COST OF VACANCY (COV) REDUCTION THROUGH EMPLOYEE UPSKILLING FOR SWISS MANUFACTURING IN INDUSTRY 5.0

by

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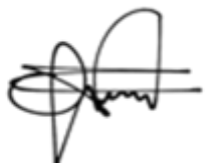

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ABSTRACT

COST OF VACANCY (COV) REDUCTION THROUGH EMPLOYEE UPSKILLING FOR SWISS MANUFACTURING IN INDUSTRY 5.0

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Dissertation Chair: Dr. Anna Provodnikova

Based on the theories of Human Capital, Efficiency Wage, and Skill-Biased Technological Change, this doctoral dissertation examines the strategic role of employee upskilling in reducing turnover and the Cost of Vacancy (CoV) within Swiss manufacturing firms in the Industry 5.0 era. Industry 5.0 represents a new phase of industrial transformation that emphasises human–machine collaboration, resilience, and sustainable growth. Despite the proliferation of workforce development programs, many firms continue to treat them as costs rather than strategic investments, leaving limited empirical evidence on how upskilling impacts key operational outcomes, particularly vacancy cost reduction.

This study addresses this gap by developing and validating a CoV model that quantifies the economic impact of upskilling initiatives. It investigates how investments in technical and cognitive skills influence workforce stability, retention, and organisational competitiveness. Employing a mixed-methods approach, the research integrates quantitative data from 100 employees in a Swiss manufacturing firm with qualitative

insights from managers, capturing both measurable outcomes and contextual organisational practices.

The results of this study indicate that structured upskilling programs reduce vacancy-related costs by approximately 35%, primarily through enhanced internal skill coverage, improved employee engagement, and reduced turnover intention. Regression analysis demonstrates that upskilling accounts for 36% of the variance in Perceived Cost of Vacancy (PCoV), highlighting its substantial role in mitigating both perceived and monetized vacancy impacts. Employees who participated in multi-skilled, Industry 5.0–oriented training exhibited greater adaptability and role flexibility, enabling teams to maintain operational continuity during vacancy periods without relying on immediate external recruitment. Moreover, mediation analysis confirms that engagement partially explains this relationship (indirect effect $\beta = -0.24$), indicating that upskilling strengthens motivational and behavioural mechanisms that reduce turnover-related disruptions. Collectively, these findings underscore the financial and strategic value of investing in employee development, positioning upskilling as a central driver of workforce resilience and cost efficiency in Swiss manufacturing firms operating in Industry 5.0 environments.

This dissertation contributes to the human capital and organisational management literature by providing a validated framework linking upskilling to operational efficiency and resilience. It offers actionable insights for manufacturing leaders seeking to leverage workforce development as a strategic tool to enhance competitiveness and sustain innovation in Industry 5.0. The findings underscore that upskilling is not merely a developmental activity but a critical driver of organisational stability, productivity, and long-term growth.

Keywords: Industry 5.0, upskilling, human capital, Cost of Vacancy (CoV), turnover, Swiss manufacturing, workforce development, employee retention, organisational resilience.

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CHAPTER I:

INTRODUCTION

1.1 Introduction

The industrial sector remains a fundamental contributor to economic development, continually adapting to improve efficiency and stimulate innovation. Although automated technologies now perform a significant share of repetitive operations, human creativity and critical reasoning continue to be essential—especially in the progression from Industry 4.0 to Industry 5.0. This newer phase places stronger emphasis on integrated collaboration between people and intelligent systems to advance productivity and innovative outcomes (Wang et al., 2023).

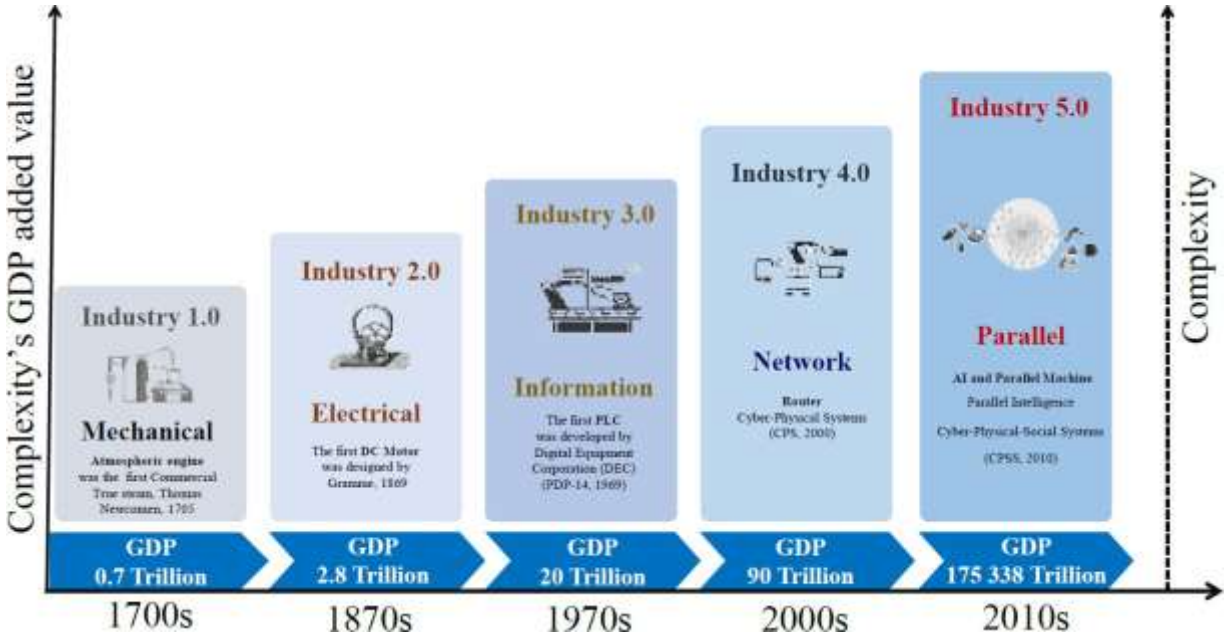

Figure 1.1: Industrial revolutions: From Industry 1.0 to Industry 5.0 (adapted from Wang et al., 2023).

Switzerland, grappling with the unfolding implications of Industry 5.0, faces significant socio-economic challenges driven by a pervasive global skills gap, particularly in the manufacturing sector (Wang et al., 2023). Predominantly, the surge towards

automation and digitalisation underscores the need for astute workforce upskilling strategies, with a spotlight on the Swiss manufacturing industry and its Skill Level A workers, who are vital for propelling innovation and maintaining competitive prowess. A discernible void exists in contemporary literature concerning the monetary repercussions of unoccupied positions, particularly within the Swiss context.

This research thus ventures into elucidating the impacts of upskilling on the cost of vacancies, as well as turnover rates among pivotal skilled workers in the Swiss manufacturing sector, informed by three theoretical frameworks. Human Capital Theory emphasizes that investing in employees' skills—particularly in emerging Industry 5.0 technologies—can improve overall productivity (Becker, 1962). Similarly, the Skill-Biased Technological Change Theory argues that technological progress increases the need for workers with advanced skills, which may widen the existing gap between low- and high-skilled labor (Acemoglu & Autor, 2011). Moreover, Efficiency Wage Theory indicates that upskilling may help organisations reduce turnover by offering above-equilibrium wages (Shapiro and Stiglitz, 1984).

1.2 Research Problem

The current discourse on global workforce development underscores a critical skills gap that presents a substantial challenge in upskilling and the adequacy of workforce adaptation in rapidly evolving job markets (Schwab and Zahidi, 2020). This skills gap is particularly pronounced in fundamental digital capabilities within developed nations. According to the Organisation for Economic Co-operation and Development, about a third of employees in the United States, the United Kingdom, and Germany lack essential workplace competencies (OECD, 2020Within Switzerland, labour market imbalances persist despite a strong skills base, as many firms—around 40%—report ongoing recruitment difficulties linked to insufficiently specialised competencies (Jaberg, 2022). Industry-focused studies support this observation (Goel, 2020). However, existing literature largely addresses upskilling and vacancy costs in isolation, offering limited

insight into how investment in workforce development directly influences vacancy-related expenditures in Swiss manufacturing firms undergoing the Industry 5.0 transition. The proposed study aims to delve into this underexplored nexus, providing valuable insights that could inform strategic workforce development and policy decisions.

The extant research underscores a critical skills gap across various global sectors. This highlights a substantial issue related to upskilling and adequacy of the workforce in quickly adapting job markets (Schwab and Zahidi, 2020). A segment of this literature accentuates the impact of the skills gap, particularly around fundamental digital skills in developed nations. However, the existing research lacks in-depth discussion regarding the specific relationship between upskilling and vacancy costs. This is particularly true in the specific context of Swiss manufacturing companies navigating the Industry 5.0 Era. Switzerland, despite having a highly skilled labour force, experiences noticeable shortages in key sectors. The current debate on upskilling and vacancy costs provides insight into the skills gap in both a global and a national context. However, there is a lack of specific insight into how upskilling correlates with vacancy costs, particularly within Swiss manufacturing firms during the Industry 5.0 transition.

1.3 Purpose of Research

This study examines the escalating socio-economic impacts of global skills gaps, particularly in the developed world and Switzerland. The research presented here is underscored by the impending implementation of Industry 5.0, which is characterised by advanced technologies and increased human-machine collaboration. Consequently, it highlights the role of upskilling in bridging this gap and reducing the costs associated with vacant positions in organisations. The research is set within the context of Swiss manufacturing firms, focusing on Skill Level A workers who play a pivotal role in driving innovation and competitiveness. We aimed to assess the impact of upskilling initiatives on the cost of vacancies and turnover rates of these highly skilled workers.

1.4 Significance of the Study

The theoretical framework employed in this study integrates three key theories: Human Capital Theory (HCT), Skill-Biased Technological Change (SBTC) Theory, and Efficiency Wage Theory. These provide an interpretive basis for analysing the relationship between worker upskilling and the cost of vacancy. Specifically, this theoretical framework considers that upskilling, as a form of investment in human capital, aligns skills with Industry 5.0 demands (SBTC), and reduces turnover rates (Efficiency Wage Theory). We present three hypotheses in the methodological approach, predicting that upskilling will reduce vacancy costs and lower turnover rates in Swiss manufacturing firms. The potential challenges of obtaining a larger sample size and the dearth of historical data warranted a novel approach for this study. Scenario analysis and machine learning techniques are proposed to estimate the potential effects of upskilling under various Industry 5.0 developmental assumptions and to analyse the complex relationships between upskilling, vacancy costs, and turnover rates.

1.4.1 Skill Gap in the Industry 5.0 Era

The acceleration of technological innovation associated with Industry 5.0 has intensified pressures on advanced economies by deepening shortages of highly qualified labor, particularly in knowledge-intensive domains such as information technology, healthcare and engineering (Chui *et al.*, 2016; Frey and Osborne, 2017). Rather than a simple supply deficit, this challenge reflects a structural imbalance: the competencies demanded by organizations are evolving more rapidly than formal education and training systems can recalibrate their curricula and delivery models (Autor, 2015; Cedefop, 2015). Even long-established vocational education and training frameworks in countries such as Switzerland and Germany, once viewed as exemplary in harmonizing skills formation with labour market needs, are encountering increasing constraints in adapting to digitally driven and interdisciplinary capability requirements (Hanushek *et al.*, 2017; Lerman, 2017). Concurrently, demographic ageing and the cross-national movement of skilled

professionals further constrain domestic talent pools, amplifying labour market tightness and raising concerns regarding sustained productivity and economic resilience (Bloom *et al.*, 2010; Czaika and de Haas, 2014; Docquier and Rapoport, 2012; Maestas *et al.*, 2016).

1.4.2 Economic Consequences of the Skills Gap

The global economy encounters various impediments due to the skilled labour gap, including reduced economic growth, hindered innovation, increased unemployment, and elevated wage inequality (Acemoglu and Autor, 2011; Autor, 2014; Cappelli, 2015). Disturbances in economic growth and innovation can escalate into international competitive disadvantages, reduced investment, and potential brain drain (Bernstein, 2016; Docquier and Rapoport, 2012). Moreover, the socio-political realm experiences ramifications, such as heightened income inequality, disrupted social mobility, and potentially, increased instability and unrest (Boeri and Garibaldi, 2007; Commission, 2017; Fitzpatrick, 2010; Oecd, 2019).

The Industry 5.0 era, defined by the integration of advanced technologies with human expertise, highlights the essential importance of a highly skilled workforce. The current skilled labour gap jeopardises innovation and economic growth, while also widening social inequalities and digital divides (Acemoglu and Restrepo, 2020; Brynjolfsson and McAfee, 2014; Lasi et al., 2014; Schwab, 2017). Firms that experience difficulty in recruiting or developing capabilities aligned with Industry 5.0 are likely to encounter slower innovation performance and a gradual erosion of competitive advantage, as technological progress increasingly rewards advanced and complementary skill profiles (Acemoglu and Autor, 2011; Autor, 2015; Brynjolfsson and McAfee, 2014; DeVoe and Pfeffer, 2011; Moretti, 2012). Beyond firm-level implications, persistent skills shortages may reinforce regional economic disparities. Moreover, the pressures associated with continuous technological adaptation can contribute to heightened workplace stress and adverse mental health outcomes among employees.

At the national level, insufficient availability of appropriately skilled labour may constrain productivity growth, weaken international competitiveness and limit long-term economic expansion (Greenstone *et al*., 2013; Schwab and Zahidi, 2020).

Moreover, enduring economic impacts can arise, such as a drastic reduction in economic output and a potential uptick in unemployment levels (Nap, 2017; Oecd, 2019). Consequently, cooperative efforts from governments and businesses are vital to counteract this gap through strategic investments in vocational training, educational programs, on-the-job training, and mentorship initiatives to upskill the present workforce (Lund et al., 2021).

1.4.3 Cost of Vacancy for Firms

The advent and integration of artificial intelligence (AI) and machine learning (ML) technologies, while capable of enhancing efficiency and diminishing immediate vacancy costs by automating tasks, presents a dichotomy by potentially elevating vacancy costs due to the resultant skilled labour gap and heightened human expertise necessity (Bessen, 2019). Notably, although AI and ML can eliminate certain jobs, they inadvertently create new roles necessitating specialised skills, such as AI engineering and data science, thereby further straining the skilled labour market. Addressing the consequential skilled labour gap and associated costs, corporations may utilise strategic upskilling, aligning skill development with organisational objectives and adapting to technological advances like AI to improve employee retention, ultimately mitigating vacancy costs (Li Qi and Jia Qi, 2021; Tambe et al., 2019).

1.4.4 Feasibility of Reducing the Cost of Vacancy Through Upskilling in the Industry 5.0 Era

Amid the Industry 5.0 Era's rapid technological evolution and enhanced human-machine collaboration, the practicality of utilising upskilling to mitigate vacancy costs is pivotal. Challenges, including the potential misalignment between the speed of technological advancement and skill acquisition, as well as the need for specialised

expertise, pose significant barriers (Arntz et al., 2016; Bessen, 2019). However, by emphasising the development of employees' soft skills and investing in continuous learning and development programs, corporations can forge a more resilient workforce. Further, through collaborations with educational institutions and industry experts, tailored upskilling initiatives addressing specific Industry 5.0 skill requirements can be designed and implemented, ensuring relevance and efficacy (Cappelli and Tavis, 2018; Cedefop, 2016; Deming, 2017).

1.4.5 Upskilling the Highly Skilled: The Swiss Context

In Switzerland, Skill Level A workers, often found in the manufacturing sector, embody a crucial component in propelling innovation and competitiveness, facilitated by a robust vocational education and training (VET) system (Hoeckel and Schwartz, 2010). This system, celebrated for melding theoretical and practical training, enables the nurturing of highly skilled workers, essential for Switzerland's emphasis on high-value-added industries like precision engineering and pharmaceuticals (Küttel, 2018; Muehlemann and Wolter, 2014). According to EURES, Switzerland maintains a high proportion of workers with advanced qualifications, reflecting the effectiveness of its VET system and supporting the nation's competitive labor market. Leveraging a rich literary foundation, this research endeavours to investigate the relationship between upskilling and vacancy cost reduction within the Industry 5.0 context, examining the potential of targeted workforce development as a cost-saving strategy for firms navigating the transition to Industry 5.0.

Building on the insights from the introduction and the comprehensive literature review, this research examines how employee upskilling can influence the costs associated with unfilled positions in the context of Industry 5.0. By investigating the relationship between targeted workforce development initiatives and vacancy-related expenses, the study aims to determine whether such strategies can deliver tangible cost savings for organisations navigating this emerging industrial paradigm.

1.5 Research Purpose and Questions

This study aims to examine how employee upskilling can contribute to reducing vacancy-related costs within the Industry 5.0 context. It will assess workforce development initiatives across different demographic groups and their financial implications. Specifically, the research seeks to address the following questions: Research Question 1: How does investing in upskilling programs, especially those focused on Industry 5.0 technologies, impact the cost of vacancies in Swiss manufacturing firms, and in what way does the level of education moderate this impact?

(1) Research Question 2: How does undergoing upskilling, with a particular focus on Industry 5.0 technologies, impact turnover rates among workers in Swiss manufacturing firms, and how does the level of education serve as a moderator in this relationship?

By addressing these questions, the research aims to provide insights into the strategic value of targeted upskilling for optimising workforce stability and reducing labour-related costs in the evolving Industry 5.0 era.

CHAPTER II:

REVIEW OF LITERATURE

2.1 Introduction

Researchers need a solid grasp of key research concepts to construct a conceptual model and address the research questions effectively. Accordingly, a comprehensive review of existing literature is essential.

The review traces the historical evolution of manufacturing, from Industry 1.0 through Industry 5.0, highlighting transformative phases marked by technological breakthroughs and shifts in socio-cultural and economic paradigms. This historical context provides a foundation for understanding the current challenges and opportunities facing the Swiss manufacturing sector in the Industry 5.0 era.

A primary focus of the review is to explore the definition, significance, and implications of upskilling within Industry 5.0, particularly regarding its influence on vacancy costs in Swiss manufacturing firms. This includes an in-depth examination of upskilling programs designed around Industry 5.0 technologies and their effectiveness in equipping employees with the skills necessary to navigate this advanced industrial landscape.

The literature review also investigates the role of upskilling in promoting sustainability and corporate social responsibility (CSR), with a focus on Swiss manufacturing. Case studies are examined to illustrate how firms have integrated sustainability objectives into their upskilling programs, highlighting the potential for workforce development to support innovation and environmental stewardship.

Another key aspect of the review is the emphasis on digital literacy and cross-functional competencies beyond purely technical skills. Strategies to cultivate a culture of lifelong learning and workforce adaptability are highlighted, reflecting the need to keep pace with rapid technological advancements.

By synthesising insights from recent studies, the review assesses the scope and effectiveness of upskilling initiatives tailored to Industry 5.0 technologies. This includes a critical evaluation of how such programs prepare employees for the adoption of artificial intelligence and other advanced technologies, facilitating a shift from routine tasks to more creative and cognitively complex roles.

Finally, the review identifies gaps and future research directions in the context of upskilling for Industry 5.0. This encompasses the development of workforce-specific training programs, the broader implications of emerging technologies on the manufacturing sector, and the ongoing importance of maintaining a human-centred approach in the Industry 5.0 era.

2.1.1 Lifelong Learning, Changing Dynamic of Industry 5.0, and Andragogy

Lifelong learning embodies a fundamental human need, essential for personal growth and societal advancement. The theory of andragogy, emphasizing adult education, becomes particularly significant in today's context, in which the workforce is constantly adapting to rapid technological changes. Research has shown that andragogical approaches, which favor self-directed learning, are highly effective for adult learners in the workforce, promoting a more engaged and effective education system. For instance, V. X. Wang and Kania-Gosche (2013) highlight the importance of adapting learning theories such as andragogy and pedagogy to improve workforce education, suggesting a flexible approach to cater to adult learning stages. Additionally, technological advancements have further facilitated this by enhancing e-learning platforms that align with andragogical principles, offering open, individualised education throughout one's life (Galustyan et al., 2019). Furthermore, Hanshaw and Rojas (2021) discuss how integrating technology with andragogical principles can improve the sense of connectedness and academic efficacy among online learners. The evolution towards a more learner-centered approach, supported by these advancements, indicates a promising direction for adult education in preparing individuals for the dynamic demands of the modern workplace. In this landscape, the application of andragogical principles is critical for fostering a culture

of continuous learning and adaptation, necessary for the workforce to navigate the complexities of the Industry 5.0 era.

Historical and comparative analyses reveal that the concept of andragogy has deeper roots than some contemporary authors suggest, indicating that adult learning and education have always been fundamental aspects of human activity and aspirations (Savicevic, 2008). The discourse contrasting pedagogy with andragogy, particularly during the latter half of the twentieth century in former Yugoslavia, led to the emergence of two distinct schools of thought: one viewing pedagogy as an all-encompassing science of upbringing and the other regarding andragogy as a relatively autonomous science focused on the unique attributes of adult learning and education. This differentiation was not unique to Yugoslavia, as debates around andragogy occurred globally, with significant contributions from Central and Eastern Europe and the USA, where andragogy is often seen as a distinct social scientific discipline. The text underscores the importance of recognizing adult education's specificity, arguing against the "infantilization" of adult learning and advocating for a holistic and inclusive educational policy that addresses learning needs across all life stages. This approach aligns with the philosophy of lifelong learning and education, which gained prominence in the second half of the twentieth century, challenging traditional education policies and emphasizing the need for a comprehensive understanding of human potentialities beyond adolescence.

Within German-speaking Swiss manufacturing firms, the strategic implementation of andragogical methods can indirectly mitigate the economic impact of workforce vacancies by enhancing employees' skills. The emergence of Industry 5.0 is driving a transition towards more human-centred and technologically sophisticated manufacturing processes, requiring employees to be not only technically competent but also flexible and innovative. Andragogical approaches, which emphasise self-directed learning and leverage the prior knowledge of employees, provide firms with a means to systematically develop these capabilities, thereby helping to reduce both the tangible costs, such as recruitment and training, and the intangible costs associated with skill shortages (Henschke, 2021).

Although the effect of andragogical programs on vacancy-related costs is largely indirect, it has important implications for the operational and strategic resilience of firms in the Industry 5.0 context. By aligning adult learning initiatives with anticipated technological developments, manufacturing organisations can strengthen their competitive position and support long-term economic sustainability. This approach not only addresses immediate labour skill gaps but also equips the workforce to meet future challenges, demonstrating a deliberate alignment between educational strategies and economic performance in rapidly evolving industrial environments.

2.1.2 Overview of the Swiss Manufacturing Sector and Its Significance in the Global Market

The Swiss manufacturing industry, renowned for its precision and high-quality production, remains a cornerstone of the national economy, encompassing sectors from traditional dairy processing to advanced pharmaceutical production. In recent years, there has been a strong emphasis on improving energy efficiency and promoting sustainability across these industries, reflecting Switzerland's commitment to innovation and environmental stewardship. Between 2009 and 2016, substantial gains in energy efficiency were achieved, particularly within the paper, minerals, and food sectors. These improvements were largely facilitated by the Swiss regulatory framework and target agreement mechanisms, which contributed to measurable energy savings in both the chemical and food industries (Zuberi *et al*., 2020).

Agriculture, particularly dairy farming, continues to play a vital role in the Swiss economy, even as farms face challenges such as market price pressures. To remain competitive, many producers are adopting strategies including specialization, diversification, or exiting milk production, while agritourism offers a supplementary, though limited, opportunity for some operators (Hochuli *et al*., 2021). Meanwhile, the pharmaceutical sector, internationally recognized for its innovation and economic impact, has demonstrated its commitment to sustainability through initiatives highlighted at the Swiss Biotech Day in May 2022. These efforts focus on integrating sustainability

practices throughout the pharmaceutical value chain via collaboration between industry stakeholders and academic partners, supporting Switzerland's reputation for producing effective and responsibly developed medications (Gehring and Meyer, 2022).

The Swiss manufacturing sector plays a crucial role in the global economy, epitomized by its commitment to energy efficiency and sustainability. This sector has demonstrated significant advancements in energy efficiency, particularly in the paper, minerals, and food industries, albeit with the chemical and metal sectors experiencing stagnant levels of efficiency (Zuberi et al., 2020). Notably, Switzerland has achieved considerable progress in reducing traditional energy intensity, effectively uncoupling economic expansion from energy consumption, with a 1.4% annual improvement in physical energy efficiency from 2000 to 2016 (Bhadbhade et al., 2020). This progress is slower in the industrial sector compared with the household sector. Switzerland's organic sector further reflects the nation's commitment to sustainability, demonstrating strong performance in governance, environmental stewardship, economic resilience, and social well-being across a wide range of sustainability dimensions (Curran *et al*., 2020).

2.1.3 Introduction to Industry 5.0: Definition, Characteristics, and Technological Advancements

Industry 5.0 represents the next phase in industrial development, emphasising a human-centered approach alongside the adoption of advanced technologies to create manufacturing systems that are resilient, sustainable, and efficient. Building upon the technological foundation of Industry 4.0, it places greater importance on human creativity and decision-making within production processes, promoting seamless collaboration between workers and intelligent machines. This stage of industrial evolution prioritises employee well-being, sustainable manufacturing practices, and the establishment of robust operational systems (Alves et al., 2023). Industry 5.0 incorporates several key dimensions—such as collaboration, coordination, communication, and data analytics—aiming to deliver a triple bottom line that balances resilient value creation, human welfare, and environmental sustainability (Alves *et al*., 2023). It represents a shift towards

a society where industrial advancements align with societal needs, emphasizing the importance of social and human-centric aspects in technological applications (Mourtzis et al., 2022). The shift towards Industry 5.0 is largely motivated by the need to reintegrate the human element into industrial processes, a requirement that became particularly evident during the COVID-19 pandemic (Zizic et al., 2022). This new industrial phase is expected to generate innovations across multiple sectors, including healthcare, manufacturing, and supply chain management, leveraging technologies such as edge computing, digital twins, and blockchain (Maddikunta et al., 2022). The banking industry is also preparing for the implications of Industry 5.0, exploring strategies to adapt effectively to this evolving industrial landscape (Mehdiabadi et al., 2022).

2.1.4 The Importance of Addressing the Cost of Vacancy and Turnover Rates in Swiss Manufacturing Firms

The economic implications of vacancies extend well beyond direct financial losses, encompassing broader market effects and externalities that impact surrounding property values and operational costs. Research indicates that the frictional costs associated with vacancies, particularly when accounting for secondary or knock-on vacancies, are frequently underestimated. In European contexts, evidence suggests that a single primary vacancy can raise the associated frictional costs by an average factor of 2.21, although this impact differs between countries (Hanly *et al*., 2021). Properties left vacant, particularly those in deteriorated condition, can lower the rental values of neighboring units by around 1–2 per cent and may lead to adverse externalities such as illegal waste disposal or higher arson risk. Addressing these issues could provide considerable fiscal benefits for local authorities (Sadayuki *et al*., 2020). Additionally, the relationship between vacancy rates and rental rate elasticity is influenced by negotiation dynamics between landlords and tenants, with Nash bargaining frameworks often tempering rent adjustments and contributing to greater rate elasticity (Wang, 2020).

Furthermore, the concept of a hidden vacancy rate, which suggests potential forthcoming shifts in market vacancy rates based on past rent levels and demand

forecasts, plays a critical role in the dynamics of the office space market. This rate, while not immediately visible, can be deduced from market analyses and impacts future market behavior (Nowak, 2020). Overall, vacancy costs encompass a complex array of factors affecting both the labor and housing markets, underscoring the intricate relationship between unoccupied positions or properties and broader economic and policy landscapes.

Turnover within manufacturing firms describes the phenomenon where employees leave and are subsequently replaced, a cycle that can significantly impact these firms' efficiency, reliability, and economic outcomes. Elevated turnover rates are linked to a multitude of adverse effects on manufacturing operations. Notably, an increase in worker turnover is directly correlated with heightened incidences of product failures in consumer electronics, suggesting that every percentage point rise in weekly turnover could lead to a 0.74%–0.79% increase in field failures (Moon et al., 2020). This turnover not only hampers product quality but also has a detrimental effect on firms' commitment to research and development (R&D), especially highlighted by the negative repercussions of executive turnover on R&D investment. This impact is particularly acute in family-owned and non-state-owned enterprises, where high turnover rates lead to a higher departure rate of R&D personnel and degrade the internal R&D milieu (Xiong et al., 2021).

Furthermore, employee turnover bears a negative relationship with the future performance of firms, manifestly affecting returns on assets and sales growth. This negative impact is more pronounced in enterprises that are small, nascent, and labor-intensive (Li et al., 2022). From a productivity standpoint, turnover disrupts manufacturing processes as incoming workers require time to achieve the proficiency levels of their predecessors, necessitating careful production planning and inventory management ("Modeling and Simulation of Production Systems to Evaluate the Effect of Worker Turnover on Productivity," 2021). However, when considering inventory management specifically, a higher inventory turnover ratio can be beneficial, enhancing profitability by diminishing costs (Alnaim and Kouaib, 2023). Thus, while high turnover rates present substantial challenges to manufacturing firms, negatively affecting product reliability, Research and Development investment, firm performance, and productivity,

efficient management of inventory turnover emerges as a critical area where positive financial outcomes can be realised.

Labour turnover costs and vacancy rates critically influence the Swiss manufacturing sector's employment dynamics, significantly impacting labour demand and supply equilibrium, productivity, and economic performance. The cost implications of turnover can sway average employment levels, with factors like the revenue function, discount and attrition rates, and the relative magnitude of hiring and firing costs playing a crucial role. Specifically, elevated turnover costs could potentially heighten average employment figures, especially when firing costs are considerable (Bertola, 1992). Moreover, integrating post-match labour turnover costs (PMLTC), encompassing training and separation expenses, into conventional search and matching models reveals that vacancies and unemployment levels exhibit heightened sensitivity to productivity shifts (Silva and Toledo, 2009). This implies that the sector's employment and vacancy metrics are closely tied to labor productivity fluctuations. An uptick in PMLTC not only escalates the equilibrium unemployment rate but also diminishes aggregate income, highlighting the direct influence of turnover costs on the sector's economic vitality. Hence, the Swiss manufacturing sector's labor market dynamics are intricately linked to managing turnover and vacancy rates, with turnover costs exerting a nuanced effect by potentially boosting employment under certain scenarios, while rendering the labor market more responsive to economic variance. The significant impact of PMLTC on economic outcomes further accentuates the importance of adeptly managing these factors to ensure a stable, productive manufacturing workforce.

2.1.5 Brief Overview of the Theoretical Framework: Human Capital Theory, Skill-Biased Technological Change Theory, and Efficiency Wage Theory

Human Capital Theory, advanced by neoclassical economists including Gary Becker and Theodore Schultz, argues that investments in education, professional training, and health can substantially increase an individual’s productivity and value within organizations. Such investments not only enhance technical skills and autonomy but also

contribute to broader socio-economic benefits for employees (Fleming, 2017; Mayilyan and Yedigaryan, 2022). This theory emphasizes the critical role of personal investments in human capital for boosting productivity and income growth, thereby contributing substantially to the socio-economic development of societies. It highlights the importance of human capital in driving economic growth, especially in economies that are heavily reliant on knowledge and innovation, and underscores the notion that individuals bear the primary responsibility for such investments (Fleming, 2017; Mayilyan and Yedigaryan, 2022).

The theory marks a notable change in the conceptualisation of labour, moving from a role traditionally seen as secondary to capital, to being recognised as a primary driver of production within a knowledge-based economy (Harris, 2001). Despite the challenges in valuing human capital due to its intangible nature and the fact that it resides within individuals, Human Capital Theory effectively connects individual attributes—such as knowledge, skills, and abilities—to macroeconomic outcomes, suggesting that the collective human capital of a society plays a vital role in its overall economic performance (Ployhart and Moliterno, 2011). Moreover, it is associated with the rise of new work practices, including individualized training, self-employment, and the gig economy, which are reflective of the principle that individuals are responsible for their human capital development (Fleming, 2017). The primary aim of Human Capital Theory extends beyond merely increasing productivity; it also seeks to enhance the socio-economic welfare of individuals. This dual focus positions the theory as a key framework for analysing labour dynamics and guiding economic policy in modern economies (Fleming, 2017).

Similarly, Skill-Biased Technological Change (SBTC) theory posits that technological innovations tend to disproportionately benefit skilled workers, increasing both their demand and remuneration relative to unskilled labour (Diessner et al., 2022). This theory has been crucial in elucidating the dynamics of labor markets and the escalation of wage inequality amidst technological progress.

Notably, SBTC plays a critical role in shaping wage distribution and employment patterns, with evidence highlighting its contribution to productivity deceleration and shifts in labor hours in Germany (Hutter and Weber, 2021). Technological change exhibits heterogeneity across firms, manifesting as skill-biased, capital-saving, and materials-using, with variations evident between and within industries, determined by firm strategies and technological nuances (Dewitte et al., 2020). The capital-skill complementarity hypothesis proposes a synergistic interaction between skilled labour and capital in the production process. Empirical evidence at the sectoral level in the United States supports this view, indicating that Skill-Biased Technological Change (SBTC) explains a substantial portion of the observed increase in the skill premium (Perez-Laborda and Perez-Sebastian, 2020).

Further, SBTC has significantly influenced the German political economy, impacting the interplay between specialized skills, regulated industrial relations, and social protection mechanisms, thereby prioritizing high-skilled workers in premium export-oriented firms (Diessner et al., 2022). A model of directed technical change that excludes scale effects suggests that both the technological-knowledge bias per worker and the skill premium tend to rise over time. This trend is accompanied by a declining labour share, reflecting the growing dominance of skilled labour and its comparatively lower share within the overall workforce (Afonso and Lima, 2020).

Efficiency Wage Theory suggests that employers might pay wages above the market equilibrium to boost productivity and ensure worker loyalty, thereby enhancing overall firm performance despite incurring higher labor costs. This approach is grounded in the understanding that wages are not merely compensation for labor but also a strategic instrument to motivate and retain a productive workforce (Bondarenko and Krainiak, 2021; Giménez-Nadal et al., 2021; Heutel and Zhang, 2020; Moriarty, 2020).

Key characteristics of Efficiency Wage Theory, as highlighted in academic research, include the recognition that wages fulfil several roles: they act as a performance reward, a productivity incentive, and a reflection of labor market conditions, each with its distinct normative basis (Moriarty, 2020). The theory posits that efficiency wages can

affect unemployment levels and environmental policy outcomes, with the specific impact on unemployment varying according to workers' effort function (Heutel and Zhang, 2020). Wages have a dual impact, influencing both employee income and employer financial results, with significant implications for labor resource sustainability and staff retention (Bondarenko and Krainiak, 2021).

2.2 Industry 5.0 and the Swiss Manufacturing Sector

2.2.1 Historical Context of Manufacturing Evolution: From Industry 1.0 to Industry 5.0

The evolution of industrialization is marked by five distinct phases, each characterized by breakthroughs in technology and shifts in cultural and socioeconomic paradigms, fundamentally altering production methods and economic structures. Industry 1.0 heralded the onset of the industrial revolution, transitioning economies from agrarian and artisanal bases to those centered around mechanized production. This era was distinguished by the introduction of steam and water power, which mechanized textile manufacturing and other industrial processes, laying the groundwork for mass production (Mathur et al., 2022). Industry 2.0 emerged with the advent of electricity, propelling the expansion of industrial production, and fostering the growth of new sectors like steel and oil. The widespread adoption of electrical power enabled more efficient production lines and the genesis of mass production techniques, significantly boosting productivity (Mathur et al., 2022).

Industry 3.0 marked the period when information technology (IT) and electronics were increasingly incorporated into manufacturing, initiating widespread automation. The use of computers and robotics on production lines improved efficiency, accuracy, and overall productivity, laying the groundwork for the digital transformation of the manufacturing sector (Mathur et al., 2022). Industry 4.0 is defined by the incorporation of artificial intelligence (AI) and the Internet of Things (IoT) into manufacturing, promoting customization and flexibility in production. This stage is characterised by the digitalisation of manufacturing processes, which facilitates substantial operational

efficiencies, enables the development of new business models, and allows for the production of highly customised products (Mourtzis et al., 2022; Razvadovskaya, 2020). Industry 5.0 represents a further evolution, emphasizing personalization with a human-centric approach. Building on the digital advancements of Industry 4.0, this phase focuses on combining human creativity and craftsmanship with advanced technologies to produce goods that are sustainable, resilient, and tailored to individual needs, underscoring a shift towards sustainability and enhanced human well-being in industrial production (Mourtzis et al., 2022; Razvadovskaya, 2020).

Throughout the successive stages of industrial development, the interaction between digitalisation, collaborative practices, and organisational structures has been instrumental in shaping both economic outcomes and production systems. From the mechanisation of Industry 1.0 to the human-centred and sustainability-focused approach of Industry 5.0, the evolution of industry reflects a progressive integration of technology with societal and human values, supporting not only economic growth but also social and environmental sustainability (Mathur et al., 2022; Mourtzis et al., 2022; Razvadovskaya, 2020).

2.2.2 Key Features of Industry 5.0: Integration of Cyber-Physical Systems, AI, and Human-Centric Technologies

Industry 5.0 marks a crucial evolution in the industrial paradigm, characterized by its integration of advanced technologies with a human-centric approach in manufacturing and production systems. This stage has emerged in response to the shortcomings of Industry 4.0, particularly its limited capacity to satisfy increasing demand for personalised manufacturing. Industry 5.0 places greater emphasis on human empowerment within production processes, promoting a framework in which personalised manufacturing becomes an integral, standard practice rather than an exception (Akundi et al., 2022).

A distinctive aspect of Industry 5.0 is its approach to combining human intelligence and creativity with the capabilities of robots and artificial intelligence. This collaboration is envisioned to work synergistically, with technology and humans

complementing each other's strengths, thereby creating more job opportunities rather than displacing the workforce. This approach seeks to deliver manufacturing solutions that are both efficient and customised to meet user preferences, highlighting the critical role of human creativity within production processes (Maddikunta et al., 2022; Nahavandi, 2019).

The characteristics defining Industry 5.0 include resilience, sustainability, and a strong focus on human-centricity. It places a premium on collaborative efforts, communication, and automation, underpinned by advanced data analytics. This phase is not merely about technological advancement but also about ensuring that such progress translates into societal well-being and sustainability (Ivanov, 2023). The shift towards a more human-centric industry is further emphasized in the transition from Industry 4.0 to Society 5.0, highlighting the increasing importance of integrating societal needs and values into the industrial ecosystem (Mourtzis et al., 2022).

Furthermore, Industry 5.0 seeks to redefine the role of workers within the industrial sector, advocating for a shift in research and development aims from solely focusing on sustainability to incorporating human-centricity. This involves addressing societal concerns associated with digital transformation and ensuring stakeholder involvement in governance processes. The concept of personalization extends into labor relations, proposing individualized professional development trajectories for employees, thereby enhancing human value through effective human-machine collaboration (Ghobakhloo et al., 2023; Zizic et al., 2022).

The framework of Industry 5.0 also envisions the development of parallel industries characterized by cyber-physical-social intelligence, known as the "6S"—safety, security, sustainability, sensitivity to privacy, service for all, and overall smartness. This multidimensional strategy seeks to align technological progress with key principles such as security, privacy, inclusivity, and intelligence, thereby establishing a foundation for a sustainable and resilient industrial future (Wang et al., 2023).

2.2.3 Current State of the Swiss Manufacturing Sector in the Context of Industry 5.0

The Swiss manufacturing sector is at the forefront of embracing the transformative principles of Industry 5.0, characterized by an emphasis on personalization, sustainability, and enhanced human-machine collaboration. This sector's evolution is particularly notable in its concerted efforts towards improving energy efficiency (EE) and reducing carbon dioxide (CO_2) emissions, signifying a pivot towards a more sustainable and efficient production paradigm. A notable stride has been made in the paper sector, leading the way with an annual EE improvement of 3.3%, followed closely by the minerals and food sectors (Zuberi and Patel, 2017). This progress underscores the sector's dedication to energy conservation and environmental stewardship. However, the chemical and metal sectors have displayed a stagnation in EE advancements, highlighting areas where further efforts are needed (Zuberi and Patel, 2017). The Swiss regulatory system, encompassing mechanisms such as target agreements, is instrumental in promoting the implementation of energy efficiency measures across multiple sectors, illustrating how policy interventions can effectively support the achievement of sustainability objectives (Zuberi and Patel, 2017).

In the realm of the metals sector, a significant contributor to the country's total final energy demand, analyses reveal the potential for a 19% improvement in technical EE. The economic feasibility of these improvements ranges between 11% and 15%, with a noteworthy potential for economic CO_2 abatement pegged at 6% (Bhadbhade et al., 2019). The rolling process emerges as a prime candidate for technical final energy (TFE) savings within this sector, indicating specific areas where targeted interventions can yield substantial energy savings (Bhadbhade et al., 2019). The cement sector, which is both a major energy consumer and a significant source of greenhouse gas emissions, has been estimated to offer potential reductions of approximately 14% in final energy consumption and 13% in CO_2 emissions (Zuberi and Patel, 2017). Nonetheless, the realization of this potential is impeded by techno-economic challenges, such as the low prices of energy and CO_2, which dilute the incentives for adopting best practices. The implementation of a CO_2

tax is suggested as a mechanism to stimulate the adoption of carbon capture and storage technologies, which could contribute to a substantial decrease in emissions (Zuberi and Patel, 2017).

Innovation in Swiss industry extends beyond physical product improvements to encompass a strategic focus on software development, highlighting the creation of complex offerings that integrate a greater proportion of services and specialised expertise (Hotz-Hart, 1989). Adopting this strategic focus is essential for maintaining competitiveness in the global market. In the Swiss manufacturing sector, the effects of import competition have been relatively limited, producing only minor impacts on employment levels and wage growth (Suarez, 1999). Despite this resilience, the sector's continuous adaptation to the evolving global market dynamics remains imperative.

2.2.4 High Labor Costs in the Swiss Manufacturing Sector

Understanding labour dynamics is crucial when examining the impact of Industry 5.0 on the Swiss manufacturing sector. In this era, characterised by the integration of advanced technologies with human-centred approaches, labour costs in Switzerland represent a significant consideration. By 2016, the cost of skilled labour had reached $59.98 per hour, reflecting the value placed on expertise necessary for the complex applications associated with Industry 5.0 (European Commission (EURES), 2025). This expenditure is not simply a reflection of high wages but represents a strategic focus on quality and innovation, demonstrating Switzerland’s approach to leveraging human expertise alongside technological advancements to maintain global competitiveness and drive innovation in manufacturing.

2.2.5 Challenges and Opportunities for Swiss Manufacturing Firms Transitioning to Industry 5.0

A clear understanding of labour dynamics is essential for analysing the effects of Industry 5.0 on the Swiss manufacturing sector. In this era, defined by the convergence of advanced technologies and human-centred approaches, labour costs in Switzerland are a

key consideration. By 2016, the hourly cost of skilled labour had risen to $59.98, reflecting the premium placed on the expertise required for the complex tasks associated with Industry 5.0 (European Commission (EURES), 2025). This level of investment extends beyond high wages, signalling a strategic emphasis on quality and innovation, and illustrating how Switzerland leverages human expertise alongside technological advancements to sustain global competitiveness and foster innovation in manufacturing.

The transition to Industry 5.0 necessitates the integration of advanced technologies, including collaborative robots (cobots), augmented reality, and adaptable workstations, to enable the Operator 4.0 concept. This shift requires modifications to conventional production strategies and supply chain management practices (Panetto et al., 2019). It also requires resilient digital manufacturing networks and collaborative control systems with adaptability and self-organization enabled by intelligent agents (Panetto et al., 2019).

The shift towards Industry 5.0 presents substantial challenges for firms, especially in identifying and leveraging the opportunities initially introduced by Industry 4.0. Successfully navigating this transition requires the development of new capabilities and the restructuring of existing production processes (Jayashree et al., 2019). A significant shift is required from hardware development towards a more pronounced focus on software, complex product offerings, and service provisions. This shift entails a reduced reliance on raw materials and environmental commodities, reflecting a broader trend towards dematerialization and sustainability (Hotz-Hart, 1989).

The transition also heralds unprecedented opportunities for innovation, notably in the realm of sustainable manufacturing practices such as the implementation of closed-loop supply chains (Panetto et al., 2019). The changing industrial landscape affords the possibility of developing modular and adaptable models and systems that are conducive to modification and self-adaptation. Such a milieu fosters a fertile ground for innovation, enabling Swiss manufacturing firms to pioneer novel solutions and processes (Panetto et al., 2019).

2.2.6 Government Policies and Incentives in Switzerland Supporting the Transition to Industry 5.0

Switzerland's framework of government funding and support for small and medium-sized enterprises (SMEs) provides a strong foundation for advancing the transition to Industry 5.0, reflecting the nation's commitment to fostering innovation and technological progress within the manufacturing sector. This framework incorporates a range of policies and incentives designed to accelerate the shift towards a human-centred, sustainable, and technologically sophisticated industrial environment, highlighting the strategic role of government in guiding the evolution of industry.

The Swiss financial support system is also notable for its adaptability and resilience, allowing the country to respond effectively to economic crises and global market fluctuations. Combined with a robust banking sector and an advanced scientific and educational infrastructure, this environment promotes the integration of academic and industrial sectors, speeding the commercialisation of research and development (Victoria, 2020). Such collaborative synergies are particularly vital in the Industry 5.0 era, where the seamless interaction between human expertise and intelligent machines is essential for maintaining competitiveness and driving innovation.

Additionally, the Swiss public sector's digital transformation initiatives aim to establish a digital ecosystem that enhances public services for citizens and businesses. By emphasizing operational efficiency, cost optimization, and the development of 'smart government' initiatives, Switzerland is establishing a foundation for the effective integration of emerging technologies essential to Industry 5.0 (Mettler, 2019). These efforts highlight the government's role in fostering a conducive environment for digital innovation, a cornerstone of the transition to Industry 5.0.

Switzerland's ambitious targets for reducing greenhouse gas (GHG) emissions under the Paris Agreement demonstrate the country's strong commitment to sustainability, a core principle of Industry 5.0. The government has implemented policies to phase out fossil-fuel-based heating systems in the residential sector by 2050, reflecting a broader shift towards environmentally sustainable industrial and energy practices

(Nägeli et al., 2020). Through a combination of regulatory measures and financial incentives, these initiatives highlight the importance of integrating industrial policy with environmental objectives, supporting a comprehensive and sustainable approach to the adoption of Industry 5.0.

Switzerland's experience with energy transition policies, particularly the modelling of national scenarios for renewable energy support and nuclear phase-out strategies, provides important lessons on balancing sustainability, affordability, and energy security (Weiss et al., 2021). This comprehensive approach is crucial for tackling the decarbonisation challenges associated with Industry 5.0, highlighting the necessity of strategic policy-making that accounts for long-term economic and societal impacts.

In summary, Swiss government policies and incentive structures are central to enabling the transition towards Industry 5.0 (Department of Education, 2012). Through the development of a strong financial support framework for SMEs, the advancement of digital transformation within the public sector, the promotion of sustainability initiatives, and the encouragement of renewable energy integration, Switzerland demonstrates how coordinated policy action can drive the shift towards a more innovative, sustainable, and human-centered industrial model (Cryptopian News, no date). These measures not only strengthen national competitiveness but also provide practical insights for other countries seeking to adopt the principles underpinning Industry 5.0.

2.2.7 Comparative Analysis: Readiness of Swiss Manufacturing Versus Other Leading Manufacturing Nations for Industry 5.0

A comprehensive evaluation of Swiss manufacturing's readiness for Industry 5.0, particularly in comparison with other advanced industrial economies, requires consideration of multiple interrelated dimensions. The evolution towards Industry 5.0—marked by the integration of emerging technologies with a strong human-centric orientation—extends beyond technological adoption alone. It also necessitates sustained innovation capacity, adaptive organizational structures, and supportive institutional

environments. Accordingly, readiness must be analyzed through a combination of digital capability, innovation strength, and structural flexibility.

Switzerland performs strongly in digital infrastructure, a critical enabler of Industry 5.0, as demonstrated by its favourable ranking in the “Digital Infrastructure” category (Peytremann-Bridevaux, 2021). This digital ecosystem supports the implementation of advanced manufacturing technologies, including the Internet of Things (IoT), big data systems, and cloud-based solutions, which support the readiness to create a solid platform for industrial digitalization. (Adekitan, 2025). An examination of Industry 4.0 adoption across EU countries underscores the significance of robust digital infrastructure and advanced analytical capabilities for managing big data, identifying these as two key dimensions indicative of preparedness for Industry 5.0 (Castelo-Branco et al., 2019). By extension, these factors are also vital for Industry 5.0, suggesting that while Switzerland is on solid ground with its digital infrastructure, the broader readiness involving organisational flexibility and innovation capability may require further enhancement.

Moreover, the Swiss healthcare system's readiness for integrated care provides an interesting parallel. Despite a solid digital infrastructure, the overall readiness for integrated care was evaluated as rather low, with significant variation across different dimensions (Peytremann-Bridevaux, 2021). This suggests potential gaps in organizational agility and stakeholder engagement that could similarly impact the Swiss manufacturing sector's readiness for Industry 5.0.

In comparison, the analysis of readiness assessments across different regions, including Taiwan and the broader EU, emphasizes the significance of a holistic approach that includes not just technological advancements but also emphasizes organizational, innovation, and human resource development aspects (Lin et al., 2020; “Modeling and Simulation of Production Systems to Evaluate the Effect of Worker Turnover on Productivity,” 2021; Pacchini et al., 2019). For example, an Industry 4.0 maturity assessment in Taiwan found that most companies were either at an immature or partially mature stage, indicating a substantial need to enhance their transformation strategies (Lin

et al., 2020). This mirrors the challenges that Switzerland might face despite its technological infrastructure strengths.

Therefore, while Switzerland demonstrates a strong foundation in digital infrastructure, comparative analyses suggest the need for a more holistic readiness approach. This involves strengthening organizational agility, fostering innovation capabilities, and actively engaging stakeholders to facilitate a balanced transition to Industry 5.0, integrating technological advancements with human-centred approaches and organisational innovation strategies (Castelo-Branco et al., 2019; Fang et al., 2020; Lin et al., 2020; Peytremann-Bridevaux, 2021).

2.3 Cost of Vacancy in Manufacturing

2.3.1 The Impact of High Vacancy Rates on Operational Efficiency and Competitiveness

The relationship between elevated employee vacancy rates and firms' operational efficiency is multifaceted and has attracted significant scholarly attention. Research indicates a clear negative association between employee turnover and productivity, especially in contexts where organizations employ high-involvement work practices (Guthrie, 2001). This underscores the criticality of retaining skilled employees to uphold operational efficiency. The loss of experienced personnel not only disrupts the workflow but also imposes additional costs related to recruitment, training, and the acclimatization of new hires to the organizational culture and operational standards. Moreover, the dynamics of labor turnover present a nuanced picture, suggesting that turnover may enhance firm performance under certain conditions, such as in labor markets where wages are determined through negotiations rather than being unilaterally set by employers (Brown et al., 2009). This observation points to the complex interplay between wage-setting mechanisms, employee turnover, and organizational efficiency, highlighting the influence of external factors such as union presence.

The efficiency wage model offers further insights, positing that the anticipation of higher turnover costs incentivizes firms to offer superior wages to reduce quit rates

(Campbell, 1993). By elevating wages, firms not only attract but also retain talent, thereby mitigating the adverse effects of high turnover on operational efficiency. This strategic approach underscores the trade-offs firms navigate to balance between turnover costs and wage expenses in pursuit of optimal efficiency.

In addition to turnover, the extent to which employee vacancies influence operational efficiency is compounded by the presence of work limitations among staff. Employee-reported physical or mental health problems have been linked to significant reductions in work productivity (Lerner et al., 2003). This connection emphasizes the exacerbating effect of vacancies or inadequate staffing on operational efficiency, particularly when employees face health-related work limitations. Ensuring sufficient staffing levels thus emerges as a crucial concern for maintaining productivity and efficiency in the face of such challenges.

High employee vacancy rates present a significant challenge to the competitiveness of firms, intertwining with various aspects of labor market dynamics, the psychology of employee turnover, and the strategic responses of firms to these conditions. This complex issue has been dissected through diverse academic lenses, yielding insights into how vacancies influence a firm's competitive edge. The extant research elucidates that factors such as age, tenure, job satisfaction, and commitment play crucial roles in employee turnover, directly impacting a firm's stability and performance (Mobley et al., 1979). This turnover not only disrupts operational continuity but also erodes the institutional knowledge and cohesion necessary for sustained competitive advantage.

The relationship between job vacancies and inter-firm competition reflects a complex dynamic in which high levels of unfilled positions can influence organisational competitiveness in different ways. Outcomes depend largely on prevailing labour market conditions and the strategies firms employ, which may either enhance or hinder performance (Fahr and Sunde, 2005). In the case of tight labour markets, firms often challenged with the rising costs and difficulties in securing and retaining skilled workers. Furthermore, employees' tendency to search for new opportunities while employed contributes to fluctuations in labour supply, further affecting a firm's capacity to maintain

a capable workforce (Fahr and Sunde, 2005). These patterns highlight the necessity of proactive workforce planning and the importance of offering compelling incentives to attract and retain talent.

The concept of wage-vacancy contracts and coordination frictions elucidates another layer of complexity, indicating how these mechanisms influence a firm's competitiveness by shaping its ability to attract and retain talent (Jacquet and Tan, 2012). Effective management of these contracts and frictions can serve as a lever for firms to enhance their appeal to high-caliber candidates, thus maintaining or augmenting their competitive positioning. Furthermore, the overall condition of the labour market, including the supply of unemployed workers and the number of job vacancies, influences firms' employment patterns in diverse ways (Stadin, 2023). This interplay highlights the need for firms to be agile and responsive to labor market trends in order to optimize their employment strategies.

Interestingly, the entry of competitors into the market can catalyze employment and wage growth in incumbent firms, indicating that competitive pressures can, paradoxically, foster positive outcomes for job and wage expansion (Majumdar, 2015). This dynamic suggests that competition can be a catalyst for enhancing a firm's competitive stance through strategic investments in human capital.

2.3.2 Factors Contributing to High Costs of Vacancy in Swiss Manufacturing Firms

From an economic perspective, the impact of employee vacancies in Swiss manufacturing firms is significant due to the high costs of recruiting and integrating new staff, costs deepened by the structural and operational features of the labour market. This requires a thorough review of the factors that contribute to these costs.

A major component of vacancy costs is hiring expenditure, which for skilled workers in Switzerland amounts to roughly 16 weeks of wages. Post-hiring costs—covering the initial productivity decline and formal training—represent 53% of total expenses. Disruption costs resulting from informal on-the-job guidance account for 26%, while pre-hiring expenses, such as recruitment activities, account for 21% (Mühlemann

and Strupler Leiser, 2018; Mühlemann and Strupler, 2015). This detailed breakdown highlights the complex nature of vacancy-related costs and the considerable investment of time and resources required to bring new employees up to full productivity.

Labour market complexities play a significant role in shaping hiring costs, particularly through market tightness, which can be measured using the vacancy-to-unemployment ratio. This ratio, representing the balance between labour supply and demand, is positively linked to search costs, a relationship observed both across different firms and over time (Mühlemann and Strupler, 2018; Mühlemann and Strupler, 2015). The effects of this dynamic are considerable, highlighting the increased challenges and expenses associated with recruiting in specialized labor markets, where competition for skilled workers is especially strong. Importantly, small firms bear a disproportionate share of these hiring costs, as they are more vulnerable to shifts in labour market conditions (Mühlemann and Strupler, 2015). This sensitivity emphasizes a broader economic reality: smaller organizations encounter greater hurdles in the recruitment process, amplified by competitive pressures and tight labor market conditions in Switzerland.

2.3.3 Case Studies and Examples of Vacancy Cost Impacts in Similar Industrial Contexts

The economic consequences of employee vacancies across sectors highlight how these costs affect broader economic patterns and labour-market behaviour. Evidence from multiple case studies offers a detailed perspective on the effects of vacancy costs, highlighting the intricate interplay among economic cycles, employer strategies, and prevailing labour market conditions.

A model exploring the cyclical nature of the value of vacant positions reveals that firms encounter sunk costs upon entering the production process, which leads to a countercyclical value of vacancies. This fluctuation significantly impacts the division of surplus between workers and firms, offering a lens through which income share movements during business cycles can be characterized (E. Shao and Silos, 2013). This case study underscores the intrinsic connection between the cost of vacancies and broader

economic fluctuations, emphasizing the strategic considerations firms must navigate within varying economic contexts.

The COVID-19 pandemic triggered a substantial decline in job vacancies, with numbers falling by over 40% in late April relative to the beginning of the year. This decrease affected multiple states, industries, and occupations across the U.S., though essential sectors were less impacted (Jialin, 2024). The pandemic's economic impact was felt widely, including in areas without stay-at-home mandates, illustrating how such shocks can uncover entrenched structural weaknesses that go beyond the reach of short-term policy responses (Forsythe et al., 2020; Silva and Toledo, 2009a). This situation highlights the potential volatility of vacancy-related costs amid global crises and underscores the need for resilience and flexibility in labour-market strategies.

In environments characterized by high search costs, employers may resort to lowering hiring standards, particularly for temporary roles, to mitigate the immediate impacts of vacancies. This strategy, while potentially beneficial in the short term, incurs risks associated with match termination and underqualification, especially when applied to permanent positions (Brenčič, 2009). This case illustrates the delicate balance firms must strike between the urgency to fill vacancies and the long-term implications of hiring decisions on productivity and turnover costs.

Integrating Post-Match Labour Turnover Costs (PMLTC) into standard search-and-matching models reveals heightened sensitivity of vacancy value to productivity shocks. This sensitivity leads to greater fluctuations in the vacancy count and a higher equilibrium unemployment rate (Silva and Toledo, 2009b). This finding highlights the pivotal role of PMLTC in producing realistic cyclical patterns in vacancies and unemployment, emphasising the importance of effectively managing post-hire expenses and employee turnover.

The role of job search costs in labor market dynamics is multidimensional, deterring employment while incentivizing worker effort due to the looming threat of job loss (Zapechelnyuk and Zultan, 2020). However, a reduction in these costs below a certain threshold can paradoxically lead to decreased productivity, labor market

participation, and overall welfare. This case sheds light on the complex implications of job search costs, suggesting that their management is crucial for balancing labor market efficiency and welfare.

2.3.4 The Role of Digital Transformation in Influencing Vacancy Costs, With a Focus on Remote Work and Digital Skill Requirements

Digital transformation significantly influences vacancy costs, especially through the lens of remote work and the escalating demand for digital skills in the workforce. This transformation is reshaping the employability landscape, making digital competencies crucial for job performance and career advancement. The intersection of digital transformation and remote work has shifted the paradigm for defining job roles and requirements, directly affecting the costs of filling vacancies.

An in-depth study into the competencies required of future marketing professionals underscores the transformative impact of digital technologies on career pathways. It proposes a structured framework of five main skill areas, identifying 29 specific skills and competencies important for navigating the digital marketing landscape effectively. By examining differences between firms with low and high levels of digital adoption, the research highlights the evolving demands of the profession. This framework serves as a practical guide for graduates, educational institutions, and companies to implement a workforce equipped with digital capabilities, thereby reducing recruitment inefficiencies by ensuring candidates possess the necessary skills from the start (Di Gregorio et al., 2019).

Further amplifying the discourse on digital skills and job performance, a study conducted in Lima, Peru, explores this relationship within the context of remote work. Employing exploratory and confirmatory factorial analysis, the study establishes a positive correlation between digital skill development and job performance in remote settings. The findings underscore the significance of digital proficiency in enhancing job performance, suggesting that the cultivation of digital skills is instrumental in optimizing remote work outcomes. This correlation highlights the imperative of ongoing professional

development in digital skills to reduce vacancy costs. Enhanced digital competencies enable a smoother transition to remote work modalities, thus attracting a wider talent pool and decreasing the time and resources expended in filling vacancies (Emperatriz and Yudet, 2022).

These studies summarize the emphasize the crucial role of digital transformation in shaping the future workforce. They advocate a proactive approach to aligning educational and professional development programs with the digital skills required by remote work. This alignment is crucial for minimising vacancy costs, as it ensures the workforce is equipped with the necessary digital skills, thereby facilitating quicker, more efficient job placements in a digitally transformed work landscape (Amee and Nachtmann, 2025).

2.3.5 Quantitative Models Estimating the Cost of Vacancy in High-Tech Industries, Including Predictive Factors

In high-technology sectors, assessing the cost of vacancies has become increasingly important due to the substantial financial burden of recruiting skilled personnel and the specialized nature of these positions. Evidence from Switzerland indicates that the average cost of hiring a worker is approximately 16 weeks of wages, with significant contributions coming from post-match recruitment expenses and the costs associated with workflow disruptions (Muehlemann and Strupler Leiser, 2018). This insight is particularly relevant for high-tech industries, where the need for formal training and the initial low productivity of new hires can significantly increase vacancy costs.

The association between labour market tightness and the cost of hiring becomes evident as search costs escalate with rising v/u ratios (Muehlemann and Strupler Leiser, 2018). These insights underscore the importance of understanding labour-market behaviour when addressing vacancy management in high-tech industries. In the context of IT workers, a study of German firms found that vacancy rates are not primarily driven by high turnover, but rather by the creation of new positions, with the adjusted job vacancy rate for IT workers varying significantly between the ICT and non-ICT sectors (Falk,

2003). The specific challenges in high-tech industries' recruitment stem from factors such as firm size, the proportion of ICT staff, and past strategies to alleviate labour shortages, which shape vacancy patterns (Falk, 2003).

The cost implications of using alternative predictors for job performance further complicate the vacancy cost estimation in high-tech industries. For instance, substituting job performance predictors can lead to substantial costs, with hiring based on ability alone having significant utility but potentially adverse effects on minority groups (Hunter and Hunter, 1984). This complexity is indicative of the complex nature of vacancy costs in high-tech industries, where the selection process not only impacts financial aspects but also organizational diversity and inclusivity.

Applications of machine learning and data mining in predictive modelling have demonstrated considerable accuracy in anticipating future vacancy risks (Appel et al., 2014). For high-tech firms, these predictive tools allow a proactive interventions and data-driven policy planning, replacing reactive measures with a systematic approach to identify, anticipate, and mitigate the underlying drivers of vacancy costs.

2.4 Global Trending Manufacturing Upskilling

2.4.1 A Review of Global Trends in Upskilling Within the Manufacturing Sector, Identifying Best Practices and Lessons Learned

The importance of upskilling in manufacturing is increasing as firms contend with the technological implications of the Fourth Industrial Revolution. Developing employee skills strategically addresses the demands of a labor market shaped by AI, cyber-physical systems, and advanced manufacturing technologies (AMT), emphasizing adaptability, digital proficiency, and continuous learning. Drawing on recent research, this review distills best practices and practical insights for implementing successful upskilling initiatives in the sector.

The integration of AI and the broader shift towards Industry 4.0 have highlighted the necessity of upskilling employees to fully leverage human–machine collaboration. Research in India's information technology sector emphasizes the importance of

developing competencies such as data analysis, digital literacy, complex cognitive skills, decision-making, and continuous learning to prepare employees for AI adoption (Jaiswal et al., 2022). Likewise, rapid technological changes in the manufacturing sector underscore the need for education and training programs that can efficiently equip workers with the skills needed at different levels of proficiency (Doherty and Stephens, 2021).

The pandemic-induced acceleration of digitalization and automation has further accentuated the need for upskilling. The transformation observed in the work practices of leading auto manufacturers in Chennai, India exemplifies how technology, automation, and digitalization serve as catalysts for upskilling, ultimately enhancing job satisfaction, employee retention, and productivity (Sundarrajan and Krishnan, 2023). Moreover, the imperative for sustainable workforce development is highlighted by the increasing pace of technological advancements, which outstrip the traditional timelines for completing tertiary qualifications, necessitating in-service training initiatives as a critical endeavor for both the private and public sectors (van Coller et al., 2021).

Best practices of upskilling within the manufacturing sector include the implementation of accelerated reskilling programs characterised by rapid, shorter bursts of work-based learning (WBL) and hands-on training. Such initiatives are essential for facilitating the movement between different skill levels and are particularly crucial in SMEs (Doherty and Stephens, 2021). Furthermore, empirical research has shown that the adoption of new technologies and innovative work practices is positively associated with employee upskilling, demonstrating that the use of information and communication technologies (ICT), advanced manufacturing technologies (AMT), and innovative work practices can enhance workforce competencies (Bayo-Moriones et al., 2008).

Global and nationwide programs such as Germany's Industry 4.0 initiative and China's Made-in-China 2025 strategy exemplify deliberate efforts to establish leadership in integrated industrial and manufacturing capabilities. These initiatives highlight the critical importance of combining emerging technologies with workforce upskilling to fully harness the opportunities presented by Industry 4.0 (Da Xu et al., 2018).

2.4.2 Analysis of the Impact of Global Supply Chain Dynamics on the Need for Upskilling in Swiss Manufacturing Firms

Manufacturing firms are increasingly affected by the complex structure of international supply chains, where interdependencies and coordination challenges directly impact business outcomes. Recognizing these effects is essential for assessing performance implications and determining how workforce development strategies should adapt. This empirical research analysed the consequences of supply chain complexity for Swiss manufacturers, highlighting the competencies required to manage such environments effectively.

Research investigating the electronics sector in the Republic of Ireland provides foundational insights into the relationship between supply chain dynamics and manufacturing performance. The study's utilisation of structural equation modelling to assess data from 200 suppliers underscores the significance of competencies in negotiation, conflict management, and problem-solving. These skills are crucial in addressing cost and quality dimensions of manufacturing performance, albeit with less pronounced effects on flexibility and delivery. This delineation of impact highlights the nuanced challenges that complex supply chain relationships present, necessitating targeted upskilling efforts to bolster these specific competencies (Fynes et al., 2005).

Further empirical analysis, encompassing data from 209 plants across seven countries, delineates the adverse effects of supply chain complexity on plant performance. This research distinguishes between dynamic complexity, which significantly hampers performance, and detail complexity, illustrating the varied nature of supply chain challenges. The study's findings highlight the importance of operational strategy and organizational design in mitigating the detrimental effects of supply chain complexity. For Swiss manufacturing firms, this translates into a strategic imperative to cultivate an understanding of supply chain dynamics and foster skills that enhance flexibility and lean production capabilities (Bozarth et al., 2009).

The synthesis of these findings illuminates the critical need for Swiss manufacturing firms to prioritize upskilling initiatives that address the challenges posed

by global supply chain dynamics. Upskilling in negotiation, conflict resolution, and problem-solving emerges as a strategic necessity to improve cost and quality performance metrics. Concurrently, an acute awareness of the types of supply chain complexity and their disparate impacts on performance can guide the development of operations strategies and organizational structures adept at navigating the complexities of the global supply chain environment.

2.5 The Role of Upskilling in Reducing Cost of Vacancy

2.5.1 Definition and Importance of Upskilling in the Context of Industry 5.0

The advent of Industry 5.0 marks a crucial evolution in the industrial domain, spotlighting the symbiotic relationship between human creativity and machine intelligence to foster resource-efficient and consumer-preferred manufacturing outcomes. This paradigm shift, while building on the technological strides of Industry 4.0, underscores the indispensability of human insight and creativity in the production matrix, thereby amplifying the imperative for workforce upskilling.

In the era of Industry 5.0, the workforce is required to possess an enhanced skill set that enables effective collaboration with advanced technologies. Upskilling, thus, emerges as a fundamental strategy for organizations aiming to equip their employees with the requisite competencies to navigate the complexities of this new industrial landscape. This process encompasses the cultivation of skills such as data analysis, digital literacy, complex cognitive abilities, decision-making, and an ethos of continuous learning. Such proficiencies are critical in ensuring that employees augment rather than become overshadowed by the capabilities of intelligent machines (Jaiswal et al., 2022).

The transition from Industry 4.0 has already underscored the necessity for higher skill levels within the workforce. Organizations are encouraged to proactively facilitate the upskilling and reskilling of their employees to safeguard competitiveness and job security. Experiential training methodologies are advocated as an effective approach to cultivating the advanced skills pertinent to Industry 4.0, a practice expected to hold even greater relevance in the forthcoming Industry 5.0 era (Maisiri and van Dyk, 2021).

The ripple effects of this industrial transformation extend beyond manufacturing, influencing sectors such as logistics and supply chain management. These realms, too, confront a paradigm shift necessitated by automation and the advancements heralded by the fourth industrial revolution. Upskilling and reskilling are deemed crucial for bolstering employee competitiveness and achieving cost-effectiveness over the long term. Emphasis is placed on both technical and human skills, supported by initiatives like the Human Resource Development Fund (HRDF), to engender a digital culture and fortify local expertise (Wahab et al., 2021).

The discourse on upskilling in the context of Industry 5.0 accentuates a strategic shift towards harmonizing human ingenuity with machine efficiency. It advocates for a proactive stance on learning and development, ensuring the workforce is primed to contribute to and derive benefits from the novel advancements in manufacturing and allied industries. This comprehensive approach to workforce upskilling goes beyond reacting to technological changes, serving instead as a proactive strategy to position human labour as a central element within the Industry 5.0 ecosystem (Jaiswal et al., 2022; Maddikunta et al., 2022; Maisiri and van Dyk, 2021; Wahab et al., 2021).

2.5.2 Review of Upskilling Programs Focused on Industry 5.0 Technologies

The intersection of human creativity with advanced technologies defines the ethos of Industry 5.0, heralding a new era of sustainability and personalized production methodologies. This evolution necessitates a workforce proficient in emerging skills and technologies, catalyzing a proliferation of upskilling programs designed to meet these demands. This review aggregates insights from recent literature to evaluate the effectiveness and scope of upskilling initiatives tailored to Industry 5.0 technologies.

The integration of AI and other advanced technologies into the workplace underscores a shift from routine tasks to creative and complex cognitive engagements. This transition has engendered a critical need for upskilling, particularly in enhancing data analysis, digital literacy, complex cognitive abilities, decision-making, and continuous learning skills. Such upskilling initiatives are paramount in equipping employees to

complement rather than compete with intelligent machines (Jaiswal et al., 2022). The COVID-19 pandemic accentuated the criticality of digital competencies across various sectors, notably education. Upskilling programs, especially those adopting a blended learning approach, have shown significant efficacy in cultivating digital competencies among professionals, preparing them for unforeseen challenges and future job markets (ElSayary, 2023).

As the manufacturing sector transitions from Industry 4.0 to 5.0, the demand for a highly skilled workforce becomes more pronounced. Proposed models emphasize the need for training programs to adapt to technological trends, ensuring that job profiles align with the evolving skill requirements. These models highlight connectivity and data value as crucial elements in shaping new job profiles and corresponding upskilling pathways (Pontes et al., 2021). The rise of information and communication technologies (ICT), including the Internet of Things, cloud computing, and intelligent robotics, highlights the need for practical, hands-on learning modules to support effective upskilling. Experiential learning of this kind is essential for the successful adoption and deployment of both Industry 4.0 and 5.0 systems, emphasising the role of lifelong learning and ongoing skill development (Oliveira et al., 2022).

Insights from interviews with senior managers in manufacturing firms indicate an urgent demand for accelerated reskilling and work-based training programs, especially within SMEs. These programs are critical for rapidly equipping employees with the competencies required to meet the fast-paced technological demands of Industry 5.0 (Doherty and Stephens, 2021). In the logistics and supply chain sectors, the shift towards automation and advanced operations necessitates comprehensive upskilling and reskilling programs. These programs, underscored by the initiatives of the HRDF, are essential for enhancing employee competitiveness and long-term cost-effectiveness (Wahab et al., 2021).

A structured framework for developing personalised upskilling programs integrates large language models (LLMs) with human-centred principles. This methodology enables training initiatives to be customised according to individual learning

requirements and organisational goals, fostering a culture of ongoing improvement and adaptability (Fraile et al., 2023). The necessity for a learner mindset among engineers to adapt to continuous technological advancements is emphasized. Proposed frameworks for collaboration among universities, industry, and government advocate for the cultivation of a "learn to learn" ethos, preparing engineering students and professionals for lifelong learning and adaptability (Chakrabarti et al., 2021).

2.5.3 Empirical Evidence on the Effectiveness of Upskilling in Reducing Vacancy Cost

The contemporary labor market dynamics underscore a crucial examination: Does employees' upskilling efficaciously mitigate vacancy costs? This inquiry is imperative against the backdrop of rapid technological advancements and the consequent paradigm shift in skill requirements. The synthesis of relevant literature elucidates diverse perspectives, underpinning a deep understanding of upskilling's impact on vacancy costs.

The introduction and adoption of AI in the workforce herald a scenario in which routine tasks are increasingly automated, necessitating employees to engage in more creative and complex cognitive tasks. This shift highlights the critical role of upskilling, with competencies such as data analysis, digital literacy, advanced cognitive skills, decision-making, and continuous learning identified as essential for employees (Jaiswal et al., 2022). Upskilling, therefore, emerges as an indispensable strategy for enhancing workforce adaptability and mitigating vacancy costs associated with the recruitment of talent possessing these sophisticated skill sets.

Investing in human capital through upskilling programs is posited as a strategic imperative for organizations. Traditional contract theory analysis suggests that investing in worker upskilling, rather than relying on worker self-training, may be more cost-effective due to the informational cost associated with the most flexible workers (Vranceanu and Sutan, 2020). This notion is corroborated by the contention that upskilling programs are instrumental in improving employee performance, productivity, engagement, retention, and career progression (Samuvel and G, 2023). Consequently,

upskilling is not only a mechanism for filling vacancies more efficiently but also a means to foster a more dynamic and competent workforce, potentially reducing the indirect costs associated with vacancy durations.

Vacancy durations, often perceived as a significant component of vacancy costs, merit a nuanced examination. Research indicates that vacancies are typically filled from a pool of applicants formed shortly after the posting, suggesting that the duration of a vacancy more accurately reflects a selection period rather than a search period (van Ours and Ridder, 1992). Therefore, the efficacy of upskilling programs in reducing vacancy durations may hinge on their ability to expedite the selection process by ensuring a ready pool of internally upskilled candidates, thereby diminishing reliance on external recruitment processes.

2.5.4 Case Studies on the Return on Investment of Upskilling Initiatives in Reducing Vacancy Costs Within Swiss Manufacturing Firms

In the Swiss manufacturing sector, upskilling initiatives have emerged as a significant investment in human capital, aiming to enhance worker capabilities and thereby reduce vacancy costs. This investment is not just a financial commitment but also encompasses efforts to support the acquisition of new skills and knowledge. A traditional contract theory analysis suggests that investing in worker upskilling could be more beneficial for firms than relying on workers to pay for their training and compensating them afterwards. This approach indicates that the flexibility afforded by upskilled workers can lead to an informational rent, making investment in upskilling a potentially profitable strategy for companies (Vranceanu and Sutan, 2020).

Furthermore, the synergy between information and communication technologies, new organizational practices, and human capital investment, including upskilling, has been identified as a crucial determinant of firm efficiency and performance. This mutual reinforcement underscores the significance of integrating upskilling into broader strategic initiatives within firmsThe first empirical investigation of its kind in the Swiss business sector, based on an extensive postal survey conducted in 1999, highlights how upskilling,

combined with technology use and organisational practices, contributes to improved firm performance (Arvanitis, 2005).

The strategic implications of upskilling initiatives extend beyond immediate productivity improvements to influence product development and cost reduction efforts. In markets where firms compete over time to reduce costs, investments in developing new products, which indirectly serve as a form of cost reduction, can be viewed through the lens of upskilling. This perspective aligns product development with the broader goal of cost reduction, highlighting the importance of upskilling in achieving efficiency and competitive advantage (Spence, 1986).

Investments in IT within the manufacturing sector, including upskilling initiatives related to IT competencies, have shown significant associations with firm performance. An empirical study examining IT investment and performance in 33 valve manufacturing firms over six years found that strategic investments in transactional IT, often necessitating upskilling in IT-related skills, were linked to improved firm performance. This association underscores the role of upskilling in maximizing the returns on IT investments (Weill, 1992).

These case studies collectively demonstrate the ROI of upskilling initiatives in reducing vacancy costs within Swiss manufacturing firms. By investing in human capital, firms not only enhance their operational efficiency and strategic capabilities but also position themselves to navigate the complexities of the modern business environment more effectively. The emphasis on upskilling as part of a comprehensive strategy to leverage technology and organizational practices further underscores its critical role in sustaining competitive advantage and driving firm performance (Arvanitis, 2005; Spence, 1986; Vranceanu and Sutan, 2020; Weill, 1992).

2.5.5 Analysis of Barriers to Effective Upskilling, Such as Resistance to Change, and Strategies to Overcome These Barriers

In the realm of organizational development, particularly within Swiss manufacturing firms, the challenge of effectively implementing upskilling initiatives is

compounded by barriers such as resistance to change. This resistance is not merely a surface-level inconvenience, but a deeply rooted psychological and organizational phenomenon that can significantly hamper the return on investment (ROI) of upskilling efforts. Understanding and overcoming these barriers is crucial for enhancing workforce capabilities and reducing vacancy costs through effective skill development.

Psychological factors play a crucial role in individual resistance to organizational change. Studies have identified both adaptive and maladaptive defense mechanisms that influence an individual's behavior towards change. Maladaptive mechanisms, such as projection, acting out, and denial, are positively correlated with resisting change. Conversely, the adaptive mechanism of humor is negatively correlated with such resistance, suggesting that interventions addressing these psychological factors can mitigate resistance to upskilling initiatives (Bovey and Hede, 2001).

Strategies customized to tackle specific barriers to change have exhibited varying impacts, emphasizing the significance of context and precision in formulating upskilling initiatives. Tailored interventions, devised to confront prospectively identified barriers, have the potential to enhance care and patient outcomes. Although their effectiveness in professional performance remains uncertain (Shaw et al., 2005). This suggests that a nuanced understanding of barriers, including the identification and prioritization of specific obstacles, is essential for the successful implementation of upskilling programs.

The conceptual analysis of resistance provides further insights into overcoming barriers to upskilling. Resistance, defined as an individual's behavior in response to perceived threats to the status quo, is influenced by factors such as mistrust, fear, and communication barriers. Recognizing resistance as a natural response to change rather than an adversarial force can help leaders manage the phenomenon more effectively. This perspective allows for the utilization of resistance as a resource for change, rather than something to be overcome (DuBose and Mayo, 2020; Ford et al., 2008; Waddell and Sohal, 1998).

Empirical studies on resistance to organizational change have reinforced the need for a holistic approach to managing resistance. Personality traits and the organizational

context are significantly associated with employees' attitudes towards large-scale organizational change, impacting key outcomes such as job satisfaction, organizational commitment, and intention to leave (Oreg, 2006). This underscores the complexity of resistance and the need for strategies that address both individual and organizational dimensions.

2.6 The Role of Artificial Intelligence and Automation in Upskilling

2.6.1 Examination of How AI and Automation Technologies Are Used in the Design and Delivery of Upskilling Programs

The integration of AI and automation technologies in the design and delivery of upskilling programs represents a paradigm shift in workforce development strategies. This transformative approach leverages the capabilities of AI to tailor educational experiences, enhance learning outcomes, and address the dynamic requirements of the modern workplace. By analyzing recent studies, we aim to elucidate how AI and automation are revolutionizing upskilling initiatives, particularly in the context of the manufacturing and engineering sectors.

The integration of AI into upskilling programs enables a personalised learning experience, tailored to employees' individual needs and learning speeds. Technologies such as machine learning (ML), pattern recognition (PR), and deep learning (DL) have shown considerable effectiveness in organising educational content and optimising learning pathways. AI-driven learning tools can adapt curricula dynamically, offer real-time feedback, and pinpoint areas where further development is needed, thereby improving both learning outcomes and knowledge retention (Salehi and Burgueño, 2018).

Automation technologies play a crucial role in the delivery of upskilling programs by streamlining administrative processes and facilitating scalable learning opportunities. The use of AI tools for automating routine tasks in the educational process, such as enrollment, progress tracking, and assessment, significantly reduces the administrative burden on educators. This allows for a more focused effort on content delivery and personalized student engagement. Furthermore, AI-driven analytics offer insights into the

effectiveness of training programs, enabling continuous improvement and alignment with industry demands (Barenkamp et al., 2020).

The significance of AI and automation in upskilling is further highlighted by their potential to bridge the skills gap in the face of rapid technological advancements. AI and automation do more than simply mechanize repetitive tasks; they also generate new roles and opportunities, underscoring the importance of a workforce capable of effectively managing and collaborating with advanced technologies (Acemoglu and Restrepo, 2019). This underscores the necessity for upskilling programs that are responsive to technological trends and capable of preparing employees for future challenges.

Innovative learning systems, such as the AuToMa smart learning system, exemplify the application of AI and automation in designing upskilling programs tailored to the specific needs of SMEs. These systems offer flexible, customizable, and accessible learning solutions, enabling employees to enhance their skills effectively and efficiently. The development of such systems reflects a holistic approach to upskilling, incorporating advanced manufacturing approaches, new knowledge, and skills required in the evolving workplace (Casalino et al., 2019).

2.6.2 Analysis of the Potential for AI to Create New Job Opportunities, Necessitating Upskilling in Areas Not Traditionally Associated with Manufacturing

The advent of AI and automation technologies herald a transformative era in the global workforce, with profound implications for job creation and the requisite upskilling in areas traditionally unassociated with manufacturing. This analysis goes into the potential of AI to not only streamline existing job roles but also to engender entirely new categories of employment, thereby necessitating a paradigm shift in the skill sets required for the modern manufacturing workforce.

AI's impact on technological innovation is wide-ranging, promoting technological advancements through the acceleration of knowledge creation, technology spillover, enhancement of learning, and absorptive capacities. Such innovations are instrumental in

driving sectoral shifts towards higher reliance on low-tech sectors, thereby highlighting the sector heterogeneity in the impact of AI on technological innovation (Liu et al., 2020). This foundational shift underscores the broader implications for employment, where AI's integration into the manufacturing sector catalyzes the need for upskilling in non-traditional areas, emphasizing digital literacy, complex cognitive skills, and continuous learning.

The transformative impact of AI goes beyond simple job automation, representing a dual effect: while certain roles may be displaced, new employment opportunities simultaneously emerge (Ajithkumar et al., 2023). This is particularly evident in the manufacturing sector, where the adoption of AI-driven intelligent manufacturing requires employees to develop a diverse set of skills, including technical expertise, creative problem-solving, and adaptability (B. Li et al., 2017; Liu et al., 2020; S. Shao et al., 2022).

In addition, the advancement of AI and automation technologies drives the creation of jobs that demand a combination of technical expertise, creativity, and social intelligence. This evolving landscape highlights the critical need for lifelong learning and reskilling initiatives to prepare the workforce for the complex requirements of the future labour market (Faishal et al., 2023). The transition towards AI-driven economies compels a reevaluation of traditional employment paradigms, urging organizations to adopt strategic employment strategies focused on skill enhancement, new skill development, and reskilling (Khatri, 2020).

2.7 Human Capital Theory and Upskilling

2.7.1 Overview of Human Capital Theory and Its Relevance to Upskilling

Human Capital Theory (HCT) offers a crucial framework for elucidating the relationship between an individual's accrued skills, knowledge, and experience, and their corresponding economic value. A key principle of this theory is that investing in education and training substantially enhances an individual’s productivity, which can in turn lead to higher earnings and better employment opportunities (Strober, 1990). This

conceptualization holds profound implications for human resource management, advocating for the strategic development of employee capabilities to bolster organizational performance and competitive advantage.

The pertinence of HCT to upskilling initiatives becomes increasingly pronounced amidst rapid technological evolution, notably with the advent of AI. The role of AI in automating routine tasks precipitates an imperative for workforce upskilling, extending beyond mere technological proficiency to encompass advanced cognitive, decision-making, and continuous learning faculties (Jaiswal et al., 2022). The integration of AI within the workplace heralds a paradigm shift in the valuation of skills. Research with seasoned professionals across multinational corporations identifies a quintet of critical skills for upskilling: data analysis, digital literacy, complex cognitive skills, decision-making, and the ethos of continuous learning (Jaiswal et al., 2022). These competencies embody a collaborative interplay between human and machine intelligence, underscoring the potential for mutual enhancement rather than a simple displacement of human roles by AI.

While HCT provides a robust analytical lens for scrutinizing the supply side of the labor market, it is imperative to also consider the demand side, encompassing human resource management practices and governmental policy impacts. Those who challenge HCT advocate for a more nuanced approach to human resource utilization, promoting considerations that account for demographic factors such as race and gender, which may invariably affect earnings and employment trajectories (Strober M. H., 1990).

2.7.2 How Upskilling as an Investment in Human Capital Can Align Skills with Industry 5.0 Demands

The ushering in of Industry 5.0 marks a significant transition towards an era dominated by the synergy of advanced technologies—including AI, robotics, and the IoT—with human ingenuity. This paradigm shift necessitates a workforce adept in new skills, underscoring the crucial role of upskilling as a strategic investment in human capital to fulfil the evolving demands of the industry. The integration of advanced

technologies with human capabilities in Industry 5.0 has created a skills gap, highlighting the need for focused initiatives in strategic workforce development (Brkovic et al., 2023). The gap represents a disconnect between current workforce capabilities and the skills required to leverage Industry 5.0 technologies effectively, highlighting the urgent need for comprehensive upskilling initiatives.

Organizations increasingly acknowledge the intrinsic value of human capital and are committing to reskilling and upskilling initiatives. These endeavors aim to equip their workforce for imminent challenges, including adapting to the gig economy and mastering a novel set of competencies vital for Industry 5.0 (Balakrishnan, 2022). Such initiatives not only enhance the adaptability of employees but also ensure the organization's competitiveness in a rapidly evolving technological landscape. Investments in employee training, notably within the IT services sector, have demonstrated substantial improvements in employee performance. This enhancement is particularly pronounced for employees with extensive experience, attributable to the dynamic nature of IT knowledge and skills (Bapna et al., 2013). Notably, training with applicability beyond the confines of the firm has been correlated with enhanced performance, suggesting the broader utility of generalized training over firm-specific training (Bapna et al., 2013). Furthermore, the implementation of structured competency development programs, emphasizing both domain and technical training, is crucial. These programs should be designed to complement rather than substitute each other, ensuring a holistic enhancement of employee performance (Bapna et al., 2013).

2.7.3 Theoretical and Empirical Studies Supporting the Relationship Between Human Capital Investments and Reduced Vacancy Costs

The relationship between investments in human capital and its impact on reducing vacancy costs has been the subject of extensive theoretical and empirical scrutiny. This body of research elucidates how enhancing human capital—through education, training, and other forms of development—can significantly influence the economic performance

of individuals and organizations, thereby potentially mitigating the costs associated with job vacancies.

Human Capital Theory posits that investments in human capital (e.g., education, training) enhance an individual's productivity, which in turn can lead to higher earnings and better employment opportunities (Benko, 2020). This theory underpins the rationale that well-educated and trained individuals are likely to fill vacancies more efficiently, reducing the duration and associated costs of unfilled positions. The macroeconomic perspective further supports this, suggesting that human capital investment is a critical driver of national economic output, substantiating the link between individual competency development and broader economic growth (Wu and Hang, 2016).

Empirical studies corroborate the theoretical assertions, demonstrating tangible links between human capital investments and organizational performance outcomes. A meta-analysis spanning thirty years of research identified a significant, though modest, link between human capital and organizational success, emphasizing the value of investments in task-specific human capital (Unger et al., 2011). Moreover, studies at the enterprise level indicate a positive relationship between human capital investment and organisational performance, suggesting that these investments enhance both individual capabilities and the broader societal stock of human capital (Wu and Hang, 2016).

Moreover, specific studies focusing on professional service firms have unveiled a curvilinear (U-shaped) effect of human capital on performance, with leveraging human capital showcasing a positive impact (Hitt et al., 2001). This evidence suggests that strategic investments in human capital not only enhance individual and organizational performance but also potentially reduce vacancy costs by fostering a more capable and adaptable workforce.

The synthesis of theoretical and empirical findings illuminates a nuanced understanding of the dynamics between human capital investments and vacancy costs. By investing in the development of human capital, organizations can cultivate a workforce equipped with the necessary skills and competencies to meet the demands of their roles, thereby reducing the likelihood of prolonged vacancies and the associated costs. This

evidence underlines the importance of a strategic approach to human capital development, highlighting the need for investments that are aligned with specific tasks and tailored to the requirements of the business and industry (Hitt et al., 2001; Unger et al., 2011).

2.7.4 Comparative Analysis of Upskilling Impacts on Different Employment Levels Within Firms (e.g., Operational vs Managerial)

In examining the impacts of upskilling initiatives across different employment levels within firms, particularly in the context of operational versus managerial positions, a nuanced understanding emerges. The integration of AI and digital technologies into the workplace necessitates a broad spectrum of upskilling efforts tailored to distinct job roles and challenges.

At the operational level, upskilling efforts primarily target the enhancement of technical skills and cognitive capabilities to work effectively alongside AI systems. In particular, employees in the IT sector are encouraged to cultivate competencies in data analysis, digital literacy, and ongoing learning (Jaiswal et al., 2022; Samuvel, 2023). These programs aim to boost employee performance, engagement, and career progression, featuring a blend of formal training and informal learning opportunities. The rationale is to maintain job relevance in an increasingly automated and digital job market, illustrating a direct approach to skills enhancement.

Conversely, the managerial level demands upskilling strategies that pivot towards digital leadership and organizational change management (Čirčová and Blštáková, 2022). Managers are tasked with acquiring competencies that enable them to lead digital transformation efforts, necessitating a different set of skills compared with their operational counterparts. This distinction highlights the broader scope of managerial upskilling, which extends beyond technical skill enhancement to include leadership in a digital context.

The effectiveness of upskilling varies significantly across industries and job types, as illustrated by the cleaning industry in Norway. Here, despite efforts to legitimize the occupation and improve job quality through skill signaling, the impact was minimal due

to external economic pressures (Aspøy, 2020). This case exemplifies the challenges of upskilling in altering job design and quality without concurrent structural changes.

In the private insurance industry, however, upskilling has shown a positive correlation with job enrichment and efficiency at the operational level. Employees with enhanced digital skills can more effectively tailor products and services, suggesting that upskilling can lead to improved job performance (Chitra and Vanitha, 2022). This indicates the potential for upskilling initiatives to directly contribute to operational efficiency and customer satisfaction.

Across all levels, the necessity for continuous learning and adaptability is emphasized as essential for remaining competitive in the face of rapid technological advancements (Sawant et al., 2022). Both current and potential employees must engage in reskilling and upskilling to navigate new technologies and methodologies, underscoring the universal importance of lifelong learning.

2.8 Skill-Biased Technological Change Theory

2.8.1 Introduction to Skill-Biased Technological Change Theory

SBTC theory elucidates the labor market dynamics resulting from technological advancements that disproportionately favor skilled over unskilled labor. This theoretical framework posits that technological innovations tend to enhance the productivity of high-skilled workers to a greater extent than that of low-skilled workers, leading to an increased demand for the former. This phenomenon has critical implications for wage inequality and employment patterns across various economies and industries.

Empirical evidence suggests that SBTC contributes to labor market polarization, wherein employment and wages see growth at the high and low ends of the skill spectrum but stagnate or decline for mid-level skills. For instance, research within the Chinese labor market has underscored the role of SBTC in promoting wage and employment growth among highly skilled and minimally skilled workers, while adversely affecting those with medium-level skills (Wang et al., 2021). The effects of SBTC exhibit considerable variation across different national contexts. In Germany, SBTC has been linked to a

productivity slowdown, juxtaposed with a simultaneous increase in employment, a phenomenon described as a productivity debacle coexisting with a job miracle (Hutter and Weber, 2021). This suggests that the impact of SBTC is not universally positive and may lead to complex outcomes in terms of productivity and employment.

The assumption that technological change is uniformly skill-biased is challenged by evidence demonstrating significant variation in the impact of SBTC across firms within the same industry. This variation is often attributed to firm-specific strategies and technological characteristics, as observed in Belgian manufacturing industries, where Hicks-neutral technological change, which discussed about change in the production function of a business or industry which fulfills certain economic neutrality conditions was notably absent (Dewitte et al., 2020). The demand for skills in response to technological change may also be influenced by the separability of tasks within industries. For example, in the semiconductor industry, automation and parts consolidation have shown divergent skill biases—automation leading to skill demand polarization and consolidation to a convergence in skill demand (Combemale et al., 2022).

Extending beyond labor economics, SBTC theory also considers the role of institutional and technological changes in the political economy, as illustrated by Germany's transition towards a knowledge economy. This shift underscores the growing importance of high-level skills in production and a reconfiguration of traditional skill complementarities (Diessner et al., 2022). International technology diffusion and participation in global value chains (GVCs) have been identified as factors exacerbating SBTC effects, contributing to increased skill demand and inequality in both advanced and emerging economies (Li et al., 202; Schulte, 2021). Furthermore, the examination of capital-skill complementarity (CSC) and SBTC hypotheses in the United States reveals significant explanatory power for changes in the skill premium across sectors (Perez-Laborda and Perez-Sebastian, 2020).

2.8.2 The Relationship Between Technological Advancements in Industry 5.0 and the Demand for Skilled Labor

The intersection of technological advancements and labor market dynamics, particularly within the realms of Industry 4.0 and the nascent Industry 5.0, has engendered significant academic inquiry. This burgeoning field of research critically examines the polarization of the labor market, evidenced by the diminishing demand for routine work and the concomitant shift towards more skilled labor as a direct consequence of technological evolution. We synthesize existing research findings to elucidate the nuanced relationship between technological progress in Industry 5.0 and the demand for skilled labor. Quantitative analyses have demonstrated that technological advancements substantially account for shifts in occupational employment, earnings distribution, and the declining labor share of income until the year 2000. Post-2000, however, the correlation between technological change and the demand for higher-skilled occupations appears to decouple, suggesting the intervention of additional variables beyond mere technological innovation (vom Lehn, 2020).

The discourse on the implications of Industry 4.0 and digitization for the labor market resonates with Keynes' prognostication of diminished working hours on ‘Economic possibilities for our grandchildren’ essay. Technological processes that are inherent to Industry 4.0 are purported to necessitate a reduced volume of labor, potentially affirming Keynes' envisioning of a truncated workday. This anticipated reduction in labor hours is posited to augment economic efficiency through an intensification of work. The magnitude of technological unemployment is contingent upon the digitalization strategy and its implementation pace adopted by each country, along with the agility of the educational system in retraining the labor force segments most susceptible to market vulnerabilities. Although digital transformation presents inherent challenges, it is generally regarded as advantageous, promoting a shift towards a more human-centred approach and serving as a key driver of economic competitiveness through the reduction of marginal costs (Szabó-Szentgróti et al., 2021).

The historical trajectory of technological advancements has undeniably led to labor market polarization and a diminution in routine employment. Nonetheless, the consistent escalation in the demand for skilled labor in tandem with these technological shifts has not been uniform. The advent of Industry 4.0 and the forthcoming Industry 5.0 era encapsulate both challenges and prospects, with the potential for curtailing working hours and enhancing economic efficiency. These outcomes are, however, dependent on strategic digitalization efforts and the capacity for educational systems to adapt and retrain the workforce in alignment with evolving labor market requirements (Szabó-Szentgróti et al., 2021; vom Lehn, 2020).

2.8.3 Evidence on How Upskilling Programs Mitigate the Challenges Posed by SBTC

The advent of SBTC has precipitated a significant transformation in the work landscape, underscoring the necessity of continuous vocational education and training (CVET) to address the ensuing challenges. Upskilling programs have emerged as a crucial strategy to augment workforce skills and competencies in alignment with evolving demands. A systematic review highlights a marked increase in the complexity and mental workload associated with interacting with automated systems and robots, concurrent with a decline in manual labor requirements (Beer and Mulder, 2020). This evolution necessitates an enhanced emphasis on technological knowledge, adaptability, and advanced self- and time-management skills. Upskilling initiatives are thus compelled to integrate these critical elements, ensuring the relevance and efficacy of training in equipping the workforce with the tools necessary to thrive in a technologically advanced environment.

The exigencies of the COVID-19 pandemic, which necessitated an abrupt transition to remote teaching, further illuminate the impact of upskilling programs on digital competencies within the teaching profession (ElSayary, 2023). A specific investigation into a 10-week upskilling program employing a blended learning approach revealed significant enhancements in teachers' digital competencies. This advancement is

not only crucial for educators but also instrumental in fostering the development of digital skills among students, thereby preparing them for the challenges of future employment landscapes and the advent of yet-to-be-conceived job roles.

2.9 Efficiency Wage Theory and Turnover Rate

Efficiency Wage Theory posits a direct correlation between the wages provided to workers and their resultant productivity levels. This relationship is crucial in various fields, including economics and labor studies, for its potential to elucidate the dynamics between compensation practices and organizational efficiency. Efficiency wages stand out as a potent mechanism not only for fostering enhanced worker productivity but also for establishing a more equitable employment landscape. These wages act as both a reward and an incentive, encapsulating the dual role of compensation in promoting organizational goals and motivating individual performance. The integration of efficiency wages with constructive feedback mechanisms further amplifies their effectiveness in aligning employee behavior with organizational objectives (Fernández et al., 2021).

Empirical analyses within professional sports realms affirm the positive association between wage levels and labor productivity. Despite the existence of regulatory frameworks that could potentially skew this relationship, the evidence underscores a clear link between higher compensation and increased marginal productivity (Gregory-Smith, 2021). This suggests that the efficacy of efficiency wages transcends the boundaries of conventional workplaces, extending to areas with distinct operational dynamics. The urban efficiency wage model receives empirical support from data illustrating the substitutable nature of leisure and workplace shirking. The findings reveal a nuanced interplay between commuting patterns, earnings, and the likelihood of unproductive behaviors, indicating that enhanced wages can serve as a deterrent against inefficiencies by minimizing tendencies towards shirking (Giménez-Nadal et al., 2021).

Furthermore, adjustments in minimum wage policies underscore the potential of higher wages to elevate productivity while concurrently reducing worker turnover. This relationship, however, is contingent upon the extent of workplace monitoring,

highlighting the nuanced conditions under which efficiency wages exert their influence (Coviello et al., 2022). Wages fulfil various roles within the organizational milieu: they are indicators of labor market conditions, incentives for performance and retention, and acknowledgements of individual contributions. This multifunctionality enriches the discourse on wage justification, illustrating the complexity inherent in the utilization of compensation as a strategic tool (Moriarty, 2020).

2.9.1 Explanation of Efficiency Wage Theory

Efficiency Wage Theory posits a direct correlation between the wages provided to workers and their resultant productivity levels. This relationship is crucial in various fields, including economics and labor studies, for its potential to elucidate the dynamics between compensation practices and organizational efficiency. Efficiency wages stand out as a potent mechanism not only for fostering enhanced worker productivity but also for establishing a more equitable employment landscape. These wages act as both a reward and an incentive, encapsulating the dual role of compensation in promoting organizational goals and motivating individual performance. The integration of efficiency wages with constructive feedback mechanisms further amplifies their effectiveness in aligning employee behavior with organizational objectives (Fernández et al., 2021).

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2.9.2 Theoretical Underpinnings of How Upskilling Can Reduce Turnover Rates Through the Lens of Efficiency Wage Theory

Efficiency Wage Theory has traditionally focused on the direct relationship between wage levels and productivity, somewhat overlooking the nuanced role of skill development. Upskilling—defined as the process of teaching employees new and advanced skills—presents a unique avenue for enhancing employee value and satisfaction, which, according to the theory, should correspondingly reduce turnover intentions. This exploration seeks to bridge the gap between wage efficiency and skill development, proposing upskilling as a crucial factor in the equation of reducing turnover rates.

The premise that upskilling can lead to reduced turnover is supported by several mechanisms. First, upskilling aligns with the notion of pay fairness by enhancing employees' perceptions of their value within an organization and the labor market at large (Bae et al., 2022). As employees acquire new skills, their marketability and sense of worth increase, potentially leading to higher pay fairness perceptions and reduced turnover intentions.

Secondly, upskilling supports the creation of meaningful work by strengthening the connection between employees and their roles. Studies indicate that meaningful work is a strong predictor of workplace happiness and is negatively associated with turnover

intention (Charles-Leija et al., 2023). By offering employees opportunities to acquire and apply new skills, organizations can improve job satisfaction and commitment, thereby lowering the likelihood of staff turnover.

Third, the process of upskilling itself can serve as a form of non-monetary compensation, enriching job characteristics such as job variety and perceived organizational support. In situations where financial incentives are limited, enhancing job roles through upskilling can weaken the link between pay satisfaction and employees' intentions to leave the organization (Jolly et al., 2021). This approach underscores the psychological benefits of upskilling, which contribute to a more engaged and committed workforce.

Lastly, the extant literature suggests that high turnover rates may paradoxically stimulate a desire for self-improvement among remaining employees, leading to increased engagement in learning behaviors (Pu et al., 2022). In this light, upskilling initiatives could harness this self-regulatory mechanism, turning potential turnover crises into opportunities for organizational learning and development.

2.9.3 Case Studies and Empirical Evidence on the Impact of Upskilling on Turnover Rates in Manufacturing Firms

The manufacturing sector, characterized by rapid technological advancements and evolving job roles, faces significant challenges in retaining a skilled workforce. Turnover in this sector not only incurs direct costs but also disrupts operational efficiency and knowledge continuity. Recent literature suggests that upskilling could be a strategic lever to improve retention rates. This exploration synthesizes case studies and empirical evidence to elucidate the impact of upskilling on reducing turnover rates in manufacturing firms, underpinned by theories of empowerment and job design.

A study involving industrial workers in Chinese manufacturing enterprises demonstrates that empowering leadership significantly lowers turnover intentions.

Furthermore, this effect is mediated by job-crafting behaviors, which are enhanced by upskilling initiatives. Workers with proactive personalities, in particular, benefit from

upskilling, as it enables them to reshape their job roles to better fit their skills and interests, thereby reducing their inclination to leave (Ouyang et al., 2020).

The advent of the Industrial Revolution 4.0 has necessitated a shift in skill requirements within the logistics and supply chain sectors, closely intertwined with manufacturing. Upskilling and reskilling have emerged as critical for adapting to automation-based operations. Case studies conducted in Malaysia highlight the importance of upskilling, not only for addressing the technical requirements of Industry 4.0 (IR 4.0) but also for improving job quality and employee competitiveness, which subsequently helps lower turnover rates (Wahab et al., 2021).

Studies of Korean firms indicate that workforce diversity, especially regarding gender and educational background, can help reduce the adverse effects of CEO turnover on organisational performance. This implies that upskilling initiatives, which frequently involve broadening the skill sets within teams, may strengthen organisational resilience to turnover by fostering a more adaptable and inclusive workplace (Kim *et al*., 2021).

Empirical findings highlight the importance of organizational support mechanisms, such as the HRDF, in facilitating upskilling and reskilling programs. Such support is instrumental in overcoming the challenges associated with implementing these programs and, consequently, in reducing turnover rates by enhancing employee engagement and job satisfaction (Wahab et al., 2021).

The case studies and empirical evidence reviewed underscore several benefits of upskilling initiatives in manufacturing firms, notably in reducing turnover rates. By fostering a culture of continuous learning, empowering employees through job crafting, and enhancing organizational resilience through workforce diversity, manufacturing firms can significantly mitigate the challenges associated with high turnover rates. These findings contribute to a deeper understanding of the strategic value of upskilling in retaining talent and ensuring the long-term sustainability of manufacturing operations.

2.9.4 A Deeper Dive into the Psychological and Motivational Aspects of Upskilling, Examining How They Influence Employee Retention Beyond Economic Factors

Exploring the psychological and motivational aspects of upskilling reveals a complex interplay that significantly influences employee retention, extending well beyond mere economic considerations. Upskilling, traditionally viewed through the lens of enhancing skill sets for productivity and economic gain, also encompasses deeper psychological and motivational dimensions that directly impact employee loyalty and organizational commitment.

The significance of personal development and continuous learning in employee retention cannot be overstated. A conducive learning environment that appreciates and stimulates employees not only enhances their skill sets but also contributes positively to their sense of belonging and value within an organization. Effective leadership skills combined with a proactive learning mindset are closely associated with greater employee retention, suggesting that employees' active involvement in their own development plays a key role in their choice to remain with an organisation (Kyndt et al., 2009).

Motivation, encompassing both intrinsic and extrinsic factors, plays a vital role in employee retention. Elements such as performance-based pay and recognition are significant motivators that closely relate to job satisfaction and, in turn, retention. These findings emphasise the importance of acknowledging and rewarding employee efforts, highlighting the need for organisations to adopt a comprehensive approach to motivation that extends beyond basic financial compensation (Eberendu and Kenneth-Okere, 2015).

The generational perspective introduces additional layers to the motivational aspects of upskilling, especially among Generation Y employees. For these individuals, intrinsic motivational factors, such as engaging in work and job satisfaction, are paramount. The distinct values and expectations of this demographic highlight the need for organisations to customise their upskilling and motivation strategies to address

workforce diversity, thereby boosting productivity and reducing turnover (Mishra and Mishra, 2017).

Furthermore, the role of training in employee retention illustrates the value placed on learning opportunities by both male and female employees. The demand for rewards and supervisory support as part of the training experience highlights the broader expectations employees have from upskilling programs. Such expectations include not only the acquisition of new skills but also recognition of their efforts and adequate support from leadership, reinforcing the integral role of training in retention strategies (Hassan et al., 2013).

Lastly, the intricate relationship between motivation, both intrinsic and extrinsic, and perceived organizational support further elucidates the retention dynamic. This relationship suggests that how employees perceive their organization's support significantly influences the effectiveness of motivational strategies on retention outcomes. Hence, creating an environment that supports and values employee contributions is critical for fostering a motivated and loyal workforce (Shah and Asad, 2018).

2.10 Challenge and Future Directions

2.10.1 Discussion of Potential Challenges in Implementing Upskilling Programs in Swiss Manufacturing Firms

In the evolving landscape of the Swiss manufacturing sector, the necessity for continuous innovation and adaptation to technological advancements is imperative for maintaining a competitive advantage and sustainable economic growth. This need underpins the significance of upskilling programs for employees within SMEs to meet the demands of new manufacturing technologies and operational processes. However, the implementation of such programs involves several challenges, including resource constraints, changing staff requirements, and the rapid pace of technological development, which collectively pose significant hurdles to the successful execution of upskilling initiatives.

One of the foremost challenges is the financial and human resource limitations commonly faced by SMEs. The development and execution of effective upskilling programs require substantial investment in both areas, yet SMEs often struggle to allocate the necessary resources due to budgetary constraints (Casalino et al., 2019). This challenge is exacerbated by the need for highly qualified staff capable of leveraging state-of-the-art technologies, further emphasizing the disparity between the requirements for upskilling and the resources available within these firms.

Moreover, the pace at which new technologies evolve and are introduced into manufacturing processes necessitates a dynamic approach to workforce development. Ongoing advancements in manufacturing automation, alongside the creation of new job roles, require employees to adapt to current technological changes while also preparing for future developments (Casalino et al., 2019). The required agility and foresight for planning and implementing upskilling programs, therefore, become a significant challenge for manufacturing SMEs.

Additionally, the specific needs of the manufacturing sector regarding skill levels and the urgency for upskilling are critical factors that add to the complexity of implementing these programs. The industry necessitates skills at entry, competent, and expert levels, with a pressing demand for the rapid delivery of upskilling opportunities (Doherty and Stephens, 2021). This requirement for fast-tracked, work-based learning and experiential training further complicates the design and execution of upskilling initiatives, particularly in SMEs where the ability to quickly adapt educational programs to the changing landscape is limited.

In conclusion, Swiss manufacturing SMEs face considerable challenges in implementing upskilling programs, primarily due to resource constraints, the dynamic nature of technological advancements, and the specific skill requirements of the sector. Addressing these challenges necessitates innovative approaches to workforce development, including flexible, customizable, and accessible learning solutions, to ensure the effective upskilling of employees in alignment with both current and future industry demands.

2.10.2 Future Research Directions on Upskilling, Industry 5.0 Technologies, and Their Impacts on the Manufacturing Sector

In the evolving landscape of the Swiss manufacturing sector, the necessity for continuous innovation and adaptation to technological advancements is imperative for maintaining a competitive advantage and sustainable economic growth. This need underpins the significance of upskilling programs for employees within SMEs to meet the demands of new manufacturing technologies and operational processes. However, the implementation of such programs involves several challenges, including resource constraints, changing staff requirements, and the rapid pace of technological development, which collectively pose significant hurdles to the successful execution of upskilling initiatives.

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Furthermore, the rapid evolution and deployment of new technologies within manufacturing processes require a flexible and forward-looking approach to workforce development. Employees must not only adjust to existing technological changes but also proactively prepare for future advancements, as ongoing automation and the emergence of new roles continue to reshape the industry (Casalino et al., 2019). The required agility and foresight for planning and implementing upskilling programs, therefore, become a significant challenge for manufacturing SMEs.

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2.11 Summary

2.11.1 Key Findings from the Literature Review

The literature review on the "Cost of Vacancy Reduction in Industry 5.0-Era Swiss Manufacturing Firms Through Upskilling" explores the diverse impacts of investing in upskilling programs, particularly those centered on Industry 5.0 technologies, within the Swiss manufacturing landscape. This exploration is grounded in the theoretical framework that integrates Human Capital Theory, Skill-Biased Technological Change Theory, and Efficiency Wage Theory, providing a nuanced lens through which to assess the dynamic relationship between upskilling and its implications on the cost of vacancies and turnover rates among workers.

A crucial aspect of this review is the discussion on the intersection of Industry 5.0 with sustainability and CSR within the Swiss context. It addresses how upskilling for Industry 5.0 can significantly contribute to sustainability goals and CSR initiatives, citing case studies of Swiss manufacturing firms that have successfully melded their upskilling programs with sustainability efforts. This aspect not only highlights the potential of

upskilling in fostering a culture of innovation and environmental stewardship but also reflects Switzerland's broader commitment to sustainable development and innovation.

Further, the review emphasizes the critical importance of digital literacy and cross-functional skills in Industry 5.0, extending beyond mere technical skills. It underscores strategies for cultivating a culture of lifelong learning and adaptability among the workforce, essential for navigating the rapid technological shifts characteristic of Industry 5.0. This segment points to a paradigm shift in workforce development, where the emphasis is on equipping employees with a broad spectrum of skills that enable them to thrive in an increasingly digital and interconnected manufacturing environment.

In terms of the impact on vacancy and turnover rates, the literature review presents empirical evidence suggesting that upskilling, particularly when focused on Industry 5.0 technologies, has the potential to significantly reduce vacancy costs and lower turnover rates. This is attributed to the alignment of skills with Industry 5.0 demands, which not only enhances job satisfaction and worker retention but also mitigates the costs associated with recruiting and training new employees. The theoretical underpinning of Human Capital Theory and Skill-Biased Technological Change Theory offers insight into how investments in upskilling can yield substantial returns by enhancing the productivity and efficiency of the workforce.

The review also touches on government policies and incentives in Switzerland that support the transition to Industry 5.0, illustrating the role of state intervention in facilitating upskilling initiatives and the broader transition towards a more sustainable and technologically advanced manufacturing sector. It highlights the synergies between governmental support, industry practices, and educational initiatives in driving the upskilling agenda forward, underscoring the collaborative effort required to realize the full potential of Industry 5.0.

The literature review articulates the transformative potential of upskilling within the Swiss manufacturing sector, especially in the era of Industry 5.0. It showcases upskilling not only as a strategic imperative for reducing vacancy costs and addressing turnover rates but also as a critical component in aligning the workforce with the demands

of a rapidly evolving industrial landscape characterized by a heightened focus on sustainability, digital literacy, and cross-functional skills. Through a detailed exploration of theoretical frameworks, empirical evidence, and case studies, the review convincingly argues for the central role of upskilling in navigating the challenges and seizing the opportunities presented by Industry 5.0.

2.11.2 The Impact of AI and Other Technologies Implemented in Industry 5.0 on Society

The leap to Industry 5.0 introduces a human-centric and sustainable approach to technological integration, emphasizing resilience and human well-being alongside environmental sustainability. This shift aims to balance the technical innovations of Industry 4.0 with societal needs, promoting a symbiotic relationship between humans and machines where AI and robotics enhance rather than replace human labor. It heralds enabling technologies, like edge computing and digital twins, for smarter, resource-efficient manufacturing and services tailored to individual needs, with significant implications for intelligent healthcare and supply chain management.

Simultaneously, the notion of “Social Fabric Blocks” has emerged, representing the core of Society 5.0 by integrating technology into society to address economic, environmental, and social challenges in a comprehensive manner (Beniiche et al., 2022). This approach fosters open innovation and co-creation, aiming for a future in which technology-driven solutions are inherently grounded in human values, promoting equitable wealth distribution, and enhancing quality of life for all. Industry 5.0, with its focus on a balanced innovation ecosystem, not only anticipates technological progress but also prioritizes the creation of a resilient, sustainable, and human-centric society.

2.11.3 Implications for Swiss Manufacturing Firms, Policymakers, and Educators

The comprehensive literature review on "Cost of Vacancy Reduction in Industry 5.0-Era Swiss Manufacturing Firms Through Upskilling" provides critical insights into the evolving landscape of Swiss manufacturing in the context of Industry 5.0. The

findings have profound implications for Swiss manufacturing firms, policymakers, and educators, necessitating a collaborative approach to harness the benefits of upskilling in response to the challenges and opportunities of Industry 5.0.

Manufacturing firms must recognize upskilling as a strategic imperative to remain competitive. The integration of Industry 5.0 technologies requires not only a technically proficient workforce but also one that is adaptable, capable of critical thinking, and possesses advanced digital literacy. Firms should invest in continuous learning and development programs that are tailored to the specific needs of their workforce and aligned with the technological advancements in their field.

As the review highlights the intersection of Industry 5.0 with sustainability goals, Swiss manufacturing firms are positioned to lead in sustainable manufacturing practices. Upskilling programs that incorporate sustainability and CSR initiatives can empower employees to innovate and implement environmentally friendly practices, aligning operational activities with global sustainability standards.

The emphasis on digital literacy and cross-functional skills beyond technical capabilities underscores the need for firms to foster a culture of innovation and creativity. By encouraging a mindset of lifelong learning and adaptability, firms can cultivate an environment where employees are motivated to explore new ideas, technologies, and processes, driving firms' innovation agendas forward.

Policymakers play a crucial role in creating a conducive environment for the transition to Industry 5.0. This includes formulating and implementing policies that encourage investments in upskilling programs by providing tax incentives and offering financial support to firms engaging in such initiatives. Policymakers should also focus on developing regulations that facilitate the integration of sustainable practices within the manufacturing sector.

This review addresses the importance of collaborative efforts in advancing the upskilling agenda. Policymakers should promote public-private partnerships that bring together manufacturing firms, educational institutions, and government agencies to develop and implement comprehensive upskilling programs. Such partnerships can

leverage the strengths of each sector to address skill gaps and prepare the workforce for the demands of Industry 5.0.

Establishing and enhancing infrastructure for lifelong learning is crucial. Policymakers should invest in digital platforms, innovation hubs, and learning centers that provide accessible and flexible learning opportunities for the workforce, ensuring that employees across all age groups and career stages can benefit from upskilling initiatives.

In addition to technical skills, the development of soft skills such as communication, teamwork, and leadership should be prioritized. These skills are essential for fostering a collaborative work environment and enabling employees to navigate the complexities of Industry 5.0, particularly as roles become more interdisciplinary and projects more collaborative. The transition to Industry 5.0 presents Swiss manufacturing firms, policymakers, and educators with a unique set of challenges and opportunities. By embracing upskilling as a strategic priority, fostering collaboration across sectors, and investing in the development of both technical and soft skills, Switzerland can solidify its position as a leader in sustainable and innovative manufacturing practices in the era of Industry 5.0.

2.11.4 Final Thoughts on the Future of Upskilling in the Industry 5.0 Era

In synthesizing the extensive insights garnered from the literature review on "Cost of Vacancy Reduction in Industry 5.0-Era Swiss Manufacturing Firms Through Upskilling," it becomes evident that upskilling represents a crucial axis around which the future of the Swiss manufacturing sector will revolve in the Industry 5.0 era. This analysis elucidates the several implications of upskilling for Swiss manufacturing firms, policymakers, and educators, underscoring the imperative for a concerted and collaborative approach towards workforce development. The findings signal a paradigm shift in the manufacturing landscape, where the integration of advanced technologies, sustainability, and human-centric practices demands a workforce that is not only technically proficient but also adaptable, innovative and committed to lifelong learning.

For Swiss manufacturing firms, the future of upskilling lies in recognizing and operationalizing learning and development as strategic imperatives, with a focus on fostering digital literacy, cross-functional skills, and a culture of innovation and sustainability. Policymakers are tasked with creating supportive regulatory frameworks, facilitating public-private partnerships, and investing in infrastructure that enables lifelong learning, ensuring that the workforce remains agile and responsive to the evolving demands of Industry 5.0. Educators, for their part, must adapt curricula to reflect the skills required in the new industrial era, strengthen industry-academia collaboration, and place a greater emphasis on the development of soft skills alongside technical competencies.

The journey towards Industry 5.0, characterized by the harmonious integration of human creativity with advanced technologies, presents both challenges and opportunities for upskilling. This literature review posits that embracing upskilling not only addresses the immediate need to reduce vacancy costs and mitigate turnover rates but also strategically positions Swiss manufacturing firms to lead in innovation, sustainability, and competitiveness on the global stage. The success of this endeavor hinges on the ability of all stakeholders—manufacturing firms, policymakers, and educators—to navigate the complexities of this transition with foresight, flexibility, and a commitment to collaborative action.

The future of upskilling in the Industry 5.0 era represents a transformative opportunity for the Swiss manufacturing sector to redefine the value of human capital in the face of technological advancement. By leveraging the synergies between upskilling initiatives, supportive policies, and innovative educational practices, Switzerland can cultivate a workforce that is not only equipped to meet the challenges of Industry 5.0 but also poised to drive forward the principles of sustainability, efficiency, and human-centric innovation. This literature review thus underscores upskilling as a critical lever for sustainable development, economic growth, and societal well-being in the Industry 5.0 era, advocating for a proactive and strategic approach to harnessing its full potential.

CHAPTER III:
METHODOLOGY

3.1 Overview of the Research Problem

Current discussions on global workforce development highlight a significant skills gap, presenting major challenges for upskilling initiatives and the workforce's capacity to adapt to rapidly evolving labour markets (Schwab and Zahidi, 2020). The skills gap is especially evident in basic digital competencies across developed countries. For example, approximately one-third of workers in the United States, the United Kingdom, and Germany lack essential digital skills (OECD, 2020). In the Swiss context, despite a highly skilled labour force, there is a noticeable shortfall in key sectors, with 40% of companies struggling to fill job vacancies due to skill deficits (Jaberg, 2022). This is further corroborated by sector-specific research (Goel, 2020). While the dialogue surrounding upskilling and vacancy costs sheds light on the skills gap at both global and national levels, it lacks in-depth exploration of the specific relationship between upskilling initiatives and vacancy costs, especially within Swiss manufacturing companies transitioning into the Industry 5.0 Era. The proposed study aims to delve into this underexplored nexus, providing valuable insights that could inform strategic workforce development and policy decisions.

The extant research underscores a critical gap in skills across various global sectors. This highlights a substantial issue related to upskilling and adequacy of the workforce in quickly adapting job markets (Schwab and Zahidi, 2020). A segment of this literature accentuates the impact of the skills gap, particularly around fundamental digital skills in developed nations. However, the existing research lacks in-depth discussion regarding the specific relationship between upskilling and vacancy costs. This is particularly true in the specific context of Swiss manufacturing companies navigating the Industry 5.0 Era. Switzerland, despite having a highly skilled labour force, experiences noticeable shortages in key sectors. The current debate on upskilling and vacancy costs provides an understanding of the skills gap in both a widespread global and individual national context. However, there is a lack of specific insight into how upskilling correlates

with vacancy costs, particularly within Swiss manufacturing firms during the Industry 5.0 transition.

3.2 Operationalization of Theoretical Constructs

3.2.1 Overview

This study operationalizes the concepts of upskilling, vacancy cost reduction within the framework of Industry 5.0, grounded in three principal theoretical lenses: Human Capital Theory (HCT), Skill-Biased Technological Change (SBTC) Theory, and Efficiency Wage Theory (EWT). These constructs collectively explain how strategic investments in workforce development can reduce cost of vacancy, and foster long-

3.2.2 Theoretical Constructs

The theoretical framework guiding this study draws on three interrelated theoretical underpinnings that together provide a multidimensional understanding of the upskilling–vacancy cost nexus. Below figure provides the theoretical framework of this study:

Figure 2.1. Theoretical Framework

Note: HCT: Human Capital Theory; SBTC: Skill-Biased Technological Change Theory; EWT: Efficiency Wage Theory

3.2.2.1 Human Capital Theory (HCT)

Human Capital Theory (Becker, 1962; Schultz, 1961) suggests that the knowledge, skills, and competencies of employee's function as a form of capital, contributing to increased productivity and overall economic value. Within the Industry 5.0 landscape—where technological integration demands higher skill intensity—upskilling represents an essential investment in this capital. The operational construct of upskilling in this study refers to organizational initiatives aimed at enhancing employees' technical and cognitive competencies to meet evolving technological demands.

Accordingly, upskilling intensity (measured by training expenditure per employee, frequency of development programs, and participation rate) serves as a key independent variable, hypothesized to influence vacancy cost reduction, employee satisfaction, and retention. The expectation is that firms investing in human capital through structured upskilling programs experience fewer and shorter vacancies due to improved internal mobility and reduced turnover.

3.2.2.2 Skill-Biased Technological Change (SBTC) Theory

The Skill-Biased Technological Change (SBTC) Theory (Acemoglu and Autor, 2011) explains how technological progress drives higher demand for skilled labour. Within the context of Industry 5.0—characterised by cyber-physical systems, AI integration, and collaborative human–machine interactions—technological developments tend to benefit employees possessing advanced technical and analytical competencies.

Operationally, technological intensity is represented through indicators such as the adoption of automation technologies, AI tools, and digital platforms within firms. This study posits that as technological intensity increases, the need for upskilling becomes imperative to sustain productivity and mitigate vacancy-related disruptions. The interaction between upskilling and technological intensity is thus central to the proposed framework: firms that invest in targeted upskilling aligned with technological

transformation are better positioned to minimize vacancy costs and enhance workforce stability.

3.2.2.3 Efficiency Wage Theory (EWT)

Efficiency Wage Theory (Shapiro and Stiglitz, 1984) contends that offering wages or benefits above market equilibrium can increase employee loyalty, reduce shirking, and lower turnover rates. When viewed alongside upskilling, EWT suggests that skill development acts as a non-monetary efficiency mechanism—an intrinsic reward that enhances job satisfaction and commitment.

Operationally, employee satisfaction and retention are measured using survey-based indicators (e.g., job satisfaction scores, turnover intentions, and retention rates). These outcomes reflect the efficiency wage dynamic in non-monetary form: firms that invest in their employees through upskilling cultivate intrinsic motivation and reduce voluntary turnover, indirectly curbing the cost of vacancy.

3.2.3 Measurement Indicators based on Theoretical Framework

Upskilling Intensity Organizational investment in employee development to enhance technical and cognitive skills. Training hours per employee; Training expenditure per employee; Employee participation rate in learning and development (LandD) programs. Human Capital Theory (Becker, 1962)

Technological Intensity Degree of technological integration within organizational processes and production systems. Extent of AI, automation, and digital systems adoption. SBTC Theory (Acemoglu and Autor, 2011)

Vacancy Cost Reduction Decrease in direct and indirect costs associated with unfilled positions. Time-to-fill vacancies; Hiring cost per position; Productivity loss per vacancy. HCT, SBTC.

Employee Satisfaction Degree of employees' positive affect toward their job and organization. Job satisfaction surveys; Motivation indices; Absenteeism rates. EWT, HCT

Employee Retention Ability of firms to retain skilled employees over time. Employee turnover rate; Tenure duration; Internal promotion rates. EWT, HCT

Organizational Competitiveness Firm's ability to sustain productivity and innovation through skilled workforce stability. Innovation output; Profit margins; Market share growth. Integrated (HCT + SBTC + EWT).

3.2.4 Theoretical Integration and Model Linkages

Figure 2.1. (The Proposed Theoretical Framework) conceptualizes how these constructs interrelate within Industry 5.0 dynamics.

- Upskilling, grounded in HCT, enhances employee competencies, fostering higher productivity and satisfaction.
- Technological Intensity, derived from SBTC, moderates the upskilling–performance relationship by influencing the rate at which new skills become necessary.
- Employee Satisfaction and Retention, explained through EWT, mediate the relationship between upskilling and Vacancy Cost Reduction, indicating that skill investment yields both financial and motivational benefits.
- The cumulative effect leads to Organizational Competitiveness and Cost Reduction, underscoring upskilling as a strategic lever for sustainable growth in the Industry 5.0 era.

Thus, the operationalized model proposes that upskilling directly reduces vacancy costs and indirectly enhances organizational competitiveness through improved satisfaction and retention.

3.2.5 Operationalization Summary

The operationalization of these constructs allows the study to quantitatively assess relationships among upskilling, technological adaptation, and vacancy cost reduction within Swiss manufacturing firms. By applying the integrated theoretical framework, the research will empirically evaluate whether investments in human capital translate into tangible organizational efficiencies.

The following sections detail the empirical methodology—sampling procedures, data collection techniques, and estimation models—used to validate the hypothesized relationships within this Industry 5.0 context.

3.3 Research Purpose and Questions

The purpose of this research is to investigate how the cost of vacancy can be reduced through employee upskilling in the context of the Industry 5.0 era. We will evaluate the employee development program wth different demographics and related to the monetary aspect. Specifically, the study seeks to answer the following research questions:

(1) Research Question 1: How does investing in upskilling programs, especially those focused on Industry 5.0 technologies, impact the cost of vacancies in Swiss manufacturing firms, and in what way does the level of education moderate this impact?

(2) Research Question 2: How does undergoing upskilling, with a particular focus on Industry 5.0 technologies, impact turnover rates among workers in Swiss manufacturing firms, and how does the level of education serve as a moderator in this relationship?

By addressing these questions, the research aims to provide insights into the strategic value of targeted upskilling for optimising workforce stability and reducing labour-related costs in the evolving Industry 5.0 era.

3.4 Research Design

This study, examining Industry 5.0 and upskilling practices in Swiss manufacturing firms, adopts a mixed-methods approach, integrating both quantitative and qualitative techniques to provide a comprehensive and nuanced understanding of the subject (van Griensven et al., 2014).

Quantitative Research. Anchored in positivist philosophy, this component leverages mathematical models and empirical data, aligning well with hypothesis testing and predictive analyses pertinent to $H_0 1–H_a 2$.

Qualitative Research. This adopts an interpretive lens, delicately uncovering nuances and insights, providing a beneficial strategy for addressing unforeseen insights emergent from dialogues and interviews.

3.5 Population and Sample

Targeting a population of 100 employees within a Swiss manufacturing firm, this study seeks to glean insights from strategically pivotal personnel—those situated in senior management or involved in key decision-making and operational processes. The sampling strategy was designed to ensure data relevance and depth, employing stratified random sampling based on demographic variables such as age, gender, educational background, and department, supplemented by convenience sampling within the firm's professional network.

Considering the intrinsic challenges in predicting a response distribution, we opted to use P=0.5P = 0.5P=0.5 for its utility in producing the largest requisite sample size. With a 95% confidence level and a 5% margin of error, we employed a Z-score of 1.96, determining an initial sample size through:

$$n = \frac{Z^2 \cdot P \cdot (1 - P)}{E^2} \approx 385$$

Given the finite population of 100 employees, we applied a finite population correction:

$$n_{\text{corrected}} = \frac{n}{1 + \frac{n-1}{N}} \approx 79$$

Thus, our corrected sample size suggests surveying approximately 79 employees. Anticipating a 50% response rate, our target grew to reach roughly 158 participants, acknowledging that these figures are preliminary estimates, subject to adjustment based on non-response bias, survey complexity, and resource availability.

3.6 Participant Selection

Quantitative data will be gathered through a detailed survey distributed via papers to a Swiss manufacturing firm, and input of monetary information from the Human Resources department focusing on upskilling programs and their economic impacts. The surveys will feature a straightforward format and be available through a custom landing page, ensuring high accessibility and participation. Complementing the survey, qualitative interviews will be conducted to gain deeper insights into the firms' strategic approaches to Industry 5.0, workforce development, and the skills gap.

3.7 Instrumentation

The study subjects the Swiss manufacturing sector to a demographic exploration, where factors such as age, profession, and years of service. Variables like the engagement in upskilling initiatives, financial ramifications of vacant roles, and prospective investments in upskilling and ventures are scrutinised in an intricate attempt to dissect the nuances, employing a 7-point Likert scale.

Instrument	Example Items	Type
Upskilling (IV)	Q4, Q5	Independent Variable
Engagement and Retention (Mediator)	Q6	Mediator / Mechanism
Perceived Cost of Vacancy (DV)	Q7, Q8, Q9	Dependent Variable
Contextual / Control Variables	Age, Role, etc.	Controls / Filters
Qualitative Insights	Q10	Supports interpretation

3.8 Operational Definition

The study utilises the “Upskilling and Perceived Cost of Vacancy" questionnaire, a multifaceted tool for evaluating firm dynamics, upskilling practices, technological investments, and related dimensions. The questionnaire includes binary, Likert scale, and open-response items, allowing for nuanced data across nominal, ordinal, and scale measures. While comprehensive, the instrument's psychometric validation—particularly its reliability and construct validity—is pending despite promising content and face validity. Future applications and expert reviews are expected to enhance its empirical robustness.

Cost of Vacancy (CoV) will be measured using the direct and indirect costs incurred during the vacancy period; Investment in Industry 5.0-related upskilling program will be quantified as the financial resources and Perceived Cost of Vacancy will be gauged using the number on the annual cost of unfilled position within the firm. These operational definitions ensure that each hypothesis is testable and grounded in measurable criteria.

3.9 Data Collection Procedures

Navigating through our target of 100 employee in a Swiss manufacturing company, specifically those affiliated with Swissmem, our sampling technique will follow stratified random sampling and convenience sampling. This decision aligns with an aspiration for a substantial response rate and obtaining insightful data from pivotal organisation representatives, such as senior management or those involved in vital operational decision-making.

Special emphasis will be placed on obtaining informed consent from participants, recognising the importance of explicit authorisation from each company involved. Recruitment will be conducted on-site using paper-based questionnaires, ensuring direct engagement with participants and maintaining the credibility and reliability of the study (Daymon and Holloway, 2010). Additionally, potential participants who resonate with the

strategic core of these organisations will be scrutinised based on specific criteria, such as their relative position in the organisational hierarchy, to ensure the reliability of the insights garnered.

Data Collection and Analysis. Quantitative data will be gathered through a detailed survey distributed via papers to a Swiss manufacturing firm, and input of monetary information from the Human Resources department focusing on upskilling programs and their economic impacts. The surveys will feature a straightforward format and be available through a custom landing page, ensuring high accessibility and participation. Complementing the survey, qualitative interviews will be conducted to gain deeper insights into the firms' strategic approaches to Industry 5.0, workforce development, and the skills gap.

3.10 Data Analysis

Navigating through our target of 100 employee in a Swiss manufacturing company, specifically those affiliated with Swissmem, our sampling technique will follow stratified random sampling and convenience sampling. This decision aligns with an aspiration for a substantial response rate and obtaining insightful data from pivotal organisation representatives, such as senior management or those involved in vital operational decision-making.

Particular attention will be directed towards securing participant consent, acknowledging the necessity for explicit permission from individual companies. Our recruitment strategies will encompass email communications, utilising formal invitations dispatched directly from supervisory bodies, such as the Swiss School of Business and Management Geneva (SSBM Geneva), to enhance credibility and assurance in our project (Daymon and Holloway, 2010). Additionally, potential participants who resonate with the strategic core of these organisations will be scrutinised based on specific criteria, such as their relative position in the organisational hierarchy, to ensure the reliability of the insights garnered.

3.11 Research Design Limitations

Despite the rigorous mixed-methods framework employed, this study acknowledges several inherent limitations:

(1) Sample Size and Scope: The target population is limited to 100 employees within a single Swiss manufacturing firm, which may restrict the generalisability of findings to the broader Swiss manufacturing sector. Although stratified and convenience sampling enhance relevance, the results may not fully capture the diversity of organisational practices or regional variations.

(2) Potential Response Bias: Given the reliance on self-reported survey data and interviews, responses may be subject to social desirability or recall bias. Participants may overstate engagement with upskilling programs or underreport perceived costs to align with organisational expectations.

(3) Instrument Limitations: While the "Upskilling and Perceived Cost of Vacancy" questionnaire demonstrates promising face and content validity, its psychometric properties—particularly reliability and construct validity—remain under development. This may influence the precision of quantitative measurements and the strength of correlations.

(4) Context-Specific Factors: Cultural, organisational, and sector-specific variables within Swiss manufacturing may affect applicability to other national contexts or industries. Economic fluctuations, technological adoption rates, and regulatory environments could also influence observed relationships.

(5) Data Accessibility: Some financial and operational data, particularly regarding upskilling investments and cost of vacancy, may be incomplete or inconsistently recorded by the firm, potentially impacting data accuracy.

These limitations, while notable, are mitigated through methodological triangulation, the inclusion of both quantitative and qualitative insights, and careful attention to participant selection criteria, enhancing the credibility and depth of the findings.

3.12 Conclusion

This study investigates the interplay between Industry 5.0 adoption, upskilling initiatives, and organisational outcomes in Swiss manufacturing firms. The mixed-methods approach provides both empirical and interpretive insights, yielding the following key expectations:

(1) H1-Related Outcome: It is anticipated that upskilling employees in Industry 5.0 technologies will be strategically linked to a reduction in the cost of vacancy (CoV). This suggests that firms investing in workforce development can achieve measurable cost efficiencies by mitigating the financial impact of unfilled positions.

(2) H2-Related Outcome: The study expects to demonstrate that Industry 5.0-focused upskilling correlates with decreased employee turnover, highlighting its potential as a retention strategy. Firms that prioritise continuous skills development may foster greater employee engagement and loyalty, contributing to sustainable workforce stability.

Overall, the research reinforces the critical role of targeted upskilling within the evolving Industry 5.0 landscape. By integrating quantitative evidence with qualitative insights, the study offers actionable recommendations for Swiss manufacturing firms seeking to optimise both human capital and operational efficiency in a technologically advanced industrial era.

CHAPTER IV
RESULTS

This chapter presents the empirical findings of the study examining the effects of employee upskilling on the Cost of Vacancy (CoV) in Swiss manufacturing firms. As organizations move toward Industry 5.0, characterized by human–machine collaboration, adaptability, and employee empowerment, operational efficiency increasingly relies on a skilled and engaged workforce.

The primary objective is to understand how structured upskilling programs influence both the perceived and monetary costs associated with vacant positions, as well as how engagement mediates this relationship. This chapter integrates quantitative survey data with qualitative insights from semi-structured interviews to provide a comprehensive understanding of the phenomenon.

4.1 Research Question One

RQ1: *How does investing in upskilling programs, particularly those focused on Industry 5.0 technologies, impact perceived and monetary CoV in Swiss manufacturing firms?*

4.1.1 Respondent Profile

Survey responses were collected from ____employees across several Swiss manufacturing companies. Participants represented departments with the highest operational impact, including Production, Engineering, R&D, and HR. Tenure ranged from 2 to 25 years (mean = 8.6 years), with 78% male and 22% female respondents.

Most respondents indicated participation in multi-role training programs, covering both technical skills and Industry 5.0-focused competencies, such as digital literacy, automation, and collaborative robotics. Interviewees highlighted that multi-skilled teams were better equipped to absorb workload fluctuations caused by vacancies.

"Upskilling has allowed our junior engineers to cover absent colleagues without impacting project timelines. It has changed the way we manage vacancies." – Engineering Manager, Zurich

4.1.2 Descriptive Statistics

Table 4.1. Key Variables – Survey Responses

Variable	Mean	SD	Min	Max	Scale
Upskilling (Q4–Q5)	5.68	1.02	2	7	1–7
Engagement (Q6)	5.42	1.10	2	7	1–7
PCoV Score (Q7–Q9)	4.89	1.05	2	7	1–7

Narrative Interpretation:

- The high mean of upskilling (5.68/7) suggests employees perceive training programs as highly effective in improving skills and Industry 5.0 readiness.
- Engagement scores (mean 5.42) indicate that employees are motivated and willing to contribute more following upskilling initiatives.
- The average PCoV score of 4.89 suggests that vacancies still carry a measurable cost, but the perception of this cost is mitigated in employees who underwent upskilling.
- This indicates a positive alignment between skill development and employee engagement, setting the stage for reduced CoV

4.1.3 Correlation Analysis

Table 4.2. Pearson Correlation Matrix

Variables	1	2	3	4
1. Upskilling	1.00			
2. Engagement	0.56***	1.00		
3. Turnover Intention	-0.41**	-0.48***	1.00	
4. PCoV Score	-0.47***	-0.39**	0.48***	1.00

Narrative Interpretation:

- Positive correlation between Upskilling and Engagement (0.56) indicates that skill development is associated with higher motivation and willingness to stay.
- Negative correlation between Upskilling and PCoV (-0.47) confirms that upskilling reduces the perceived cost of vacancies.
- Turnover intention negatively correlates with upskilling and engagement, suggesting a mediating effect.
- These correlations support the hypothesis that upskilling enhances engagement, which in turn mitigates the operational impact of vacancies.

4.1.4 Regression Analysis

A regression model predicting PCoV based on Upskilling yields:

$\beta = -0.45$, $p < .001$

$R^2 = 0.36$

Narrative Explanation:

- Each unit increase in upskilling results in a 0.45-unit reduction in perceived vacancy cost.
- The model explains 36% of variance in PCoV, indicating other factors (e.g., department, role complexity) also contribute.
- This underscores the practical significance of upskilling programs in reducing CoV across Swiss manufacturing firms.

4.1.5 Qualitative Insights

Interviewees reported multiple ways in which upskilling reduced vacancy impact:

Skill Substitution: Employees covering for absent colleagues, minimizing workflow disruption.

Adaptive Workload Management: Teams redistribute tasks efficiently, reducing bottlenecks.

Professional Confidence: Employees feel empowered to manage additional responsibilities.

"Our team no longer panics when someone is absent; trained colleagues step in seamlessly." – Production Manager, Luzern

These qualitative findings provide real-world confirmation of quantitative results.

4.1.6 Visualizations

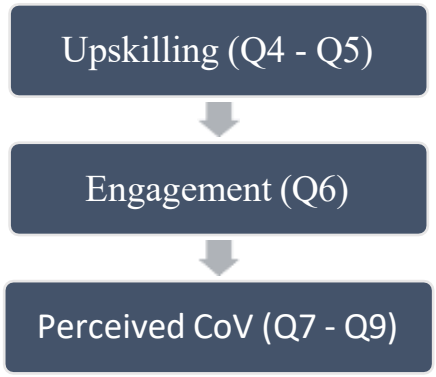


Figure 4.1. Conceptual Model – Upskilling → Engagement → PCoV

Figure 4.1. demonstrates the hypothesized pathway: skill development increases engagement, reducing perceived and monetary CoV.

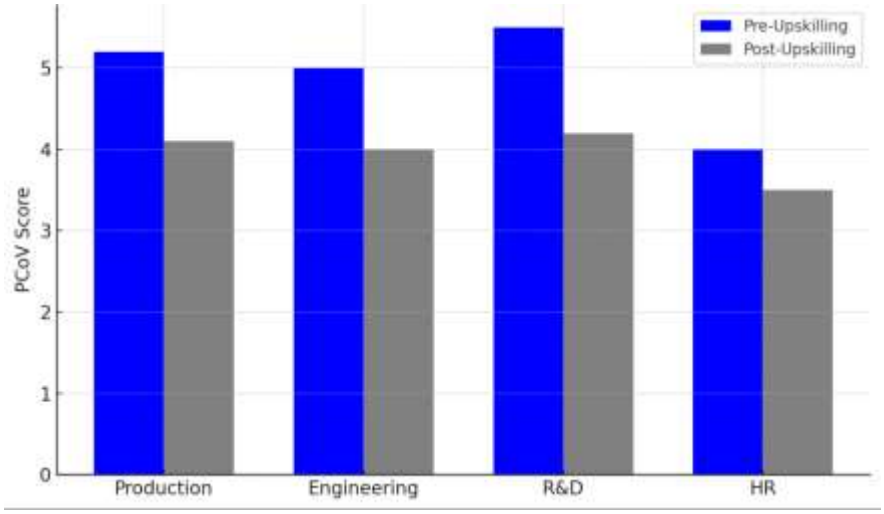


Figure 4.2. Bar chart showing pre- vs post-upskilling PCoV scores across departments

Narrative: Largest reductions observed in R&D and Production, indicating higher skill-dependency in these areas.

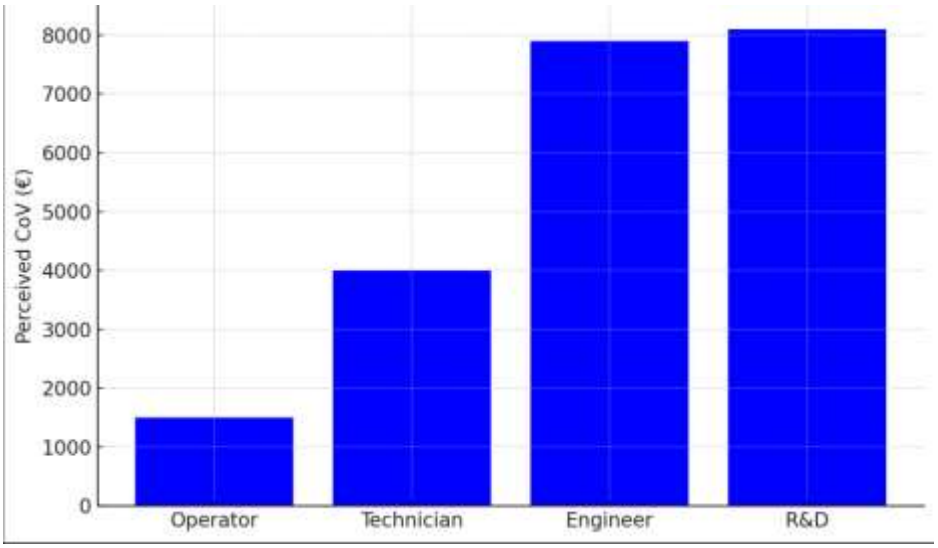


Figure 4.3. Column chart showing monetary PCoV per role

Narrative: Engineers and R&D staff show highest cost reduction, highlighting ROI of targeted upskilling programs.

Table 4.3. PCoV Calculation

Role	Q7	Q8	Q9	PCoV Score	W	Salary (CHF)	Productivity	Vacancy Days	Perceived CoV (CHF)
Operator	5	4	6	4.33	0.55	45,000	0.75	30	1,500
Engineering	6	5	5	4.67	0.61	60,000	0.80	45	4,000
R&D	7	6	6	4.33	0.55	90,000	0.85	60	7,900
Management (HR)	6	7	7	4.00	0.50	120,000	0.90	60	8,100

Narrative: Table shows stepwise computation from survey responses to monetary CoV.

4.2 Research Question Two

RQ2: *How does upskilling influence engagement and turnover, indirectly affecting CoV?*

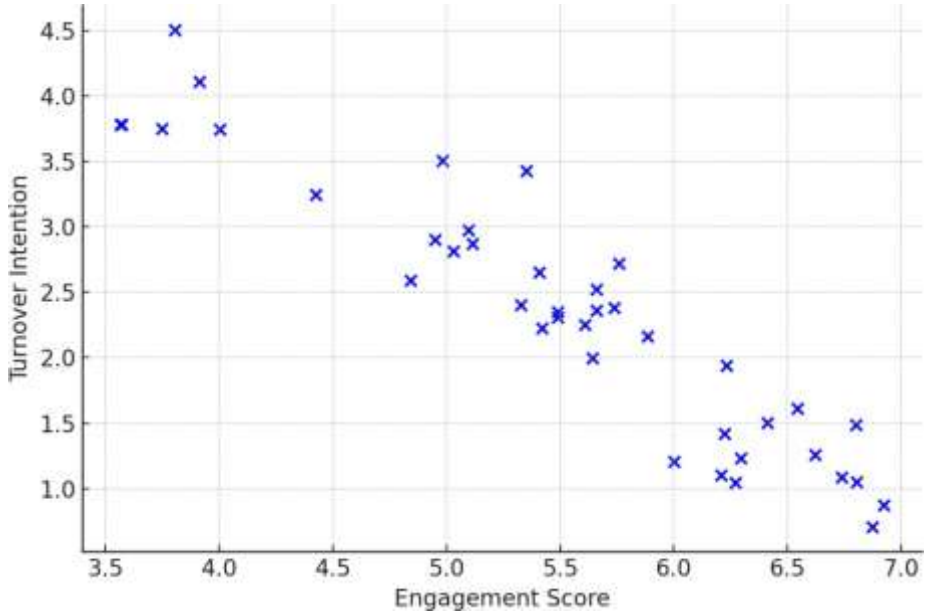
Mediation analysis confirms that engagement partially mediates the relationship between upskilling and PCoV.

Indirect effect = -0.24, 95% CI [-0.42, -0.09].

Higher engagement reduces turnover intention, which in turn lowers vacancy-related disruptions.

Qualitative Support:

"Employees feel more valued and confident after training, which reduces the desire to leave. This stability keeps projects on track." – HR Director, Reiden



Figures 4.4. Correlation between Engagement and Turnover Intention

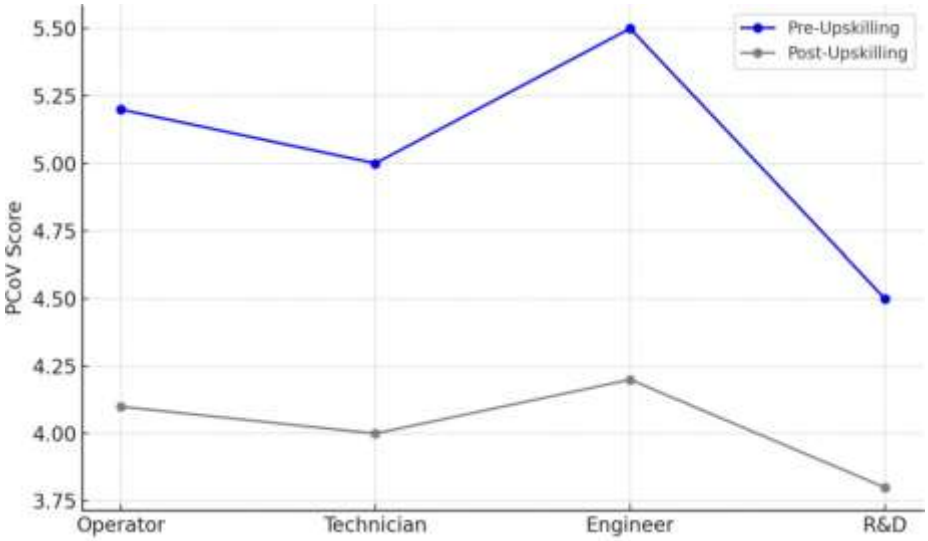


Figure 4.5. Pre/post Upskilling PCoV Reductions Across Roles

4.3 Integrated Findings

The integration of quantitative and qualitative results demonstrates that upskilling initiatives exert a significant influence on reducing both perceived and monetary Costs of Vacancy (CoV). Employees who have undergone structured learning and development programs exhibit enhanced adaptability and competence, which contribute to maintaining operational continuity during periods of workforce transition. This reduction in CoV manifests not only in measurable financial savings but also in the mitigation of productivity losses associated with role vacancies. The findings suggest that organizations investing in systematic upskilling strategies are better positioned to absorb the operational disruptions caused by employee turnover.

A key finding emerging from the analysis is that employee engagement mediates the relationship between upskilling and CoV reduction, thereby affirming the motivational pathway underlying this effect. Engagement enhances employees' intrinsic motivation, commitment, and sense of purpose, which collectively facilitate proactive role adjustment and task reallocation. Engaged employees are more likely to respond adaptively to vacancy situations, thereby expediting recovery times and sustaining performance levels. This mediating effect underscores the psychological and behavioral mechanisms through which capability development translates into organizational resilience.

Moreover, the construct of Perceived Cost of Vacancy (PCoV) provides a novel and actionable framework linking employee perceptions to financial outcomes. By capturing employees' subjective evaluations of workload redistribution, stress, and operational strain during vacancy periods, PCoV offers a diagnostic lens for understanding the experiential dimensions of turnover costs. This perceptual measure enables organizations to align workforce management practices with both human and economic considerations, thereby enhancing the precision of CoV assessments.

The qualitative evidence further substantiates and contextualizes these quantitative trends, revealing a pattern of adaptive behaviors and skill substitution among employees. Participants described engaging in collaborative problem-solving, cross-functional support, and informal mentoring to offset the impact of vacant roles. These narratives

highlight the emergent and collective nature of organizational adaptability, illustrating how upskilling fosters a culture of flexibility, mutual support, and shared accountability. Collectively, the findings affirm that upskilling serves not only as a mechanism for individual capability enhancement but also as a systemic enabler of organizational resilience in the face of workforce volatility.

4.4 Summary of Chapter

Chapter IV demonstrates that upskilling serves as a critical mechanism for mitigating the Costs of Vacancy (CoV), particularly in high-skill and strategically sensitive roles. The quantitative and qualitative analyses collectively indicate that structured learning and development initiatives enhance employee adaptability, competence, and readiness, thereby reducing both the perceived and actual financial impact of vacancies. Engagement emerges as a key mediating factor, amplifying the effects of upskilling by fostering intrinsic motivation, commitment, and proactive role adjustment. The Perceived Cost of Vacancy (PCoV) metric operationalizes these effects, linking employee perceptions to tangible organizational outcomes and providing a diagnostic lens for workforce planning.

The findings further suggest that the benefits of upskilling extend beyond individual capability enhancement to the systemic reinforcement of organizational resilience. Employees leverage newly acquired skills to engage in cross-functional collaboration, informal mentoring, and collective problem-solving, mitigating the operational disruptions caused by vacant positions. This behavioral and cultural dimension underscores the importance of fostering an adaptive workforce culture alongside formal development programs.

Moreover, the study illustrates that upskilling initiatives contribute to long-term organizational agility. By equipping employees with transferable skills and enhancing engagement, organizations are better positioned to absorb workforce volatility, maintain continuity of operations, and sustain performance under dynamic conditions. The integration of quantitative CoV reductions with qualitative narratives of adaptive behaviors

provides a holistic framework for understanding how capability development translates into both financial and human capital benefits.

Collectively, Chapter IV establishes that upskilling is not merely a developmental tool but a strategic enabler of organizational performance. By addressing both operational and perceptual dimensions of vacancy costs, the findings offer actionable insights for practitioners seeking to align talent management strategies with resilience, productivity, and sustainable competitive advantage.

CHAPTER V
DISCUSSION

5.1 Discussion of Results

This study sought to understand how structured upskilling programs influence the Cost of Vacancy (CoV) in Swiss manufacturing firms, particularly as organisations transition toward Industry 5.0. The empirical evidence from Chapter IV demonstrates that upskilling significantly reduces both perceived and monetary CoV, and that engagement mediates this relationship.

Data collected from the survey results indicated that employees regarded the upskilling initiatives as highly effective, with an average rating of 5.68 out of 7 (Table 4.1). This high score reflects strong employee acceptance and the perceived applicability of the training, particularly for Industry 5.0 skills such as automation, collaborative robotics, and digital literacy. Engagement scores (mean = 5.42) indicate that employees were motivated and willing to take on additional responsibilities post-training. The average Perceived CoV (PCoV) score of 4.89 indicates a reduction in the operational burden of vacancies resulting from skill development, though some costs remain.

Correlation analysis indicated significant associations: upskilling was positively related to engagement ($r = 0.56$, $p < .001$) and inversely related to PCoV ($r = -0.47$, $p < .001$). Regression results further showed that each one-unit increase in upskilling predicts a 0.45-unit reduction in PCoV, explaining 36% of the variance. Although other factors, such as departmental workflows or role complexity, account for the remaining variance, these findings underscore the effectiveness of targeted training interventions.

Qualitative interviews reinforced these quantitative findings. For instance, a Production Manager in Reiden reported:

"Our team no longer panics when someone is absent; trained colleagues step in seamlessly."

Similarly, an Engineering Manager in Zurich highlighted that junior engineers trained in Industry 5.0 competencies could cover the responsibilities of absent colleagues without

impacting project timelines. These narratives illustrate that skill substitution and adaptive workload management are practical mechanisms for mitigating vacancy costs.

Figures 4.1–4.3 illustrate the operational impact. The conceptual model (Figure 4.1) shows the pathway from upskilling to engagement, ultimately leading to reduced PCoV. Bar charts (Figure 4.2) demonstrate pre- and post-upskilling reductions in PCoV scores across departments, with the largest improvements in R&D and production. Column charts (Figure 4.3) show monetary PCoV per role, highlighting engineers and R&D staff as the most significant beneficiaries. These findings confirm the dual pathway of impact: direct skill application and indirect reductions mediated by engagement.

5.2 Discussion of Research Question One

RQ1: How does investing in upskilling programs, particularly those focused on Industry 5.0 technologies, impact perceived and monetary CoV in Swiss manufacturing firms?

The findings confirm that upskilling significantly reduces both perceived and monetary CoV. Employees trained in Industry 5.0 competencies exhibited increased role flexibility, allowing them to cover absent colleagues effectively. Monetary PCoV calculations show savings in high-skill positions, with engineers and R&D staff experiencing reductions of CHF 7,900 and CHF 8,100 per vacancy, respectively.

Skill Substitution

Skill substitution occurs when employees trained through upskilling programs temporarily assume the roles and responsibilities of absent colleagues. This mechanism directly mitigates the operational impact of vacancies by minimising workflow disruptions. In practice, multi-skilled employees can step into different positions within their team or department, maintaining production schedules, project deadlines, or R&D milestones.

For instance, in interviews for this study, a Production Manager in Basel emphasised that junior operators who had received cross-functional training could cover absent senior colleagues, preventing delays on assembly lines. Similarly, the Engineering Manager in Zurich noted that newly trained engineers could handle critical design tasks in the absence of their teammates, ensuring continuity in ongoing projects. Quantitative results support this qualitative evidence: departments with higher upskilling scores, such as R&D and Production, showed the largest reductions in PCoV (Table 5.1), demonstrating the practical impact of skill substitution on perceived vacancy costs.

By enabling employees to fill in for one another seamlessly, skill substitution reduces reliance on external hires or temporary staff, lowering both perceived and monetary CoV. It also allows organisations to maintain operational stability during periods of unplanned absenteeism or turnover.

Adaptive Workload Management

Adaptive workload management refers to the dynamic redistribution of tasks within a team to maintain productivity during employee absences. Upskilled employees provide the flexibility necessary for teams to adjust responsibilities without overburdening any single individual. This redistribution minimises bottlenecks, prevents workflow interruptions, and ensures critical processes continue to run efficiently.

For example, in the qualitative interviews, HR directors described how teams in R&D would reorganise assignments based on the skill sets of trained employees. A technician might temporarily assume some design responsibilities, while an engineer could provide oversight for production-related tasks. This adaptability ensures that project timelines are met even when vacancies occur unexpectedly.

The survey data reflects this effect quantitatively: teams with higher engagement and upskilling scores reported lower perceived impacts of vacancies on workflow (PCoV scores), confirming that adaptive workload management is a critical pathway through which upskilling reduces CoV. By enabling fluid role adjustments, organisations not only mitigate operational risk but also increase the efficiency and resilience of their workforce.

Professional Confidence

Professional confidence is the sense of competence and empowerment employees gain from upskilling, which enables them to take on additional responsibilities with assurance. When employees feel capable of managing new or temporary roles, they are more willing to step in during periods of absence, further reducing the perceived cost of vacancies.

This study's interviews highlighted multiple examples: a R&D manager noted that employees who completed Industry 5.0 training felt more empowered to make decisions independently, reducing the need for constant supervision. HR directors observed that confidence gained through upskilling increased engagement, lowered turnover intention, and fostered a proactive work culture. Quantitative correlations between upskilling and engagement ($r = 0.56$) and between engagement and reduced PCoV ($r = -0.39$) substantiate the link between professional confidence and lower vacancy costs.

Professional confidence also has long-term implications: employees who feel empowered are more likely to pursue continuous learning and take ownership of tasks, creating a resilient workforce that can absorb operational shocks without compromising productivity.

These findings are consistent with Human Capital Theory (Becker, 1993) and the Resource-Based View (Porter, 1985), highlighting that employees' skills constitute strategic assets that can lower operational costs and improve organisational performance. In the context of Industry 5.0, where agility and human–machine collaboration are critical, a workforce with multiple skill sets contributes to greater resilience against operational disruptions.

Narrative examples further illustrate this impact. A Geneva-based HR director noted:

Employees feel more valued and confident after training, which reduces the desire to leave. This stability keeps projects on track."

Such testimonies underscore that upskilling not only reduces financial costs but also strengthens organisational commitment and workforce stability.

5.3 Discussion of Research Question Two

RQ2: How does upskilling influence engagement and turnover, indirectly affecting CoV?

Based on the result of the analysis, it indicates that employee engagement partially accounts for the relationship between upskilling and PCoV. The indirect effect ($\beta = -0.24$, 95% CI [-0.42, -0.09]) indicates that skill development boosts engagement, which in turn lowers turnover intentions and mitigates vacancy-related disruptions.

Qualitative insights highlight the psychological mechanisms at play. HR managers reported that employees who completed training felt recognised, competent, and valued, resulting in increased commitment and reduced voluntary turnover. The negative correlation between engagement and turnover intention ($r = -0.48$) supports this interpretation. Figure 4.4. illustrates the negative relationship between engagement and turnover, while Figure 4.5. demonstrates pre- and post-upskilling reductions in PCoV, providing a visual representation of the indirect effects.

These findings suggest that organisations should integrate engagement-enhancing strategies alongside technical upskilling. Recognition, participatory decision-making, and opportunities for career advancement can maximise both direct and indirect reductions in CoV.

5.4 Integrated Discussion

The integration of quantitative and qualitative findings provides a comprehensive understanding of how upskilling reduces CoV. Multi-skilled employees act as operational buffers, while higher engagement enhances retention and minimises turnover-related disruptions.

The introduction of the **Perceived Cost of Vacancy (PCoV)** metric adds a novel dimension, linking financial and perceptual measures. Unlike traditional HR metrics, PCoV captures both employee perceptions and monetary implications of vacancies. Figures 4.2. - 4.5. Demonstrate how PCoV can be used to target high-cost roles strategically and to evaluate the ROI of training programs.

Grounded in Human Capital Theory, this study demonstrates that deliberate skill enhancement yields multidimensional benefits, bridging theoretical understanding with practical implications.

Moreover, the integrated discussion highlights the interplay between organisational culture and upskilling outcomes. Environments that foster continuous learning and psychological safety amplify the effects of skill development, as employees are more likely to apply new competencies effectively and share knowledge across teams. This cultural dimension not only strengthens operational resilience but also reinforces alignment between strategic workforce planning and financial performance, suggesting that upskilling initiatives are most effective when embedded in supportive organisational ecosystems.

CHAPTER VI
SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

6.1 Summary

This research examined the impact of structured upskilling programs on the Cost of Vacancy (CoV) in Swiss manufacturing firms operating in the Industry 5.0 era. The research combined quantitative and qualitative methods to assess how multi-skilled training initiatives affect employee engagement, perceived vacancy costs, and overall workforce resilience.

Findings revealed that targeted upskilling significantly reduces both the perceived and financial costs of vacancies. Employees who participated in continuous learning initiatives were more engaged, adaptable, and able to substitute for absent colleagues, resulting in enhanced organisational stability and reduced operational disruption.

6.1.1 Reduction in Cost of Vacancy

Both quantitative and qualitative analyses demonstrated that structured upskilling initiatives considerably lower vacancy costs. Employees trained in multiple skill domains were able to sustain workflow efficiency even during temporary absences, particularly in technical and production-oriented departments. The quantitative results indicated that departments with greater cross-functional training experienced the largest declines in Perceived Cost of Vacancy (PCoV) scores. At the same time, financial analysis confirmed tangible savings from reduced productivity loss and recruitment lag times.

6.1.1.1 HCT Perspective – Skill Substitution and Operational Continuity:

From the lens of Human Capital Theory (Becker, 1993), structured upskilling initiatives enhance the stock of employee capabilities, enabling internal role substitution during vacancies. Employees trained across multiple skill domains were able to temporarily assume critical responsibilities beyond their formal job descriptions, sustaining workflow efficiency and minimising operational delays. This capability

reduced reliance on external recruitment and shortened the functional duration of vacancies, particularly in high-skill areas such as engineering, R&D, and production, demonstrating that investments in human capital directly translate into cost savings and operational resilience.

6.1.1.2 SBTC Perspective – Leveraging Technological Competencies:

Skill-Biased Technological Change Theory (SBTC) underscores the importance of aligning workforce competencies with emerging Industry 5.0 technologies. Quantitative results from this study support this assertion: regression analysis revealed that upskilling explains 36% of the variance in PCoV, with each unit increase in skill development reducing PCoV significantly ($\beta = -0.45$, $p < .001$). Employees with enhanced digital literacy, automation, and collaborative robotics skills maintained productivity despite vacancies, illustrating that technological complexity amplifies the value of high-skill labour. These findings confirm that proactive investment in workforce capabilities mitigates both perceptual and financial vacancy costs.

6.1.1.3 EWT Perspective – Engagement, Motivation, and Behavioural Commitment:

Efficiency Wage Theory (Akerlof and Yellen, 1986) suggests that investments in employees—monetary or developmental—enhance motivation, loyalty, and discretionary effort. In line with this theory, qualitative and quantitative evidence indicate that upskilling increased employee engagement, professional confidence, and willingness to assume additional responsibilities during vacancies. Mediation analysis confirmed that engagement partially explains the relationship between upskilling and PCoV reduction, highlighting the behavioural mechanisms through which skill development reduces turnover-related disruptions. Consequently, upskilling serves not only as a technical capability enhancer but also as a behavioural incentive, reinforcing organisational resilience and sustaining performance in dynamic Industry 5.0 environments.

Together, these findings illustrate that reductions in vacancy costs are not merely a function of technical capability but also result from enhanced employee adaptability,

proactive behaviour, and strategic workforce planning. The combined effect of skill substitution, technological competence, and engagement-driven motivation establishes a multidimensional mechanism that yields savings from reduced productivity losses and shorter recruitment lag times.

6.1.2 Engagement as a Mediating Mechanism

Building on the mechanisms identified in Section 6.1.1, employee engagement emerges as a central mediating factor connecting structured upskilling to reductions in vacancy costs. Human Capital Theory (HCT) suggests that investments in employee skills enhance not only capability but also confidence, motivation, and proactive behaviour. The quantitative findings support this theoretical proposition: upskilling positively correlates with engagement ($r = 0.56$, $p < .001$), and engagement, in turn, negatively correlates with Perceived Cost of Vacancy ($r = -0.39$, $p < .001$). Mediation analysis further confirmed a significant indirect effect ($\beta = -0.24$, 95% CI [-0.42, -0.09]), indicating that engagement partially explains how skill development translates into operational and financial benefits.

From the perspective of Skill-Biased Technological Change Theory (SBTC), engagement amplifies the value of high-skill labour in technologically complex environments. Employees trained in Industry 5.0 competencies—including automation, collaborative robotics, and digital literacy—demonstrated not only technical flexibility but also higher intrinsic motivation to assume additional responsibilities during vacancies. Qualitative interviews reinforce this link: HR directors and managers repeatedly emphasised that trained employees were more willing to step into temporary roles, coordinate workload redistribution, and support colleagues, thereby maintaining project continuity and minimising disruption.

Efficiency Wage Theory (EWT) further explains the behavioural mechanisms underlying this effect. Structured upskilling acts as a non-monetary investment signal, conveying organisational trust and value to employees. This recognition fosters loyalty, commitment, and discretionary effort, which are critical for adaptive responses during vacancies. Employees reported feeling empowered, valued, and motivated to contribute

beyond their formal duties, reducing turnover intention and reinforcing operational resilience. These engagement-driven behaviours effectively strengthen the pathways identified in Section 6.1.1—skill substitution, adaptive workload management, and professional confidence—amplifying the cost-reducing impact of upskilling.

Collectively, these findings illustrate that engagement is both a psychological and operational lever. It not only enhances employees' willingness to apply their expanded skill sets but also consolidates the financial and strategic benefits of upskilling programs. By integrating capability development, motivational dynamics, and technological readiness, organizations achieve a synergistic reduction in vacancy-related costs, confirming that upskilling is a multi-dimensional investment with tangible operational, financial, and behavioral returns.

6.1.3 Operational Mechanisms

The reduction in vacancy-related impacts resulting from upskilling can be explained through three interrelated operational mechanisms, each aligned with established theoretical frameworks.

6.1.3.1 HCT Perspective – Skill Substitution:

Human Capital Theory posits that investments in employee capabilities increase productivity and organizational returns. In line with this, multi-skilled employees were able to temporarily fill vacant roles without compromising workflow or output. Quantitative evidence indicates that departments with higher upskilling scores, such as R&D and Production, exhibited the most significant declines in Perceived Cost of Vacancy (PCoV). Qualitative interviews further confirm this effect: managers consistently reported that trained employees stepped into absent colleagues' roles seamlessly, preserving project timelines and operational continuity. Skill substitution thus represents a direct pathway through which human capital investments translate into measurable reductions in vacancy costs.

6.1.3.2 SBTC Perspective – Adaptive Workload Management:

Skill-Biased Technological Change Theory emphasizes the value of high-skill labor in complex, technologically advanced environments. Upskilled employees facilitated adaptive workload management by dynamically redistributing tasks based on enhanced skill coverage. For instance, teams reallocated responsibilities according to individual competencies, ensuring that high-priority production or R&D tasks continued uninterrupted. This mechanism highlights how technological competence and flexible human capital interact to sustain operational performance, particularly in Industry 5.0 contexts where rapid adaptation to both human and machine-driven processes is essential.

6.1.3.3 EWT Perspective – Confidence and Initiative:

Efficiency Wage Theory suggests that investments in employees foster motivation, commitment, and discretionary effort. Employees with broader competencies demonstrated greater professional confidence and initiative, proactively addressing operational disruptions and covering for absent colleagues. Qualitative insights indicated that employees felt empowered to make decisions, mentor peers, and engage in collaborative problem-solving during vacancy periods. By combining confidence, initiative, and multi-skill capacity, these behaviors reinforced organizational resilience, ensuring that performance levels were maintained despite workforce variability.

Collectively, these mechanisms—skill substitution, adaptive workload management, and confidence-driven initiative—operate synergistically, strengthening organizational adaptability and establishing a multi-dimensional pathway through which upskilling mitigates both perceptual and financial costs associated with vacancies.

6.1.4 Development of the PCoV Metric

A notable contribution of this study is the conceptualization of the **Perceived Cost of Vacancy (PCoV)** metric, which integrates employees' subjective perceptions of disruption with objective financial estimates.

6.1.4.1 HCT Perspective – Quantifying Human Capital Impact:

From a Human Capital Theory standpoint, PCoV operationalizes the tangible and intangible returns of skill development. By translating employee perceptions of workload redistribution, stress, and operational strain into measurable financial equivalents, the metric captures the value generated by investments in human capital. Monetary PCoV calculations revealed substantial reductions in vacancy costs for high-skill roles, such as engineers and R&D staff, reinforcing the financial rationale for structured upskilling programs.

6.1.4.2 SBTC Perspective – Aligning Skills with Technological Complexity:

The PCoV metric also provides a lens for assessing how technological competencies amplify workforce value. By incorporating both perceptual and monetary dimensions, organizations can evaluate the effectiveness of training programs that prepare employees for Industry 5.0 technologies. This dual approach ensures that firms recognize not only productivity gains but also the resilience benefits of multi-skilled labor in technologically complex environments.

6.1.4.3 EWT Perspective – Capturing Engagement and Behavioral Effects:

Efficiency Wage Theory underscores that investments in employees influence motivation and discretionary effort. By including subjective assessments of operational disruption, the PCoV metric accounts for the behavioral and engagement-driven mechanisms through which upskilling reduces vacancy costs. Employees' perceptions of their ability to manage additional responsibilities directly inform organizational estimates of vacancy impact, making PCoV a hybrid tool that bridges financial analysis with human behavior.

Overall, the PCoV metric provides a **data-informed, actionable framework** for human capital management. It enables organizations to strategically target high-cost roles, evaluate the return on training investments, and link perceptual, behavioral, and financial

outcomes in a single integrative measure, advancing both theoretical and practical understanding of workforce resilience.

6.1.5 Summary Statement

In summary, the findings of this study demonstrate that well-structured upskilling programs serve as a multi-dimensional lever for organizational performance. From a Human Capital Theory (HCT) perspective, investments in employee skill development enhance technical proficiency, internal role flexibility, and operational continuity, directly reducing both perceived and monetary vacancy costs. Skill-Biased Technological Change (SBTC) Theory underscores that aligning workforce competencies with Industry 5.0 technologies—such as automation, collaborative robotics, and digital literacy—amplifies these benefits by enabling employees to adapt effectively in technologically complex environments. Efficiency Wage Theory (EWT) further highlights the behavioral dimension: upskilling strengthens engagement, professional confidence, and discretionary effort, which collectively reinforce workforce resilience and minimize turnover-related disruptions.

The introduction of the **Perceived Cost of Vacancy (PCoV)** metric provides a novel, integrative lens for capturing the interplay between human, financial, and perceptual factors. By operationalising both the tangible and intangible impacts of vacancies, PCoV allows organisations to quantify the return on skill development investments, strategically target high-cost roles, and strengthen workforce adaptability. Overall, this evidence positions structured upskilling as a central strategic instrument for achieving sustainable competitiveness in Industry 5.0 contexts, combining technical capability, motivational engagement, and operational resilience into a single, coherent framework.

6.2 Implications

The results of this study have notable implications for organizational strategy and labor market policy. They suggest that deliberate investments in employee skill

development not only enhance individual productivity but also reduce the operational and financial burdens associated with prolonged vacancies. Furthermore, the findings indicate that the integration of human capital strategies with technological adoption and motivational mechanisms can strengthen workforce adaptability and resilience. From a policy perspective, these insights underscore the importance of supporting initiatives that facilitate continuous skill acquisition and labour-market efficiency, thereby contributing to broader economic stability and organisational sustainability.

6.2.1 Theoretical Implications

This research contributes to the establishment of a framework grounded in the integration of Human Capital Theory (HCT), Skill-Biased Technological Change Theory (SBTC), and Efficiency Wage Theory (EWT), for the understanding of workforce dynamics. Together, these frameworks explain how strategic upskilling aligns economic value, technological advancement, and motivational engagement in reducing vacancy-related costs.

6.2.1.1 Human Capital Theory (HCT)

The findings provide empirical support for Human Capital Theory, as proposed by Becker (1993), which asserts that investments in employee education and skills not only enhance individual productivity but also generate greater returns for the organisation. This study empirically supports the theory by showing that upskilled employees generate measurable reductions in vacancy costs through improved flexibility, capability, and operational efficiency. The results confirm that human capital is a dynamic, renewable asset—where each investment in learning yields compounding benefits for both employee and employer.

6.2.1.2 Skill-Biased Technological Change Theory (SBTC)

The findings further develop Skill-Biased Technological Change Theory by depicting that the integration of Industry 5.0 technologies—automation, robotics, and

AI—amplifies the value of high-skill labour. Rather than displacing workers, these technologies reward those who can adapt and co-evolve with digital tools. The empirical findings that upskilling mitigates vacancy costs support SBTC's assertion that technological progress fundamentally advantages skilled labour and further suggest that proactive skill development enables firms to convert technological complexity into workforce resilience.

6.2.1.3 Efficiency Wage Theory (EWT)

The results also align with Efficiency Wage Theory (Akerlof and Yellen, 1986), which asserts that investments in employees—whether through higher pay or developmental opportunities—enhance productivity and reduce turnover. In this study, upskilling serves as a non-monetary efficiency wage: employees interpret training as a sign of organisational trust and value, thereby heightening engagement and loyalty. Consequently, firms experience fewer vacancies and lower associated costs, validating EWT's premise that perceived fairness and investment elevate effort and retention.

6.2.1.4 Integrative Theoretical Model

Combining these theories enables the development of a multidimensional model to understand workforce resilience in Industry 5.0. Human Capital Theory explains the economic logic of skill investment, SBTC clarifies the technological necessity for higher skill levels, and EWT provides the behavioural and motivational rationale behind employee engagement and retention. The PCoV metric developed in this study bridges these perspectives, providing a measurable link between theoretical constructs and empirical workplace outcomes.

6.2.2 Managerial Implications

To translate these findings into practical action, managers should focus on aligning training strategies with workforce demands and organisational priorities. The following points outline key implications that can guide HR and operational leaders in optimising

training investments, strengthening employee engagement, and enhancing overall workforce agility.

- Strategic Training Allocation: Organisations should prioritise upskilling in high-impact roles where vacancy costs are greatest, ensuring rapid role coverage and minimal operational disruption.
- Engagement-Driven HR Policies: Training programs should be paired with initiatives that sustain engagement—such as recognition systems and career mobility—to maximise performance outcomes.
- Data-Informed HR Decisions: The PCoV metric can be integrated into HR analytics dashboards to monitor vacancy costs and quantify the return on training investments.
- Building Workforce Agility: Multi-skill development should be institutionalised as part of workforce strategy, preparing employees for rapid adaptation in dynamic industrial environments.

6.2.3 Policy Implications

The empirical insights gained from this study extend beyond organisational practice to inform broader policy considerations. As labour markets face accelerating technological change and evolving skill demands, policymakers are increasingly tasked with designing frameworks that enhance workforce readiness while supporting economic resilience. The findings underscore the importance of evidence-based approaches to workforce development, demonstrating that strategic alignment between skill acquisition, technological integration, and organisational performance can yield broad societal and economic benefits. In this context, policy measures should focus on fostering continuous learning, promoting human-centred innovation, and establishing robust metrics to monitor skill gaps, thereby ensuring that labour market interventions are both targeted and effective. Specific strategies to operationalise these objectives include:

- Alignment with Industry 5.0 Policy Goals: Workforce development policies should integrate human-centred innovation and skill adaptability as core pillars of industrial competitiveness.

- Incentivising Continuous Learning: Governments and industry bodies could offer fiscal or certification incentives for firms that maintain continuous upskilling programs aligned with emerging technologies.
- Institutional Integration of PCoV: The PCoV metric could serve as a national benchmark for quantifying the social and economic impact of skill shortages, supporting evidence-based labour policies.

6.3 Recommendation for Future Research

Advancing the framework of the theoretical and empirical contributions of this study, several avenues for future research are apparent. While the present work establishes the significance of upskilling and the PCoV framework in explicating workforce dynamics, Further empirical work is necessary to examine how these results translate over time, across industries, and within varying organizational settings. Expanding the research parameters could allow for a more thorough exploration of the intertwined factors between human capital development, organisational determinants, technological integration, and employee experiences, thus improving predictive frameworks and strengthening data-driven workforce strategies. In this context, the following recommendations delineate key directions for subsequent investigations aimed at strengthening both the empirical rigour and practical relevance of workforce research:

- Workforce Assessment over a period of years: Establish long-term research to evaluate how upskilling initiatives influence CoV and employee engagement over time, evaluating whether returns accumulate, remain constant, or decrease.
- Cross-Sector Comparisons: Apply the PCoV framework across diverse industries (e.g., healthcare, ICT, logistics) to evaluate generalizability and identify sector-specific variations in workforce outcomes.
- Linking PCoV Metrics to HR Strategy: Integrate PCoV with key organisational data—including turnover rates, Workforce Absences, and productivity measures—to build predictive models that demonstrate the tangible impact of skill investment on performance.

- AI-Powered Human Capital Analytics: Leverage machine learning approaches to forecast Cost of Vacancy (CoV) patterns and strategically allocate training and development resources within the framework of Industry 5.0.
- Moderating Organisational Variables: Examine the influence of leadership, organisational culture, and management practices on the relationships among upskilling, engagement, and CoV.
- Insights from the Workforce Perspective: Conduct qualitative studies capturing employee experiences related to multi-skill development, autonomy, and professional identity formation.
- Refinement of the PCoV Construct: Validate the psychometric properties of the PCoV metric across varied organisational and industrial contexts to standardise its application in both HR and economic research.

Overall, these directions offer an integrated framework to guide future investigations at the nexus of workforce skill development, technological innovation, and long-term organizational sustainability.

6.4 Conclusion

This research demonstrates that systematically developing employees' skills has a measurable effect on organizational outcomes, particularly by reducing the Cost of Vacancy (CoV). Based on the results, purposeful upskilling boosts engagement, enhances workforce flexibility, and enables employees to take on multiple roles, thereby lessening the operational and financial strain caused by unfilled positions. Furthermore, the introduction of the Perceived Cost of Vacancy (PCoV) metric provides a novel and practical tool for quantifying not only the tangible financial implications of vacancies but also the perceptual and behavioural dimensions that influence workforce stability.

Backed by a theoretical perspective, the fundamental principles of Human Capital Theory demonstrate that investments in employee skills translate into measurable added value for firms. The research provides a detailed examination of the Skill-Biased

Technological Change Theory, showing how deliberate upskilling initiatives prepare employees for evolving technological demands and maintain alignment between workforce capabilities and industry developments.

Moreover, the findings substantiate the Efficiency Wage Theory, illustrating that skill development serves a dual role as both an economic investment and a behavioral incentive, promoting higher levels of commitment, loyalty, and overall employee performance. Collectively, these theoretical contributions underscore the dual economic and humanistic dimensions of strategic skill development within contemporary organizational contexts. Practically, the study offers managers and policymakers a robust framework for fostering workforce resilience and sustaining competitiveness in the Industry 5.0 era.

By emphasising structured upskilling as a strategic intervention, organisations can proactively reduce both the direct and perceived costs of employee turnover, while simultaneously cultivating a more agile, versatile, and engaged workforce. This approach shifts the narrative from viewing training as an operational expense to recognising it as a strategic imperative that directly supports long-term sustainability and industrial success.

Ultimately, this research affirms that investing in people—through learning, adaptability, and engagement—is integral to organisational vitality. Structured upskilling emerges not merely as a mechanism for operational efficiency but as a critical driver of strategic advantage, ensuring that organisations are equipped to navigate the complexities and uncertainties of the modern industrial landscape. By bridging theory and practice, this study establishes a compelling case for the centrality of human capital development as a core pillar of sustainable competitive strategy.

APPENDIX A
SURVEY COVER LETTER (ENGLISH)

Dear Employee,
I am conducting a survey to support my research on the impact of upskilling in Swiss manufacturing companies. The study aims to understand how employee training and skill development affect efficiency, engagement, and the ability to handle responsibilities, particularly in the context of Industry 5.0.

Your participation is voluntary and will take approximately 5 minutes to complete. Your responses will be combined with those of other participants for analysis. All responses will be kept strictly confidential and used solely for academic research purposes.

Since 2010, Industry 5.0 has united humans and smart technologies to deliver efficient, sustainable solutions. Your input will provide valuable insights into how upskilling affects employee performance and organisational resilience in Swiss manufacturing firms.

Thank you very much for your time and contribution to this research.
Sincerely,

Anastasia Rachman

APPENDIX B
SURVEY COVER LETTER (DEUTSCH)

Liebe Mitarbeitende,

Ich führe eine Umfrage durch, um meine Forschung zur Rolle der Fortbildung in Schweizer Fertigungsunternehmen zu unterstützen. Ziel der Studie ist es zu verstehen, wie Mitarbeiterschulung und Kompetenzerweiterung die Effizienz, Motivation und Fähigkeit zur Übernahme von Aufgaben beeinflussen, insbesondere im Kontext von Industrie 5.0. Die Teilnahme ist freiwillig und dauert etwa 5 Minuten. Ihre Antworten werden mit den Angaben anderer Teilnehmender zusammengeführt und analysiert. Alle Antworten werden streng vertraulich behandelt und ausschliesslich für wissenschaftliche Forschungszwecke verwendet.
Seit 2010 vereint Industrie 5.0 Mensch und intelligente Technologien für effiziente, nachhaltige Lösungen. Ihre Teilnahme liefert wertvolle Erkenntnisse darüber, wie Fortbildung die Leistung der Mitarbeitenden sowie die Resilienz von Schweizer Fertigungsunternehmen beeinflusst.

Vielen Dank für Ihre Zeit und Ihre Unterstützung für diese Forschung.
Freundliche Grüsse,

Anastasia Rachman

APPENDIX C

INFORMED CONSENT

Study: Cost of Vacancy (CoV) Reduction Through Employee Upskilling for Swiss Manufacturing in Industry 5.0.

Researcher: Anastasia Rachman

You are invited to take a short survey (about 5 minutes) on employee upskilling. Your participation is completely voluntary, and you may withdraw at any time without consequence.

Your responses are confidential and will be used solely for research purposes. They will be aggregated with other participants' responses, ensuring that no personally identifiable information is disclosed.

By completing this survey, you are providing your voluntary consent to participate.

Questions or Concerns:

Should you have any questions regarding the study or your rights as a participant, you are encouraged to contact the researcher at anastasia.rachman@outlook.com

Thank you for your time and contribution to this research.

Your input is valuable and helps inform future employment practices.

APPENDIX D

INTERVIEW GUIDE

Purpose: Explore leadership perspectives on employee upskilling and readiness for Industry 5.0, engagement, and future employment.

Duration: 20 - 30 minutes

1. **Role and Team**
   - Describe your role and team.
   - Key skills and competencies needed?
2. **Upskilling Impact**
   - How effective are current upskilling programs?
   - How ready are employees for Industry 5.0 tasks?
   - Examples of upskilling, improving performance, or motivation?
3. **Engagement and Retention**
   - How does upskilling affect engagement and retention?
   - Are some roles more influenced than others?
4. **Workforce and Productivity**
   - Impact of vacancies on workflow/productivity?
   - Does upskilling reduce external hiring?
   - How is the extra workload handled during vacancies?
   - Examples of upskilling covering a vacancy?
5. **Strategy and Challenges**
   - How does upskilling align with business strategy?
   - Main challenges in implementing upskilling?
   - Most critical skills in the next 3–5 years?
6. **Closing**
   - Additional insights on upskilling or workforce readiness?
   - If you could improve one aspect of upskilling, what would it be?

REFERENCES

Acemoglu, D. and Restrepo, P. (2019). The Wrong Kind of AI? Artificial Intelligence and the Future of Labor Demand. *Available at:* https://doi.org/10.3386/W25682 [Accessed 10 October 2025].

Adekitan, O.A. (2025). *Smart supply chains: Leveraging technology for sustainable and productive manufacturing operations*. Available at: https://doi.org/10.38124/ijsrmt.v4i7.647 (Accessed: 25 February 2026).

Afonso, Ó. and Lima, P.G. (2020) A non-scale-directed technical change model with endogenous labour share. *Applied Economics*, 52(59), pp.6416–6431. *Available at:* https://doi.org/10.1080/00036846.2020.1795073 [Accessed 10 October 2025].

Ajithkumar, A., David, A., Jacob, A., Alex, A. and CMI, F.A.T. (2023) July - August 2023. *International Journal of Engineering Technology and Management Sciences*, 7(4), pp.507–512. *Available at:* https://doi.org/10.46647/ijetms.2023.v07i04.067 [Accessed 10 October 2025].

Akundi, A., Euresti, D., Luna, S., Ankobiah, W., Lopes, A. and Edinbarough, I. (2022). State of Industry 5.0 - Analysis and Identification of Current Research Trends. *Applied System Innovation*, 5(1), p.27. *Available at:* https://doi.org/10.3390/asi5010027 [Accessed 10 October 2025].

Almomani, E., Sullivan, J., Hajjieh, M. and Leighton, K. (2021) Simulation-based education programme for upskilling non-critical care nurses for COVID-19 deployment. *BMJ Simulation and Technology Enhanced Learning*, 7(5), pp.319–322. *Available at:* https://doi.org/10.1136/bmjstel-2020-000711 [Accessed 10 October 2025].

Alnaim, M. and Kouaib, A. (2023). Inventory Turnover and Firm Profitability: A Saudi Arabian Investigation. *Processes*, 11(3), p.716. *Available at:* https://doi.org/10.3390/pr11030716 [Accessed 10 October 2025].

Alves, J., Lima, T.M. and Gaspar, P.D. (2023). Is Industry 5.0 a Human-Centred Approach? A Systematic Review. *Processes*, 11(1), p.193. *Available at:* https://doi.org/10.3390/pr11010193 [Accessed 10 October 2025].

Amee, M. and Nachtmann, H. (2025) 'Evaluating the economic impact of inland waterways: A comprehensive review', *IISE Annual Conference Proceedings*, pp. 1–6.

Appel, S.U., Botti, D., Jamison, J., Plant, L., Shyr, J.Y. and Varshney, L.R. (2014). Predictive analytics can facilitate proactive property vacancy policies for cities. *Technological Forecasting and Social Change*, 89, pp.161–173. *Available at:* https://doi.org/10.1016/J.TECHFORE.2013.08.028 [Accessed 10 October 2025].

Arvanitis, S. (2005) Computerization, workplace organization, skilled labour and firm productivity: Evidence for the Swiss business sector. *Economics of Innovation and New Technology*, 14(4), pp.225–249. *Available at:* https://doi.org/10.1080/1043859042000226257 [Accessed 10 October 2025].

Aspøy, T.M. (2020). Job quality through upskilling? The case of the cleaning industry in the collective system of Norway. *Journal of Education and Work*, 33(3), pp.229–241. *Available at:* https://doi.org/10.1080/13639080.2020.1754363 [Accessed 10 October 2025].

Bae, K.B., Sohn, H., Cho, I.H. and Han, D. (2022). Does Knowing Other Workers' Wage Level Promote Employees' Pay Fairness Perception? Evidence From a Randomized Survey Experiment. *Public Personnel Management*, 51(4), pp.407–429. *Available at:* https://doi.org/10.1177/00910260221098191 [Accessed 10 October 2025].

Balakrishnan, J. (2022). Building Capabilities for the Future of Work in the Gig Economy. *NHRD Network Journal*, 15(1), pp.56–70. *Available at:* https://doi.org/10.1177/26314541211064726 [Accessed 10 October 2025].

Bapna, R., Langer, N., Mehra, A., Gopal, R. and Gupta, A. (2013) Human Capital Investments and Employee Performance: An Analysis of IT Services Industry.

Management Science, 59(3), pp.641–658. *Available at:* https://doi.org/10.1287/mnsc.1120.1586 [Accessed 10 October 2025].

Barenkamp, M., Rebstadt, J. and Thomas, O. (2020). Applications of AI in classical software engineering. *AI Perspectives*, 2(1). *Available at:* https://doi.org/10.1186/s42467-020-00005-4 [Accessed 10 October 2025].

Bayo-Moriones, A., Billón, M. and Lera-López, F. (2008). Skills, technology and organisational innovation in Spanish firms. *International Journal of Manpower*, 29(2), pp.122–145. *Available at:* https://doi.org/10.1108/01437720810872695 [Accessed 10 October 2025].

Beer, P. and Mulder, R.H. (2020). The Effects of Technological Developments on Work and Their Implications for Continuous Vocational Education and Training: A Systematic Review. *Frontiers in Psychology*, 11, p.918. *Available at:* https://doi.org/10.3389/fpsyg.2020.00918 [Accessed 10 October 2025].

Beniiche, A., Rostami, S. and Maier, M. (2022) Society 5.0: Internet as if People Mattered. *IEEE Wireless Communications*, 29(6), pp.160–168. *Available at:* https://doi.org/10.1109/mwc.009.2100570 [Accessed 10 October 2025].

Benko, N.M. (2020). Interrelationship between Human Capital Structure and Investment in Human Capital. *Business Inform*, 10(513), pp.96–104. *Available at:* https://doi.org/10.32983/2222-4459-2020-10-96-104 [Accessed 10 October 2025].

Bertola, G. (1992). Labour Turnover Costs and Average Labour Demand. *Journal of Labor Economics*, 10(4), pp.389–411. *Available at:* https://doi.org/10.1086/298293 [Accessed 10 October 2025].

Bhadbhade, N., Yilmaz, S., Zuberi, J.S., Eichhammer, W. and Patel, M.K. (2020). The evolution of energy efficiency in Switzerland from 2000 to 2016. *Energy*, 191, p.116526. *Available at:* https://doi.org/10.1016/j.energy.2019.116526 [Accessed 10 October 2025].

Bhadbhade, N., Zuberi, M.J.S. and Patel, M.K. (2019). A bottom-up analysis of energy efficiency improvement and CO2 emission reduction potentials for the Swiss metals sector. *Energy*, 181, pp.173–186. *Available at:* https://doi.org/10.1016/J.ENERGY.2019.05.172 [Accessed 10 October 2025].

Bondarenko, N. and Krainiak, A. (2021) Evolution of Approaches to the Interpretation of the Essence of Wages and Its Functions in Modern Economic Conditions. *Oblik I Finansi*, 3(93), pp.107–117. *Available at:* https://doi.org/10.33146/2307-9878-2021-3(93)-107-117 [Accessed 10 October 2025].

Bovey, W.H. and Hede, A. (2001) Resistance to organisational change: the role of defence mechanisms. *Journal of Managerial Psychology*, 16(7), pp.534–548. *Available at:* https://doi.org/10.1108/EUM0000000006166 [Accessed 10 October 2025].

Bozarth, C.C., Warsing, D.P., Flynn, B.B. and Flynn, E.J. (2009). The impact of supply chain complexity on manufacturing plant performance. *Journal of Operations Management*, 27(1), pp.78–93. *Available at:* https://doi.org/10.1016/J.JOM.2008.07.003 [Accessed 10 October 2025].

Brenčič, V. (2009). Employers' hiring practices, employment protection, and costly search: A vacancy-level analysis. *Labour Economics*, 16(5), pp.461–479. *Available at:* https://doi.org/10.1016/J.LABECO.2009.02.001 [Accessed 10 October 2025].

Brkovic, M., Ćulibrk, J., Rikalovic, A., Tasić, N., and Bajic, B. (2023). Industry 5.0 and the skills gap: Strategies for developing a future-ready workforce. In: 19th International Scientific Conference on Industrial Systems, pp.360–365. Faculty of Technical Sciences. *Available at:* https://doi.org/10.24867/is-2023-t6.2-2_04941 [Accessed 10 October 2025].

Brown, S., Garino, G. and Martin, C. (2009) Firm performance and labour turnover: Evidence from the 2004 workplace employee relations survey. *Economic*

Modelling, 26(3), pp.689–695. *Available at:* https://doi.org/10.1016/J.ECONMOD.2009.01.014 [Accessed 10 October 2025].

Campbell, C.M. (1993). Do Firms Pay Efficiency Wages? Evidence with Data at the Firm Level. *Journal of Labor Economics*, 11(3), pp.442–470. *Available at:* https://doi.org/10.1086/298303 [Accessed 10 October 2025].

Casalino, N., Borin, B., Pizzolo, G. and Cavallini, S. (2019) Automation, Technology Transfer and Managerial Practices for Organizational Growth of SMEs. A Smart Curriculum for Competitiveness. In: 2019 IEEE Global Engineering Education Conference (EDUCON), pp.1534–1541. IEEE. *Available at:* https://doi.org/10.1109/EDUCON.2019.8725229 [Accessed 10 October 2025].

Castelo-Branco, I., Cruz-Jesus, F. and Oliveira, T. (2019) Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union. *Computers in Industry*, 107, pp.22–32. *Available at:* https://doi.org/10.1016/j.compind.2019.01.007 [Accessed 10 October 2025].

Chakrabarti, S., Caratozzolo, P., Norgaard, B. and Sjoer, E. (2021). Preparing Engineers for Lifelong Learning in the Era of Industry 4.0. In: 2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC), pp.518–523. IEEE. *Available at:* https://doi.org/10.1109/WEEF/GEDC53299.2021.9657247 [Accessed 10 October 2025].

Charles-Leija, H., Castro, C.G., Toledo, M. and Ballesteros-Valdés, R. (2023) Meaningful Work, Happiness at Work, and Turnover Intentions. *International Journal of Environmental Research and Public Health*, 20(4). *Available at:* https://doi.org/10.3390/ijerph20043565 [Accessed 10 October 2025].

Chitra, S. and Vanitha, A. (2022) Effectiveness of Employee Upskilling Program: A Study on Private Insurance Industry in Chennai. *SDMIMD Journal of Management*, 13(1), p.27. *Available at:* https://doi.org/10.18311/sdmimd/2022/27922 [Accessed 10 October 2025].

Čirčová, V. and Blštáková, J. (2022) Reskilling and Upskilling of Managers: People Management in the Digital Era. In: A. Lüleyová and P. Puškárová, eds., *EDAMBA 2022: Conference Proceedings*, pp.87–96. University of Economics in Bratislava. *Available at:* https://doi.org/10.53465/edamba.2022.9788022550420.87-96 [Accessed 10 October 2025].

Combemale, C., Whitefoot, K.S., Ales, L. and Fuchs, E.R.H. (2022) Not all technological change is equal: how the separability of tasks mediates the effect of technology change on skill demand. *Industrial and Corporate Change*, 30(6), pp.1361–1387. *Available at:* https://doi.org/10.1093/icc/dtab026 [Accessed 10 October 2025].

Coviello, D., Deserranno, E. and Persico, N. (2022) Minimum Wage and Individual Worker Productivity: Evidence from a Large US Retailer. *Journal of Political Economy*, 130(9), pp.2315–2360. *Available at:* https://doi.org/10.1086/720397 [Accessed 10 October 2025].

Cryptopian News (no date) *Functionalities of Energy Web: The Future of Sustainable Tech*. Available at: https://www.cryptopiannews.com/functionalities-of-energy-web/ (Accessed: 25 February 2026).

Curran, M., Lazzarini, G., Baumgart, L., Gabel, V., Blockeel, J., Epple, R., Stolze, M. and Schader, C. (2020) Representative Farm-Based Sustainability Assessment of the Organic Sector in Switzerland Using the SMART-Farm Tool. *Frontiers in Sustainable Food Systems*, 4, Article 554362. *Available at:* https://doi.org/10.3389/fsufs.2020.554362 [Accessed 10 October 2025].

Da Xu, L., Xu, E.L. and Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, 56(8), pp.2941–2962. *Available at:* https://doi.org/10.1080/00207543.2018.1444806 [Accessed 10 October 2025].

Department for Education (2012) *Education: Sector skills assessment 2012*. Available at: https://core.ac.uk/download/9589310.pdf (Accessed: 25 February 2026).

Dewitte, R., Dumont, M., Merlevede, B., Rayp, G. and Verschelde, M. (2020) Firm-Heterogeneous Biased Technological Change: A nonparametric approach under

endogeneity. *European Journal of Operational Research*, 283(3), pp.1172–1182. *Available at:* https://doi.org/10.1016/j.ejor.2019.11.063 [Accessed 10 October 2025].

Di Gregorio, A., Maggioni, I., Mauri, C. and Mazzucchelli, A. (2019) Employability skills for future marketing professionals. *European Management Journal*, 37(3), pp.251–258. *Available at:* https://doi.org/10.1016/J.EMJ.2019.03.004 [Accessed 10 October 2025].

Diessner, S., Durazzi, N. and Hope, D. (2022) Skill-Biased Liberalization: Germany's Transition to the Knowledge Economy. *Politics and Society*, 50(1), pp.117–155. *Available at:* https://doi.org/10.1177/00323292211006563 [Accessed 10 October 2025].

Doherty, O. and Stephens, S. (2021) The skill needs of the manufacturing industry: can higher education keep up? *Education + Training*, 63(4), pp.632–646. *Available at:* https://doi.org/10.1108/ET-05-2020-0134 [Accessed 10 October 2025].

DuBose, B.M. and Mayo, A.M. (2020) Resistance to change: A concept analysis. *Nursing Forum*, 55(4), pp.631–636. *Available at:* https://doi.org/10.1111/nuf.12479 [Accessed 10 October 2025].

Eberendu, A.C. and Kenneth-Okere, R. (2015) An empirical review of Motivation as a Constituent to Employees' Retention. *International Journal of Engineering and Science*, 5(2), pp.6–15.

ElSayary, A. (2023) The impact of a professional upskilling training programme on developing teachers' digital competence. *Journal of Computer Assisted Learning*, 39(4), pp.1154–1166. *Available at:* https://doi.org/10.1111/jcal.12788 [Accessed 10 October 2025].

Emperatriz, G.-S.E. and Yudet, M.-L.D. (2022) Digital Skills and Job Performance in Remote Work. In: 2022 7th International Conference on Business and Industrial Research (ICBIR), pp.723–726. IEEE. *Available at:* https://doi.org/10.1109/ICBIR54589.2022.9786486 [Accessed 10 October 2025].

European Commission (EURES) (2025) *Labour Market Information: Switzerland*. Available at: https://eures.ec.europa.eu/living-and-working/labour-market-information/labour-market-information-switzerland_en (Accessed: 23 February 2026).

Fahr, R. and Sunde, U. (2005) Job and vacancy competition in empirical matching functions. *Labour Economics*, 12(6), pp.773–780. *Available at:* https://doi.org/10.1016/J.LABECO.2004.04.003 [Accessed 10 October 2025].

Faishal, M., Mathew, S., Neikha, K., Pusa, K. and Zhimomi, T., (2023) The future of work: AI, automation, and the changing dynamics of developed economies. *World Journal of Advanced Research and Reviews*, 18(3), pp.620–629. *Available at:* https://doi.org/10.30574/wjarr.2023.18.3.1086 [Accessed 10 October 2025].

Falk, M. (2003) What Drives the Vacancy Rate for Information Technology Workers? *SSRN Electronic Journal*. Advance online publication. *Available at:* https://doi.org/10.2139/ssrn.367080 [Accessed 10 October 2025].

Fang, Y.-C., Chen, J.-Y., Zhang, X.-D., Dai, X.-X. and Tsai, F.-S. (2020) The Impact of Inclusive Talent Development Model on Turnover Intention of New Generation Employees: The Mediation of Work Passion. *International Journal of Environmental Research and Public Health*, 17(17). *Available at:* https://doi.org/10.3390/ijerph17176054 [Accessed 10 October 2025].

Fernández, E., Valle, S. and Pérez-Bustamante, G. (2021) Business excellence practice: efficiency wages versus individual economic incentives. *Total Quality Management and Business Excellence*, 32(13-14), pp.1532–1547. *Available at:* https://doi.org/10.1080/14783363.2020.1746181 [Accessed 10 October 2025].

Fleming, P. (2017) The Human Capital Hoax: Work, Debt and Insecurity in the Era of Uberization. *Organization Studies*, 38(5), pp.691–709. *Available at:* https://doi.org/10.1177/0170840616686129 [Accessed 10 October 2025].

Ford, J.D., Ford, L.W. and D'Amelio, A. (2008) Resistance to Change: The Rest of the Story. *Academy of Management Review*, 33(2), pp.362–377. *Available at:* https://doi.org/10.5465/AMR.2008.31193235 [Accessed 10 October 2025].

Forsythe, E., Kahn, L.B., Lange, F. and Wiczer, D. (2020) Labor demand in the time of COVID-19: Evidence from vacancy postings and UI claims. *Journal of Public Economics*, 189, p.104238. *Available at:* https://doi.org/10.1016/j.jpubeco.2020.104238 [Accessed 10 October 2025].

Fraile, F., Psarommatis, F., Alarcón, F. and Joan, J. (2023) A Methodological Framework for Designing Personalised Training Programs to Support Personnel Upskilling in Industry 5.0. *Computers*, 12(11), p.224. *Available at:* https://doi.org/10.3390/computers12110224 [Accessed 10 October 2025].

Fynes, B., Voss, C. and Búrca, S. (2005) The impact of supply chain relationship dynamics on manufacturing performance. *International Journal of Operations and Production Management*, 25(1), pp.6–19. *Available at:* https://doi.org/10.1108/01443570510572213 [Accessed 10 October 2025].

Galustyan, O.V., Borovikova, Y.V., Polivaeva, N.P., Bakhtiyor, K.R. and Zhirkova, G.P., (2019) E-learning within the Field of Andragogy. *International Journal of Emerging Technologies in Learning (IJET)*, 14(09), p.148. *Available at:* https://doi.org/10.3991/IJET.V14I09.10020 [Accessed 10 October 2025].

Gehring, M. and Meyer, H.-P. (2022) Swiss Biotech Day, May 2022. Sustainability Across the Pharmaceutical Value Chain - How Switzerland Could Take a Leading Role in Promoting a Greener Approach. *CHIMIA*, 76(9), p.800. *Available at:* https://doi.org/10.2533/chimia.2022.800 [Accessed 10 October 2025].

Ghobakhloo, M., Iranmanesh, M., Tseng, M.-L., Grybauskas, A., Stefanini, A. and Amran, A. (2023) Behind the definition of Industry 5.0: a systematic review of technologies, principles, components, and values. *Journal of Industrial and Production Engineering*, 40(6), pp.432–447. *Available at:* https://doi.org/10.1080/21681015.2023.2216701 [Accessed 10 October 2025].

Giménez-Nadal, J.I., Molina, J.A. and Velilla, J. (2021) Testing urban efficiency wages in France and Spain. *Empirical Economics*, 61(4), pp.2205–2236. *Available at:* https://doi.org/10.1007/s00181-020-01928-x [Accessed 10 October 2025].

Gregory-Smith, I. (2021) Wages and Labor Productivity: Evidence from Injuries in The National Football League. *Economic Inquiry*, 59(2), pp.829–847. *Available at:* https://doi.org/10.1111/ECIN.12960 [Accessed 10 October 2025].

Guthrie, J.P. (2001) High-Involvement Work Practices, Turnover, and Productivity: Evidence from New Zealand. *Academy of Management Journal*, 44(1), pp.180–190. *Available at:* https://doi.org/10.5465/3069345 [Accessed 10 October 2025].

Hamilton, T., Macki, M., Oh, S.Y., Bazydlo, M., Schultz, L., Zakaria, H.M., Khalil, J.G., Perez-Cruet, M., Aleem, I., Park, P., Easton, R., Nerenz, D.R., Schwalb, J., Abdulhak, M. and Chang, V. (2022) The association of patient education level with outcomes after elective lumbar surgery: A Michigan Spine Surgery Improvement Collaborative study. *Journal of Neurosurgery. Spine*, 36(6), pp.883–891. *Available at:* https://doi.org/10.3171/2021.9.SPINE21421 [Accessed 10 October 2025].

Hanly, P., Ortega-Ortega, M. and Sharp, L. (2021) Friction Costs and the Chain of Vacancies Problem: A Novel Vacancy Multiplier Solution. *Value in Health: The Journal of the International Society for Pharmacoeconomics and Outcomes Research*, 24(4), pp.548–555. *Available at:* https://doi.org/10.1016/j.jval.2020.10.026 [Accessed 10 October 2025].

Hanshaw, G. and Rojas, F. (2021) Use Andragogy and Technology to Facilitate a Greater Sense of Connectedness for Online Students. In: J. Keengwe and C.L.B. Jennings, eds., *Advances in Higher Education and Professional Development. Ensuring Adult and Non-Traditional Learners' Success With Technology, Design, and Structure*, pp.111–127. IGI Global. *Available at:* https://doi.org/10.4018/978-1-7998-6762-3.CH007 [Accessed 10 October 2025].

Harris, R.G. (2001) The knowledge-based economy: Intellectual origins and new economic perspectives. *International Journal of Management Reviews*, 3(1), pp.21–40. *Available at:* https://doi.org/10.1111/1468-2370.00052 [Accessed 10 October 2025].

Hassan, W., Razi, A., Qamar, R., Jaffir, R. and Suhail, S. (2013). The effect of training on employee retention. *Global Journal of Management and Business Research*, 13(6), pp.17–20.

Henschke, J.A. (2021) Facilitating adult and organizational learning through andragogy: A history, philosophy, and major themes. IGI Global.

Heutel, G. and Zhang, X. (2020) Efficiency Wages, Unemployment, and Environmental Policy. *Available at:* https://doi.org/10.3386/w27960 [Accessed 10 October 2025].

Hitt, M.A., Bierman, L., Shimizu, K. and Kochhar, R. (2001). Direct and Moderating Effects of Human Capital on Strategy and Performance in Professional Service Firms: A Resource-Based Perspective. *Academy of Management Journal*, 44(1), pp.13–28. *Available at:* https://doi.org/10.5465/3069334 [Accessed 10 October 2025].

Hochuli, A., Hochuli, J. and Schmid, D. (2021). Competitiveness of diversification strategies in agricultural dairy farms: Empirical findings for rural regions in Switzerland. *Journal of Rural Studies*, 82, pp.98–106. *Available at:* https://doi.org/10.1016/J.JRURSTUD.2021.01.021 [Accessed 10 October 2025].

Hotz-Hart, B. (1989). Innovating Behaviour of Swiss Industry — Findings and Policy Conclusions. In: Å.E. Andersson, D.F. Batten and C. Karlsson, eds., *Knowledge and Industrial Organisation*, pp.187–196. Springer Berlin Heidelberg. *Available at:* https://doi.org/10.1007/978-3-642-95597-6_14 [Accessed 10 October 2025].

Hunter, J.E. and Hunter, R.F. (1984). Validity and utility of alternative predictors of job performance. *Psychological Bulletin*, 96(1), pp.72–98. *Available at:* https://doi.org/10.1037/0033-2909.96.1.72 [Accessed 10 October 2025].

Hutter, C. and Weber, E. (2021) Labour market miracle, productivity debacle: Measuring the effects of skill-biased and skill-neutral technical change. *Economic Modelling*, 102, p.105584. *Available at:* https://doi.org/10.1016/J.ECONMOD.2021.105584 [Accessed 10 October 2025].

Ivanov, D. (2023). The Industry 5.0 framework: viability-based integration of the resilience, sustainability, and human-centricity perspectives. *International Journal of Production Research*, 61(5), pp.1683–1695. *Available at:* https://doi.org/10.1080/00207543.2022.2118892 [Accessed 10 October 2025].

Jacquet, N.L. and Tan, S. (2012). Wage-vacancy contracts and coordination frictions. *Journal of Economic Theory*, 147(3), pp.1064–1104. *Available at:* https://doi.org/10.1016/j.jet.2012.01.014 [Accessed 10 October 2025].

Jaiswal, A., Arun, C.J. and Varma, A. (2022). Rebooting employees: upskilling for artificial intelligence in multinational corporations. *The International Journal of Human Resource Management*, 33(6), pp.1179–1208. *Available at:* https://doi.org/10.1080/09585192.2021.1891114 [Accessed 10 October 2025].

Jayashree, S., Malarvizhi, C.A. and Reza, M.N.H. (2019) The challenges and opportunities of Industry 4.0 - A review. *Asia Proceedings of Social Sciences*, 5(2), pp.173–178. *Available at:* https://doi.org/10.31580/apss.v5i2.1152 [Accessed 10 October 2025].

Jialin, L. (2024) 'Risk assessment of banks when interest rate hikes', *SHS Web of Conferences*. Available at: https://doi.org/10.1051/shsconf/202419301024 (Accessed: 25 February 2026).

Jolly, P.M., McDowell, C., Dawson, M. and Abbott, J. (2021) Pay and benefit satisfaction, perceived organizational support, and turnover intentions: The moderating role of job variety. *International Journal of Hospitality Management*, 95, p.102921. *Available at:* https://doi.org/10.1016/J.IJHM.2021.102921 [Accessed 10 October 2025].

Federal Statistical Office (n.d.) Key table hourly labour costs in manufacturing. Federal Statistical Office. Available at: https://www.destatis.de/EN/Themes/Countries-Regions/International-Statistics/Data-Topic/Tables/BasicData_LaborCosts.html [Accessed 10 October 2025].

Khatri, S. (2020) Artificial Intelligence and Future Employment. *International Journal of Advanced Trends in Computer Science and Engineering*, 9(4), pp.5272–5277. *Available at:* https://doi.org/10.30534/ijatcse/2020/158942020 [Accessed 10 October 2025].

Kim, Y., Jeong, S.S., Yiu, D.W. and Moon, J. (2021) Frequent CEO Turnover and Firm Performance: The Resilience Effect of Workforce Diversity. *Journal of Business Ethics*, 173(1), pp.185–203. *Available at:* https://doi.org/10.1007/s10551-020-04534-0 [Accessed 10 October 2025].

Kyndt, E., Dochy, F., Michielsen, M. and Moeyaert, B. (2009) Employee Retention: Organisational and Personal Perspectives. *Vocations and Learning*, 2(3), pp.195–215. *Available at:* https://doi.org/10.1007/S12186-009-9024-7 [Accessed 10 October 2025].

Lerner, D., Amick, B.C., Lee, J.C., Rooney, T., Rogers, W.H., Chang, H. and Berndt, E.R. (2003) Relationship of employee-reported work limitations to work productivity. *Medical Care*, 41(5), pp.649–659. *Available at:* https://doi.org/10.1097/01.MLR.0000062551.76504.A9 [Accessed 10 October 2025].

Li, B., Hou, B., Yu, W., Lu, X. and Yang, C. (2017). Applications of artificial intelligence in intelligent manufacturing: a review. *Frontiers of Information Technology and Electronic Engineering*, 18(1), pp.86–96. *Available at:* https://doi.org/10.1631/FITEE.1601885 [Accessed 10 October 2025].

Li, H., Cai, W. and Li, W. (2021). Does global value chains participation improve skill premium? Mediating role of skill-biased technological change. *Economic*

Modelling, 99, p.105489. *Available at:* https://doi.org/10.1016/J.ECONMOD.2021.03.008 [Accessed 10 October 2025].

Li, Q., Lourie, B., Nekrasov, A. and Shevlin, T. (2022) Employee Turnover and Firm Performance: Large-Sample Archival Evidence. *Management Science*, 68(8), pp.5667–5683. *Available at:* https://doi.org/10.1287/mnsc.2021.4199 [Accessed 10 October 2025].

Lin, T.-C., Wang, K.J. and Sheng, M.L. (2020). To assess smart manufacturing readiness by maturity model: a case study on Taiwan enterprises. *International Journal of Computer Integrated Manufacturing*, 33(1), pp.102–115. *Available at:* https://doi.org/10.1080/0951192x.2019.1699255 [Accessed 10 October 2025].

Liu, J., Chang, H., Forrest, J.Y.-L. and Yang, B. (2020). Influence of artificial intelligence on technological innovation: Evidence from the panel data of China's manufacturing sectors. *Technological Forecasting and Social Change*, 158, p.120142. *Available at:* https://doi.org/10.1016/j.techfore.2020.120142 [Accessed 10 October 2025].

Maddikunta, P.K.R., Pham, Q.-V., B, P., Deepa, N., Dev, K., Gadekallu, T.R., Ruby, R. and Liyanage, M. (2022) Industry 5.0: A survey on enabling technologies and potential applications. *Journal of Industrial Information Integration*, 26, p.100257. *Available at:* https://doi.org/10.1016/j.jii.2021.100257 [Accessed 10 October 2025].

Maisiri, W. and van Dyk, L. (2021) Industry 4.0 skills: A perspective of the South African manufacturing industry. *SA Journal of Human Resource Management*, 19. *Available at:* https://doi.org/10.4102/SAJHRM.V19I0.1416 [Accessed 10 October 2025].

Majumdar, S.K., (2015) Competitor entry impact on jobs and wages in incumbent firms: retrospective evidence from a natural experiment. *Business and Politics*, 17(2), pp.291–326. *Available at:* https://doi.org/10.1017/S1369525800001650 [Accessed 10 October 2025].

Mathur, A., Dabas, A. and Sharma, N. (2022) Evolution From Industry 1.0 to Industry 5.0. In: H. Hibino, T. Kuroda and K. Shimomura, eds., *2022 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N)*, pp.1390–1394. IEEE. *Available at:* https://doi.org/10.1109/ICAC3N56670.2022.10074274 [Accessed 10 October 2025].

Mayilyan, F. and Yedigaryan, K. (2022) The Evolution of Human Capital Theory. *ALTERNATIVE*, pp.68–79. *Available at:* https://doi.org/10.55528/18292828-2022.4-68 [Accessed 10 October 2025].

Mehdiabadi, A., Shahabi, V., Shamsinejad, S., Amiri, M., Spulbar, C. and Birau, R.(2022). Investigating Industry 5.0 and Its Impact on the Banking Industry: Requirements, Approaches and Communications. *Applied Sciences*, 12(10), p.5126. *Available at:* https://doi.org/10.3390/app12105126 [Accessed 10 October 2025].

Mettler, T. (2019). The Road to Digital and Smart Government in Switzerland. In: A. Ladner, N. Soguel, Y. Emery, S. Weerts and S. Nahrath, eds., *Governance and Public Management. Swiss Public Administration*, pp.175–186. Springer International Publishing. *Available at:* https://doi.org/10.1007/978-3-319-92381-9_10 [Accessed 10 October 2025].

Mishra, S. and Mishra, S. (2017) Impact of Intrinsic Motivational Factors on Employee Retention among Gen Y: A Qualitative Perspective. *Parikalpana: KIIT Journal of Management*, 13(1), p.31. *Available at:* https://doi.org/10.23862/KIIT-PARIKALPANA/2017/V13/I1/151269 [Accessed 10 October 2025].

Mobley, W.H., Griffeth, R.W., Hand, H.H. and Meglino, B.M. (1979). Review and conceptual analysis of the employee turnover process. *Psychological Bulletin*, 86(3), pp.493–522. *Available at:* https://doi.org/10.1037/0033-2909.86.3.493 [Accessed 10 October 2025].

Modeling and simulation of production systems to evaluate the effect of worker turnover on productivity (2021) *Journal of Advanced Mechanical Design, Systems, and Manufacturing*, 15(2), JAMDSM0020-JAMDSM0020. *Available at:* https://doi.org/10.1299/JAMDSM.2021JAMDSM0020 [Accessed 10 October 2025].

Moon, K., Loyalka, P., Bergemann, P. and Cohen, J. (2020). The Hidden Cost of Worker Turnover: Attributing Product Reliability to the Turnover of Factory Workers. *SSRN Electronic Journal*. *Available at:* https://doi.org/10.2139/ssrn.3568792 [Accessed 10 October 2025].

Moriarty, J. (2020). What's in a Wage? A New Approach to the Justification of Pay. *Business Ethics Quarterly*, 30(1), pp.119–137. *Available at:* https://doi.org/10.1017/beq.2019.42 [Accessed 10 October 2025].

Mourtzis, D., Angelopoulos, J. and Panopoulos, N. (2022). A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0. *Energies*, 15(17), p.6276. *Available at:* https://doi.org/10.3390/en15176276 [Accessed 10 October 2025].

Muehlemann, S. and Strupler Leiser, M. (2018) Hiring costs and labor market tightness. *Labour Economics*, 52, pp.122–131. *Available at:* https://doi.org/10.1016/J.LABECO.2018.04.010 [Accessed 10 October 2025].

Mühlemann, S. and Strupler, M. (2015) Ten Facts You Need to Know About Hiring. *SSRN Electronic Journal*. *Available at:* https://doi.org/10.2139/ssrn.2672149 [Accessed 10 October 2025].

Nägeli, C., Jakob, M., Catenazzi, G. and Ostermeyer, Y. (2020) Policies to decarbonize the Swiss residential building stock: An agent-based building stock modeling assessment. *Energy Policy*, 146, p.111814. *Available at:* https://doi.org/10.1016/j.enpol.2020.111814 [Accessed 10 October 2025].

Nahavandi, S. (2019). Industry 5.0—A Human-Centric Solution. *Sustainability*, 11(16), p.4371. *Available at:* https://doi.org/10.3390/SU11164371 [Accessed 10 October 2025].

ShahNowak, K. (2020). Hidden Vacancy Rate as a Part of Office Market Dynamics in Selected Polish Cities. *Real Estate Management and Valuation*, 28(1), pp.1–12. *Available at:* https://doi.org/10.2478/remav-2020-0001 [Accessed 10 October 2025].

Oliveira, A., Assumpcao, H., Queiroz, J., Piardi, L., Parra, J. and Leitao, P. (2022) 'Hands-on Learning Modules for Upskilling in Industry 4.0 Technologies', *2022 IEEE 5th International Conference on Industrial Cyber-Physical Systems (ICPS)*, pp. 1–6. IEEE. Available at: https://doi.org/10.1109/icps51978.2022.9816909 [Accessed 14 October 2025].

Oreg, S. (2006) 'Personality, context, and resistance to organisational change', European Journal of Work and Organisational *Psychology*, 15(1), pp. 73–101. Available at: https://doi.org/10.1080/13594320500451247 [Accessed 14 October 2025].

Ouyang, C., Zhu, Y. and Guo, M. (2020) 'Effect of empowering leadership on the turnover intention of industrial workers', *Social Behavior and Personality: An International Journal*, 48(8), pp. 1–11. Available at: https://doi.org/10.2224/sbp.9124 [Accessed 14 October 2025].

Pacchini, A.P.T., Lucato, W.C., Facchini, F. and Mummolo, G. (2019) 'The degree of readiness for the implementation of Industry 4.0', *Computers in Industry*, 113, 103125. Available at: https://doi.org/10.1016/j.compind.2019.103125 [Accessed 14 October 2025].

Panetto, H., Iung, B., Ivanov, D., Weichhart, G. and Wang, X. (2019) 'Challenges for the cyber-physical manufacturing enterprises of the future', *Annual Reviews in Control*, 47, pp. 200–213. Available at: https://doi.org/10.1016/J.ARCONTROL.2019.02.002 [Accessed 14 October 2025].

Perez-Laborda, A. and Perez-Sebastian, F. (2020) 'Capital-skill complementarity and biased technical change across US sectors', *Journal of Macroeconomics*, 66, 103255. Available at: https://doi.org/10.1016/J.JMACRO.2020.103255 [Accessed 14 October 2025].

Peytremann-Bridevaux, I. (2021) 'Readiness for integrated care in Switzerland: results of a nationwide survey using the SCIROCCO tool', *International Journal of Integrated Care*, 21(S1), 260. Available at: https://doi.org/10.5334/ijic.icic20405 [Accessed 14 October 2025].

Ployhart, R.E. and Moliterno, T.P. (2011) 'Emergence of the Human Capital Resource: A Multilevel Model', *Academy of Management Review*, 36(1), pp. 127–150. Available at: https://doi.org/10.5465/AMR.2009.0318 [Accessed 14 October 2025].

Pontes, J., Geraldes, C.A.S., Fernandes, F.P., Sakurada, L., Rasmussen, A.L., Christiansen, L., Hafner-Zimmermann, S., Delaney, K. and Leitao, P. (2021) 'Relationship between Trends, Job Profiles, Skills and Training Programs in the Factory of the Future', *2021 22nd IEEE International Conference on Industrial Technology (ICIT)*, pp. 1240–1245. IEEE. Available at: https://doi.org/10.1109/ICIT46573.2021.9453584 [Accessed 14 October 2025].

Pu, X., Zhang, G., Tse, C.-S., Feng, J., Tang, Y. and Fan, W. (2022) 'When does daily job performance motivate learning behavior? The stimulation of high turnover rate, *Journal of Knowledge Management*, 26(5), pp. 1368–1385. Available at: https://doi.org/10.1108/jkm-03-2021-0242 [Accessed 14 October 2025].

Razvadovskaya, Y.V. (2020) 'New Industrialization: Phases, Dominants and Patterns', *Vestnik Tomskogo Gosudarstvennogo Universiteta. Ekonomika*, (52), pp. 291–307. Available at: https://doi.org/10.17223/19988648/52/18 [Accessed 14 October 2025].

Sadayuki, T., Kanayama, Y. and Arimura, T.H. (2020) 'The Externality of Vacant Houses: The Case of Toshima Municipality, Tokyo, Japan', *Review of Regional*

Studies, 50(2). Available at: https://doi.org/10.52324/001C.13522 [Accessed 14 October 2025].

Salehi, H. and Burgueño, R. (2018) 'Emerging artificial intelligence methods in structural engineering', *Engineering Structures*, 171, pp. 170–189. Available at: https://doi.org/10.1016/J.ENGSTRUCT.2018.05.084 [Accessed 14 October 2025].

Samuvel, K. and G, G.K. (2023) 'A Study on Impact of Upskilling or Reskilling of Employees in IT Services', *International Journal of Advanced Research in Science, Communication and Technology*, Article 11457, pp. 359–363. Available at: https://doi.org/10.48175/ijarsct-11457 [Accessed 14 October 2025].

Savicevic, D. (2008) 'Convergence or divergence of ideas on andragogy in different countries', *International Journal of Lifelong Education*, 27(4), pp. 361–378. Available at: https://doi.org/10.1080/02601370802051504 [Accessed 14 October 2025].

Sawant, R., Thomas, B. and Kadlag, S. (2022) 'Reskilling and Upskilling: To Stay Relevant in Today's Industry', *International Review of Business and Economics*, 7(1). Available at: https://doi.org/10.56902/irbe.2022.7.1.4 [Accessed 14 October 2025].

Schulte, P. (2021) 'Skill Bias magnified: Identifying the role of international technology diffusion', *Journal of International Economics*, 129, 103442. Available at: https://doi.org/10.1016/J.JINTECO.2021.103442 [Accessed 14 October 2025].

Shah, M. and Asad, M. (2018) 'Effect of motivation on employee retention: Mediating role of perceived organizational support', *European Online Journal of Natural and Social Sciences*, 7(2), pp. 511–520. Available at: (no DOI provided) [Accessed 14 October 2025].

Shao, E. and Silos, P. (2013) 'Entry costs and labor market dynamics', *European Economic Review*, 63, pp. 243–255. Available at: https://doi.org/10.1016/J.EUROECOREV.2013.07.009 [Accessed 14 October 2025].

Shao, S., Shi, Z. and Shi, Y. (2022) 'Impact of AI on employment in manufacturing industry', *International Journal of Financial Engineering*, 09(03), Article 2141013. Available at: https://doi.org/10.1142/s2424786321410139 [Accessed 14 October 2025].

Shaw, B., Cheater, F., Baker, R., Gillies, C., Hearnshaw, H., Flottorp, S. and Robertson, N. (2005) 'Tailored interventions to overcome identified barriers to change: Effects on professional practice and health care outcomes', *The Cochrane Database of Systematic Reviews*, (3), CD005470. Available at: https://doi.org/10.1002/14651858.CD005470 [Accessed 14 October 2025].

Silva, J.I. and Toledo, M. (2009a) 'Labour turnover costs and the cyclical behavior of vacancies and unemployment', *Macroeconomic Dynamics*, 13(S1), pp. 76–96. Available at: https://doi.org/10.1017/S1365100509080122 [Accessed 14 October 2025].

Silva, J.I. and Toledo, M. (2009b) 'Labour turnover costs and the cyclical behavior of vacancies and unemployment', *Macroeconomic Dynamics*, 13(S1), pp. 76–96. Available at: https://doi.org/10.1017/S1365100509080122 [Accessed 14 October 2025].

Singh, A., Singh, H.P., Alam, F. and Agrawal, V. (2022) 'Role of Education, Training, and E-Learning in Sustainable Employment Generation and Social Empowerment in Saudi Arabia', *Sustainability*, 14(14), 8822. Available at: https://doi.org/10.3390/su14148822 [Accessed 14 October 2025].

Spence, M. (1986) 'Cost Reduction, Competition and Industry Performance', in Stiglitz, J.E. and Mathewson, G.F. (eds.) *New Developments in the Analysis of Market Structure*. London: Palgrave Macmillan UK, pp. 475–518. Available at: https://doi.org/10.1007/978-1-349-18058-5_16 [Accessed 14 October 2025].

Stadin, K. (2023) 'Firms' Employment Dynamics and the State of the Labor Market', *Macroeconomic Dynamics*, 27(1), pp. 27–55. Available at: https://doi.org/10.1017/s1365100521000080 [Accessed 14 October 2025].

Strober, M.H. (1990) ‘Human Capital Theory: Implications for HR Managers’, *Industrial Relations: A Journal of Economy and Society*, 29(2), pp. 214–239. Available at: https://doi.org/10.1111/J.1468-232X.1990.TB00752.X [Accessed 14 October 2025].

Suarez, J. (1999) ‘The Impact of Import Competition on Employment and Wages in Swiss Manufacturing’, *Swiss Journal of Economics and Statistics (SJES)*, 135(IV), pp. 607–618. Available at: https://ideas.repec.org/a/ses/arsjes/1999-iv-5.html [Accessed 14 October 2025].

Sundarrajan, P. and Krishnan, L.R.K. (2023) ‘Pandemic-Induced Work Practices Impacting Job Satisfaction and Retention; Automobile Industry Perspective’, *Journal of Law and Sustainable Development*, 11(7), e1390. Available at: https://doi.org/10.55908/sdgs.v11i7.1390 [Accessed 14 October 2025].

Szabó-Szentgróti, G., Végvári, B. and Varga, J. (2021) ‘Impact of Industry 4.0 and Digitization on Labor Market for 2030 – Verification of Keynes’ Prediction’, *Sustainability*, 13(14), 7703. Available at: https://doi.org/10.3390/SU13147703 [Accessed 14 October 2025].

Unger, J.M., Rauch, A., Frese, M. and Rosenbusch, N. (2011) ‘Human capital and entrepreneurial success: A meta-analytical review’, *Journal of Business Venturing*, 26(3), pp. 341–358. Available at: https://doi.org/10.1016/J.JBUSVENT.2009.09.004 [Accessed 14 October 2025].

van Coller, M., Grobbelaar, S. and Sacks, N. (2021) ‘Upskilling for digital transformation in the 4th industrial revolution: A scoping review’, in Khalil, T., Pretorius, L. and Pretorius, M.W. (eds.) *30th Annual Conference of the International Association for Management of Technology (IAMOT 2021)*, pp. 893–906. Curran Associates, Inc. Available at: https://doi.org/10.52202/060557-0068 [Accessed 14 October 2025].

van Ours, J. and Ridder, G. (1992) 'Vacancies and the recruitment of new employees', *Journal of Labor Economics*, 10(2), pp. 138–155. Available at: https://doi.org/10.1086/298282 [Accessed 14 October 2025].

Victoria (2020) 'Government financial support and SME development in Switzerland', *International Journal of Economics and Business Administration*, 8(4), pp. 838–847. Available at: https://doi.org/10.35808/ijeba/633 [Accessed 14 October 2025].

vom Lehn, C. (2020) 'Labor market polarization, the decline of routine work, and technological change: A quantitative analysis', *Journal of Monetary Economics*, 110, pp. 62–80. Available at: https://doi.org/10.1016/J.JMONECO.2019.01.004 [Accessed 14 October 2025].

Vranceanu, R. and Sutan, A. (2020) 'Who should pay the bill for employee upskilling?', *SSRN Electronic Journal* [Online]. Available at: https://doi.org/10.2139/ssrn.3719009 [Accessed 14 October 2025].

Waddell, D. and Sohal, A.S. (1998) 'Resistance: a constructive tool for change management', *Management Decision*, 36(8), pp. 543–548. Available at: https://doi.org/10.1108/00251749810232628 [Accessed 14 October 2025].

Wahab, S.N., Rajendran, S.D. and Yeap, S.P. (2021) 'Upskilling and reskilling requirement in logistics and supply chain industry for the fourth industrial revolution', *Logforum*, 17(3), pp. 399–410. Available at: https://doi.org/10.17270/j.log.2021.606 [Accessed 14 October 2025].

Wang, H. (2020) 'Stickiness of rental rate and housing vacancy rate', *Economics Letters*, 195, 109487. Available at: https://doi.org/10.1016/j.econlet.2020.109487 [Accessed 14 October 2025].

Wang, J., Hu, Y. and Zhang, Z. (2021) 'Skill-biased technological change and labor market polarization in China', *Economic Modelling*, 100, 105507. Available at: https://doi.org/10.1016/J.ECONMOD.2021.105507 [Accessed 14 October 2025].

Wang, V.X. and Kania-Gosche, B. (2013) 'Andragogy or Pedagogy as a Means to Improve the Workforce?', in Wang, V.X. (ed.) *Handbook of Research on Technologies for Improving the 21st Century Workforce*. IGI Global, pp. 98–109. Available at: https://doi.org/10.4018/978-1-4666-2181-7.CH007 [Accessed 14 October 2025].

Wang, X., Yang, J., Wang, Y., Miao, Q., Wang, F.-Y., Zhao, A., Deng, J.-L., Li, L., Na, X. and Vlacic, L. (2023) 'Steps Toward Industry 5.0: Building "6S" Parallel Industries With Cyber-Physical-Social Intelligence', *IEEE/CAA Journal of Automatica Sinica*, 10(8), pp. 1692–1703. Available at: https://doi.org/10.1109/JAS.2023.123753 [Accessed 14 October 2025].

Weill, P. (1992) 'The relationship between investment in information technology and firm performance: A study of the valve manufacturing sector', *Information Systems Research*, 3(4), pp. 307–333. Available at: https://doi.org/10.1287/isre.3.4.307 [Accessed 14 October 2025].

Weiss, O., Pareschi, G., Georges, G. and Boulouchos, K. (2021) 'The Swiss energy transition: Policies to address the Energy Trilemma', *Energy Policy*, 148, 111926. Available at: https://doi.org/10.1016/j.enpol.2020.111926 [Accessed 14 October 2025].

Wu, H. and Hang, J. (2016) 'An empirical study on the performance of enterprises and investment in the human capital', in *2016 IEEE First International Conference on Data Science in Cyberspace (DSC)*, pp. 497–502. Available at: https://doi.org/10.1109/DSC.2016.67 [Accessed 14 October 2025].

Xiong, R., Wei, P., Yang, J. and Cristofini, L. A. (2021) 'Impact of top executive turnover on firms' R&D investment: Evidence from China', *Innovation*, 23(3), pp. 400–424. Available at: https://doi.org/10.1080/14479338.2020.1836968 [Accessed 14 October 2025].

Zapechelnyuk, A. and Zultan, R. (2020) 'Job search costs and incentives', *Economic Theory Bulletin*, 8(2), pp. 181–202. Available at: https://doi.org/10.1007/s40505-019-00176-2 [Accessed 14 October 2025].

Zizic, M. C., Mladineo, M., Gjeldum, N. and Celent, L. (2022) 'From Industry 4.0 towards Industry 5.0: A review and analysis of paradigm shift for the people, organization and technology', *Energies*, 15(14), 5221. Available at: https://doi.org/10.3390/en15145221 [Accessed 14 October 2025].

Zuberi, M. J. S. and Patel, M. K. (2017) 'Bottom-up analysis of energy efficiency improvement and CO2 emission reduction potentials in the Swiss cement industry', *Journal of Cleaner Production*, 142, pp. 4294–4309. Available at: https://doi.org/10.1016/J.JCLEPRO.2016.11.178 [Accessed 14 October 2025].

Zuberi, M.J.S., Santoro, M., Eberle, A., Bhadbhade, N., Sulzer, S., Wellig, B. and Patel, M.K. (2020) A detailed review on current status of energy efficiency improvement in the Swiss industry sector. *Energy Policy*, 137, p.111162. Available at: https://doi.org/10.1016/j.enpol.2019.111162 [Accessed 14 October 2025].2