and retention, the interaction between migration and technological adoption, the distributional effects of automation and immigration, and the conditions under which upskilling produces sustainable employment and productivity gains.

Greater attention should also be given to longitudinal and sectoral comparable evidence. The literature remains fragmented and frequently relies on employer perceptions, narrow case studies or indicators that capture only one dimension of mismatch. Combining administrative data, direct skill assessments, vacancy information, wage data and digital labour-market sources would allow for more reliable identification of persistent shortages and their underlying causes.

Appendix 1. Extraction prompt

2.1.1 Location

TASK: Understand and extract the study's location mentioned in the abstract. Interpret the context to determine the actual country of the study. If the location is not given, return "Unspecified." If multiple locations are provided, list all locations, separated by a comma.

INSTRUCTIONS:

- Extract the name(s) of the country/countries mentioned in the abstract. Consider country names (for example "Poland", "Germany"), and their language forms (for example "Polish", "German").
- Recognize country abbreviations as well, such as "US," "USA," and "UK."
- Recognize regions and treat them as locations too, for example "EU", "European", "CEE", "LATAM".
- If the abstract contains multiple countries, list all of them, separated by a comma.
- If the abstract does not provide any country information, return "unspecified."

ADDITIONAL GUIDANCE:

- Ignore cities.
- Ignore affiliations of authors or publishers, as these do not indicate the location of the study itself.

EXAMPLES:

- "The study of the distribution of ranks, Index digital literacy is considered the rating of Federal districts of the Russian Federation and the main trends of territorial differentiation of the integrated administrative-territorial units of the country". Output: "Russian Federation".
- "This research focuses on German healthcare policies and their impact on the elderly." Output: "Germany".
- "The study examines the economic implications of renewable energy adoption in the US." Output: "US".
- Abstract example with multiple locations: "Data were collected from healthcare facilities in France, Germany, and Italy to assess the impact of different policy measures." Output: "France, Germany, Italy".
- Abstract example without a specified location: "This research analyzes global economic trends in the context of technological innovation." Output: "unspecified."
- "The Facility Service (FS) industry is the third largest sector in the EU. In Europe, as well as in the US, around 10% of all employees work in this sector. Macro economic studies estimate that in general 47% of all jobs will be automated due to digitalization. Fifty German speaking Facility Managers were asked about the technical and economic feasibility of smart building technologies in the FS sector. Based on the smart building technologies identified as relevant, the authors carried out a quantitative literature review." Output: "Germany"

OUTPUT: Return the extracted location(s) for each abstract in the format "Abstract [number]: [Location]", each on a new line.

Abstracts: 30 illustrative abstracts were provided to train the assistant

2.1.2 Period

TASK: Understand and extract the study's time period mentioned in the abstract. Interpret the context to determine the actual time period. If the time period is not given, return "Unspecified." If multiple time periods are provided, list all, separated by a comma.

INSTRUCTIONS:

- Extract the studied data period mentioned in the abstract. This could include a specific year, a range of years, or a phrase indicating a time frame.
- If the abstract mentions a range of years (e.g., "1980-1985" or "from 2010 to 2012"), extract that period.
- If the abstract mentions a single year (e.g., "2022"), extract that year.
- If the abstract contains multiple time periods, list all of them, separated by a comma.
- If the abstract does not provide any studied period information, return "Unspecified."

ADDITIONAL GUIDANCE:

- Pay attention to different variations of time period expressions, such as "from 1990 to 2000", "between 2015 and 2018", or "the year 2021".
- Ignore mentions of publication years, author affiliations, or references that are not explicitly the studied data period.

EXAMPLES:

- "The study examines climate change impacts on agriculture from 1980 to 1985." Output: "1980-1985".
- "In 2022, the researchers analyzed the effect of urbanization on local biodiversity." Output: "2022".
- "Data were collected between 1990 and 1995, and later between 2005 and 2010 to assess the long-term effects of policy changes." Output: "1990-1995, 2005-2010".
- "This research analyzes global economic trends in the context of technological innovation." Output: "Unspecified".

OUTPUT: Return the extracted studied data period(s) for each abstract in the format "Abstract [number]: [Studied Period]", each on a new line.

2.1.3 Industry

TASK: Extract the industry that the study concerns from the abstract. If the industry is not mentioned, return "Unspecified." If the study concerns the economy as a whole, return "economy."

INSTRUCTIONS:

- Extract the name of the industry that the study concerns. This could include specific industries such as "Construction," "Retail," "Healthcare," etc.
- If the abstract concerns the entire economy, return "economy."
- If the abstract mentions multiple industries, list all of them, separated by a comma.
- If the abstract does not provide any specific industry information, return "Unspecified."

ADDITIONAL GUIDANCE:

- Pay attention to explicit mentions of industries, sectors, or economic activities (e.g., "Construction," "Retail," "Healthcare").
- Ignore phrases like "Industry 4.0" as it does not specify a particular industry.
- Interpret the context to determine the correct industry if it is indirectly mentioned.

EXAMPLES:

- "The Facility Service (FS) industry is the third largest sector in the EU." Output: "Facility Services"
- "However, there is a need to appraise the impact of Covid-19 on construction labor force while making a case for construction automation." Output: "Construction"
- "We develop a dynamic general equilibrium model where robots can be substituted for unskilled labour and public authorities can use fiscal and monetary policies to influence the macroeconomic aggregates." Output: "Unspecified"
- "The retail sector is the largest employer in Australia providing significant work opportunities for low and semi-skilled persons." Output: "Retail"

OUTPUT: Return the extracted industry for each abstract in the format "Abstract [number]: [Industry]", each on a new line.

2.1.4 Research method:

TASK: Understand and extract the research method that the study used, based on its abstract. If the research method is not mentioned or cannot be inferred, return "Unspecified".

INSTRUCTIONS:

- Extract the research method used in the study. If it is specifically mentioned (for example "we conducted a survey in..."; output: survey), extract it directly. If the name is not mentioned, but with high certainty can be deduced (for example "we asked 1000 to answer if..."; output: survey), infer it. Otherwise, return "Unspecified".
- Research method could include experiments, surveys, economic studies, econometric studies, reviews, or any other academic research methods that you know.
- If the abstract mentions multiple research methods, list all of them, separated by a comma.
- If the abstract does not provide any specific industry information, return "Unspecified."
- Interpret the context to determine the correct research method if it is not directly mentioned. If you are unsure, return "Unspecified".
- Before writing the output verify if the data you extracted from the abstract is an actual research method.

EXAMPLES:

- "With reference to statistical data, we will try to show that automation can be seen at least as a contributory cause of unemployment." Output: "statistical methods".
- "The survey, which includes responses from 158 CPG leaders in 17 countries, found that CPG manufacturers are using emerging technologies such as smart manufacturing and automation to maximize workforce potential and minimize risk." Output: "survey"
- "The article highlights the positive impact of AI and RPA (Robotic Process Automation) on the Order to Cash (O2C) cycle in credit management. It discusses how these technologies are streamlining processes, improving document retrieval, enhancing collections," method: "review"

- "A comparative analysis of the most well-established estimates of labour automation, the Occupational Information Network (O*NET) degree of automation estimates and Frey and Osborne's future probability" Output: "comparative analysis"
- "This paper explores the synergistic approach of leveraging AI technologies within HRM to address the unique challenges faced by social enterprises. By analyzing existing literature, case studies, and industry practices, we identify key areas where AI can significantly contribute to social entrepreneurship" Output: "review"
- "Some proposals have been made for taxing the robots; these are presented in the current article, together with some personal contributions on the subject." Output: "Unspecified"
- "To do this, partially based on the research of Shoss and Ciarlante (2022), it is employed a multilevel model with variables at the individual and country levels, incorporating to study, as a contribution," Output: "statistical methods"

OUTPUT: Return the extracted research method for each abstract in the format "Abstract [number]: [Method]", each on a new line.

Appendix 2. Thematic classification prompt

You are an expert research assistant tasked with screening academic abstracts for a systematic review on **skill shortages as a labor market and macroeconomic phenomenon**.

This the study we are working on: This literature review study **centrally** investigates the phenomenon of skill shortages **in labor markets and economies**. It focuses on how these shortages are defined, measured, and quantified across regions and economic sectors, and their **broader economic impact**. It explores the key drivers behind skill shortages including demographic changes, educational dynamics, and labor market imbalances **at a sectoral or national level**, and evaluates **labor market strategies and policies** such as recruitment models, migration of skilled workers, and alternatives like upskilling and automation **with macroeconomic or sectoral implications**.

The following are synonyms for skill shortages that can be found in abstracts and are equivalent to skill shortages: skills shortages, skill mismatches, skill gaps, skill surpluses, skill deficits.

Task: Analyze each abstract and decide whether it is **centrally relevant** to our study on **skill shortages as a labor market and macroeconomic phenomenon**. Relevance is verified by reading the abstract and establishing its thematic fit to the study. The **primary** theme of the abstract **MUST** address issues related to **labor markets and economies** and significantly focus on one or more of the following aspects of skill shortages: definition, measurement, trends, drivers, or labor market strategies/policies.

Crucially, to be classified as "YES", the abstract must:

- Primarily focus on skill shortages as a labor market and macroeconomic issue.
- Go beyond simply mentioning "skill gaps" in a specific context.
- For sector-specific studies, the abstract must discuss skill shortages with broader labor market or economic implications.

If the abstract is not relevant, classify as "NO".

OUTPUT:

For each abstract, return EXACTLY one line in the following format:

Abstract <number>: <Yes|No> Justification: <justification>

Where:

- <number> is the abstract number (i.e., 1, 2, 3, ...), matching how we present it in the user prompt.
- <Yes|No> is your classification of the abstract.
- <justification> is a concise reason why you chose Yes or No.

Important: Use a single line per abstract, no extra line breaks in the justification. Do not add extra text, disclaimers, or bullet points. Keep the format EXACTLY, including the capitalization and spacing around "Justification:".

Appendix 3. Research questions mapping prompt

You are an expert research assistant tasked with screening academic abstracts for a systematic review on **skill shortages as a labor market and macroeconomic phenomenon**.

This the study we are working on: This literature review study **centrally** investigates the phenomenon of skill shortages **in labor markets and economies**. It focuses on how these shortages are defined, measured, and quantified across regions and economic sectors, and their **broader economic impact**. It explores the key drivers behind skill shortages including demographic changes, educational dynamics, and labor market imbalances **at a sectoral or national level**, and evaluates **labor market strategies and policies** such as recruitment models, migration of skilled workers, and alternatives like upskilling and automation **with macroeconomic or sectoral implications**.

The following are synonyms for skill shortages that can be found in abstracts and are equivalent to skill shortages: skills shortages, skill mismatches, skill gaps, skill surpluses, skill deficits.

Your task:

Mapping to Research Questions (RQs):

Decide which of the following research questions the abstract addresses.

- **RQ1: Definition and Measurement:**
 - **RQ1a:** How can skill shortages be systematically defined and measured across EU member states and regions?
 - **RQ1b:** What are the indicators and metrics to quantify skill shortages in economy sectors and timeframe?
- **RQ2: Drivers and Dynamics:**
 - **RQ2a:** What are the primary causes of skill shortages in the EU, and how do they vary by sector and region?
 - **RQ2b:** How do the ageing population and shrinking workforce contribute to skill mismatches in the EU?
 - **RQ2c:** Is educational expansion coupled with skills diffusion/improvement in (foundational/cognitive) skills? (Alternatively phrased: Is overeducation a reason for skill shortages in Europe?)
- **RQ3: Recruitment Models:**
 - **RQ3a:** How do economic incentives for raising wages compare with recruitment of foreign workers in mitigating skill shortages?
- **RQ4: Alternatives to Migrant Labor:**
 - **RQ4a:** What are the trade-offs between upskilling the local workforce and automation versus reliance on migrant labour?
 - **RQ4b:** How feasible are automation solutions in sectors that heavily depend on migrant workers, and what incentives are needed to promote such investments?

If the abstract does not directly address any of the research questions, return “None”

OUTPUT:

For each abstract, return EXACTLY one line in the following format:

Abstract <number>: <RQs>

Where:

- <number> is the abstract number (i.e., 1, 2, 3, ...), matching how we present it in the user prompt.

- <RQs > are numbers of research questions addressed in the abstract. If there are multiple, separate them with comma (e.g. “RQ1a, RQ3a”).

Important: Use a single line per abstract, no extra line breaks in the justification. Do not add extra text, disclaimers, or bullet points. Keep the format EXACTLY, including the capitalization and spacing.

Abstracts: