Technology adoption and skills changes in Scottish manufacturing small and medium enterprises (SMEs)

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Declaration Form

Declaration

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2. This dissertation is the result of my own independent work and investigation, except where otherwise stated.

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ABSTRACT

The aim of this research is to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing small and medium enterprises (SMEs). An array of large-scale studies, such as Osbourne and Frey (2013); Arntz *et al.* (2016); and Thomas and Gunson (2017), examine the disruptive effects of technological innovations on jobs, and consequently, skills. This research, however, highlights the need for a more nuanced view on technologies when examining technology adoption and skills changes. To gain a better understanding of the diverse effects of different technologies, the implementation of two types of technologies (namely management system technologies and automation) and their consequent effects on skills utilisation are compared. Following the social shaping of technology approach (Howcroft and Taylor, 2014), the research explores changes to skills utilisation at the intersection of people, technology and organisational context, to better understand the variety of skills changes that can happen in an organisation after technology adoption. For this, the study adopts a qualitative research method, including interviews with sectoral stakeholders and policymakers in the Scottish manufacturing sector; and case studies on four manufacturing SMEs that recently adopted new technologies.

The research finds that across the four case organisations, all group of workers experienced positive skills changes, with the most common skills utilisation change being the higher extent use of workers' pre-existing skills. In support of the social shaping of technology approach, the research showed that technology-driven outcomes are not pre-determined, and the choices that employers make regarding technology adoption and skills utilisation in the organisation are influenced by an array of contextual factors.

Overall, the research contributes to the evidence base on the impact of technology adoption on skills utilisation. By demonstrating the mutual interdependency of technology, people and organisation, the research supported the social shaping of technology literature and further developed the approach by offering an alternative explanation for the key driver behind managerial choices in relation to technology adoption and consequent skills utilisation. In addition, the study also contributes to skills research on the effect of technological change. By exploring the effects of technology adoption at the organisational level, the research highlighted the influential role of contextual factors in the interplay of technology and skills and demonstrated nuanced skills utilisation changes in the case organisations that go beyond the quantitative changes in the division of work between technology and people.

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My time starts now.

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CHAPTER 1: INTRODUCTION

Technological progress has always had a transformative effect on the world of work. The past decade especially has witnessed an exponential growth in technological innovations, which brought significant changes to industrial production by pairing digital technologies and the Internet with traditional production methods. Impressive technological advancements can be observed, for example, in the field of Artificial Intelligence and advanced robotics; and these new innovations are increasingly capable of performing tasks that were previously unique to humans. Indeed, the ever-increasing technological advancements and the falling costs of computing are leading to technology gaining prominence in the world of work. This seemingly unavoidable possibility has created an anxious narrative on the fear of increasing levels of technology-driven unemployment. It is argued that to ensure that humans can keep up with the fast-paced changes, and therefore avoid obsolescence in the workplace, they need to adopt their skill sets for areas where they can still outperform, or at best cooperate, with new technologies.

It is against this backdrop that this research investigates the skills implications of new technology adoption in Scottish manufacturing small and medium enterprises (SMEs). The first part of this chapter introduces the rationale for the research, which is then followed by the proposed research questions that the study has set out to answer. The final section of the chapter outlines the structure of the thesis.

1.1 Research rationale

There has been a wide range of studies examining jobs' vulnerability to automation (Frey and Osbourne, 2017; Arntz *et al.*, 2016); and debates on which skills will be instrumental for maintaining human relevance in the workforce (WEF, 2020). In order to begin to understand what skills workers need to possess to best accommodate and adopt to the current wave of technological change, we must first understand how new technologies might change skills in the workplace. This research contributes to human resource management literature on the effects of technological change on skills by exploring the ways in which technology adoption impacts skills utilisation of workers in Scottish manufacturing SMEs.

Studies on the effects of technological change on future skills often engage in a binary discussion whether technology will ultimately benefit workers or not. However, the changes that new technologies might bring to the workplaces should not be seen as a monochrome picture. Whilst a majority of the recent, mainstream debates and forecasts on the effects of the current wave of technological change (for example Frey and Osbourne, 2017; Arntz *et al.*, 2016; Thomas and Gunson, 2017) see new technologies as autonomous entities causing linear, predetermined outcomes in organisations, another stream of literature increasingly recognizes the key role of the social context in technological change. This research followed the social shaping of technology approach (SST), and studies technologies, people and organisation as separate entities that mutually shape each other, in order to best explore and capture the nuances of skills utilisation changes that might happen in the studied organisations. The SST approach recognizes that, first of all, technological feasibility does not necessarily lead to technology adoption, as there is an array of external and internal factors at play that might influence organisations' choice to introduce new technology or not (Howcroft and Taylor, 2022; Joyce *et al*., 2023). Secondly, even if new technologies are introduced into a workplace, their effects on skills may differ in multiple ways, depending on both the material (technology) and the social (organisational context).

The first potential point of difference that this study aims to explore focuses on the material characteristics of technologies, more specifically the type of the adopted technologies. Dhondt *et al.* (2019) highlighted the various effects of different types of technologies on work processes and employment in their study on the Dutch manufacturing sector. Whilst their study provides valuable information on the direction of technological change at the sectoral level, it did not examine the technologies' effect on workers' skill utilisation. This research takes their approach forward and examines the skill effects of two types of technologies – management system software and automation.

Turning to the social factors, there is a wide range of external and internal organisational factors that can influence both technology adoption and the consequent interplay of technologies and skills (Behrend *et al*., 2022). In order to capture the nuances of the resulting skills changes, therefore, research must study technology adoption at the organisational level. This provides an in-depth insight into the context of the changes and helps to better understand how employers' choices might be influenced by contextual factors, and consequently, how the choices they make impact technology-driven skills outcomes in organisations. This research studies technology adoption and related skills changes in Scottish manufacturing SMEs.

Small and medium enterprises play a pivotal role in Scotland's economy. Nevertheless, the Scottish government has identified SMEs as a hesitant population when it comes to adopting technological innovation and developing digital skills for its workforce (Scottish Government, 2019). Indeed, in 2021, 46 per cent of Scottish SMEs reported any kind of innovation activities, and only 10 per cent of those adopted market leading new innovations (Scottish Government, 2022). According to the Small Business Survey Scotland 2021, SME owners reported that the second biggest obstacle to business success was the lack of skills in the sector. This suggests that SMEs not only need support that encourages technology adoption in the sector, but the skills development pipeline might also need adjustments. In order to better support them, it is vital to understand the issues that these organisations face when it comes to technology adoption and skills development. This research makes a contribution by offering an insight into SMEs' lived reality when it comes to technology adoption and relevant skills changes

Beyond exploring the material characteristics of the technologies themselves and the contextual factors that influence their adoption and consequent utilisation in organisations, it is also crucial to recognise that even in the same organisations, various group of workers may be affected by the same type of technology differently. There is an array of studies that examined which group of workers will benefit from technological change (Autor and Salomons, 2018; Li, 2022). The two key opposing debates are the upskilling and deskilling debates. The upskilling view claims that new technologies will ultimately benefit workers by taking over mundane, repetitive, low-skilled tasks, leaving the more engaging and high-skilled tasks for humans. Therefore, overall, the current wave of technological change will lead to a general rise in demand for higher skills in the labour market (Bessen, 2016; Dellot and Wallace-Stephens, 2017). The deskilling view paints a more negative picture and argues that new technologies will repeat the past effects of Taylorism by fragmenting work processes and ultimately narrowing work tasks for humans. In this way, humans will become specialised in low-skilled, repetitive tasks (Kunst, 2019). Both of these views tend to focus on different groups of workers – the upskilling view on high-skilled individuals, whilst the deskilling view on low-skilled individuals. Considering that organisations are not homogenous entities, and employ different groups of workers simultaneously, it can be argued that the upskilling and deskilling effects can coexist within organisations (Vallas, 1990). What is more, taking into consideration the influential role of not only the characteristics of technologies but also the organisational factors that impact technology adoption and utilisation, the analysis of skills utilisation outcomes of technology adoption should extend beyond the limited, binary view of upskilling or deskilling. This research explores technology adoption and related skills utilisation changes at the organisational level to investigate the various skills utilisation changes in Scottish manufacturing SMEs after technology adoption, and to inform future research on how to further develop the analytical lenses used for studying skills changes in the face of technological change.

1.2 Research aim and questions

The overarching aim of this research is to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing small and medium enterprises (SMEs). The research aims to answer the following questions:

> **RQ1**: How does the adoption of new technologies change skills utilisation in Scottish manufacturing SMEs?
>
> **RQ2**: In what ways do organisational factors interact with the interplay of technologies and skills in Scottish manufacturing SMEs?

1.3 Research methodology

To answer these questions, the research adopts a qualitative research method, collecting data from sectoral stakeholders from Scottish manufacturing, and conducting case studies in four Scottish manufacturing SMEs. The data collection methods include semi-structured interviews and field notes from site visits in the case organisations.

The interviews with sectoral stakeholders focus on issues relating to the Scottish manufacturing sector's skills landscape, technological innovations in manufacturing, and the SME community of the sector. The stakeholder participants represent a wide range of organisations, including trade bodies, government agencies, industry-led research and development facilities and the financial sector. These interviews offer an insight into the Scottish manufacturing sector, allowing the exploration of the external contextual factors that might influence technology adoption and skills changes in the studied case organisations.

The four case studies provide insight into the companies' operations and their experiences with technology adoption and consequent skill changes. The case studies include one small-sized (37 employees) gear manufacturing company, which adopted a management system software; a micro-sized (ten employees) engineering workshop in the process of implementing a job recording tool, which resemble an embryonic management system; a small-sized (22 employees) brewery that adopted an automated brewing kit; and a medium-sized (250 employees) precision engineering company in the process of implementing an automated tool-setter. By conducting in-depth case studies, the research can explore technology adoption within its context, which provides a more holistic understanding of skills changes upon technology adoption.

1.4 Thesis structure

The thesis explores the impact of technology adoption and related skills changes in Scottish manufacturing SMEs. This first chapter introduced the rationale for the research and outlined the research questions, along with the research methodology. The second chapter of the thesis discusses the relevant literature to this topic, discussing the key concepts of skills, technologies, and organisation, and the potential impact of their interplay on skills utilisation. Chapter Two ends with a summary of the conceptual framework of the study and the research questions that the study has set out to answer. The third chapter then outlines the chosen methodology for the research, including an introduction to the research design, a description of the research process, as well as the data analysis process. Finally, the third chapter ends with a brief discussion of the research's limitations and the researcher's reflection on the research process.

The second half of the thesis introduces the main findings of the study. Chapter Four is a context chapter that discusses the findings from interviews with sectoral stakeholders and offers an insight into the current global and national factors that influence the Scottish manufacturing sector's skills landscape and technology adoption, and the challenges that SMEs face in the sector. Chapter Five, Six, Seven and Eight introduces the key findings from the four case studies of the research. These are followed by the Comparative Analysis Chapter, Chapter Nine, which discusses the key findings of the research following the structure of the contextual framework of the research and ends by answering the proposed research questions. The penultimate chapter is the Discussion Chapter, Chapter Ten, which discusses the theoretical implications of the findings of the study and offers recommendations for future research. The final chapter, Chapter Eleven, concludes the thesis by summarising the study, and outlining the research's implications for policy and practice and recommendations for future action. Finally, the conclusion chapter ends with the researcher's brief reflection on the overall research project.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The aim of this research is to explore changes to skills utilisation after new technology adoption in Scottish manufacturing SMEs. This chapter of the thesis outlines the relevant academic debates on the interplay of skills, technologies and organisations. Since the research explores technology adoption and subsequent skills changes in Scottish manufacturing SMEs, context-relevant references are made throughout the chapter. The chapter starts by clarifying the key concepts of the research – technologies, skills and organisation, and establishing the core assumptions behind the chosen definitions.

As Chapter One discussed, technological change has a transformative effect on the world of work, and recent innovations revitalised the academic debates on the potential effect of new technologies on the future of work. To offer a historic background to the current changes, section 2.3.1 discusses previous waves of technological change and their broader impact on the world of work. This is followed by the various academic discussions on the potential changes that the current wave of technological change might bring. Whilst these debates and forecasts offer an insight into what the future could look like, as section 2.3.2 argues, these studies are often underpinned by an exogenous view of technologies, which believes that technologies will impact the world of work in a pre-determined, linear manner. However, as some alternative streams of literature recognize, the effects of new technologies are influenced by an array of social factors that are at play at the societal and organisational levels. This research follows the social shaping of technologies approach (discussed in section 2.3.2), and studies technology adoption at the organisational level in Scottish manufacturing SMEs.

To discuss the influential role that organisational context can have on technology adoption, section 2.4 turns to discussing the second key concept of the research – organisation. First, section 2.4.1 introduces the debates on what external and internal factors influence technology adoption decisions in organisations. Section 2.4.2 then argues that even if technologies are adopted, different types of technologies will have varying impact on organisations, not only due to their differing functionality, but also due to the ways in which they interact with work organisation. However, work organisation, and the overall organisational context do not only shape technology driven-outcomes, they also play a crucial role in skills utilisation even without the introduction of new technologies. Therefore, section 2.4.3 discusses both the external and internal contextual factors that influence skills utilisation in organisations. Section 2.4.4 outlines the specific characteristics of the

SME organisational form that can have an impact on both technology adoption and skills utilisation in the studied case organisations.

Section 2.5 turns to the third key concept of the research, skills, and discusses current academic debates and empirical literature on the interplay of technologies and skills. As Chapter One noted, the two dominant opposing debates are the upskilling and deskilling view. These debates follow the logic of task-based approach to technologies, which examines how technologies can influence the division of work between machines and humans and explains the mechanism of the changes by which technologies can replace or complement human input in the work process. Section 2.5.1, therefore, briefly introduces this approach that underpin the logic of the upskilling and deskilling debates. Section 2.5 then moves onto outlining the current academic debates of upskilling, deskilling and the polarisation view. The discussion argues that these debates are limited, and they do not take into consideration the role that organisational context might play in technology-driven skills changes, as outlined in section 2.4.

To conclude, section 2.6 summarises the conceptual framework of this research, which led the data analysis. Finally, the chapter ends with section 2.7 outlining the research questions that the study aims to answer.

2.2 Definitions

2.2.1 Technology

Discussions on technologies' effects on the world of work are bountiful, and so are the definitions. Traditionally, in social sciences – including organisation studies and economics, technology has been defined as "*the way in which scientific knowledge evolves in the production of goods and services"* (Skilton & Hovsepian, 2018, pg.3). The OECD's official glossary (2001) describes technology as *"the state of knowledge concerning ways of converting resources into outputs*". According to these broad definitions, technology means the application of scientific knowledge to find solutions to problems. From this point of view, technology in broader terms incorporates almost everything that will augment, enhance, or even substitute human activity in work, from work organisation to various techniques or equipment (Lewis, 1979; Faulkner *et al.*, 2010). Indeed, the term technology has been used to refer to material objects (such as computers), to fields of scientific endeavour (such as nanotechnology), and to procedures or productive techniques (such as lean manufacturing) (Faulkner, *et al*., 2010).

This thesis focuses on digital technology, which is a specific field of technology. In this narrower definition, technology refers to (i) computer-controlled equipment that aids the work process (including computer and telecommunication systems that are used for storing, recalling and sending information); and (ii) electronic technologies that generate, process and store data (Bessen, 2016; Lewis, 1979). There are two core parts of digital technologies – hardware and software. Hardware refers to physical, tangible electronical devices that enable data processing, but cannot work without software. Software refers to the set of instructions that are programmed to tell computers what to do exactly. As hardware cannot work without software, software cannot be executed without hardware. Digital technologies have been chosen as a focus of this study, because they are arguably the most significant general-purpose technology of our era, which intertwines a wide range of recent technological developments (Nathan and Ahmed, 2018; Schwab, 2016).

As digital technologies are increasingly entering most areas of our lives, the growing prominence of these technologies in the world or work is indisputable. The effects of digital technological advancements on work can be approached from two viewpoints. Firstly, they can change the production systems of goods and services ('digitalisation of production') (Nathan and Ahmed, 2018; Warhurst and Hunt, 2019); and secondly, they can impact the employment relationship ('digitalisation of work') (Clark, 2018; Thompson, 2018; Wood, 2018). These two types of transformative effects of technology can cause different disruptions.

The 'digitalisation of production' is where new technologies can increasingly perform both physical and cognitive tasks in production processes (Frey and Osborne, 2017; Warhurst and Hunt, 2019; Susskind, 2020); and hence, may reduce the need for human input at work. This phenomenon has occurred in various forms over previous Industrial Revolutions, which are discussed in section 2.3.1; and the current wave of technological innovations also have the potential to significantly increase production capabilities. Overall, the 'digitalisation of production' approach studies new technologies' effects on job tasks and their potential to replace human input into production processes.

The 'digitalisation of work' is where the employment relationship between employees and employers are transformed by technology-enabled platform companies that require on-demand freelancing, such as Uber or Deliveroo (Wood, 2018; Warhurst and Hunt, 2019). This form of digitalisation allows organisations and individuals to access an indefinite pool of workers or organisations that can provide specific products or services. Here, the new digital technologies serve as a platform for outsourcing work to individuals. Whilst this form of digitalisation may not reduce the need for human input into the work process, it transforms the nature of employment relationship, which in turn can lead to changes in employment contracts and other legal conditions surrounding work and employment.

While these two approaches to technologies' impact on work study changes from different angles, in practice, the distinction can be blurred, and the same technologies can impact jobs in both ways. This research studies the effects of digital technology adoption on skills utilisation in organisations. As the above section showed, digital technologies are not only tools for carrying out tasks, but they also shape work and employment in an organisation more broadly. This suggests that digital technologies can influence job tasks, as well as the context into which they are introduced. Therefore, to fully capture the effects of technology adoption in an organisation, the focus of research should not be limited to individual jobs but rather should include broader socio-economic and organisational level factors, too.

2.2.2 Organisation

Turning to the second key concept of the research, organisations can be discussed at various levels. As a whole, business organisations are establishments that were created with the intention to carry out commercial activities by producing goods or services to meet its customers' demand (Boy, 2020). Management model of technology, organisations and people (TOP) sees business organisations as an integrated system of three domains: technologies, people and work organisation (Boy, 2020; Behrend, *et al.,* 2022; Hirsch-Kreinsen, 2023).

Organisations can be investigated from the two viewpoints of structure and function (Boy, 2020). Organisational structure refers to the way in which organisations are built up from its various divisions; whilst function refers to the workflow that is generated across the organisation. Organisational function incorporates the concept of work organisation, which refers to how work is planned, organised and managed within companies and it incorporates aspects such as managerial control, division of roles and responsibilities in the organisations, access to information and communication, and the subsequent company culture (Dhondt *et al.*, 2019). Work organisation plays a significant role in both technology adoption and skills utilisation, therefore, the concept is an integral part of the contextual framework of this research (see in section 2.6), and it is later discussed in more details in section 2.4 of this chapter.

When discussing the concept of organisation, more specifically the changes that could be observed in organisations after technology adoption, the research often discusses changes to work organisation. However, as section 2.4.3 below shows, there are further external and internal organisational factors that can influence the interplay of technology adoption and skills utilisation. To reflect this, the research does not narrow down its conceptual focus to work organisation. It rather specifies what aspect of organisation is referred to throughout the discussion.

2.2.3 Skills

Turning to the third key concept of the research, skills have been defined in various ways across different disciplines, which resulted in highly diverse concepts across different school of thoughts. In general terms, the International Labour Organization (ILO) defines the concept of skill as "*the ability to carry out the tasks and duties of a given job*" (ILO website, 2004). However, various academic disciplines developed more nuanced definitions over time. Bryson (2017) identified three broad views on skill in the academic literature that examine and theorize the instrumentality of skills: the political economy of skills; skills as an organisational resource; and learning theory approaches. While these three categories are not strictly bounded, and there are overlaps amongst them, they are a useful way to map the diverse views on skills.

The first broad view on skills is the political economy of skills. In general, this view examines the role of institutions and actors of economies in relation to skill formation, utilisation and value within society (Bryson, 2017). One stream of research within the political economy view analyses the operation of labour markets for different types of skills and labour (for example Autor, 2015; Autor and Dorn, 2013; Helsenke *et al.*, 2018; Green, 2013; WEF, 2019). This approach sees skill as an economic resource and emphasizes its instrumentality in terms of its contribution to the economy. This view is based on the Human Capital Theory proposed by Becker in 1964 (Becker, 1993), which sees skills development as an investment decision for short-term and long-term returns – for individuals, employers and the economy. While this theory has been challenged (Stevens, 1999) and reviewed (Kessler and Lülfesmann, 2002) over the years, it is still influential in skill debates and policies as a driving set of assumptions for studying skills. As for the limitations of the political economy view, economic analyses tend to separate economic theory from the social context. Therefore, generally, these studies often lack consideration for changes in demand – which can be influenced by employers' behaviour and various global and local contextual factors (Bryson, 2017; Morgan, 2019).

Within the political economy view, another stream of research – often used in the fields of political science, sociology and industrial relations, sees skill as an individual or social resource, rather than an economic one. From this perspective, skill is socially constructed through social networks and institutions (Warhurst, *et al.*, 2017). Sociology approaches skills within occupations by looking at the nature and structure of work. Industrial relations scholars are interested in how skills are recognised and valued by the employers; how skill is designed into or out of jobs, and what is the division of labour within work roles (Bryson, 2017). Skill discussions in industrial relations are often driven by the Labour Process Theory literature. This theory builds on Marx's work and seeks to understand how labour power is transformed into productive labour and the social and economic sources that structure the transformation (Thompson and Newsome, 2004). This theory starts its analysis from the employment relationship by examining employers' modes of control over employee's capacity of work. This control over how work is organized is often manifested through the reduction of autonomy, enjoyment, fulfilment and skills needed for the work and used by the worker. This view, therefore, considers the organisational context of work to a certain extent by highlighting employers' influence on work and skill requirements of workplaces. From a technological change perspective, the 'deskilling' view has emerged from this approach to skills, which argues that due to technological change and increasing automation, work experience worsens for many workers, mainly low-skilled and semi-skilled workers, due to a decline in the real content of jobs (Gallie *et al*., 2004).

The second broad view on skills in academic literature sees skills as an organisational resource. This view is often adapted in Human Resource Management and organisation studies. Human Resource Management focuses on the individual nature of skills (skill in the person) and job characteristics (skill in the job). This field's main interest in skills is about how organisations can acquire skills and then how to utilise them, recognise them and value them – based on the assumption that skill affects organisational performance. Organisation studies emphasize the social construction of skills and the impact of different institutions on the formulation of skills (Bryson, 2017). Organisation studies also hold the assumption that skills affect organisational performance. This field is, however, more concerned with why organisations have skills and how are those skills used (Bryson, 2017). Both of these disciplines are in line with the Resource-based view on organisations. This model argues that organisations' competitive advantage comes from their valuable internal resources – including skills (Paauwe and Boselie 2003, 2005; Boselie *et al.,* 2005). The Resource-based view (RBV) was first proposed by Edith Penrose in 1959, who argued that all organisations are homogenous, consisting of 'physical' and 'human' resources. Since physical resources can be easily replicated by rival companies, the real source of competitive advantage is the human element of organisations. These human resources of organisations can create advantage if: they add value to the organisation's performance;

the skills they possess are rare; they are non-substitutable by technology; they are able to capture benefits to shareholders; and they are inimitable (Huselid, 1995). This approach has been criticized, similarly to the economist view on skills, for its lack of consideration of the external context of organisations (Boxall and Purcell, 2016).

The final third broad view on skills according to Bryson (2017) is the Learning Theory view. This approach is popular in psychology and education. It sees skills as an individual attribute, a competency, which is in the person, rather than in the organisation (Winterton *et al.*, 2005). From this perspective, the most important impact of having skills is that they contribute to personal and interpersonal well-being. This leads to the argument, that in jobs where workers can utilise their skills, they will be more productive and more likely to have job satisfaction, and ultimately, overall mental and physical well-being (Bos-Nehles, *et al*., 2013).

Green (2013) aimed to create a definition that brings together the above discussed three broad viewpoints of three disciplines: psychology, sociology and economics (PSE). He argues that skills are "*personal qualities that can produce value at work, are expendable, and are socially determined*" (pg. 25). While this definition captures the diverse nature of the concept of skills, Payne (2017) raises that this loose definition might invites analytical, conceptual and normative issues.

This research sees skills as an organisational resource that contributes to the overall organisational performance when utilised. The research studies the relationship between technologies and skills to explore the ways in which skills utilisation might change in organisations upon new technology adoption. Overcoming the critiques of the resource-based view's lack of consideration for context, this study recognizes the importance of external and internal organisational context and explores the interplay of technologies, skills and organisation.

Skills utilisation

As the above section shows, the study of skills can be approached in many different ways, based on area of interest. This research studies changes to skills utilisation after technology adoption at the organisational level. Skills utilisation refers to the ways in which employees use their skills in the workplace, which is shaped not only by their abilities, but also by a range of choices that employers make about how to manage and organise the workplace (Ashton, *et.al*., 2017; Warhurst and Luchinskaya, 2018). The following sections below discuss what factors shape decisions around skills utilisation in more detail. This section introduces the two key aspects to measure skills utilisation – the function of skills and skills levels.

Based on their functions, skills can be grouped together in various ways. Green (2011) proposes three main types of skills: technical skills, behavioural-social skills and basic skills. Buchanan *et al.* (2010) uses the similar classification of Mounier (2001), and groups skills into categories of technical skills, behavioural skills and cognitive skills. Technical skills relate to skills necessary to undertake particular set of tasks in the production process and are often determined by particular production methods and technologies. Behavioural (or social) skills refer to the personal qualities of individuals that are necessary for dealing with interpersonal relationships in a work environment. These interpersonal relationships can include workers' interactions with management, representing authority within the employment relationship; co-workers to perform teamwork during various production activities; and based on the job role, customers of the company. The final type of skills, cognitive skills, refer to teachable, measurable skills that workers gain through general education and training.

Skill level is a function of the complexity and range of tasks and duties involved in a job. Various skill levels might be determined by using the measurable qualification requirements that are associated with given skills (Henseke *et al*, 2018). In this classification, literature often differentiates between high-skilled, middle-skilled and low-skilled jobs. However, as Susskind (2020), Bender (2020) and Douch *et al.* (2019) highlight, this is often an inadequate indicator for the type and complexity of jobs and tasks that those skills are needed for. For example, some behavioural skills that are unique to humans often do not require long years of education or vocational training. Yet, the tasks that require these skills, for example childcare, are still complex. Therefore, qualification as a proxy for the skill levels required for a job does not provide the full picture on the complexity of jobs (Bakhshi *et al.*, 2017; Susskind, 2020). To overcome this limitation, Green (2013) argues that the use of skills is best observed through reports about tasks that workers perform, making the measurement of skills grounded in behaviour rather than qualifications. Skill-level based classification often forms the basis of discussions around future skill changes, which are further discussed in section 2.5.

Warhurst and Luchinskaya (2018) identify two views on skill levels that differentiate between relative and absolute approaches to skill levels. The absolute skill level refers to the overall stock of skills in the labour market and organisations, typically using qualifications to measure skill levels. The relative approach to skills levels differentiates between skills possessed by individuals and skills required for jobs (Warhurst and

Luchinskaya, 2018). This relative approach helps to discuss skills changes of individuals and skills changes of jobs separately, which can potentially uncover fine-tuned changes to skills utilisation in organisations after technology adoption, which is the focus of this research. The distinction of skills of individuals and skills on jobs follows the above-introduced view on skills as organisational resource, widely adopted in human resource management research. This research also differentiates between skills of individuals and skills on jobs, to better understand the skills changes that can happen after technology adoption.

Skills utilisation changes can take various forms. As discussed above, changes to skill-levels and function of skills are strong indicators of skills utilisation changes. However, similarly the absolute and relative skills levels, differences can also be made between workers utilising their pre-existing skills but to a larger extent (more of the same), or workers utilising skills that were not required for their job roles previously. What is more, considering the absolute and relative skills level changes, even when we discuss workers utilising skills that were note required for their job roles previously, a difference can be made between new skills to the individual, or new skills to the job.

As Buchanan *et al.* (2010) argue, the combination of skills used for any given job are time and space dependent, and the development and deployment of skills are influenced by various social, political and economic settings. Therefore, in the analysis of skills utilisation, the dynamic connections of between the different context levels must be considered. Section 2.4 below discusses labour-market and organisational-level contextual factors that can shape skills utilisation in organisations, and the relevant contextual factors to the case organisations are discussed in Chapter Four.

2.3 Technology

As the technological capabilities of the 4th Industrial Revolution are increasing, coupled with the decreasing costs of computing (Borland and Coelli, 2017), technology is undoubtedly gaining increased prominence in the world of work. To best prepare for the potential changes that these advancements might bring, research must understand the ways in which new technologies can influence work. To provide a historical background to the current changes, section 2.3.1 first introduces past waves of technological change and their overall impact on the world of work. This is followed by a discussion on recent technological advancements and the various academic literature that explores the potential impact of the current wave of technological change.

2.3.1 Technological change

Historical overview of technological change

Illustrating technology's influential role in the world of work, previous waves of technological change brought significant shifts in the labour market and society as a whole (Mathias, 1983; Preston, 1987). These transformations included changes to dominant sectors in economies and occupational shifts across labour markets. The first Industrial Revolution, during which steam and waterpower were dominant, transformed the way physical work was carried out and shifted the production of goods from family-sized guild businesses towards industrial levels (Mathias, 1983). Innovations during this revolution were based on the division of labour and they substituted for artisan skills through the simplification of various tasks (Mokyr *et al.,* 2015; Frey and Osbourne, 2017). This favoured workers with relatively low skills, since they could replace skilled individuals. However, technological innovations of the time also created demand for new skills, such as maintenance of machinery (Mathias, 1983). The consequent sectoral shifts, created by changing skill requirements in the economy, led to short-term disruptions, which were illustrated by various riots against new machinery in the textiles industry (Silva and Lima, 2017). However, as Mokyr and colleagues (2015) suggest, reports on these riots might have been exaggerated and workers were more concerned with the overall low levels of wages and poor working conditions, rather than their displacement by new technologies. In other words, these rioters' complaints were potentially mostly about the quality, rather than the quantity of work. Nevertheless, the technology-driven sectoral shifts of the era heightened the social inequalities; and the sectoral shifts from agriculture to manufacturing has created social issues around housing and overall urbanisation (Mathias, 1983; Fukuyama, 1999).

The second Industrial Revolution saw another shift in dominant sectors within the economy and skill requirements. A shift from using steam and waterpower towards electricity enabled the automation of many production processes. This automation, in combination with continuous-process and batch production method-based work organisation, made many low-skilled workers obsolete in the production process. At the same time, new machinery required maintenance, increasing the need for skilled technician workers (Mokyr *et al.*, 2015; Silva and Lima, 2017). The increased productivity due to automation and innovations in transport also resulted in geographically expanded markets, which required complex managerial tasks, creating an enhanced need for white-collar and clerical workers such as supervisors and accountants (Mokyr *et al.,* 2015). Consequently, the British education system needed to catch up to the technology-driven demand changes in order to facilitate a smoother sectoral transition in the labour market. However, as Bakhsi *et al.* (2017) highlight, education has generally been slow to respond to the changing needs within the economy, which is clearly illustrated by the Education Act of 1902 – marking the consolidation of a national education system and the creation of a secondary school system- that came to existence a century after the first Industrial Revolution. This slow response from the education system made the economic disruptions of the first two Industrial Revolutions, caused by sectoral shifts, more challenging, as skill shortages took longer to fill.

In the third Industrial Revolution, the key growth industries were microelectronics, computing and telecommunications (Preston, 1987). Popular technological forecasting in the 1970s and 80s (Toffler, 1980; Stonier, 1983) predicted that this third technological revolution will be characterized by the growth of the service sector, where the majority of new jobs will be created in the higher level services, and information producing and handling. Whereas the mature industry of manufacturing, that was dominant in Britain prior to this wave of technological change, will see a decline in employment levels and significance in the economy. This view predicted a radical break from previous revolutions, suggesting a need for higher-skilled workers in order to fulfil the increasingly emerging roles of research, scientific and technical workers in the information industry. The more modest predictions, such as Preston (1978), using the long waves perspective on technological change suggested that while the new emerging service and information sector will play an important role in the British economy, the mature manufacturing industry will not lose its importance in the face of the technological and economic changes of the time. Indeed, as Preston (1987) argued, new service types of jobs were created in the manufacturing industry at the time, and the new information sector also included many middle-skilled, operator and clerical jobs. Considering the historical data, the long waves technological change perspective's more modest predictions on change in employment level became reality as opposed to the popular, radical predictions of the time (Silva and Lima, 2017).

Although these previous revolutions did not bring significant reduction in the overall employment levels, many authors highlight the importance of distinguishing long-term and short-term effects of technological change (Mokyr *et al.*, 2015; Montealegre and Cascio, 2017; Zysman and Kenney, 2018). While in the long-term, creative destruction evens out employment levels, job creation often falls to different places from job destruction. This can result in disruptions in employment in the short-term, causing distress for effected workers (Mokyr *et al*., 2015; Silva and Lima, 2017). These short-term disruptions can be observed nowadays in the fourth Industrial Revolution as well, which leads to the emergence of an overall negative narrative on the future of work and employment. Despite the above introduced long-waves of technological change, and the repeating cycle of unmet negative forecasts on technological unemployment, current literature on technological innovations predicts that this time it will be different. These arguments are discussed next.

Current wave of technological change

In the 4th Industrial Revolution, emerging technologies fusion into and interact across the physical, digital and biological domains of our lives and increasingly intertwine human and machine intelligence (Schwab, 2016). The 4th Industrial Revolution, or as Brynjolfsson and McAfee (2014) refer to it, the Second Machine Age, has been defined in multiple ways, and is often used as a term to describe the digitisation of the economy and society in general. Warhurst and Hunt (2019) define the concept as "*the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology, and the internet with conventional industry*" (pg. 4).

This era has led to an increased interaction between humans and machines in the production process. The technological developments of this 4th Industrial Revolution are entering almost all sectors of our economy, examples including the use of Artificial Intelligence in banking and the finance sector, in Higher Education and health care (Dellot and Wallace-Stephens, 2017; Haw, 2019; Kent, 2019; The Economist, 2019). Consequently, in this revolution, not necessarily a new sectoral shift can be expected, rather an increased diffusion of new technologies into all sectors. Therefore, going forward, for positive future growth, economies will need healthy base sectors where technological progress is encouraged, as much as emerging new sectors harvesting the opportunities of new technological innovations. This research offers an insight into technology adoption and related skills changes in one of Scotland's key base sectors, manufacturing.

As previous Industrial Revolutions show, new technologies can cause significant changes in economies and labour markets. Over time, they have the potential to shift dominant sectors in economies and change overall skills demands in labour markets. The exponential rate at which technological advancements develop in the current Industrial Revolution suggests that significant changes can be expected in this current era, too (Brynjolfsson and McAfee, 2014). The next section discusses the ongoing debates regarding the potential future outcomes of this current wave of technological change.

Future of technology and work

Due to the increasing technological capabilities of Industry 4.0, coupled with the ever-decreasing costs of computing (Borland and Coelli, 2017) and the vast amount of available information and technologies that can be further combined to create new innovations (Brynjolfsson and McAfee, 2014), debates on the future of work has revitalised once again. The current debate on the effects of technological change on employment is rather polarized in the fields of academia, industry and policy.

Willcocks (2019) identifies two radical teams, 'hype' – who argue that technology will have positive effects on the world of work and will highly benefit from the various innovations- and 'fear'- who argue that the new machines will take over our jobs and the 4th Industrial Revolution will result in mass unemployment. Dellot and Wallace-Stephens (2017) identified four voices on technology: alarmists, dreamers, incrementalists and sceptics.

Alarmists, who are in line with Willcocks's fear-team, believe that humanity is doomed and technologies will create mass unemployment. Examples for this group may include Oxford economists Frey and Osbourne (2013), who in their influential study suggested that 47 per cent of jobs in America are at high risk of automation, and consequently, obsolescence in the coming decade; and Thomas and Gunson (2017), who applied the same methodology proposed by Frey and Osbourne, and came to the conclusion that 47 per cent of jobs in Scotland are at high risk of automation.

Dreamers also believe that machines will take over the majority of jobs, but they see this as a positive and believe that this will lead to an utopian leisure society (Dellot and Wallace-Stephens, 2017). This group's main argument is often labelled as the post-capitalistic argument or the 'accelerationist utopia' (Coyne, 2020), claiming that the end of work is here, and it is actually desirable. This view believes that new technologies have the power to enhance economic productivity with decreasing human input, which frees up time for humans without the fear of worsening livelihood. Supporters of this view include Mason (2015), Srnicek and Williams (2015) and Susskind (2020).

Whilst these two views on the future of work disagree whether the effects of new technologies will be beneficial for humans or not; they both see technology as a deterministic force, over which humans have no influencing power. However, as current critics (e.g. Thompson, 2019; Morgan, 2019; Lloyd and Payne, 2019; and Coyne, 2020) highlight, the development, implementation, operation and the effects of technology are not pre-determined, they are rather highly dependent on the context into which they come to exist (if so), and decisions and choices that individuals make at multiple levels within the economy. Therefore, they argue that technological feasibility does not equate implementation. This view is further explored in the next section of the chapter. Considering this position, these critics identify more with the following two groups of Dellot and Wallace-Stephen's (2017) classification: incrementalists and sceptics.

Incrementalists argue that technological innovations of Industry 4.0 will be implemented gradually, and they will substitute for some work. However, overall, they will evolve jobs, rather than eliminate them. This view sees new technologies as complementary to human activities at the workplace. According to Autor (2015) and the task-based approach, the reason for this lack of technology-driven mass unemployment lies in the limitations and bottlenecks of technological advancements, such as their lack of tacit knowledge and emotional intelligence, which still means that work requires a complimentary relationship between machines and humans. This task-based approach is discussed in more detail in section 2.5.1.

The final group that Dellot and Wallace-Stephens (2017) identified are 'sceptics', who argue that the current innovations are mediocre in significance compared to past inventions such as electricity and railway. Robert J. Gordon, for example, argued that innovations in transport, housing and medicine that took place between 1870 and 1970 had more significant transformative effects on productivity and standards of living, as opposed to modern computer technology (Zysman and Kenney, 2018).

Overall, the above classification of the views might be useful for categorizing the extensive body of literature on the future of work; but it is important to note that these labels are often rested on questionable assumptions (Willcocks, 2019); and therefore, no position will have the ultimate truth on the future of jobs - if there is one. The next section of the chapter dissects the assumptions that these debates rest on and introduces the approach that this research take towards exploring technology adoption and related skills utilisation changes in Scottish manufacturing SMEs.

2.3.2 The study of technology and work

As the above discussion showed, researching the role of technologies in the world of work has long been an area of interest in management literature. The development, use and subsequent effects of technological advancements have been approached and addressed in numerous ways over the years. These different approaches are discussed next.

Exogenous view

Early management studies, following a positivist ontological approach, view technology as an exogenous force that is a powerful driver for change in organisations. This position assumes that technology is a relatively autonomous entity that has significant and predictable impacts on various human and organisational outcomes (Orlikowski, 2010; Joyce *et al.*, 2023). Here, technology is seen as imperative, whilst humans are simply regarded as extensions, passive users of said machines (Trist, 1980). Trist (1980) argues that this view of technology is characteristic of the old, 'traditional organisation' paradigm, which is based on the principles of technocratic bureaucracy that encourages maximum work breakdown, narrow job descriptions and skill sets of workers, as well as strict external control of production, leading to low levels of worker autonomy. Guest *et al.* (2022) echo Trist and describe this stream of literature as the 'mechanical school of organisational theory' that resembles the principles of scientific management, advocating for managerial authority, worker specialism, clear divisions of labour and a separation of conception and execution – all that can impact skills utilisation in organisations, as it is discussed in section 2.4.3. Within the exogenous view of technology, technology forms an integral part of the organisational system since it underpins production infrastructure which follows a strict division of labour (Guest *et al.*, 2022). This suggests a limited and restricted view on the way work is organised in companies, which is in line with the rigid, 'pre-determined' view on the effects of new technologies that this school of thought promotes. However, as later argued, there is an array of work organisation decisions that can influence the way work is carried out in organisations.

Studies taking the exogenous approach seek to theorise the relationship between technologies and organisations generally enough that predictions can be made across organisations, different types of technologies, various sectors and even economies. This approach, however, has been criticized due to a number of its assumptions. Joyce *et al.* (2023) summarise the limitations of this deterministic approach to studying technological change in two core basic conceptual assumptions. The first one is that technological change happens due to scientific advances, and technologies in the workplace will follow their 'inner logic' as autonomous entities. In other words, the deterministic view on technologies assumes that advancements in technological capability automatically leads to the implementation of new technologies, and it neglects the array of decisions that stakeholders make in relation to technology adoption (Hayton, 2023). To broaden this restrictive assumption of the exogenous view, a wide range of research emphasized the crucial role of the socio-economic and organisational context in organisations' technology adoption decisions. These are discussed in more detail below.

The second core assumption of the exogenous view of technologies that Joyce *et al.* (2023) dispute relates to the effects of technologies. The exogenous view argues that new technologies in the workplace will cause social and organisational changes in a linear, deterministic manner (Joyce *et al.*, 2023). This assumption can lead to studies overstating the influence of technologies in the workplace, whilst understating the influential power that the social and contextual factors might have on technology adoption and their subsequent effects on the organisation (Thompson, 2019; Hunt *et al.*, 2022; Joyce *et al.*, 2023). In addition, Joyce *et al.* (2023) highlight a further limitation of studies adopting the exogenous view on technologies, which concerns technologies' effects in organisations over time. Joyce and their colleagues (2023) argue that the rigid view on technology fails to recognize that technologies evolve in organisations with time; and studies should not underestimate the influence humans have over how technologies are used in organisations and their subsequent effects.

Despite the above criticism, the core assumptions of the exogenous view on technologies underpins much of the research and forecasts on the potential effects of the current wave of technological change. One of the most widely cited study that aimed to quantify the effects of recent technological progress on overall employment is by Frey and Osbourne (first published in 2013; revisited in 2017). They estimated the probability of computerisation for occupations in the US labour market. Occupation is defined as "*a set of jobs whose main tasks and duties are characterized by a high degree of similarity*" (ILO, 1990). Frey and Osbourne (2017) based their analysis on the task-based approach that argues that routine tasks can easily be translated into rule-based logic, which can in turn be programmed into computers and machines (Levy and Murnane, 2005; Autor and Dorn, 2013). Therefore, jobs that mostly involve routine tasks are more vulnerable to automation than jobs that consist of non-routine tasks. However, Frey and Osbourne (2017) argue that recent developments in Machine Learning and robotics led to the inadequacy of the assumption that non-routine tasks are invulnerable to automation. Due to this, they examined the susceptibility of jobs to automation from a technological capability point of view. Based on their analysis, they identified three job categories in relation to automation: high, medium and low risk. According to their methodology, if the main tasks of an occupation involve routine tasks or non-routine tasks that can be automated with new technological capabilities, then the occupation is at high risk. As their findings showed, 47 per cent of the jobs in the US labour market are in the high risk category, meaning that associated occupations are potentially automatable – including office and administrative occupations, transportation and logistics jobs, and production occupations (Frey and Osborne, 2017). Occupations that involve complex perception and manipulation tasks (for instance, management and business occupations), creative intelligence tasks (for example, arts and media jobs) and social intelligence tasks (such as care work), however, are unlikely to be automated in the coming decade. Their study concludes with the argument that "*over the next decades, the extent of computerisation will be determined by the pace at which the above-described engineering bottlenecks to automation can be overcome.*" (Frey and Osbourne, 2017, pg. 265). Frey and Osbourne's study has been widely discussed in academia and have been picked up by think tanks and policy makers, too (Morgan, 2019).

Subsequent studies adopting similar methodological approach to Frey and Osbourne's study also emerged, albeit with slightly different assumptions. For example, the OECD's study by Arntz *et al.* (2016) relaxed the assumption that full occupations can be replaced based on their main tasks. They argue that occupations are build up from a bundle of tasks, not all of which has the same level of vulnerability to automation (Arntz *et al.* , 2016; 2017). By taking into consideration task-heterogeneity within occupations, Arntz and her colleagues found that only 9 per cent of jobs are vulnerable to automation in the 21 OECD countries they examined (Arntz, *et al.*, 2016). In Scotland, Thomas and Gunson's (2017) study predicted that 46 per cent of jobs will be at high risk of automation by 2030.

While these forecasts have been widely discussed in academic literature and mainstream media alike (Hunt *et al.*, 2022; Morgan, 2019), they received extensive criticism due to methodological and conceptual issues. As for the former, one line of criticism of Frey and Osbourne's methodology concerns the database they used for their analysis, namely the Occupational Information Network (O*NET). O*NET uses mostly self-reports from representative samples of employees to measure occupational characteristics (Handel, 2017; Hunt *et al.*, 2022). However, Handle (2017) argues that while it might be a comprehensive dataset, O*NET also often uses complex, abstract and vague survey items, which can lead to interpretive difficulties. Many survey items of this database have moderately strong predictive validity, but with the use of rating scales it is difficult to interpret what O*NET scores actually mean in terms of specific, real-life work tasks. Therefore, the dis-attachment of Frey and Osbourne type methodology carries limitation in terms of empirical value.

Furthermore, Morgan (2019) highlights that Frey and Osbourne's methodology is based on task structures of current occupations and does not take into consideration the job creation effect of new technologies. It is important to point out, that this limitation has been addressed by Frey and Osbourne (2017). They noted that while their paper is limited to the destructive effect of technologies on employment, there is scope for counterbalancing the negative effects by job creation in occupations where humans still possess the competitive advantage over machines.

A further criticism is that Frey and Osbourne determine whether an occupation can be displaced by technology or not in a binary fashion based on the capability of technologies to duplicate the main tasks of the given occupation. This is in line with the above-mentioned critique of the exogenous view on technologies, which argues that studies following this approach often overstate the significance of technologies in the workplace and neglect the influence of the abundance of social factors that are also at play in organisations (Thompson, 2019; Joyce *et al.*, 2023). For instance, since Frey and Osbourne's classification can either be yes or no, the method does not incorporate the possibility that technology changes occupations in any other way, for example by rearranging tasks (Morgan, 2019; Thompson, 2019). Therefore, Frey and Osbourne's study is based on rigid classification and technological capabilities, and they are not a direct evidential test of technologies' effects on occupations (Morgan, 2019). This results in predictions that lack empirical enquiry, yet still create an anxious narrative surrounding the future of work (Morgan, 2019). However, it is important to note that Frey and Osbourne (2017) did not claim to forecast the future composition of the labour market; they merely tried to measure current jobs' vulnerability to automation.

While their lower percentage is less debated than Frey and Osbourne's 47 per cent; Arntz *et al.*'s (2016) task-based approach also received criticism. Firstly, Morgan (2019) claims that this method is similarly restrictive to Frey and Osbourne's occupation-based approach in terms of not addressing the job creating effect of new technologies and the wide range of contextual factors that influence technology adaptation. A further criticism of this 'bundle of tasks' based approach is that by emphasising discrete groups of tasks within occupations, researchers neglect a higher order coherence that defines job roles (Bakhshi *et al.*, 2017). In isolation, it is reasonable to think that similar tasks have similar levels of demand. However, as part of an occupation, discrete tasks also belong to different industries with different level of skill requirements (Handel, 2017). Finally, as Arntz and their colleagues (2016) addressed, the predicted job losses that might be caused by automation might not materialise. There are numerous reasons for this: first, new technologies might not get adopted; or second, humans can adjust to new working arrangements and tasks, which often require workers to use different skills in their roles.

Overall, the exogenous view on technology discusses the great influence that technology has on the world of work. This stream of literature, which still underpins much of research on the effects of Industry 4.0, sees technology as an autonomous entity in organisations.

As the examples showed, even though this exogenous view explores the technical side of recent changes, it pays little attention to the socioeconomic and organisational level factors that can also influence technology adoption and its potential effects. To explore this in more detail, the socio-technical systems view on technological change emerged (Trist, 1980), which was further developed over the years. This view is discussed next.

Socio-technical systems view

This school of thought recognizes that technology adoption and impacts of new technologies must be studied through 'wide lenses', as a variety of factors beyond decisions around adoption can have influence over outcomes for work and organisations. This view, therefore, emphasizes that technologies' impact on work and workers are not technologically determined, as the exogenous view would argue (Hayton, 2023).

The concept of the socio-technical system arose in conjunction with a series of field research undertaken by the Tavistock Institute intended to understand productivity problems in the British coal mining industry in the 1970s. At the time of the fieldwork, the dominant organisational model in research was the above described 'traditional organisation' characterized by technocratic bureaucracy (Trist, 1980), which was based on the principles of Weber's bureaucracy and Taylor's scientific management (Trist, 1980; Guest *et al.*, 2022). However, with the Tavistock Institute's field research, a hope for an alternative approach emerged. The research showed that the technological imperative could be disobeyed in practice with positive economic as well as human results. This finding led to the view that technological change in itself is shaped by social circumstances within which it takes place. Studies based on the socio-technical system show that the development and implementation of new technologies involve many choices between technical options and these choices shape the technologies themselves, as well as their implications for work and workplaces (Wajcman, 2017). From this point of view, technology is a socio-technical product, shaped by the conditions of its creation and use.

The socio-technical system model studies work systems that incorporate a set of activities that make up a functioning whole. This means that the basic unit of analysis moves away from single jobs, and work groups become central to the analysis, rather than single individuals (Trist, 1980). By studying socio-technical relations in systems, the model is suitable for exploring interdependencies. The model also promotes internal regulation within work teams, as opposed to external control performed by supervisors. This principle of the socio-technical system approach moves the concept of control away from the dominant organisational paradigm that is based on scientific management and techno-bureaucracy. This stream of literature also treats individuals as complementary to technologies, as opposed to being extensions of it (Trist, 1980). Socio-technical system studies are carried out at three levels: primary work systems, whole organisational systems and macrosocial systems; and they argue that changes in technology have the potential to bring about changes at all three broad levels, and the socio-technical phenomena are contextual.

The basic principle of socio-technical system model is the ambition for joint-optimization of social and technical systems. According to Trist (1980), these two systems are independent of each other, where technical systems follow the laws of natural sciences, whilst social systems follow the laws of human sciences. The relationship between these two systems is a coupling of dissimilars, which can only be jointly optimised, because if one system is pursued at the expense of the other, it will result in the suboptimisation of the whole system (Guest *et al.*, 2022). To promote joint optimisation, the school of socio-technical systems advocates for work groups to be given the autonomy and skills to make decisions themselves locally. This ambition to improve the social aspects of an organisation in tandem with technology adoption illustrates the crucial role of work organisation in successful technology adoption, and highlights that technology does not exist in isolation, and it affects, and it is affected by the social context into which it is introduced. Indeed, more recent studies developed the principles of the socio-technical systems further and argue that organisations should be studied as systems of three domains – technology, people and organisation. This line of research places a strong emphasis on the interplay of these three dimensions and argues that the joint optimisation of these three dimensions defines the skills requirements in organisations (Behrend *et al.*, 2021; Hirsch-Kreinsen, 2023).

Out of the aspiration to improve the social system of organisations in face of technological change and move away from the restrictive principles of scientific management was born the concept of quality of working lives (QWL), which was first formed in conjunction with the socio-technical system literature, and later became a distinct movement (Guest *et al.*, 2022). The original QWL initiatives aimed to improve working lives of workers generally, and it helped firms to make voluntary changes to work design (Warhurst and Knox, 2022). Characteristics of early QWL initiatives included fair compensation; safe and healthy working conditions; opportunity to use and develop human capacities; opportunities for continued growth and security; and social integration in the work organisation.

Despite the socio-technical system studies and QWL initiatives addressed important gaps in organisational literature at the time, there were challenges that undermined their ambitions. As Guest *et al.* (2022) argue, early socio-technical system scholars were social scientists, which led to limitations in implementing socio-technical change, often resulting in higher emphasis on social optimisation, but not enough of technical optimisation. In spite of emphasizing joint optimisation, the lack of technical expertise amongst scholars promoting the socio-technical systems meant that they failed to translate their ambitions into practice. Moreover, the socio-technical system model emerged from the Tavistock field studies, and subsequent studies were also based on practice focused fieldwork that applied action research. These studies, however, were later criticized for being too case specific with limited generalisability, which undermined the diffusion of the socio-technical model (Guest, *et al.*, 2022; Hayton, 2023). Warhust and Knox (2022) argue that both the socio-technical system model and early QWL initiatives emerged in a specific socio-economic context, and they failed to evolve as the economic and social climate changed. In addition, the recommendations of socio-technical system studies and QWL initiatives are based on voluntary action, and the often inadequate organisational and national institutional support hampered their widespread uptake (Guest *et al.*, 2022). However, the socio-technical systems view on technologies has been revisited and further developed over the years (Leonardi, 2013; Behrend *et al.*, 2022; Bailey *et al.*, 2022; Hirsch-Kreinsen, 2023) and its principles can serve as a basis for exploring the effects of the current wave of technological change on skills and organisations.

Social shaping of technology

A core argument of the socio-technical model is that technologies do not have deterministic impact on outcomes in the workplace - the social construction and social shaping theories develop this principle even further. The social construction view argues that outcomes are a result of interaction between the social elements of work, the features of the given technology and the context in which it is being deployed (Hayton, 2023). From this perspective, technology does not cause change in organisations, it rather acts a catalyst for a social process, which then itself constructs change. As some critics (Grant *et al.,* 2006; Howcroft and Taylor, 2022) note, however, this approach is also deterministic in its nature. Instead of being technologically deterministic, the social construction theory assumes that the sole concern of research should be the ways in which society and organisations use technologies, rather than the technology itself. Therefore, it can be argued that the social constructionist view of technology downplays the material and structural aspects of interaction with technology (Orlikowski, 1992).

The social shaping of technology (SST) approach takes a less socially deterministic position and examines what is shaping technological change and its predicted effects. The label of shaping is used instead of construction, to reflect the importance of the materiality of technologies (Mackenzie and Wajcman, 1999; Howcroft and Taylor, 2022). The SST approach was born out of four broad academic traditions, namely the sociology of scientific knowledge, sociology of industrial organisation, technology policy studies and economics of technological change (Williams and Edge, 1996). These four traditions approach the study of technological change through the same angle of analysing the ways in which power is exercised through the adoption of new technologies in organisations, recognizing the crucial role of choice in technological development and adoption processes (Williams and Edge, 1996). As its origins reflect, the SST approach incorporates a wide range of theoretical approaches and disciplinary foci, therefore it has been labelled as a 'broad church' (Joyce *et al.*, 2023). Certain streams of this approach explore technological change at a labour market and society level, examining the implications of wider phenomena, such as financialisation (Thompson, 2019; Thompson and Laaser, 2021) and globalisation (Taylor, 2019; Howcroft and Taylor, 2014), for the direction of technological change and work at large. These studies offer valuable insight into the broader trends and forces in society and economy at large that shape the direction of the current wave of technological change. This research, however, uses the SST approach to explore organisational-level changes that could be observed after technology adoption.

The social shaping of technology approach argues that social aspects of organisations shape each other interdependently and in iterative ways, rather than linearly as the techno-deterministic view claims (Williams and Edge, 1996). This means that technologies and work organisation are mutually constitutive in an organisation, where technologies are prefigured by existing forms of work organisation and embody divisions of labour and expertise, whilst at the same time, technologies are often adopted with the intention to change, improve and transform work organisation (Howcroft and Taylor, 2022, Williams and Edge, 1996). This highlights the mutually shaping influence between technologies and the organisational context into which they are introduced (Llyod and Payne, 2021; Gobena, 2024).

Following this argument, the SST approach demonstrates that there is nothing inevitable about the process in which technologies evolve. As the commonality of the varied disciplinary origin of the approach highlights, the development of technologies, their use and their effects include choices, with potentially differing outcomes and implications for various social groups with contrasting interests. This line of argument suggests that technologies are not neutral and their inherent determinism serves an ideological function promoting the interests of those who benefit from their adoption (Howcroft and Taylor, 2022). By highlighting this ideological influence, the SST approach stresses the importance of politics, power relations and negotiation processes through which technology deployment decisions are made. In line with this view is the labour process theory, which focuses on how labour power is transformed into productive labour, and the social and economic sources that structure the transformation, such as the use of technologies (Thompson and Newsome, 2004; Smith, 2015). At the organisational level, this tension between the different groups with conflicting interests, such as employers and employees, is manifested through the mechanisms of control and workers' autonomy. From a technological perspective, changes in the organisation upon technology adoption can be captured by examining whether the new technology has changed the way control is exercised in an organisation and/or if it has impacted workers' autonomy. Consequently, as section 2.4.3 argues, changes in control and workers' autonomy can influence skills utilisation in organisation, too.

Whilst control is argued to be the main mechanism through which technologies' inherent ideological objectives are exercised, Joyce *et al.* (2023) challenge the idea that the only, or even the main, driver for employers to adopt new technologies is to exercise control over their workers. As alternative explanations beyond politics and power relations, SST scholars further argue that technology can be shaped by preexisting technologies (Dhondt *et al.*, 2019); economic factors such as labour cost (Spencer, 2017) and employment levels; social relations of production and class relations (Winton and Howcroft, 2020); gender (Wajcman, 2002); and the role of state in regulating technological change (Scottish Government, 2018). Despite the variety of alternative explanations, empirical SST research is still predominantly analyses technology driven changes through the narrow focus of control (Amorim and Moda, 2020; Anwar and Graham, 2021; Wood, 2018). Additionally, as Joyce *et al.* (2023) claim, recent empirical SST research is also narrowed down by its overemphasis on platform work technologies and their effects on the employment relationship. This research aims to avoid these trends of the SST scholarship and contributes to empirical SST research by exploring a variety of organisational factors beyond control that might shape the adoption of two types of production technologies and their consequent skills utilisation effects.

As section 2.3. showed, the way we approach the study of technology shapes core assumptions, conceptual focus and understanding of the role and potential effects of technologies in the workplace. This research explores technology adoption and related skills utilisation changes in SMEs following the core principles of the social shaping of technology approach, where technologies, humans and organisations are studied as separate entities that mutually shape each other. This position recognizes that the choice of technologies are influenced by pre-existing work organisation and contextual factors; yet, at the same time, technologies might be implemented with the intention to change the pre-existing work organisation (Howcroft and Taylor, 2022), which would ultimately have implications for skills utilisation in organisations, too, as the next section demonstrates. In addition, the social shaping of technology approach recognizes that the material characteristics of technologies influence the choice of technologies, as well as the impact that they might have on work organisation and skills in organisations. This research explores technology adoption and related skills utilisation changes in Scottish manufacturing SMEs. The next section of this chapter further explores the influential role of the external and internal organisational context on technology adoption, as well as skills utilisation in organisations.

2.4 Organisation

As the socio-technical systems view and the social shaping of technology approach show, there are a wide range of contextual factors that influence the effects of technology adoption in organisations. This section further elaborates on the crucial role that contextual factors play in technology adoption and skills utilisation. First, section 2.4.1 outlines the contextual factors that can influence employers' decisions of technology adoption. Second, section 2.4.2 shows that even technologies are adopted, different types of technologies can lead to different organisational and skills outcomes, depending on their functionality and the way in which they interact with different aspects of work organisation. This section highlights the importance of the materiality of technologies, as the social shaping of technology approach also emphasizes. However, the organisational context does not only influence technology related decisions in organisations, but skills utilisation as well. Therefore, section 2.4.3 discusses the external and internal organisational factors that can impact skills utilisation in organisations. Finally, section 2.4.4 discusses the organisational characteristics of small and medium enterprises, which could influence technology adoption and related skills utilisation changes in the case organisations of the research.

2.4.1 Organisational context and technology adoption decisions

Despite the exponential rate of technological innovation and the decreasing computing costs, technological feasibility does not always translate into technology adoption, as there are a wide range of factors that can impact organisational decision-making. An earlier influential body of work on technology adoption is the diffusion of innovations (DOI) paradigm, which studies the rate of diffusion of new innovations to best understand the factors that influences the adoption of new innovations. Rogers (1962) identified five main characteristic of an innovation that impacts its diffusion, namely: the relative advantage of the technology over pre-existing tools and methods in the workplace; the compatibility of the new technology with existing norms, values, needs and the culture of an organisation; the perceived complexity of the technology compared to the existing knowledge and capability of the workforce; the observability of the workings and impact of the new technology; and the opportunity to test the technology prior to its adoption. According to Rogers (1962), organisations adopted the new technologies if they found that the new innovations suit these criteria and meet the organisation's needs. On a broader level, the DOI approach also examined differences between late and early adopters of technologies (Hayton, 2023). The approach received both empirical and conceptual criticism for its limited focus on a single characteristic of innovation, taking individuals as a unit of analysis rather than organisations, assuming that all organisations have equal opportunities and resources to adopt a new innovation, and for treating technology as static and not considering how technology might evolve over time (Hayton, 2023).

As the DOI approach evolved, the Technology Acceptance Model (TAM) emerged. This model shares the core values of DOI, such as the emphasis on technologies' usefulness and complexity, but it believes that at its core, the key decisive factor whether a new technology is adopted or not is individuals' motivation (Davis, 1989; Hayton, 2023). The TAM approach, therefore, argues that technology adoption is dependent on individuals' beliefs about its benefits and usability, that can in turn influence behavioural intentions and adoption (Davis, 1989). Similarly to DOI, this model also sees technology adoption as an individual's choice, rather than a result of an organisational decision-making process. For this reason, the key criticism towards this model is that its limited consideration for the organisational context (Hayton, 2023).

To widen the horizon of studying the influencing factors of technology adoption even further, the technology, organisation and environment (TOE) model emerged. As its name suggests, this model divides the potential drivers for technology adoption coming from three contextual areas (technological context, environmental context and organisational context) and adds external pressures as drivers for technology adoption, such as product market competition and trading partners' influence (Tornatzky and Fleischer, 1990; Hsu *et al.,* 2006). In the technological context, factors such as the preexisting technologies in the company, the dominant technologies in the sector and the available technological capabilities are influential in technology adoption decisions (Ramdani, *et al.*, 2013; Dhondt *et al.*, 2019). The external environmental context includes pressures from supply chain partners, trading partners, competitors and industry partners; whilst the organisational context refers to the scope and the size of the organisation and the managerial structure (Hsu *et al.*, 2006).

By taking the organisation as its unit of analysis, this model frames perceived ease of use of new technologies as organisational readiness, rather than individual abilities, which is the case for DOI and TAM. Based on an array of empirical studies, the two key dimensions of organisational readiness are financial resources and organisations' technological sophistication (Hayton, 2023). Applying the TOE model for SMEs, Iacovou et al (1995) finds that in SMEs organisational readiness tends to be low in general, and the most influential drivers for technology adoption are external pressures, especially from trading partners. Indeed, European Commission data shows that the lack of financial resources were reported to be most significant barriers to technology adoption in SMEs (Muller *et al.*, 2019). Moreover, the TOE model also examines both the direct, such as the organisational, and the indirect, strategic benefits of technology adoption, that considers both the intended and unintended consequences of technology adoption in firms. Whilst a key strength of this model is its consideration of external drivers and taking organisations as its unit of analysis, it still ignores the dimensions of normative characteristics and value fit of new innovations, such as organisational culture's influence in the choice of technology adoption (Haynes, 2023).

Further studies highlighted the key role of organisational factors in technology adoption decisions. Damanpour's (1991) meta-analysis studied the relationship between organisational innovation and potential determinants, and found an array of factors that positively influence technology adoption, such as the degree of specialisation in an organisation, functional differentiation, professionalisation, favourable managerial attribute towards change, deeper technical resources, administrative intensity that supports needed coordination and leadership, slack resources to buffer failure, external orientation of the organisation and internal communication in a company. Whilst these organisational level factors tend to be in support of successful technology adoption, centralisation of power and concentration of decision making in an organisation might reduce awareness, commitment and involvement from employees, which can ultimately sabotage technology adoption. Importantly, Damanpour (1991) notes that these factors are often interdependent, and their effects on technology adoption might be moderated by the type of innovation, stage of adoption, type or organisation and the scope of the innovation. For example, successful implementation requires managerial control, which might be established by standardised work processes in manufacturing organisations. Whilst specialisation is found to be supportive of successful technology adoption, this prior example shows that the type of organisation can influence the importance of certain factors. Indeed, Damanpour (1991) claims that the type of organisation should be a primary variable when studying technology adoption in organisations.

Berger *et al.* (2021) and Lee and Xia (2006) further argue that organisational size is an important variable in technology adoption. Indeed, the most recent survey on Scottish SMEs demonstrated these differences even within SMEs, and showed that medium-sized companies were more likely to innovate than micro- or small businesses (Scottish Government, 2022). Berger *et al.* (2021) argue that SMEs are less likely to adopt new technologies due to their tendency of CEO centralisation, low levels of role specialisation and the lack of slack resources that Damanpour claimed to be important for buffering adoption failure. However, this does not mean that SMEs do not have the capability to adopt new innovations, but they might face more challenges in the process. For example, Meyer (2011) found in his study of German manufacturing SMEs that the demographic composition of the workforce can also impact technology adoption. His findings show that the proportion of new technologies is negatively associated with the proportion of older workers in the firm, which can suggest related skills issues. As it will be discussed in more details in Chapter Four, the Scottish manufacturing sector is characterised by a digital skills gap, where older workers find it difficult to navigate increasingly digitalised workplaces. Based on Meyer's findings, this skills issue can influence organisations' decisions whether to adopt new technologies or not. Indeed, the lack of skills were reported as the second top barrier to technology adoption in European SMEs (Muller *et al.*, 2019).

As the above introduced models showed, there are a wide range of contextual factors that can influence organisations' decisions on technology adoption. In line with the social shaping of technology approach, the above section reflects the importance of choice in technological change, contradicting the popular deterministic views on the future of work. In addition, the discussion supports Joyce *et al.* (2023)'s call for the SST approach to go beyond the narrow focus on control as the main driver for technology adoption and widen its perspective to consider further influences on organisation's decisions.

2.4.2 Type of technologies and work organisation

Even if the above discussed external and internal organisational factors are favourable and employers decide to adopt new technologies, the impact of the technologies can vary. From a technical perspective, one of the key determinants of the effects of the new technology is the function of the technology itself. As technological change has progressed over the centuries, technological innovations also evolved overtime and became increasingly sophisticated.

The World Economic Forum's (WEF, 2023) Future of Jobs report has identified fifteen types of technologies that were predicted to be most likely to be adopted by 2027, examples including education and workforce development technologies, Big-data analytics, cloud computing, encryption and cybersecurity, and non-humanoid robots. Despite a great variety in the latest innovations, research studying their impact often make the implicit assumption that these different areas of technologies have a homogenous effect on the scope and quality of work. Considering the varied functions and roles of these technologies in organisations, a closer study on their effects may contradict this assumed homogeneity.

Hirsch-Kreinsen (2023) differentiates between two broad technology designs based on the technology and human interface– 'technology-centred' and 'human-oriented' technology designs. On the one hand, technologies are designed to limit individuals' space for action and skills utilisation. On the other hand, 'human-oriented' technologies play a more supportive, complementary role to human input with sensitivity to its context; and support workers in engaging in a widening and varied job tasks that require higher levels of skills utilisation (Hirsch-Kreinsen, 2023). Hirsh-Kreinsen (2023) also emphasizes the importance of humans having secure control over production processes, where work processes overseen by technologies are characterised by high levels of transparency.

Dhondt and their colleagues (2019) put more emphasis on the interface of technologies and work organisation. They propose that not all technologies have the same effect in organisations, and different types of technologies not only influence the complexity of tasks, but also the way work is organised. Therefore, they suggest that the classification of technologies should not be approached from a technological capability perspective, but rather from an organisational point of view that focuses on the role of technologies in organisations. They identified five mutually non-exclusive categories of technologies, which are introduced next.

From a work organisation point of view, the first distinction that can be made concerns Information and Communication Technology (ICT). Bloom and their colleagues (2014) propose that Information technologies and Communication technologies fulfil different organisational purposes, and therefore, have heterogenous impact on jobs and consequently, skills. Communication technologies (examples include emails and communication networks), on the one hand, focus on the communication between different actors in organisations and facilitate specialisation. This is because communication technologies reduce tasks variety performed by individual workers, who can rely on other actors in the organisation better with the help of these technologies (Bloom *et al.*, 2014). This might lead to the strengthening of hierarchy in organisations. Information technology (such as data storage systems or CAD/CAM systems), on the other hand, increases the accessibility of information in organisations, which has an empowering effect on individuals. With the help of IT, workers can handle more problems without relying on others, and therefore, can take on more responsibility (Bloom *et al.*, 2014). Contrary to communication technologies, information technologies might lead to de-centralization in organisations and broaden task variety. Role specialisation versus the widening range of responsibilities have varying, sometimes even opposite impact on skills utilisation in companies. This is further discussed in section 2.4.3.

Another type of technology is hard automation that refers to the classic automation process where, by translating complex work processes into programmable tasks, new technologies reduce the amount of human labour required to perform tasks (Autor and Dorn, 2013). This can lead to the disappearance or the redistribution of tasks in the organisation, which can alter the content of jobs and have the potential for certain skills becoming obsolete in the process (Bessen, 2016; Bessen *et al.*, 2019). This type of technologies is often the focus of discussions around the fear of technology-driven unemployment (Morgan, 2019). However, new technologies might require new skills, and human input, such as digital skills for using the technology itself or cooperation skills for enabling human-machine interaction.

Human enhancement technology - the fourth type of technologies according to Dhondt *et al*. (2019), shows the augmentation effects of new technologies as they support workers in the execution of their tasks. This can enlarge operator capabilities and increase productivity in the workplace. Whilst Raisch and Krakowski (2020) note that the increasing use of augmentative technologies may later lead to increasing levels of automation in the future, overall, human enhancement technology works in tandem with human input in workplaces, and therefore, enhance humans' performance in production activities, as opposed to replacing them.

The final type of technology that Dhondt and his colleagues (2019) discuss is management systems. Management systems include technologies that enable standardisation in organisation, such as ERP systems (Dhondt *et al.*, 2019). Other technologies, such as communication technologies, might help in this process, too. Standardisation in organisation may lead to task specialisation in organisations, which would have an effect on skills utilisation. In addition, management system technologies can act as a vehicle for increased managerial control in organisations, as they allow the monitoring of workers' performance and increased delegation of tasks in companies. This can, in turn, impact organisational culture that can affect employees' motivation and overall performance, too.

Overall, the above discussed five categories of technologies by Dhondt *et al.* (2019) illustrate the nuanced changes that technologies can have on jobs and potentially, on wider, work organisation-related factors in companies – all, which can have an impact on skills utilisation, as it is later discussed in section 2.4.3. However, it is highly important to note that while different types of technologies have various inherent characteristics and intended functions, as the socio-technical systems literature and the social shaping view on technologies highlight, the way technology is used in organisations are dependent on individuals' decisions in organisations (Howcroft and Taylor, 2022). Behrend *et al.* (2022) also find that in the interplay of technologies and organisations, not only the characteristics and capabilities of the technologies matter, but the way technologies are used are the key determinants of the interplay. In other words, the impact of technologies is not predetermined based on the characteristics and capabilities of technologies. This reinforces the argument that for an in-depth understanding of technology adoption and related skills changes, which is the aim of this research, the type of technologies and the context of the changes must be explored and analysed, too. This research follows Dhondt *et al.*'s (2019) classifications of technologies and provides empirical evidence of the adoption of two types of technologies – hard automation and management systems, and the skills utilisation changes that might be related to their introduction.

It is also important to note that not only technologies have a mutually shaping relationship with various organisational level factors. Skills utilisation of workers is also dependent on an array of external and internal organisational factors, and in order to best understand the interplay between skills and technologies, we first must understand how skills utilisation is shaped in organisations in the first place. The next section discusses the various external factors and internal organisational factors that shape employers' choices regarding their skills strategies and workers' skills utilisation in organisations.

2.4.3 Skills in organisations

External factors

Skills play a crucial role in economies' well-being and having a responsive and effective skills supply in the labour market is a prerequisite for staying resilient in face of many changes and challenges that economies are facing, such as ageing demographics, technological progress, climate change and the effects of Covid-19. In addition, the availability and quality of skills in a labour market shape organisations' choices around a range of organisational issues, such as work organisation, the division of labour, use of technology, and subsequently, skills utilisation (Sung and Ashton, 2016; Ashton, *et al.*, 2017; Clark, 2018).

As for the global issues that influence the availability of skills in an economy, many western countries, including the UK, are experiencing the social demographic issue of an ageing population (WEF, 2018; World Bank, 2019). As the population ages, the pool of talented and experienced workers in the labour market is gradually shrinking, which can lead to significant skill gaps in the economy.

Another influential global factor is the ongoing climate change, which mostly impacts skills demand in the economy. The already visible negative effects of climate change on our planet draws attention to the importance of adopting sustainable practices and striving towards a low-carbon economy, where carbon intensive industries are encouraged to restructure their operations. Digital technologies will play a crucial role in the move from a carbon-reliant economy towards a low-carbon economy (WEF, 2020). Hence, commitment to sustainable production practices drives technology adoption in an economy, and has implications for skill requirements in the labour market (SDS, 2019a).

A further global phenomenon that has significantly impacted the world of work and continues to do so, is the Covid-19 pandemic. The pandemic has not only caused economic, market and employment disruption in the short term, and raised discussions around the value of skills, it also caused issues in skills development worldwide. The relevant implications of Covid-19 to the Scottish manufacturing sector are discussed in more detail in Chapter Four.

Turning to national-level influences on skills, the government has influence over an array of national and international factors that can determine the available stock of skills in the labour market, and organisations' demand for them (Sung and Ashton, 2016). From a supply perspective, the national educational system and post-education training play a major role in the economy's skills infrastructure, as cognitive skills are mostly developed through the education system or formal training initiatives outside of organisations (Buchanan *et.al.*, 2010; Behrend, *et al.*, 2022). Policy, education and training initiatives must respond to changes in employers' skills demand, otherwise a mismatch can occur between supply and demand, which can hinder productivity, and ultimately, economic growth (Warhurst and Luchinskaya, 2018). Skill gaps and mismatches, however, do not occur solely due to inadequate educational and training system. Economic governance, cost of labour and employee relation systems also shape skills in a labour market and can influence employers' decisions around skills use (Sung and Ashton, 2016; Behrend, *et al.*, 2022).

The UK's neoliberal market economic policy minimises state intervention and relies on the market to deliver growth. Employers still have relative freedom in terms of employment practices. The use of zero-hour contacts, gig workers, flexible contracts and agency work put many workers into a precarious position with limited protection. Under these contracts, employers are not always legally obligated to offer certain 'benefits' to workers, such as paid sick leave and annual leave entitlement or redundancy compensations. Consequently, employers see benefits in building their business strategies around low-cost labour, where investments in skills development are not a priority (Payne, 2012; Warhurst and Finlay, 2012). Additionally, the low labour costs in these organisations can often outweigh the benefits of any potential new technology adoption, as in many instances cheap labour is more profitable for the companies (Clark, 2018). These contractual arrangements predominantly favour employers within the employment relationship; and they are often used in sectors with low levels (if any) of trade union protection. Overall, it can be argued that the legislative environment in the UK are favourable to employers, which creates a political environment where employers have little incentive to take the 'high road' approach in managing their workforce (Payne 2012).

To summarise, this section showed that there are global and national-level factors that influence the overall availability of skills in economies. The external socio-economic context of organisations shape employers' decisions on a range of organisational factors that can ultimately impact skills use. These organisational factors are discussed next.

Internal factors

When studying employees' skills utilisation in the workplace, it is important to recognise that skills strategies and skills development do not tend to be top priorities in organisations. In fact, Warhurst and Luchinskaya (2018) argue that skills strategies and workforce development are only third-order considerations after business development and organisational development. Nevertheless, Behrend *et al.* (2022) claim that the organisational context has the most immediate influence on skills demand and skills utilisation. This section discusses how business strategies and work organisation decisions can affect the use of skills in organisations.

Business strategy is claimed to be one of the key drivers to influence skills demand in an organisation (Schuler and Jackson, 1987), which consists of a company's product market strategy and competitive strategy (Sung and Ashton, 2016). Schuler and Jackson (1987) have adopted Porter's framework for competitive strategy and argue that different competitive strategies require different behaviours and organisational practices, and therefore, influence skills demand in organisations significantly. Companies that compete on the basis of innovation require high degrees of creativity from its workers and the ability to work independently and collaboratively (Schuler and Jackson, 1987). Consequently, these companies tend to employ highly-skilled individuals, give their workers discretion and independence with minimal control, invest into human resource development and provide resources for experimentation and failure. Based on Schuler and Jackson's (1987) framework, companies that focus on quality expects their employees to be flexible, reliable and open to new job assignments, teamwork and technological change. Here, employees are involved in decision-making and feedback systems are in place. The third competitive strategy is the cost-reduction approach, where production is tightly controlled, and is often characterised by overhead minimalization. Employees are expected to engage in repetitive tasks and portray predictable behaviours. In these organisations there is little room for ambiguity, jobs are narrowly designed and specialised with focus on efficiency. Management monitors and controls the workforce closely and tend to be short-term, result oriented.

The chosen competitive strategy of the company depends on a wide range of factors, including customer requirements and the competition in the market. Empirical research found evidence for a link between business strategy and human resource practices and skills in manufacturing, but the results were mixed in service industries (Knox and Warhurst, 2018). Moreover, empirical studies found varied results even within sectors, which indicates that there are additional, more complex explanations for the relationship between business strategy and skills demand in organisations. Sung and Ashton (2016) explain the varied results by differentiating product market strategies and competitive strategies within business strategy. They argue that product market strategy decisions impact the technical relations of production, such as machinery used for production processes and division of labour. According to their argument, varying combinations of technical relations of production makes different demands from managers, high-skilled individuals and manual workers, and determine the overall skill-levels demanded by employees in organisations (Sung and Ashton, 2016). Knox an Warhurst (2018) agree that skills utilisation can be predicted from company's competitive strategies, but they find evidence for this only in 'strategic' jobs that affect firm's overall business success through holding the strategic capabilities needed to execute strategy. Okay-Somerville and Scholarios (2019) also support this argument and find that organisations' investment in workers' skills varies based on the value and uniqueness of workers' knowledge, skills and abilities. Overall, Sung and Ashton's strategic skills model allows the business owners some degree of choice in selecting a combination of product market and competitive strategies in organisations, which might change over time. However, considering the varying evidence found within product market and competitive strategies in the literature, a new alternative theory emerged that puts higher emphasis on the role of managerial choice (Knox and Warhurst, 2018), which is more in line with the social shaping of technology approach.

Employers make a wide range of work organisation decisions in companies that are influenced by the aforementioned external and internal factors in organisations. In turn, these work organisation choices impact skills demand and skills utilisation in companies (Payne, 2012). As outlined in Section 2.2.2, work organisation refers to how work is planned, organised and managed within companies and it incorporates aspects such as managerial control, division of roles and responsibilities in the organisations, access to information and communication, and the subsequent company culture (Dhondt *et al.*, 2019).

The way roles and responsibilities are divided in organisations is a key determinant of skill requirements and skills utilisation. It determines the content of jobs, and therefore, the function of skills that are needed from employees (Warhurst and Luchinskaya, 2018; Behrend, *et al.*, 2022). Furthermore, the complexity and range of tasks involved in jobs determine the level of skills required. Based on the range of tasks, roles can be highly specialised, where workers perform a relatively small range of tasks, requiring the utilisation of lower number of skills (Payne, 2012). In more varied roles, however, workers perform a wider range of tasks, and therefore, utilise a higher number of skills (Buchanan *et al.*, 2010). This argument shows that job design influences skills utilisation in organisations (Grant *et al.*, 2012; Payne, 2012). However, it is important to note that the range of tasks do not always predict the complexity and level of skills that workers use for performing their tasks. Highly specialised roles can still include complex tasks that require high levels of skills that are developed over a long period of time.

Managerial control relates to how closely workers are monitored and disciplined during performing their tasks. Tight managerial control systems are based on the assumption that due to a lack of intrinsic motivation, workers do not perform their tasks to a satisfactory level unless they are closely monitored and supervised at work (Thompson and Newsome, 2004). High levels of managerial control results in low levels of worker authority, where employees have little to no control over their work tasks and they are not entitled to make decisions about them, either (Nikolova, *et al.*, 2023; Hughes, 2024). Where managerial control is low, workers have more authority over their jobs, and they can make decisions relating to their work processes. Workers who have authority over their job and are involved in decision-making relating to their tasks utilise more skills, as opposed to workers who have no control over their work processes.

Moreover, employees' access to information and communication can also have an impact on employees' skills utilisation in the workplace. Access to information enable workers to take on a wide range of tasks without the assistance of others; whilst adequate communication structures facilitate teamwork and collaboration in organisations, and support cooperation across different specialised functions (Dhondt *et al.*, 2019). From a skills utilisation perspective, access to information can result employees working more independently and utilising a wider range of skills to perform a variety of tasks themselves. Effective communication can support division of labour to a greater extent, where workers might take on more specialised roles requiring a lower number of skills. At the same time, through teamworking, workers utilise higher levels of social skills as opposed to when working independently.

Finally, the above discussed aspects of work organisation are linked to and reflected in the organisational culture. Organisational culture refers to the organisational values communicated through organisational norms that influence the way people think, act and experience work (Anning-Dorson, 2021). Workplaces that are characterised by high levels of managerial control, strict discipline measures, low levels of worker autonomy often lack trust between the managers and employees of the organisation, which can have a negative impact on staff turnover in the company. In contrast, studies argue that when workers have more control over their job tasks and are involved in decision making, they feel valued and become intrinsically motivated to perform well in their tasks (Payne, 2012; Grant *et al.*, 2006). In these instances, the manager-worker relationship is based on trust and on the assumption that workers, who feel valued, perform better in their tasks because they are committed to their organisations. Whilst organisational culture might not be directly linked to skills utilisation, it impacts choices around HR practices in companies, which can have an effect on skills development and deployment.

As the above discussion shows, work organisation shapes skills demand and skills utilisation in organisations in varied and significant ways. This research explored technology adoption and skills utilisation in small and medium enterprises. The next section introduces the unique organisational form of SMEs and discusses how their characteristics might shape technology adoption and skills utilisation.

2.4.4 SMEs

The term 'small and medium enterprise' incorporates a highly diverse range of organisations, starting from family-owned micro-organisations to companies with over two hundred employees (Scottish Government, 2022). The rest of this section of the literature review, however, discusses SMEs more broadly as a homogenous group for the sake of simplicity of argument.

In terms of work organisation, compared to large organisations, SMEs have a more flexible organisational structure; and they also tend to use more informal procedures than large organisations would (Kurochkina *et al.*, 2019). In these organisations, a lot of the work practices take shape organically in informal and uncoded ways (Dhondt *et al.*, 2019). This organisational structure has implications for skills in the companies. Due to the relatively small number of employees in these organisations, individual workers often have multiple roles and responsibilities in their companies, leading to undefined job roles and unclear boundaries around responsibilities (Nolan and Garavan, 2016; Kindström *et al*., 2022). As discussed above, the division of roles and responsibilities influence skills use in organisations. In these varied roles, SME workers perform a wide range of tasks, and therefore, utilise a higher number of skills than they would in strictly specialised job roles (Buchanan *et al*., 2010). This requires flexibility and adaptability from workers, and the ability to develop new capabilities as and when needed. Hence, skills development activities in SMEs are characterised by informal, ad hoc learning; and are often a response to immediate business needs (Wapshott and Mallett, 2015; Harney and Alkhalaf, 2021). Whilst this informal way of working allows flexibility to the organisations, it can hinder long-term planning in companies, without which skills development of staff might be challenging. Indeed, a general lack of strategic planning and limited financial, time and human resources, various rules and regulations and ever-changing grants and support initiatives have all been mentioned by owner-managers of SMEs as challenges hindering innovation and skills development in these organisations (Nolan and Garavan, 2016; Muller *et al*., 2019; Idris *et al*., 2020; Harney and Alkhalaf, 2021).

In terms of control, research places high emphasis on owner-managers' influence and managerial discretion in these organisations (Nolan and Garavan, 2016). SMEs are often led by entrepreneurs, who have strong ambitions, extensive knowledge and experience, but might lack formal managerial and organisational training. This strong professional vision can lead to situations where operational aspects are emphasized and other areas, such as people management, might be neglected (Kindström *et al*., 2022). In these organisations, control and decision-making are centralised, as owner-managers often find it hard to include others in decision-making, extend leadership teams, improve delegation and create formal management structures. As Kindström *et al.* (2022) summarise: "*many of the owner-managers have controlled their firms from the very beginning and the preservation of power and control is typically an essential part of their thinking*" (pg. 13.). As discussed above, in organisations where managerial control is tight, workers tend to have low levels of authority and control over their work tasks (Nikolova, *et al.*, 2023; Hughes, 2024). In addition, since power is centralised, information sharing tends to be low in these organisations, too. From a skills utilisation perspective, based on the above discussed, this might result in low levels of skills utilisation. However, other work organisation factors, such as having multiple roles and responsibilities, might have the potential to counterbalance the negative impacts of tight managerial control on skills use in these organisations.

As for organisational culture, SMEs often take pride in having a "family atmosphere" that builds on cooperation, teamwork and flexibility (Kindström, *et al.*, 2022). This culture suggests an open, supporting environment, which can have a positive impact on employees' work experience (Anning-Dorson, 2021). From workers' skills utilisation perspective, whilst workers might have low levels of authority and control over their job tasks, teamwork and cooperation require the utilisation of a range of social and behavioural skills (Buchanan *et al*., 2010). This illustrates how various aspects of work organisation interact with skills differently, and how this interplay is highly context dependent. Therefore, research that studies skills utilisation and potential changes to skills use should also consider the various organisational-level contextual factors at play.

To summarise section 2.4, the organisational context significantly shapes organisations' decisions on technology adoption, as well as skills utilisation. Section 2.4.1 showed that technology adoption decisions depend on a wide range of contextual factors that employers must take into considerations when choosing technological solutions. Even if they decide to adopt a new technology, section 2.4.2 showed that not only the function of technology matters, but their interaction with work organisation also shapes the organisational outcomes that can be observed in companies after technology adoption. However, this mutually shaping relationship is not only observable between organisations and technologies, but also between organisations and the skills demand and utilisation as well. Section 2.4.3 showed that there are a wide range of factors, both external and internal to organisations, that impact decisions around skills utilisation – the availability of skills in the labour market, company's business strategy, as well as different aspects of work organisation. This research explores technology adoption and skills utilisation in small and medium enterprises. Section 2.4.4, therefore, outlined the unique organisational characteristics of these organisations that can shape both technology adoption and consequent skills utilisation in the case organisations.

Overall, section 2.3 discussed technologies and the ways in which they might impact the world of work. As the social shaping of technology approach highlights, however, technology-driven outcomes are not predetermined, and they are shaped by choices that employers make. Section 2.4 showed the how the context of organisations, both external and internal, influences technology adoption decisions, and how new technologies can in turn, influence work organisation after adoption. Section 2.4 also showed that skills are also significantly shaped by the organisational context, even without the introduction of new technologies. This research explores how technology adoption changes skills utilisation in SMEs. The next part of this chapter, section 2.5., brings the concepts of technology and skills together and discusses the literature on how technologies and skills interact with each other in organisations, to better understand the potential skills outcomes of the current wave of technological change.

2.5 Skills of people

As previously discussed, technology adoption and the subsequent effects of new technologies on work and skills are not predetermined, and humans have control over the outcomes that new technologies might bring to economies and organisations. This means that the effects of technology adoption on skill requirements and skills utilisation in organisations cannot be predicted. Research can, however, study general trends in labour markets and potential direction of changes in skill requirements, that can offer an insight into the possible changes that might happen to skills utilisation in organisations after technology adoption. Existing research on the overall direction of technology-driven skills changes examines how new technologies can change the content of jobs, job tasks, and consequently, how those changes might influence the overall skill requirements of the jobs.

The first part of this section discusses how technologies can change the context of jobs by changing the division of work between machines and workers.

2.5.1 Technology and the division of work

Since all jobs consist of tasks that require skills and knowledge, studies that aim to quantify the effects of technological change often base their analysis on the task content of jobs. Every occupation includes a wide range of tasks, all of which has different levels of vulnerability towards technological replacement (Arntz *et al.*, 2016). Tasks are actions by which employees turn their inputs into outputs (Autor, 2013; Peng *et al*., 2018). There are numerous classifications of tasks. They can be categorized as manual – tasks requiring the movement of the physical body; or cognitive tasks – tasks relying on the use of a brain and thinking process (Peng *et al.*, 2018). Tasks can also be categorized as routine or non-routine tasks, based on the level of analysis they require to respond to a pre-defined stimuli (Levy and Murnane, 2005). Routine tasks have fixed responses to pre-defined stimuli that are consistent over time. While non-routine tasks require deeper analysis, and therefore effort, to take responsive action (Levy and Murnane, 2005; Peng, *et al.*, 2018). This classification has been the basis of the task-based approach studying the effects of technologies on work.

Routine tasks are highly vulnerable to automation. Since routine tasks have fixed responses to pre-defined stimuli, they can be translated into rule-based logic, which can then be programmed into computers and machines (Levy and Murnane, 2005; Autor and Dorn, 2013). Computers are often more efficient in the execution of these tasks than humans are, because they can perform them at a higher speed in a more consistent way. Therefore, a wide range of literature argues that jobs that consist of mainly routine tasks are increasingly replaced by technology and workers in these occupations are substituted by automation (Autor and Dorn, 2013; Autor, 2015; Borland and Coelli, 2017).

Non-routine tasks are argued to be less vulnerable to automation, because they do not follow rule-based logic (Levy and Murnane, 2005). They often involve pattern recognition, which serves as a basis for complex problem-solving. Pattern-recognition – for humans – require tacit knowledge and complex recognition (Levy and Murnane, 2005; Brynjolfsson and McAfee, 2014). Tacit knowledge refers to knowledge that humans possess but cannot easily articulate, which makes its automation highly challenging. This issue with tacit knowledge and its intuitive nature made early AI research efforts fail to mimic humans in a reliable way (Autor, 2015; Susskind, 2020). The lack of tacit knowledge is, however, not a significant barrier for the latest pragmatist AI developments. With the help of new, advanced Machine Learning, computers perform pattern-recognition not by relying on tacit knowledge, but rather by using the high amount of stored data as a context (Susskind, 2020). In this way, future technologies that use Machine Learning might have the potential to overcome the disadvantage that tacit knowledge has previously caused.

A further engineering bottleneck for technology in relation to non-routine tasks is complex communication (Frey and Osborne, 2017; OECD, 2018). Complex communication is also dependant on context knowledge, involving the recognition of audio and visual cues within conversation and their interpretation based on social intelligence and social norms (Onyeulo and Gandhi, 2020). While these tasks are still predominantly performed by humans in today's workplaces; advances in social robotics opened up new opportunities for technologies to aid and replace certain elements of care work (Hao, 2020). However, for the time being, workers performing non-routine tasks are still predominantly complemented by technologies, rather than substituted.

The task-based approach to technological change has served as a basis of most studies that aimed to understand the effects of new technologies on work and employment. However, due to recent developments in technology, new studies argue that this theory has limitations when it comes to our current wave of technological change - critiques including the approach's neglect of the complex cyclical relationship between automation and augmentation (Raisch and Krakowski, 2020), and developments in Artificial Intelligence that are now able to turn non-routine tasks into routine ones, by carrying out these tasks in fundamentally different ways from humans (Susskind, 2020). However, despite these criticisms, the task-based approach is proven to be a useful starting point for studies researching the future of employment and it is widely utilised in studies forecasting technology-driven changes, as discussed in section 2.3.1 above, and in the next section, which focuses on debates about the future of skills.

2.5.2 Upskilling view

The broadly positive view on the effects of technological change on skills is the upskilling view. This argument proposes that the widespread adoption of new technologies will result in an overall 'upgrade' of workers' skills set, which means that they will need to develop and utilise higher-level skills in order to work alongside new technologies (Hirsch-Kreinsen, 2016; Warhurst and Luchinskaya, 2018; Behrend, *et al.*, 2022). The explanations for this positive change fall into two categories in the literature.

The first perspective approaches technology-driven skills changes from a substitution angle and mostly focuses on broader, labour market level changes. It argues that since new technologies can replace humans in carrying out routine tasks, they free up time for people to focus on more complex, non-routine tasks. Considering that these complex tasks require higher skills than routine ones do, this view argues that the introduction of new technologies will lead to a general rise in demand for higher skills in the labour market (WEF, 2018; Beyond 4.0, 2019; Warhurst and Hunt, 2019). Studies following this perspective analyse changes in skill requirements at the macro-level, using qualification-levels as an analytical lens for determining skill changes (Ashton, *et al.*, 2017). Therefore, studies adopting this broader, macro approach to the upskilling view are suitable for exploring and identifying large-scale trends in the labour market. However, as section 2.2.3 noted, qualification levels are not the most accurate measure for workers' actual skill utilisation in organisations (Bakhshi *et al.*, 2017). Therefore, these results should be considered with caution and viewed as general trends, rather than an empirical proof of what happens to skills in organisations upon technology adoption.

In line with the upskilling view's substitution angle is the skill biased technological change debate, which states that by replacing humans in low-skilled tasks and occupations, new technologies will favour higher-skilled individuals in the labour market (Hirsch-Kreinsen, 2016). This view sees a correlation between increased rate of technology adoption and increased volume of high-skilled individuals in the labour market (WEF, 2018; Dellot and Wallace-Stephens, 2017; Bessen, 2016). However, it is important to note that changes to qualification levels in the labour market and the higher demand for high skilled workers can be also associated with issues separate from technological change, such as the inflation of qualifications, education system changes, or employers having separate levels of skills demand for workers to get the job and to do the job (Warhurst and Findlay, 2012). Whilst the exact reason for increases in skills demand in the labour market might not be possible to eliminate, in order to keep up with the changing skills demand, workers need to be upskilled (WEF, 2018; PWC, 2019).

Many forecasts on the effects of new technologies on employment and skills use this substitution angle. One of the most widely cited study that aimed to quantify the effects of recent technological progress on overall employment is by the aforementioned Frey and Osbourne (2013; 2017). According to their methodology, if the main tasks of an occupation involve routine tasks or non-routine tasks that can be automated with new technological capabilities, then the occupation is at high risk of obsolescence, and in order to stay relevant in the labour market, humans need to gain new skills in areas where new technological developments face engineering bottlenecks (Frey and Osborne, 2017).

Based on the technological capabilities, the skills that are forecasted to remain important in the coming decades are interpersonal social skills, advanced cognitive skills, creative intelligence and adaptability (World Bank, 2019; UKCES 2016; Frey and Osborne, 2017; WEF, 2019; Future of Work Commission, 2017; Deloitte, 2018). This view also follows the logic that some workers will benefit from the adoption of new technologies, whilst others will be disadvantaged.

The second perspective on upskilling studies skills changes at the organisational level and sees the positive changes as a process that captures all employee groups (Hirsch-Kreinsen, 2016). From this perspective, the increased adoption of digital technologies makes production processes more transparent by providing bountiful information and data along the way. This in turn can bring new skill requirements for most activities if the new technology is widely used across the organisations. As a result, there will be a growing need for cognitive skills, such as data literacy and technical skills, including process understanding, so workers can make sense of the information that new technologies offer (Zuboff, 2010). Hirsch-Kreinsen (2023) shows the example of machine operations, who equipped with new technologies, can make decisions about workflow sequences based on the information available to them. However, it is worth noting that increased understanding of the production process and the related cognitive skills' development might happen organically, informally through workers' work experience, and therefore, these new skills might not be recognized with formal qualifications (Li, 2022) – which are often used as a proxy for measuring skills changes, as discussed in section 2.2.3. This shows that certain technology-driven skills changes cannot be captured through the use of qualitative, statistics-based data. This research explores technology adoption and skills changes at the organisational level to be able to study the nuanced changes to skills utilisation upon technology adoption.

2.5.3 Polarisation view

The second broad stream of literature on the effects of technological change on skills is the polarisation view. This view argues that due to technological change, demand for jobs and skills in the high-skilled end of the labour market will increase, along with the demand in the low-skilled end of the labour market; meanwhile, the middle-skilled jobs will increasingly disappear (Autor and Dorn, 2013; Autor, 2015; Beyond 4.0, 2019; World Bank Group, 2019; Montresor, 2019; Eurofound, 2019). This polarisation can be explained by the limitations of new technologies. In high-skilled occupations that are characterized by more complex tasks, technology usually plays a complementary role (Autor and Dorn, 2013). Therefore, employment levels will not decrease at the top of the labour market significantly, according to the polarisation view. Similarly, in occupations that are regarded as low-skilled, such as care work or customer care work that require soft skills, technology cannot fully replace humans. Therefore, employment levels will not decrease at the bottom part of the labour market, either (Hirsch-Kreinsen, 2016). In middle-skilled occupations, however, that tends to be characterised by predominantly routine tasks that can be automated, employment is likely to decrease with the introduction of new technologies. The logic of the polarisation view is also the basis of the routine biased technological change theory, which claims that middle-skilled, routine-based occupations are increasingly disappearing from labour markets due to technological innovations (Payne, 2017; Behrend *et al.*, 2022).

Evidence for this polarisation view can be observed in the UK labour market and across Europe, too (Montresor, 2019; Future of Work Commission, 2017; Avis, 2018; Anton *et al.*, 2020). Findings from Frey and Osbourne's study on the US labour market (2017) and Thomas and Gunson's research on Scotland (2017) also support this view, arguing that the most vulnerable occupations that are predicted to disappear at the fastest rate are middle-skilled, administrative occupations. However, it is important to highlight that these views on the effects of new technologies on the overall labour market are based on broad, sectoral-level data (Anderson, 2009) and they do not capture potential changes within jobs (Levy and Murnane, 2005; Autor, 2013).

At the organisational level, the polarising view also shows a progressive 'deskilling' of middle-skilled work as a result of technology adoption. The deskilling view follows the principles of scientific management, which refers to the act of dividing up the work process in to specialised tasks in order to maximise production efficiency. By adding technologies into this fragmentation of the work process and automating routine activities, the deskilling view argues that adoption of new technologies lead to a narrowing of work tasks (Kunst, 2019; Nikolova, *et. al.*, 2023). In this way, workers become specialised in repetitive activities, whilst the need for their technical skills and their ability to exercise authority decreases (Green, 2013). Therefore, the deskilling view argues that technology adoption in organisations can lead to an increased need for low-skilled workers, whilst it disadvantages individuals with intermediate skill levels (Green, 2013). An important aspect of the deskilling view is that it approaches the relationship between technologies and skills from the concept of control and argues that the key driver behind deskilling workers through the use of increasing automation is to exercise greater managerial control over their work process (Hughes, 2024). This view is in line with the aforementioned principles of the Labour Process Theory (see in section 2.2.3). Considering this aspect of deskilling, changes to skills are not necessarily the direct result of workers using the new technologies, but rather result of changes in the way work is monitored and controlled in organisations (Hughes, 2024). Therefore, it can be proposed that technologies only act as enablers to these skills changes instead of being the drivers of them.

In summary, the upskilling and polarisation views largely agree that the increased use of new technologies benefit workers at the top of the skills distribution, but the two theories slightly diverse on what the changes mean for workers with intermediate and low skill levels. Both of these views examine skills changes by adopting a binary view on the potential outcomes for individuals and jobs – either good (upskilling) or bad (replacement/deskilling). However, change is rarely straightforward, and the outcomes of technology adoption should not be examined through black or white lenses. Even within organisations, both the upskilling and deskilling effects of new technologies co-exist. Vallas (1990) argues that *"deskilling and upskilling are not mutually exclusive possibilities but rather conflicting trends that can and often do coexist within the same firm or industry."* (pg. 387). At the organisational level, the two seemingly contradictory forces might emerge simultaneously, meaning that one group of workers might be influenced by the adoption of a new technology differently than another (Hötte *et al.*, 2023). Since organisations are heterogenous entities, they include different groups of workers with varying skill levels. This brings an extra layer of complexity to the relationship between technologies and skills, which further reinforces the importance of exploring this relationship through the use of organisational-level data.

To deepen this complexity, a further distinction can be made between changes to skills of individuals or skills on the job. As Green (2013) argues, the use of skills is best observed through reports about tasks that workers perform, making the measurement of skills grounded in behaviour rather than qualifications. In this way, the potential differences in changes to individuals' skills set and job requirements can be explored. For example, when studying changes to skills utilisation at an individual level, the increased utilisation of employees' pre-existing skills can be labelled as upskilling, because the skill requirements of the job have changed, even if the individuals did not need to acquire new skills. Adopting the skills of individuals and skills on the job distinction to the upskilling view offers a more nuanced insight into technology-driven skill changes and complements the broader labour-market level studies with more detailed account on the relationship of skills and technologies in the workplaces.

Moreover, both the upskilling and polarisation views discuss technologies as a homogenous variable. Nevertheless, despite of not overtly defining in the studies, the two different angles to upskilling describe two different types of technologies. The substitution angle focuses on replacement effects of technologies, which are characteristics of automation. The inclusive angle places the emphasis on technologies providing more information and data on work processes, making production processes more transparent. These effects are often associated with management system technologies and information technologies (Dhondt *et al.*, 2019). Similarly, the polarisation view focuses on the substitutive effect of technologies, mostly discussing the effects of automation on routine jobs. However, as section 2.4.2 outlined, the type of adopted technologies has a significant impact on work organisation and skills utilisation in organisations. For example, the adoption of information technologies may lead to upskilling for workers, since it enables increased access to information, which in turn can encourage workers to take on more responsibilities and engage in more cognitive activities (Bloom *et al.*, 2014). Meanwhile, communication technologies can lead to the narrowing of tasks and increased specialisation for workers, which can have a deskilling effect on the workers. These examples show the complexity of the relationship between technology adoption and skills in the workplace, which is often overlooked by upskilling and deskilling debates. This research explores the adoption of two types of technologies in two organisations each – automation and management systems technologies.

In addition, as section 2.4.2 showed, various types of technologies interact with different aspects of work organisation, and consequently, changes skills utilisation in different ways. In upskilling, the substitution perspective focuses on changes to the division of tasks, whilst the inclusive, human-oriented approach discusses the implications of increased access to information in organisations (Hirsch-Kreinsen, 2023). The deskilling view also focuses on the division of tasks between humans and technologies, as well as control in organisations (Kunst, 2019). As shown in section 2.4, there is a mutually shaping relationship between technologies and organisational context, as well as between organisational context and skills utilisation. Therefore, to best understand the interplay of technologies and skills, work organisation must also be considered. As Lloyd and Payne (2021) stated, empirical support can be found for all directions of skills changes after technology adoption to a various extent, which reflects the indeterminate relationship between technology, work and skills that is shaped by the context of their interplay. Yet, research on the relationship between technologies and skills rarely considers the crucial role of organisational context in the interplay of these entities. This study aims to fill this gap by exploring technology adoption and skills utilisation changes in Scottish manufacturing SMEs through the use of organisational-level data, which helps to analyse the skills changes with consideration to the context in which they take place. The next section of the chapter summarises the conceptual framework that guides the research.

2.6 Conceptual framework

The overall aim of this research is to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing small and medium enterprises.

The research follows the core principles of the social shaping of technology approach, which recognizes that the material characteristics of technologies and social processes at work mutually shape each other in organisations (Howcroft and Taylor, 2022), and any outcomes of their interplay are dependent on contextual factors and choices that employers make (Williams and Edge, 1996). SST also argues that technologies and work organisation are mutually constitutive in an organisation, where the adoption and utilisation of technologies are influenced by existing forms of work organisation, whilst at the same time, technologies are often adopted with the intention to change, improve and transform work organisation (Williams and Edge, 1996). To explore this link further, this research uses Dhondt *et al.* (2019)'s classification of five different technologies, because the classification reflects different technologies' varied influence on different aspects of work organisation, which in turn, can impact skills utilisation in organisations.

Similarly, employees' skills utilisation is not only shaped by individual workers' ability, but also by a range of choices that employers make about the way work is organised in the organisations. Employers' choices are influenced by the global, national and sectoral environment of organisations; and within the organisations, the overall business strategy and different aspects of work organisation have a significant impact on skills utilisation (Clark, 2018; Sung and Ashton, 2016).

Despite of the influential role of organisational context on both technologies and skills, existing research on the effects of new technologies on skills often focuses only on the division of tasks between technologies and humans. Research examining the skills outcomes of this interplay between technologies and workers either believe that the adoption of new technologies leads to the general upskilling of workers (Hirsch-Kreinsen, 2016), or have a polarising effect on skills outcomes, where high-skilled and low-skilled workers benefit from changes, whilst middle-skilled workers are disadvantaged (Anton, *et al.*, 2020).

Considering the importance of work organisation in technology adoption and utilisation, as well as in skills utilisation, research exploring changes to skills utilisation upon technology adoption should extend its scope beyond the division of work between technologies and humans, and should take into account organisational level factors that can shape this interplay. Current research on the effects of new technologies often focuses only on two of the three key dimensions. For example, Hirsch-Kreinsen (2023)'s case study research in the German industry studies the effects of technologies on skills and work organisation but does not differentiate between various types of technologies. Dhont *et al.*'s (2019) research, on the other hand, studies the effects of different types of technologies on work organisation but does not discuss its potential implications for skills in Dutch manufacturing organisations.

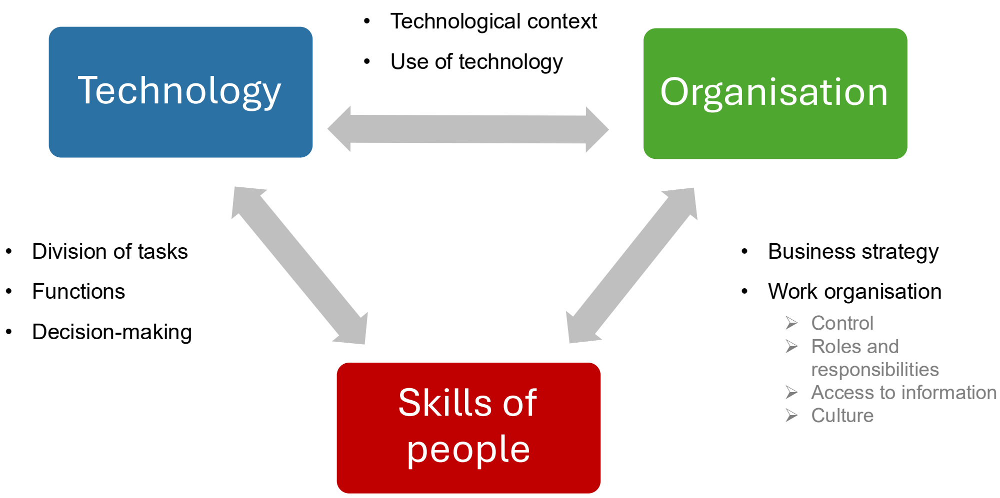


Figure 2.1: Conceptual framework

This research develops these studies' approaches further and studies technology adoption and skills utilisation in Scottish manufacturing SMEs with consideration of the influential interplay between all three dimensions (see Figure 2.1). The research explores changes to skills utilisation of different groups of workers after the adoption of two types of technologies – management systems technologies and automation. By doing so, the research provides an empirical exploration of the complex interplay between technologies, people and organisation in SMEs, and shines light to the lived realities of small and medium enterprises in the face of the 4th Industrial Revolution.

Considering the outlined conceptual framework, the research aims to answer the following questions:

> **RQ1**: How does the adoption of new technologies change skills utilisation in Scottish manufacturing SMEs?
>
> **RQ2**: In what ways do organisational factors interact with the interplay of technologies and skills in Scottish manufacturing SMEs?

To answer these questions, the research adopts a qualitative research method, conducting case studies in four Scottish manufacturing SMEs, and collecting data from sectoral stakeholders in Scottish manufacturing to best understand the broader context of the studied SMEs. The next chapter discusses this chosen methodology further.

2.7 Conclusion

To summarise, this chapter discussed the literature relevant to the overall aim of this research, which is to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing SMEs. The chapter started by defining the key concepts of the research – technologies, skills and organisation, and discussed the core assumptions behind the chosen definitions in section 2.2.

Section 2.3 discussed the first core concept of the research, technology. Section 2.3.1 offered a historic background to the current changes by discussing previous waves of technological change and their broader impact on the world of work. This is followed by a discussion on the vast academic debates around the potential effects of the current wave of technological change. As section 2.3.2 argued, these studies are often underpinned by an exogenous view of technologies, forecasting that technologies will impact the world of work in a pre-determined, linear matter. However, as the succeeding discussion in section 2.3.2 showed, the effects of new technologies are influenced by an array of social factors that are at play at the societal and organisational levels. As the chapter established, this research follows the social shaping of technologies approach.

Highlighting the influential role that organisational context can have on technology adoption, section 2.4 discussed the second key concept of the research – organisation. First, section 2.4.1 outlined the debates on technology adoption decisions in organisations, showing that a vast array of contextual factors influence employers' decision. As section

2.4.2 showed, even if technologies are adopted, different types of technologies have varying impact on organisations, not only due to their differing functionality, but also due to the ways in which they interact with work organisation. Section 2.4.3 discussed that similarly to technology adoption and utilisation, skills demand and utilisation is also influenced by an array of external and internal organisational factors. Since this research explores technology adoption and related skills utilisation changes in small and medium enterprises, Section 2.4.4 introduced the organisational characteristics of SMEs and discussed how this organisational form might influence technology adoption and skills utilisation.

Section 2.5 discussed the third key concept of the research, skills, and the relevant current academic debates and empirical literature on the interplay of technologies and skills. Section 2.5.1 introduced the task-based approach, which explained the mechanisms by which new technologies might change the division of work between machines and humans. Section 2.5.2 then moved onto outlining the current academic debates of upskilling, deskilling and the polarisation view. The discussion showed the limitations of these debates in not taking into consideration the role that organisational context might play in technology-driven skills changes.

The chapter then summarised the conceptual framework in section 2.6 and outlined the research questions that the study set out to answer by exploring the adoption of two types of technologies – management systems and automation, and their effects on skills utilisation in Scottish manufacturing SMEs. The next chapter of the thesis outlines the overall research methodology.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter introduces the methodology that the study adopted in order to meet its overarching aim and answer its research questions. The first part of the chapter outlines the overall research design, including a discussion on the philosophical position of the thesis and its methodological implications in section 3.2.

This is followed by a detailed discussion on case study research design in section 3.3.1. The chapter then introduces the chosen data collection method of the research, semi-structured interviews (section 3.3.2.). The issues of validity, reliability and generalisability are outlined in section 3.3.3. This part of the chapter ends with a discussion on the implications of online data collection in section 3.3.4.

The next part of the chapter outlines the sampling strategy of the research (section 3.4.1) and introduces the stakeholder research participants (section 3.4.2) and case organisations (section 3.4.3). The chapter then describes the data collection process in section 3.5 and discusses the data analysis method in section 3.6. These are followed by a discussion on the ethical issues that needed to be considered for the research project, and a brief list of the study's limitations. Finally, the chapter ends with the researcher's reflections (section 3.9) and concludes in section 3.10.

3.2 Research design

3.2.1 Philosophical position and methodological implications

This section introduces the critical realist theoretical approach that underpins the research. The section first outlines the ontological position of the study, including discussion on stratified reality, entities, emergence and causality. It then introduces the epistemological position of critical realism, discussing theory development and methodological implications. This is followed by a brief discussion on generalisation and critiques of critical realism.

Critical realism is a research philosophy that emerged from the critique of positivist research's view on reality in the social world, predominantly associated with Roy Bhaskar and further developed in collaboration with other social scientists, including Margaret Archer, Tony Lawson, Allan Norrie and Andrew Sayer (Taylor, 2018). This philosophy is based on a realist ontological approach, which recognizes that there is a real world exists independently from human beings and their observation of it (Bhasakar, 2008). This makes critical realism a fallabilist philosophy, as the existence of reality is independent of our knowledge of it (Sayer, 2000).

Bhasakar (2008) identified two dimensions of object of knowledge – a transitive dimension and intransitive dimension. In the intransitive dimension, the object of knowledge is the real structure or mechanisms and the conditions that allow people to access it; whereas the transitive dimension includes our understanding of the object and the theories and discourses researchers create based on their understanding (Bhasakar, 2008; Sayer, 2010). This approach to knowledge differs from both positivistic and constructivist philosophical approaches, yet it has similarities with both (Taylor, 2018). From an ontological perspective, critical realism accepts that there is a reality, independent from mankind – this realist position draws parallel with positivistic research philosophies that also believe in the existence of reality (O'Mahoney and Vincent, 2014; Taylor, 2018). However, as opposed to the positivist view, critical realists believe that our knowledge on that reality is subjective and filtered by our ability to perceive it, which implies an epistemological position closer, but not equal, to constructivism (Taylor, 2018). Therefore, critical realism sees *"social scientists are cast in the modest role of construing rather than 'constructing' the social world"* (Sayer, 2000, pg. 11).

From a critical realist standpoint, reality is stratified, composed of the real, the actual and the empirical (Bhasakar, 2008; Sayer, 2000; O'Mahoney and Vincent, 2014). The real refers to whatever is in existence, regardless of it being an empirical object for humans or not. It also refers to the realm of objects, their constituent structures and powers (Sayer, 2000; Mukumbang, *et al.*, 2021). In the social world, power depends on mechanisms that relate one entity to another, and realist research is based on identifying underlying mechanisms to explain observations made in the empirical. However, it is important to note that critical realists recognize that powers might not be exercised (Mukumbang, *et al.*, 2021). This means that "*what has happened or been known to have happened, does not exhaust what could happen or has happened*" (Sayer, 2000, pg. 12). Therefore, critical realists are open to identifying possibilities, tendencies or potentials, but do not believe that the future can be forecasted (Bhasakar, 2008). The actual refers to what happens when the said powers are activated – to their actions, effects and the eventualities that happen upon their activation and occur in space and time (Sayer, 2000; O'Mahoney and Vincent, 2014). The actual, however, might differ from what humans perceive. The empirical then refers to humans' sensory experiences and perceptions – what we perceive to be the case (O'Mahoney and Vincent, 2014). This domain of experience is related to the real and actual, whether humans have a knowledge and perception on the real and actual or not (Sayer, 2000). This observability helps humans to gain confidence about the existence of ‘the reality’, but the existence itself does not depend on this observability and humans’ perception. Following a realist ontological approach, this research does not focus on the role of individuals in the technology implementation process, but rather aims to examine the mechanisms by which new technologies change jobs, tasks within jobs and their skill requirements.

Through the lenses of critical realism, reality is an open system of emergent entities, and the social world is open to a complex array of influences that can change both temporarily and geographically even in unexpected ways (O’Mahoney and Vincent, 2014). In the open systems of the social world, the same casual power can produce different outcomes, depending on how the conditions for closure have been broken (Sayer, 2000). This creates a tension between positivist epistemology and critical realism, as positivists prefer to develop theories and create knowledge on the social world by creating models on their reality, which requires a closed-system analysis (Fleetwood, 2017).

Entities in this open system can be defined as “*a persistent whole formed from a set of parts, the whole being significantly structured by the relations between these parts*” (Elder-Vass, 2005, pg. 317). For example, in this research, new technologies or workers’ job tasks are studied as entities. Entities have causal powers and liabilities that cause events to occur (Easton, 2010). There are two kinds of relationships between entities – necessary and contingent. In a necessary relationship, one object is dependent on its relation to the other. For instance, in this research, workers’ ability to perform a task is dependent on their skill sets, which is in turn dependent on skills development. Whereas in a contingent relationship, it is neither necessary nor impossible that the entities stand in any particular relation (Easton, 2010). In case of this research, a contingent relationship might be observed between technologies and any of the contextual factors that were introduced in the previous chapter.

Causality, which is imperative to the understanding of the relationship between entities and their powers and the consequent effects on the social world, is in the centre of critical realist scientific enquiry. Critical realist research, much like this one, aims to identify causal mechanisms and their ways of working and understand if they have been activated and under what conditions (Sayer, 2000). Mechanisms can be described as the ways in which structured entities by exercising their powers and liabilities act and cause particular events. Therefore, mechanisms are mediators between causes and effects in a way that causality can only be assumed between two events when mechanisms connect them (Cornelissen and Kaandorp, 2023). These mechanisms offer a rich source of explanatory devices.

However, it is important to recognize that since causal mechanisms are time and context dependent, the critical realist view does not create certainty and recognizes that every case is unique (Sayer, 2000). The effects of mechanisms are contextual, because different context have the potential to change the processes by which outcomes occur through activating or deactivating various mechanisms. Due to this causal contingency, studying the context in which changes may or may not occur is vital (Vincent and Wapshott, 2014; Mukumbang, *et al*., 2021). This context dependency implies that critical realists do not claim to predict the future. As Bhaskar (2008) states: "*It is the task of the philosophy of science to capture science's essential movement, not to guess its eventual destination*" (pg. 137). This research explores the role of context in the interplay of technology adoption and skills utilisation in two ways. First, it includes explores the four case organisations' external, sectoral context through interviewing key stakeholders in the Scottish manufacturing sector. These data help to understand sectoral technology uptake, the availability of skills in the sector and skills development initiatives, as well as the state of the sector's SME community. The findings from these interviews are discussed in the next chapter of the thesis. The second way focuses on the role of the organisational context of the case organisations. This is explored through cross-case analysis between the four case studies, which is discussed in Chapter Nine.

Due to the above-described time and context dependence, critical realist research aims to make analytic generalisation about theoretical propositions that tries to offer plausible context reliant claims, plausible explanatory claims – as opposed to generalizing findings for empirical populations (Sayer, 2000; O'Mahoney and Vincent, 2014). This is crucial to note, as one of the most common criticisms towards qualitative studies, like this research, is that their findings are non-generalisable. The strength of critical realist research claims lies in the causal framework that they offer. A causal explanation is one that identifies entities and the mechanisms that connect them and combine to cause events to occur under certain conditions (Sayer, 2000; Easton, 2010). It seeks to explain how the higher level entities can be emergent by examining its parts and their relations to each to each other (Elder-Vass, 2005). However, in practice, such formal explanations are not always possible due to the complexity of real-world behaviour. In the complex social world, mechanisms that generate certain phenomena might be observable, but cannot be isolated and reduced to the phenomena they generate (Bhaskar, 2008). This means that there should always be room for competing explanations and revision since different interpretations of data are necessary to ensure that the best possible interpretation is made (Bhasakar, 2008; O'Mahoney and Vincent, 2014; Easton, 2010).

The critical realist scholarship is an iterative process – moving from considering the intransitive world of actual events, mechanisms and structures to the transitive world of measures, descriptions and theories on a continuous basis (Bhasakar, 2008; O'Mahoney and Vincent, 2014). Critical realist research often follows the explanatory logics of abduction and retroduction. Abduction is an exploratory process, which begins with incomplete set of observations and aims to obtain the most logical and useful explanation that is possible to arrive to in the absence of perfect information (Mukumbang, *et al*., 2021; Thompson, 2022; Cornelissen and Kaandorp, 2023). Through abduction, researchers describe the observable objects in a more general, abstracted sense with the intention to *construct/describe* the sequence of causation. By combining the 'observed' and the theory, critical realists aim to produce the most plausible explanation of mechanisms that causing events to occur. Through moving back and forth between empirical data and established theoretical understandings, abduction combines logic with cognition that results in a generative reasoning process (Mukumbang, *et al.*, 2021). Retroductive reasoning is an overarching interpretive strategy that adopts a pluralist approach to reasoning, which is characterised by the interplay of inductive, deductive and abductive reasoning. In retroduction, researchers attempt to identify the often hidden mechanisms by observing their effects in the empirical overtime in order to theorize what the world must be like in order for the mechanisms we observe to be as they are and not otherwise (O'Mahoney and Vincent, 2014). As Mukumbang *et al*. (2021) summarise, retroduction entails moving from a surface phenomenon observed in the 'empirical' domain, through interpreting and contextualising actions and events in the 'actual' domain, to a deeper, causal understanding located in the domain of 'real'. In this way, retroductive reasoning allows researchers to develop explanatory theories of causality that are well-embedded in context. The use of these explanatory logics have implications for data analysis in critical realist studies. The implication in this study are discussed in section 3.6 below.

As for the methodological implications, critical realism applies methodological pragmatism. They believe that the decision over the methods applied should be based on the methods' suitability for the research problems. In simpler words, methods are tools for tasks and for answering research questions. Therefore, critical realism is non-descriptive in terms of research methodology and methods (Easton, 2010). This research adopted a case study research design to understand the relationship between technology adoption and related skill changes in the context of Scottish manufacturing SMEs, and complemented the case study data with semi-structured interviews to explore the sectoral context of Scottish manufacturing that might have an impact on organisational-level technology adoption and related skills changes.

3.3 Research methodology

The research included the collection of sectoral-level data by conducting semi-structured interviews with sectoral stakeholders; and organisational-level data from four case studies. The data were collected separately, and they were combined during the data analysis process. By complementing the data from the case studies with the data from the stakeholder interviews, the research developed a deeper understanding of the interplay of technologies and skills and the context in which this interplay takes place. Moreover, by adopting this empirical approach, the research also achieved greater validity through triangulation, which is discussed in section 3.3.3 (Hammond, 2005).

3.3.1 Case study research

The research included four case studies with Scottish manufacturing SMEs. Case study research methodology suits research projects that aim to explore highly complex social phenomena (Yin, 2009; Easton, 2010; Creswell and Poth, 2018). By exploring the social phenomena in their own context, the case study approach allows investigators to gain a holistic picture of the studied real-life events. Yin (2009) offers a twofold definition of case study research. The first part focuses on the scope of the approach: "*A case study is an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"* (pg.18).

Case study research is well-suited for studying business organisations, as they operate within well-defined boundaries (Creswell and Poth, 2018; Eriksson and Kovalainen, 2016). Research carried out within these well-defined boundaries has the benefit to allow a close focus on the studied cases. In this way, case study research allows the researcher to gain a holistic view on the studied organisations by exploring multiple perspectives, investigating contested viewpoints and documenting the influences of key actors and interactions within these organisations (Eriksson and Kovalainen, 2008; Tight, 2017). The case study research design is a suitable research approach for critical realist research, as it is consistent with the realist ontological position (Tight, 2017; Vincent and Wapshott, 2014; Easton, 2010). Since case study is an intensive research approach and focuses on individual agents within the context, it allows the exploration of causal mechanisms within organisations, which is one of the main foci of critical realism and this research. In this research, the studied phenomenon is the relationship between technology adoption and skills in the context of Scottish manufacturing SMEs. As the organisational characteristics of SMEs have potential influences on both technology adoption and skills development, following Yin's argument, a case study approach is suitable for this exploratory research.

The second part of Yin's definition focuses on the technical characteristics of case study research: *"The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result, it relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis"* (Yin, 2009, pg. 18). As this definition shows, data collection in case study research design involves gathering in-depth information from multiple sources that are rich in context (Eriksson and Kovalainen, 2016). This way, case study research is suitable for presenting complex and hard-to-grasp business problems in a practical, more accessible way. This can often attract criticism, where case study is labelled as anecdotal descriptions that lack scientific rigour (Eriksson and Kovalainen, 2016). Claims on the lack of rigour and reliability will be discussed in section 3.3.3. This particular study included data collection in four case studies with the use of semi-structured interviews with multiple stakeholders in the case organisations, which allowed the exploration of different viewpoints on technology adoption and skills changes.

3.3.2 Data collection methods

This research used semi-structured interviewing as its main data collection method, which was complemented by the collection of field notes and photographs during the case study site visits.

Qualitative interviewing is a popular data collection method in social sciences, and it was a key source of evidence in both the sectoral-level data collection and in the case studies. Interviews can be structured, semi-structured and unstructured. This research involved semi-structured interviews, that can be defined as "*an interview with the purpose of obtaining descriptions of the life world of the employee in order to interpret the described phenomena*" (Kvale and Brinkmann, 2014, pg. 3). Semi-structured interviews have a great knowledge-producing potential where the researcher, the interviewer, have flexibility to follow up on topics and themes that are most relevant to the research; and participants, the interviewees, are able to raise questions and concerns in their own words and from their own perspectives (Easton, 2010; Brinkmann, 2013).

As the definition above shows, semi-structured interviews are conversations conducted for a purpose, which in case of this research was to learn about the complex interplay between technology adoption and skills in the manufacturing sector at large, and in the studied SMEs. This purpose and the existing relevant literature on the topic inform the interview guides that help the interviewer to cover the key themes of the research (for this research's interview guides, see Appendix 1). However, it is important to highlight that the questions in the interview schedules remain neutral of personal or professional opinions or beliefs of the research. As Brinkmann (2013) argues, all questions lead the interviewee into certain directions, but it is the responsibility of the researcher to lead the interviewee towards talking about the key themes of the research, but not towards any particular opinions on those themes. Another important issue regarding the purpose of semi-structured interviews is the knowledge-production agenda behind it, where the researcher invites the participants to talk about their experiences with the intention to use those personal experiences as data for their research project. While participants are made aware of this prior to the interviews through the Participant Information Sheet and the Consent Form (see Appendices 2 and 3); this agenda still raises issues about power and control between the interviewer and the interviewee, which are important to reflect on in any research projects. This is further discussed in more details in section 3.9 of this chapter.

The flexibility of semi-structured interviews is an important aspect of this data collection method, as it allows issues and comments to surface that are outwith the pre-determined interview schedule. Very often these unexpected data can be important for the research and help the researcher to understand the participants' perspective better (Brinkmann, 2013). The flexibility of semi-structured interviews was particularly beneficial for the case study interviews conducted during site visits. For example, in the BrewCo case study, the interviews sometimes included detailed, longer discussions on the way new technologies worked, which gave the interviewer opportunities to ask questions about the complex brewing kit. In MotorCo, the early interviews revealed the new technology's considerable impact on work organisation, which was then further explored in subsequent interviews, where the updated interview guide included questions on changes to roles and responsibilities in the company.

During the case studies, the data collection also involved the collection of supporting field notes and pictures of work processes in the case organisations. During the interviews and site visits, extensive notes were taken, ensuring that the researcher can recall sufficient details of what happened during data analysis (Laurier, 2010). The collection of the supporting data during site visits enriched the case studies and allowed a greater insight into the studied organisations' inner world. The site visits allowed access to actual workplace behaviour, which were not possible through the other data collection method in the research, as interviews largely rely on self-reporting from participants (Morgan *et al.*, 2017; Laurier, 2010).

3.3.3 Validity, reliability and generalisability

Qualitative research, and case study research in particular, has often been criticized for its low levels of validity, reliability, rigour and its inability to create generalizable findings. However, it is important to highlight that the issue is not with qualitative research, or the case study research design itself, but rather the execution of the research methodology. As Goffin and his colleagues (2019) showcase in their study on innovation management literature, researchers often either do not follow the methodological guidelines that help to ensure rigour of case study research, or they do not explicitly address the steps they took in order to ensure case study research quality. Therefore, they suggest that case study researcher's work may be "*presumed guilty, until proven innocent*" (Goffin *et al.*, 2019, pg. 612). In order to assess the quality of this research design, four test can be undertaken for: internal validity, construct validity, external validity and reliability (Yin, 2009).

In order to ensure construct validity across the research, this research involved data triangulation. Triangulation can be described as "*a means of corroboration through the convergence of sources, interpretations, or even perceptions, thus checking the study's validity, ensuring a version of the truth or verifying the repeatability of an observation/interpretation*" (Farquhar *et al.*, 2020, pg. 161). Triangulation can involve the triangulation of data, method, researcher, theory or various units of study. This research involved data triangulation of the collected data from the semi-structured interviews and field notes in the case studies, along with the stakeholder interviews. The triangulation of the collected data from the different informants helped to improve the internal and construct validity of the research (Eisenhardt, 1989; Farquhar *et al.*, 2020; Goffin *et al.*, 2019). Besides making case study research more robust, triangulation might also, arguably, helps to capture the independent reality claimed by the critical realist philosophy through the exploration of mechanisms with cross-case analyses (Järvensivu and Törnroos, 2010). To allow the triangulation, all data sources were analysed together, and conclusions were drawn from this analysis. The data analysis process also involved the iterative tabulation of evidence for each construct, to ensure construct validity, but also to put down a strong ground basis for explanation building. Data analysis is discussed in more details in section 3.6.

To address internal validity, the research engaged in explanation building and cross-case synthesis. This meant that the findings on casual relationships between skills, technologies and contextual factors were identified through the iterative abductive process of comparing the existent theory (both conflicting and supportive) in literature and evidence gathered during the study. During the data analysis, cross-case pattern search was used to understand the collected evidence through different perspectives; and to ensure, that the researcher has a sound understanding of the participants' viewpoints in order to minimise researcher bias in data interpretation and presentation.

As for external validity, the data analysis ensured that the research findings generate a theory of causation, not a theory of events. This is an important aspect of critical realist case studies, as case study research is often criticized for its inability for producing findings that are applicable to other settings. By focusing on causation, not eventuality, case study research can produce valuable findings for theory generation. Therefore, it is important to make a distinction between statistical generalisation and analytical generalisation (Diefenbach, 2009; Yin, 2009; Thompson, 2022). The aim of this research is to understand the causal relationship between technology adoption, changes to skills utilisation and contextual factors, which means that the outlined research methodology is suitable for this project.

Reliability of research can be ensured by making sure that researcher reduces error and potential bias during the research (Goffin *et al.*, 2019). A thorough documentation of the research process allows the research to be repeated by another researcher. However, it is important to note that the exact replicability of the research itself might not be possible, as case study research is an emergent research design. The semi-structured interviews are supported by pre-prepared topic guides, which are constructed based on the existing literature. However, this data collection method is flexible in its nature, therefore, its replicability is limited. Nevertheless, the preparation of interview schedules helps to enhance the study's reliability to a certain extent. A further step that was taken to ensure reliability was adopted during data analysis. In order to avoid unintentionally changing the definition of codes during the coding process, codes were constantly compared with the data; and lists were maintained and continuously revised on the codes and their definitions. The data analysis process is introduced in more depth in section 3.6.

3.3.4 Online research

Due to Covid-19 restrictions, the majority of data collection for the research was carried out online (only nine interviews were conducted face-to-face). In this way, the researcher could ensure that the health and safety of participants and the researcher were protected. The online platform provides a quick, inexpensive and convenient way to carry out one-to-one interviews (Fox, 2017). Online data collection can be a more convenient channel for both researcher and participants during research, as there is no need to travel to any locations, and participants can join from an environment, which is comfortable for them

(Hanna and Mwale, 2017). To carry out research online, participants must have secure Internet connections. This can potentially limit representation in research as it discriminates against individuals, who do not have access to the Internet. This point was supported by the research, as one of the case studies did not have the equipment to carry out remote interviews, which meant that the data collection from this case organisation had to be postponed until Covid-19 restrictions allowed site visits.

Online data collection, however, is not without its limitations. During online data collection the researcher has less control of the interaction as they would in face-to-face research (Gaiser, 2011). With reduced visibility, semi-structured interviews can lack visual cues, such as body language and facial expressions. This can be problematic for the researcher to understand their participant's emotional state and to pick up sarcasm. To overcome the difficulties that the lack of visual cues present, the researcher must show emotional presence and be more attentive to verbal cues. The interviews in this research were conducted using video calls, which allowed the exchange of visual cues (Hanna and Mwale, 2017), albeit less than face-to-face interactions would.

Another limitation to online research is that in an online setting, the researcher has no knowledge of the conditions under which participants responding – such as their physical environment. Therefore, researchers must be prepared to deal with participants, who might be distracted or facing technical difficulties (Fox, 2017; Hanna and Mwale, 2017). Poor connections can be frustrating for researchers and participants alike and sudden interruptions to the discussions can have a negative impact on the flow of conversations and ultimately on the quality of the collected data. Interviews may take longer, too (Hanna and Mwale, 2017). Due to delayed Internet signal, it can be difficult to observe basic conversation etiquette in online research. On the one hand, this can lead to repeated interruptions and awkwardness during conversations. On the other hand, this can also be used as an opportunity to build rapport with participants discussing shared connection related annoyances that one might face due to remote working (Hanna and Mwale, 2017). Connection issues and disruptions rarely occurred during this research's online data collection. In a couple of instances, the interviews took longer than planned, and a second call had to be arranged to finish the conversation later on the same day. Whilst these two-part interviews both had a break in the flow of the conversation, the interviews restarted with ease both times. In fact, in both of the instances the participants made comments to complement their answers from the first half of the interviews, because the break between the two calls gave them an opportunity to reflect on the conversation and the topic in general. Therefore, the disruption to the interviews, which can have negative impacts, were overall beneficial in this research.

Another potential drawback of online data collection is that building trust between researcher and participants and signalling the tone of the discussion might be more challenging online than it is face-to-face. To overcome this, the interviews started with a brief small talk to set the tone for the conversations ahead, and in many instances, the interviews were arranged over the phone, which meant that the interviews were not the first verbal interaction between participants and the researcher.

3.4 Research sample

3.4.1 Sampling strategy

After the research objective was determined, it was decided that this study will be exploratory in nature, and it will study technology adoption and skills through the use of primary empirical data collected in manufacturing small and medium enterprises. Upon identifying the research gaps that were outlined in the previous chapter, the selection criteria for the research sample were further narrowed down, as the researcher wished to study the adoption of at least two different types of technologies. Overall, the case studies were chosen based on two criteria: the number of employees (no more than 250) and recent technology adoption (within the past 7 years).

As section 3.6 later discusses, securing case studies for this research proved to be challenging. Due to the time limitations of the study and many unsuccessful attempts to find case organisations, the researcher decided to complement the planned case study data with semi-structured interviews carried out with sectoral stakeholders, to better understand the external context in which Scottish manufacturing SMEs operate.

For choosing research participants, the research adopted a non-random, purposive sampling method, where participants are chosen based on the qualities that they possess (Etikan, 2016). In this research, participants in the case studies were chosen based on their job roles and use of the new technology; and external stakeholders were chosen based on their relevant expertise to the sector's skill landscape, SME support, and policy landscape. Non-probability purposive sampling has been criticized for being subjective when choosing sample for studies, as well as its inadequacy for representing research populations (Etikan, 2016). However, as the discussion on the research's critical realist philosophy also discussed, this research does not aim to generalise its findings to a research population, which would have required the adoption of a random sampling strategy that is representative of the given research population (Byrne, 2001; Etikan, 2016). Rather, it aims to explore and analyse the causal relationship between technology adoption and skills changes; and then the potentially causal mechanisms between the relationship between technologies and skills and the contextual factors in which they interact. To meet this aim, the research has collected data from four SMEs and a group of external sectoral stakeholders. The next section introduces the study's sample.

3.4.2 Sectoral stakeholders

The research included fourteen online interviews with external sectoral stakeholders. These participants were selected based on their past experience or current job role, working on issues relating to the Scottish manufacturing sector's skills landscape, technological innovations in manufacturing and/or the SME community of the sector. Out of the fourteen interviews, six of them focused on sectoral skills development, five of them discussed stakeholders' experiences in working with SMEs, and three of them covered the topic of the latest technological innovations in manufacturing and their adoption across Scotland. The participants had insights due to their work in a wide range of organisations, including trade bodies, government agencies, industry-led research and development facilities, and the financial sector. Table 3.1 below summarises the interviewed stakeholders' areas of expertise.

Pseudonym	Area of expertise
Stakeholder 1	Sectoral skills development
Stakeholder 2	Industry support and sectoral skills development
Stakeholder 3	Industry support and sectoral skills development
Stakeholder 4	Technological innovations
Stakeholder 5	Sectoral skills development – engineering focus
Stakeholder 6	Sectoral skills development – sustainable manufacturing focus
Stakeholder 7	Sectoral skills development – digital focus
Stakeholder 8	SME support
Stakeholder 9	Industry support
Stakeholder 10	Industry support
Stakeholder 11	SME support
Stakeholder 12	Financial sector – manufacturing focus

Table 3.1: Summary of the stakeholder participants

These interviews offered an in-depth account on the Scottish manufacturing's health at the time of the research, the state of its existing skills pipeline, the sector's progress on implementing Industry 4.0 innovations, and the various challenges and support initiatives that are available for the sector's SME community in relation to skills development, technology adoption or general business support. By doing so, data collected from external stakeholders allowed the exploration of the external contextual factors that might influence technology adoption and skill changes in the sector's SMEs. Findings from the stakeholder interviews are discussed in Chapter Four.

3.4.3 Case organisations

Overall, twenty-three interviews were conducted across four organisations, with a mix of online interviews and face-to-face interviews. Each case organisation allowed the researcher to visit their sites, showed their adopted technologies working-in real time. Interviews with case studies and the complementing site visits offered an invaluable insight into the studied companies' operations, their experiences with technology adoption, skills development and utilisation, and the changes that the new technologies have brought to the organisations as a whole.

MotorCo

The first case organisation, MotorCo, is an engineering company that specializes in gear manufacturing. The organisation's customers are predominantly other manufacturing businesses from the oil and gas sector, steel industry, and the rubber and plastics industry. The company is located in a small-town with developed infrastructure. The location is in commuting distance from numerous large cities, which makes the business easily approachable for customers. The location is also convenient from a skills development perspective, as it is within commuting distance from various training facilities.

MotorCo is a family-business and currently has 37 employees, including 24 workers in the workshop, and 4 engineers in the engineering office. The rest of the employees are office-based. The majority of the employees in the workshop are described as machine operators. They operate CNC machines, automated machines tools, as well as manual ones. The company offers modern apprenticeships, which helps individuals to complete HCN-level qualifications in mechanical engineering. Moreover, MotorCo helps its employees to gain professional qualifications, such as forklift licence or Health and Safety qualifications. The engineering team of four consists of two engineering graduates; and two individuals, who completed their mechanical engineering apprenticeships with the company, after years of working in its workshop as machine operators.

MotorCo adopted an Enterprise Resource Planning (ERP) system, which is a management system technology that integrates several data sources and processes into one unified system. The ERP system helps to store, retrieve and share information on any aspects of an organisation's operation in real time. Findings from MotorCo's technology adoption journey are discussed in Chapter Five.

Eleven interviews were conducted in MotorCo in total, which are summarised in Table 3.2 below. Seven of the interviews were conducted online, and four interviews were carried out face-to-face during the researcher's site visit to the organisation.

Job role	Interview
Managing Director	• 1 online interview • 1 face-to-face interview
Engineering Director	• 1 online interview • 1 face-to-face interview
Admin Lead	• 1 online interview • 1 face-to-face interview
Engineer	• 1 online interview
Production Controller	• 1 online interview • 1 face-to-face interview
Workshop Employee	• 1 face-to-face interview
External Consultant	• 1 online interview

Table 3.2: MotorCo interviews

FixShop

The second case organisation, FixShop, is an engineering workshop that specialises in repairing and maintenance services. The workshop offers hydraulic engineering, machine shop services, engine re-manufacturing, diesel workshop services and engine and machinery repairs and servicing. The business' customers include other businesses and individuals alike with bespoke machines and equipment. The company is located in a large city with well-developed infrastructure, which makes it easily accessible for customers by public transport or car. This location is not only convenient from an operational infrastructure point of view; it is also beneficial for accessing nearby colleges and training centres for staff development.

FixShop is a family-owned micro business with ten employees in total, eight engineers (including the owner-manager of the business), one accountant and one cleaner. The majority of the engineers in the workshop are apprenticeship-level mechanical engineers. The owner-manager of the business is an engineering graduate. The company offers modern apprenticeships, which helps individuals in the business to gain HNC-level qualifications in mechanical engineering.

The owner-manager of FixShop developed an embryonic management system, which was developed for FixShop initially, and the app went live for the public in 2022. This technology is used to keep a record of all the jobs in the organisation, making storing, retrieving and sharing information on any projects easily accessible from multiple devices in real time. Findings from FixShop's technology adoption are discussed in Chapter Six.

Five interviews were conducted in FixShop in total, summarised in Table 3.3. Since the owner-manager of the organisation developed the new technology, a separate interview was conducted with them about the technology development process. In the below table, their role as the owner-manager of FixShop and the technology developer are marked separately.

Job Role	Interview
Owner-manager	• 1 online interview • 1 face-to-face interview
Technology Developer	• 1 online interview
Employee 1	• 1 online interview
Employee 2	• 1 online interview

Table 3.3: FixShop interviews

BrewCo

The third case organisation, BrewCo, is a family-owned farm brewery, which operates two breweries on site: one manual, rustic brewery for farmhouse beers, and a new brewery using state-of-the-art technology. The brewery produces high-quality, core beers and some special releases in the new brewery. These products are sold directly to customers online and in the brewery's shop, and through retailers such as supermarkets and beer shops, as well as to pubs and restaurants across Scotland. The brewery also releases farmhouse beers, which are limited and can only be bought online, in the brewery's shop and in a few special beer shops. Overall, the brewery produces for both a wider audience with its core beers, and some niche, specialist audience through their farmhouse releases.

The brewery is located in a rural area with limited infrastructure. Whilst its location offers a tourist attraction to the brewery's customers; the remote location requires high levels of self-dependence from an operational perspective. The rural location of the brewery also affects staff recruitment, as discussed in Chapter Seven.

BrewCo is a family-owned business with 22 employees – including four brewers, two warehouse and packaging assistants, three drivers, one farmer, three brewery tap shop workers, and seven office-based support staff.

There are four qualified brewers in the brewery. The head brewer is a Brewing and Distillery graduate, and his role is to oversee the production in both breweries. One brewer is a self-taught with previous experience in farmhouse brewing, and they are responsible for production in the older brewery. One brewer gained their professional qualifications in Germany, and their main responsibility is quality control. One brewer has mechanical engineering background, and they are now going through a professional qualification run by the Institute of Brewing and Distillery. They oversee production on the new brewing kit.

BrewCo commissioned the building of a new automated brewery kit to the site in 2014, which has significant contrasts with the original manual equipment. The automated system in the new brewery kit follows each step of the beer production – the loading of raw materials into the equipment; monitoring temperatures, pH levels and speed of movements across the brewing process; emptying the waste materials after production; monitoring the cleaning process; and dispatching the ready product for delivery. Findings on BrewCo's automation journey is discussed in Chapter Seven.

Three interviews were conducted in BrewCo in total, which are summarised in Table 3.4 below. Since the brewery did not have equipment to arrange videocalls, each interview was conducted face-to-face during the two site visits.

Job Role	Interview
Head Brewer	• 2 face-to-face interviews
Lead Brewer of the old kit	• 1 face-to-face interview

Table 3.4: BrewCo interviews

PartLtd

The fourth case organisation, PartLtd, is an engineering company that specializes in high-precision engineering. The company manufactures highly-specialized, custom-made complex components for customers in the aerospace industry and the defence industry. The company is located in a large city with well-developed infrastructure with easy access to airports, motorways and public transport. Similarly to FixShop, PartLtd's location is beneficial for accessing nearby colleges and training centres for staff development.

PartLtd is a privately-owned company with 250 employees in Scotland. At the site where the case study was conducted, 50 employees are working in the machine shop and are supported by a team of engineers and office-based staff. The majority of the employees in the workshop are machine operators, operating a wide range of equipment including automated and manual tools. The engineering team is responsible for planning production, programming automated equipment and supporting production processes.

At the time of the research, PartLtd was in the process of rolling out an automated, high-accuracy laser tool-setting system across its business to replace the manual tool setting, which was used in the organisation before. This technology gets incorporated into existing machines in the engineering workshop. By replacing the offline pre-setter, the new automatic non-contact tool setter enables constant resetting on the machine tools at every cycle of the production. The tool setter is planned to be implemented into all machines in the shopfloor by 2023. Findings from PartLtd's tool-setting automation journey are discussed in Chapter Eight.

Four interviews were conducted in PartLtd, as summarised in Table 3.5 below. Three interviews were carried out online, and one of them was conducted during the site visit. In addition, two more individuals contributed to the collected field notes by explaining their work processes. These conversations were not recorded as interviews, but the individuals' consent was asked to take notes during the conversations and used during the data analysis process.

Job Role	Interviews
Managing Director	• 1 online interview
Head of Development	• 1 online interview
Manufacturing Engineer	• 1 online interview • 1 face-to-face interview
Additional data from: • Inspector • Machine Operator	

Table 3.5: PartLtd interviews

3.5 Research process

Once the selection criteria for the research sample have been determined and the research received ethical approval from the General University Ethics Panel (GUEP) on 22nd March 2021, the participant recruitment process started in April 2021. This process started with the creation of a recruitment poster (see in Appendix 4), which was shared on the researcher's social media pages, and with industry organisations, such as Scottish Engineering, Scottish Enterprise, and CeeD, who then shared it with their members. In addition, the researcher emailed forty manufacturers directly, using the Make Works directory (Make Works, 2023). Each invitation email has included a copy of Research Summary (see in Appendix 5). Unfortunately, this first round of participant recruitment did not succeed.

The second round of participant recruitment, which was launched after the researcher's return from a three-month internship leave, did secure the case organisations, albeit at a slow pace. Whilst waiting for reply from potential participants, pilot interviews were conducted with professionals from trading SMEs, who worked closely with Scottish manufacturing SMEs. These interviews allowed the researcher to test the proposed topic guides for the interviews with professionals, who were familiar with, but independent from, the research context.

Considering the time limit of the project, the researcher decided to include external stakeholders in the research sample, in order to gain an understanding of the external, sectoral factors that influence the SME community. Twelve out of fourteen stakeholder interviews were carried out and two case studies were completed in 2021; whilst the site visits and the other two case studies and stakeholder interviews were completed by April 2022.

Overall, thirty-seven interviews were conducted, out of which nine of them were carried out face-to-face. The interviews were voice recorded with the participants' consent, which was given before each of the interviews (see Appendix 3). The online interviews lasted on average forty-five minutes, with the shortest being 30 minutes and the longest an hour and a half. The face-to-face interviews were conducted during site visits, and they took on average seventy-five minutes each, as they included visual explanation of processes and technologies. The interviews were guided by the interview guides (see Appendix 1), which were flexible enough to explore additional topics that emerged during the interviews. Moreover, the researcher also updated some of the interview guides during data collection, adapting to each case organisations' technologies and production processes. These interviews were also complemented by field notes and pictures taken during the site visits to the case studies.

Once the data was collected, the researcher transferred the voice recordings and the pictures taken during site visits to her password protected, GUEP approved data storage folder, and transcribed the recordings. The data analysis started after the first transcripts were completed. The data analysis process is discussed in section 3.6.

During data analysis and the writing of the thesis, the researcher maintained contact with the research participants, and sent them an update on the research progress six months after the data collection was finished. Finally, once the data analysis was finished and the full thesis was drafted, the researcher sent the participants a Summary Report on the key findings (see Appendix 6), to thank their invaluable contribution to the research.

3.6 Data analysis

The research adopted a retroductive interpretive strategy that combines the use of abduction, deduction and induction. The inductive research process is a data-driven, where the collected data is coded without a pre-existing coding framework (Braun and Clarke, 2006). The deductive approach, however, uses an analytical lens that is informed by existing research and theory, which is then used for analysing and interpreting the data (Braun and Clarke, 2021). The abductive approach, as discussed above, examines breakdowns where empirical data differs from what is expected based on pre-existing theoretical understandings (Thompson, 2022).

This research approached the collected data through a deductive approach at first. Before data collection, the researcher carried out an initial review of relevant literature. The review of the various theoretical understandings on the interplay of technologies and skills set initial parameters for enquiry and informed the interview guides (Appendix 1), as described in the above section. This initial direction for data collection implies certain levels of deduction, as the researcher did not go into data collection with a clean slate and used the 'upskilling' and 'deskilling' debates as guiding analytic lenses.

To unpack the collected empirical data, the research used a reflexive thematic analysis (TA) approach. This data analysis approach acknowledges "*the importance of the researcher's subjectivity as an analytic resource and their reflexive engagement with theory, data and interpretation*" (Braun & Clarke, 2021, pg 3.). Reflexive TA, therefore, recognizes data analysis as an interpretative activity and the researcher's theoretical, social, cultural disciplinary, political and ideological position (Braun and Clarke, 2021; Wiltshire and Ronkainen, 2021). Through this theoretical freedom, reflexive TA acts as a useful research tool, which can provide an in-depth, complex account of data (Braun and Clarke, 2006). As above discussed, this research adopts a critical realist approach, which has an impact on the data analysis, too. Within this realist approach, the data analysis process allows the theorization of motivations, experience and meaning in a straightforward way, since the position assumes indirectional relationship between meaning, experience and language, as opposed to the interpretivist epistemological position (Wiltshire and Ronkainen, 2021).

The process of data analysis started with multiple, thorough readings of the interview transcripts and notes to develop a sense of familiarity with the data. The second stage of the analysis was structural coding, where the data corpus was broken down into broad topics across the interviews (Saldana, 2016), which then helped with the more in-depth analysis later. Based on these structural codes, the researcher developed a table for cataloguing these codes in each case studies and one table for the stakeholder interviews. The next step in the data analysis process was the generation of themes from the coded data. Themes refer to patterns in data with shared meaning united by a central concept or idea (Braun and Clarke, 2021). Braun and Clarke (2006) differentiate between two types of themes, semantic and latent themes, which illustrates how data analysis progresses from description to interpretation. Semantic themes are identified in the surface meaning of the data using structural codes. The researcher here, essentially, examines *what* the participants have said. In the next stage, where the latent themes are identified, the researcher looks beyond the descriptive themes and explores the *why* behind the semantic themes. Generating latent themes is where the researcher examines the underlying ideas, assumptions and conceptualisations within the data (Braun and Clarke, 2006; Thompson, 2022). Whilst these described steps of data analysis might present a straightforward and linear process written down, in reality, data analysis and theme generating is an inherently iterative and recursive process, where the researcher goes back and forth between the data, codes and themes (Wiltshire and Ronkainen, 2021). Therefore, the data analysis process cannot be rushed. Indeed, the data analysis process of this research has started in January 2022 and only ended in October 2022.

Whilst using the initial theoretical lenses of upskilling and deskilling, there were emergent codes and themes that pointed towards explanations beyond these theories and the researcher did not consider in-depth prior to data analysis. The coding process of the data relating to those issues took the inductive approach. For example, the nuances within skill changes where technologies indirectly affect skills through changes to work organisation were identified through a multi-step reflexive engagement with data, theory and interpretation.

A further complexity of the collected data, which is common in research with multiple participants representing various viewpoints, was the contradictions within the data. As Braun and Clarke (2006) also highlights, there is no dataset without contradiction, and the tensions and inconsistencies within and across datasets must be taken into consideration. Inconsistencies could be observed from data coming from the same case organisation at times. These inconsistencies represented the different viewpoints of various individuals on subjective experiences that are open to individual interpretation, such as what classes as smooth technology implementation. The reason for these contradictions could be subjective opinions and the collection of data on technology adoption retrospectively. The inconsistencies and contradiction in data encouraged the researcher to question the collected data, the different theoretical understandings and the potential underlying causations and connections between themes and codes even further. This involved revisiting the initial structural codes and compared data across case studies, too. Finding these inconsistencies within data and the consequent revisiting of the themes and codes further illustrate the iterative, abductive elements of data analysis and reasoning, which makes the process time-consuming, but even more rewarding.

3.7 Ethics

As with any research, this research also needed to consider some potential ethical issues before data collection. First of all, the health and safety of participants and the researcher must be protected. Therefore, the majority of data collection, which was planned to be carried out face-to-face, moved online due to Covid-19. Twenty-eight interviews were done through online communication with the researcher, in a normal, remote workplace setting. The risk of hacking was there as with any online communication. To minimise this risk, the interview meetings were set up by the researcher and conducted over the university authorized Microsoft Teams service.

Anonymity and confidentiality must also be ensured in any research project. In this study, anonymity of the participants was protected with the use of pseudonyms. Each participant was assigned a pseudonym during the transcription process. A key that links the research participants to their pseudonyms, are in a separate password-protected file, stored separately from the interview transcripts on the researcher's password-protected computer. The names of the case organisations are also kept confidential, and they are not included in the PhD thesis and will not be included in any relating publication or the summary reports. Nevertheless, it is important to note that ensuring anonymity of participants within their own organisations was not possible. Access to the participants was gained with the help of the owner-manager of the company. However, all participants were made aware that participation is voluntary and the collected data will be anonymised.

Participation in the study was completely voluntary. Participants of the study were fully informed on the details of the study and the use of collected data (see Appendix 2). The data collection only started after the researcher received written consent from each participant (see Appendix 3). The interviews were recorded with the permission of the participants.

All recordings and collected data are stored on the university's Microsoft OneDrive server and they were and will only be accessed by the researcher through her own, password protected personal computer that no one else has access to. The collected data will be stored securely for 10 years after the research - participants gave their consent to this by signing the consent form (see Appendix 3).

Finally, as noted in section 3.5, the researcher did not carry out any form of data collection until she received the university's ethics panel's permission to do so. The ethics approval from the university's ethics panel was received on 22nd March 2021, and the data collection started on 13th October 2021.

3.8 Limitations

This study is not without its methodological limitations. The most significant challenge that influenced the scope of the research was the Covid-19 pandemic. Prior to the pandemic, discussion on the future of work were focused on technological innovations and their impact on economies and workplaces (WEF, 2018; World Bank, 2019). However, as the Covid-19 pandemic brought the world to its knees, the priorities of research and general discussions have changed, understandably. Scottish manufacturing SMEs faced many significant challenges that threatened their survival. Against this backdrop, case study participant recruitment became highly challenging during this research, as its timing coincided with ever-changing governmental updates and restrictions.

Once the research participants were secured, the effects of the Covid-19 pandemic also made an impact during data collection. Lockdown restrictions and the aftermath of the initial Covid-19 lockdown were fresh on participants' mind, and occasionally, the interview discussions deflected from the focus of the research to the more recent experiences of Covid-19. Since the studied technologies also played a role in how SMEs coped with the Covid-19 challenges, especially the management system technologies, discussions around altered work practices due to the pandemic also gave an insight into how the external factors can influence technology use in companies. Nevertheless, the researcher had to stay alert and navigate the interviews back to the focus of the research on occasions, and the inherent flexibility of the semi-structure interview method allowed the freedom to do so.

Another impact that Covid-19 had on data collection was the move from planned face-to-face data collection to online data gathering. As section 3.3.4 discussed, online data collection has implications for the researcher's control over the conversation, the limitations of monitoring non-verbal cues and building trust between researcher and participants. The researcher aimed to limit the negative implications of online data collection by using video during interviews, which gave an opportunity for participants and the researcher to engage through non-verbal communication too, albeit at a reduced rate. To minimise the barriers to building trust with research participants, the researcher arranged interviews over the phone, where possible, to build a sense of familiarity with participants ahead of the interviews. Since this was not possible before all interviews, the researcher started every interview with a few minutes of informal, rapport-building conversation, to build trust between interviewer and interviewee.

The hard-won sample of the study also carries certain limitations. Since the overall aim of the research is to explore technology adoption and related skill changes in Scottish manufacturing SMEs, having case studies that went through technology adoption suits this research project. However, this research sample is not capable of providing information on the barriers that can hinder technology adoption in SMEs. Therefore, the sample of this research is not representative to the overall SME community in Scottish manufacturing. Furthermore, two case study organisations were recruited with the help of sectoral support organisations. These SMEs had working relationship with these sectoral support organisations, which means that they might hold certain biases towards the support system. Additionally, as section 3.4.3 showed, the case studies included limited number of interviews. However, since the research sample covered a variety of job roles in each organisations, different groups of workers with varying views were represented during the study. As only a small number of individuals were interviewed, the findings from the case studies cannot be generalised for wider research populations. However, statistical generalisation is not the aim of the research. As sections 3.2 and 3.3.3 discussed, the external validity of the research is based on generating theory of causation. By collecting data from individuals with different job roles in each case organisation, the findings of the study provided insight into the causal relationship between technology adoption and skills at multiple stages of production in the organisations.

Finally, the research had a limited timeframe to collect and analyse data, which meant that the findings of the study represent participants' views on the adopted technologies and related skill changes only at a given time. However, considering the evolving nature of technology adoption and skills utilisation, the research topic would benefit from a longitudinal view on technology adoption and skills changes. By exploring technology adoption and skills changes overtime, research could capture changes along the process and could provide an insight into the impact of contextual factors on the implementation process. Furthermore, data collection overtime could also examine how the influence of each factor changes as time progress. Additionally, this research focused solely on small and medium enterprises. By widening the research sample to include larger organisations, research could also explore the differences between experiences of various sized organisations, and consequently, could examine the influence of business size on technology adoption and skills at a larger scale than this research had the scope to.

3.9 Researcher's reflection

Based on my previous research projects, I knew from the beginning that securing research participants is one of the most challenging parts of any research projects. Even before the pandemic, I was told by professionals working with the manufacturing sector that small and medium enterprises are difficult to connect with. Adding Covid-19 restrictions to the equation, securing access to case organisations almost seemed impossible at times. However, I believe that having to wait for case organisations not only taught me patience and persistence, but it also made me highly appreciative of the opportunity to conduct research in organisations, and I knew I wanted to make the most of the opportunity.

My first interviews were conducted online with external stakeholders and owner-managers of SMEs. These individuals all felt at ease with having video calls, and the interviews went smoothly. However, despite the good flow of the conversations and the open communication, I could feel that the online platform limited the depth of the case study interviews, since owner-managers often noted that it would be much easier to show how the new technology works, rather than trying to explain it. Nevertheless, I felt that I had a good enough grasp of the technologies to conduct further interviews with other members of the organisations, and I looked forward to complementing the online interviews with site visits.

It was during the interviews with workshop employees, when I would first feel conscious about my role as a researcher and the power dynamics that came with such relationship. I approached the interviews ready to learn from my participants, but one of the shopfloor workers in my first case organisation acted shy and vocalised his embarrassment, stating that he felt inadequate to talking to a researcher because he only had apprentice-level qualifications and was not as 'clever' as me, the researcher. This statement surprised me, as I share England's (1994) view that "*the knowledge of the person being researched (at least regarding the particular questions being asked) is greater than that of the researcher*" (pg. 243). In this interview, I took extra care that my interviewee felt at ease, I spent slightly longer time in the beginning building rapport with them and checked in with them throughout the interview, asking if they are happy to proceed at regular intervals. After that interview, I made sure that I express my gratitude, appreciation and respect towards my participants even more.

Being a researcher naturally comes with the role of the 'outsider', but conducting research as a young female in a male-dominated industry made me realise how much the personal characteristics of a researcher can influence data collection. I do not know whether my age, gender, lack of engineering qualifications, or the fact that English is not my first language is it to blame, but there were instances where I could feel that my interviewees were distant towards me and less willing to share details about their jobs, because they believed that I would not understand it. For example, one participant became frustrated whilst trying to explain their job tasks to me and ending their attempt with '*ahh it doesn't* *matter*'. Another interviewee kept emphasizing the phrase '*in non-technical terms…*' at every explanation they gave. Whilst these situations felt uncomfortable, I was willing to learn from my participants, and I summarised my understanding of their explanations regularly, to make sure that my interpretation was correct, and also to signal to them that their explanations were not futile. To ease my participants' reserved attitude, I occasionally shared relevant personal experiences with them about my past job roles, or my family members' experiences of working in manufacturing. This helped to build trust with the interviewees. At times, however, my lack of engineering background was the very reason that I was able to bond with my research participants. Some of my interviewees worked with manufacturing organisations, but they themselves did not have engineering background. Sharing the experience of being an 'outsider' helped to create a sense of camaraderie with these interviewees.

Overall, this research has taught me a great deal about how to overcome challenges and be flexible when plans change. Moving from planned face-to-face interviews to online data collection has given me practical experience in conducting research online, which I believe made me a more knowledgeable researcher. More importantly, this research taught me the influence that I, as a person and researcher, can have on my research participants. Reflecting on these experiences became a source of a lot of learning for me, and I believe that I became a more well-rounded researcher as a result.

3.10 Conclusion

To summarise, this chapter introduced the research methodology that the study adopted. Namely, the research studied technology adoption and skill changes through the critical realist philosophical approach, which accepts that reality exists independently from mankind. This reality, however, can only be seen through the subjective perceptions of individuals. The research studied the causal relationships between technologies and skills and examined the mechanisms by which these entities connect. To do so, the research adopted a case study methodology for studying technology adoption at organisational level, which suited the study's exploratory nature and allowed the researcher to study technology adoption and related skill changes in depth within its real-life context. The case study data were also complemented by sectoral-level data gathered from sectoral stakeholders in manufacturing. The research collected data through the use of semi-structured interviews and complemented the case organisation interviews with field notes collected during site visits to the case organisations. The majority of the interviews were conducted online, which had implications for the researcher’s control over the interviews and trust building between the researcher and participants.

As the chapter discussed, recruiting research participants during Covid-19 was highly challenging, and led to the widening of the research sample, including sectoral stakeholders in the study. The interviews with sectoral stakeholders provided an in-depth view on the Scottish manufacturing sector, the context in which the case study organisations operate. The research included four case studies, which were introduced in section 3.4.3. The data collection process, which included thirty-seven interviews in total, nine face-to-face and twenty-eight online ones, started in October 2021 and ended in April 2022. Once the data was collected, the researcher analysed the data with the use of reflexive thematic analysis, which was introduced in section 3.6. The next part of the chapter discussed the ethical considerations of this research, followed by a brief discussion on the limitations of the study. Finally, the chapter ended with the researcher’s reflection on the overall research process. The next five chapters of the thesis outline the findings from this research process.

CHAPTER 4: CONTEXT

4.1 Introduction

The fourth chapter introduces the context of the study, including an outline of the key global and national issues that might affect Scottish manufacturing organisations, an overview of the skills landscape and technology uptake in the sector, and challenges that sectoral SMEs might face when it comes to technology adoption and skills changes. The chapter incorporates the key findings from interviews with sectoral stakeholders to establish the context in which the four case organisations operate. The sectoral stakeholders included individuals working in various trade bodies, government agencies, industry-led research and development facilities, and the financial sector, and the discussions covered topics relating to the Scottish manufacturing sector's skills landscape, technological innovations and or the SMEs of the sector.

4.2 Global and national context of Scottish manufacturing

As discussed in section 2.4.3 of Chapter Two, the external environment of organisations can influence organisation level decisions around skills. There is an array of global and national level factors that can have an impact on economies, structure of labour markets, and overall skills availability. This part of the chapter discusses how the external context influences the Scottish manufacturing sector's labour market by reviewing relevant academic and industry literature, as well as discussing sectoral stakeholders' view and experiences on how these contextual factors influence Scottish manufacturing SMEs.

4.2.1 Demographic change

Many western countries, including the UK, are experiencing the social demographic issue of an ageing population (WEF, 2018; World Bank, 2019). The ageing population means having an increasing number of elderly people in the economy, who rely on the social welfare system. This increasing demand on the social welfare system is essentially maintained by taxpayers, who are the active actors of a labour market. In simpler words, less people need to create wealth for more people. From a skills perspective, as the population ages, the pool of talented and experienced workers in the labour market is gradually shrinking, which can lead to significant skill gaps in the economy.

From a Scottish manufacturing point of view, the ageing workforce poses a significant challenge (MacBryde *et al.*, 2021), not only due to the above discussed demographic decline, but also due to the historic underfunding of the sector dating from the deindustrialisation era in the early 1980s (Tomlinson, 2021). As a result of these past political and economic decisions, the sector has low rates of mid-career workers. Indeed, four stakeholder interviewees working in industry support organisations noted that the Scottish manufacturing sector suffers from an ageing demographic, where the majority of the highly skilled workforce are either retired or nearing retirement in the coming years. This means employers are at risk of losing the vast amount of technical knowledge and experience that older workers possess, and employers might face challenges when trying to replace these workers. As a result of losing a high proportion of experienced workforce, young workforce must take on high-level skills in order to be able to take on higher-level positions in companies that the soon retiring workforce is expected to leave behind, since there is a general lack of mid-career workers in the sector as a result of historic underfunding. In addition, as discussed in Chapter Two, small and medium enterprises often put less emphasis on succession planning, than larger organisations do (Wapshott and Mallett, 2015), which means that they often face heightened skills challenges when their senior colleagues are reaching retirement. This puts further pressure on sectoral level skills development to create an effective skills pipeline for ensuring the future prosperity of the sector.

The generational gap in the sector can also have implications for the digital skills divide, where the younger workers as digital natives can find navigating the increasingly digital workplaces easier than the older workers, who may need more support on this journey. Indeed, Skills Development Scotland's Sectoral Skills Assessment report on manufacturing (2022) notes that the increasing digitalisation of the sector has exposed digital skill gaps in the sector. This can become an issue in relation to the current wave of technological change, which is the focus of this research.

4.2.2 Covid-19

A further global phenomenon that has significantly impacted the world of work and continues to do so, is the Covid-19 pandemic. As the world came to a standstill, the UK's economy experienced a significant shock. One month after the first lockdown was announced in March 2020, the UK's Gross Domestic Product (GDP) rate fell by twenty per cent. The nation's GDP only reached pre-pandemic levels in May 2022 (ONS, 2023a). The full extent of the long-term economic impact of Covid-19 is still unknown, but it is without a doubt that the pandemic affected the country greatly.

As for the Scottish manufacturing sector, businesses were divided into ‘essential’ and ‘non-essential’ services, and a lot of the ‘non-essential’ manufacturers stopped their production activities during the first lockdown, which created significant issues for these businesses (MacBryde *et al.*, 2021). Data on Scottish manufacturing shows that the sector’s workforce has declined at a rate which is above the Scottish average over the pandemic, and employment levels are only expected to fully recover to pre-pandemic levels by 2024 (SDS, 2022). Indeed, MacBryde *et al.* (2021)’s research also reports concerns about people and skills in the sector. These concerns include an increasing proportion of older workforce (over 50s) leaving the sector due to retirement or early retirement motivated by the pandemic; and a decrease of young workforce entering the sector due to lower levels of apprenticeship uptake during lockdown. Whilst the pandemic has not been the sole driver of these skills issues, as the above section shows, it certainly has accelerated the negative impact of the demographic divide in the sector. What is more, the pandemic potentially delayed the sectoral demographic issues’ remedy through the decreased number of young workers entering the sector. This example demonstrates how contextual factors can impact the availability of skills in labour markets in a complex, intertwined manner, which further emphasises the importance of studying the social context of organisations when researching skills changes.

Data from the stakeholder interviews supported MacBryde *et al.* (2021)’s findings. Overall, the stakeholder research participants reported that whilst companies had to face some temporary closures, operational challenges adopting to the compulsory 2-meter distancing and global supply chain shortages, the sector has weathered the immediate effects of the Covid-19 pandemic better than expected. However, it is important to highlight that the research’s data collection took place between the autumn of 2021 and spring of 2022, and some of the pandemic’s effects may only cause disruptions in the sector on the long-term. As for the sectoral impact of the pandemic, losing a considerable proportion of experienced workers and disruptions to the development of the upcoming generation in the sector were the key skills issues that Covid-19 contributed to, according to the stakeholder interviewees.

The most often highlighted issue during interviews was the reduction of apprentice uptake as a result of the pandemic. The number of engineering apprentices who started in Scotland in 2020 was almost half of the year before. According to the latest figures, apprenticeship uptake in the sector is now returning to pre-pandemic levels (SDS, 2022). Nevertheless, according to the interviewed stakeholders, the Covid-driven disruptions to apprenticeships are likely to cause some serious issues in skills supply in three or four years.

Beside lower apprenticeship uptake, a further negative impact on the sectoral skills development caused by Covid-19 was the move towards online learning. Whilst participants have praised colleges and other education providers in the sector for swiftly developing online resources, they still highlighted the importance of hands-on work experience and work-based learning, which has deep traditions in the sector. Face-to-face work experience, however, is not only important for mastering technical skills, but it also helps early career individuals with networking, and industrial collaboration in general. As a one of the participants put it:

> *"I think there was probably about six months into the lockdown, there was lots of talk about actually how companies have seen an improvement in productivity. Well, of course, because people don't have anything else to do, and you know they're not paying for heating and lighting, and so what costs would have been down. But actually, all the productivity that's gained through the swapping of ideas and the innovation and what comes off the back of that, I think we're now seeing that a lot of that productivity gains has dissipated and actually maybe moved backwards."*
>
> *(Stakeholder 1)*

The restrictions relating to the pandemic did have a negative effect on training opportunities and face-to-face networking across the sector. This in turn, can negatively impact the skills and career development of young workforce, which can hinder the future prosperity of the manufacturing sector.

As mentioned above, the pandemic has also acted as a catalyst for a wave of redundancies, mostly voluntary, amongst high-paid, senior workforce with wealth of experience, close to retirement age. In the short term, this had a positive financial impact on organisations' survival during the pandemic. However, due to the lack of succession planning in place and a generational gap in the sector, this wave of redundancies simultaneously created a situation, where companies trying to fill the void left behind by upskilling younger individuals. As one participant stated:

> *"So what we are seeing is a shuffling up, and you've got relatively inexperienced people trying to obtain higher level skills. So upskilling in a big requirement."*
>
> *(Stakeholder 5)*

This suggest a need for upskilling in the sector, where organisations are looking to increase the skills of their workers and expect that young workers in the labour market meet those increased skill requirements.

4.2.3 Climate change

Another influential global factor that impacts skills in economies is the ongoing climate change. The already visible negative effects of climate change on our planet draws attention to the importance of adopting sustainable practices and striving towards a low-carbon economy, where carbon intensive industries are encouraged to restructure their operations. Digital technologies will play a crucial role in the move from a carbon-reliant economy towards a low-carbon economy (WEF, 2020). Hence, commitment to sustainable production practices drives technology adoption in an economy, and has implications for skill requirements in the labour market (SDS, 2019a).

The Scottish manufacturing sector is committed to lead on embracing technological innovations that help the move towards more sustainable production practices in the country (Scottish Government, 2023, SDS 2019b). From a skills perspective, the adoption of new technologies and production practices might require new skills from workers in their existing roles, as Skills Development Scotland outlines in the Climate Emergency Skills Action Plan (SDS, 2019a); and some displaced workers might require reskilling for a new job due to sectoral transitions (Li, 2022).

A drive towards NetZero ambitions for Scotland offers great opportunities for the manufacturing sector, according to research participants. Shifting already existing manufacturing processes and creating a mindset change around the use of raw materials and circular production will require changes from the manufacturing sector. Whilst climate change is a global issue and collective action is required in all economies around the world, the Scottish Government highlights the importance of each company taking responsibility and ownership over the need for action (Scottish Government, 2023). In the Scottish manufacturing sector, trade body collaborations amongst CeeD (Centre for Engineering, Education and Development), Sottish Engineering, Skills Development Scotland and NMIS are underway to raise awareness, for SMEs in particular, to NetZero and steps that manufacturing companies could take towards adopting more sustainable production practices. Whilst progress has been made in engaging with SMEs around green initiatives, the research participants noted that there is still a long way to go for smaller companies on the path towards a more sustainable future in Scottish manufacturing. This journey will, however, not succeed without embracing new technological innovations and improvements in digital uptake in the sector, which is the focus of this research.

As for the skill requirements of NetZero transition, the stakeholders argue that workers in the sector will need to gain technical knowledge on new, more sustainable types of production, for example for moving from servicing gas boilers to servicing heat pumps.

However, the stakeholder participants believe that learning these new production processes will not require overwhelming effort from workers, as these are based on the same engineering principles as the old procedures.

4.2.4 Brexit

Turning to national-level context, as Chapter Two discussed, the UK's political climate and economic policies also have implications for organisations' human resource decisions. The most often mentioned national issue that was discussed during the stakeholder interviews is Brexit.

In Scotland, the political uncertainty that was created by Brexit and EU negotiations had a negative impact on international business investments (Born *et al.*, 2019); and the exit from the European Union significantly reduced the availability of migrant workers (Scottish Government, 2021; SDS, 2022). The reduced availability of EU workers has created further skill shortages in the manufacturing sector, particularly in the food and drink industry (Scottish Government, 2021). In addition, the overlap between the timing of Brexit negotiations with the negative effects of the pandemic has created a perfect storm in the sector, which was clearly illustrated in the Small Business Survey 2021. In this survey, the most commonly reported obstacles to success for businesses were the Covid-19 pandemic (76 per cent), recruitment and skills (43 per cent) and Brexit (40 per cent). This result summarises the impact that external factors can have on businesses, which then in turn can influence organisations' technology adoption and skill requirements.

According to the stakeholder interview data, the UK's exit from the European Union has resulted in labour shortages and supply chain issues for manufacturing businesses. This finding echoes Scottish Government's and Skill Development Scotland's reports on the negative influences of Brexit on the Scottish labour market (Scottish Government, 2021; SDS, 2022). According to the research participants, the reduction of free labour movement from EU has made it difficult for companies in the sector to fill vacancies and put further pressures on skills development activities to provide training for available people in the labour market.

As section 4.2 outlines, external contextual factors influence organisations' opportunities and decisions around skills utilisation and technology uptake. The age demographic divide in the sector has created skill gaps in Scottish manufacturing, which highlights not just the need for developing the skills of young workers in the sector, but also the importance of strategic succession planning in SMEs. Disruptions caused by Covid-19 has further deepened the issues of generational divide in the sector, as it created a wave of senior workers voluntarily leaving the sector, whilst also hindered the skills development of the younger workforce through lower apprenticeship uptake and lessened in-person training opportunities. The pandemic, however, not only led to skills issues, but it also created financial challenges for organisations due to temporary closures. This has potentially had more negative impact on SMEs, as these organisations tend to have less resources to fall back on than large organisations do. These financial difficulties can also reduce SME's opportunities to innovate and adopt new technologies. Along with the challenges of Covid-19, Brexit also negatively impacted skills availability in the Scottish labour market. However, despite these skills challenges, the interviewed stakeholders are optimistic about the future of the sector and see many opportunities for future skills development and innovation in Scottish manufacturing. The next section discusses the stakeholders' view on the sector's skills landscape.

4.3 Skills in the Scottish manufacturing sector

Despite the above discussed challenges of the ageing workforce, and the broader issues of Covid-19, Brexit and NetZero affecting the sector, the research participants, overall, have a positive outlook on the current state of the manufacturing sector. They argue that there is a good sectoral leadership in the manufacturing and engineering trade bodies and public sector organisations with the intention to help the companies of the sector not just to overcome the current challenges, but to enjoy economic prosperity in the coming decades. To achieve this ambition, organisations must be prepared and equipped with the right skillsets.

The interviewed stakeholders agree on that the direction of skills changes in the manufacturing sector will predominantly take the form of upskilling, when it comes to the level of skills. As for the function of skills, whilst the research does not aim to forecast which skills will be most important in the coming years, the research participants identified a range of skills that will be pivotal to adapt to the predicted changes in the sector and prerequisites for engaging in more widespread technology uptake.

Despite the lack of skills investment in the past, the sectoral stakeholders believe that the current workforce is well-equipped with technical engineering skills, and therefore, participants do not regard specific engineering skills as the most urgent area of skills development in the sector. They believe that the most important skills to be able to deal with the upcoming changes are transferable skills, including logical-order thinking, problem-solving, adaptability, flexibility, creativity and information management skills.

"Good transferable skills, they're required from cradle to grave. So no excuse for anyone, these skills are required at every level right now, because right now the technological development is so fast that any worker of any age or experience needs to stay on top of all the tools and capabilities and knowledge and so on. Considering innovation, it's a constant learning process." *(Stakeholder 8)*

Another skillset that was highlighted by most stakeholders is good communication skills – oral, written and presentation skills. These were reported pivotal not only for smooth collaboration in the workplace, but they were also highlighted as a requirement for successful technology implementation.

Good leadership skills were named as key skills by most of the stakeholders during the interviews for creating a transparent, open culture in their companies and to support their staff throughout changes such as technology adoption.

"You have to bring your workforce with you, unless, they will drag you back." *(Stakeholder 10)*

"Senior management, we don't expect them to come down to the line and pick up a spanner and install it [technology]*. That's what the engineer does. But if he* [the engineer] *doesn't feel supported, and if he feels every time there's a bit of a setback, nobody got his back there, they'll basically disconnect and will say 'I'm not going to do that again'. And then the company suffers."* *(Stakeholder 2)*

Three participants also noted that business skills for managers in general, which includes leadership skills, must be developed in the sector. These are regarded especially important for SMEs. This finding shows that skills development requirements are not always focused on improving manufacturing processes, but there is also a need for improving more operational, work organisation related skills in order to enable overall improvement in companies' productivity and to aid their preparation for the future. This further emphasizes the pivotal role that work organisation plays in organisations' success.

As for the technical engineering skills, stakeholders believe that the knowledge of basic engineering principles will remain vital for the sector. However, organisations will increasingly look for 'generalist engineers', as interviewees called them, with the ability to gain nuanced knowledge as and when it is necessary.

"… organisations, both SMEs and large, are increasingly looking for people to be generalist, but also at the same time to have more nuanced knowledge within that generalism. Because the rate of pace of change means that they need to be more agile. So they need to be able to do more things across a broader scope, but also have the ability to go into, you know, little pockets and drill down in those and become specialists in that or relative specialists in that." (Stakeholder 1)

Whilst the above discussion showed what skills stakeholders believe to be important in the coming decade, they also identified some out-dated technical engineering skills that are specific to old machinery and are related to non-sustainable engineering processes that will become redundant in the near future.

Finally, basic digital skills were also highlighted as key skills in the sector. The interviewed stakeholders are optimistic that the younger workforce now entering the sector are more comfortable around technologies. But they also emphasized the need for involving older workforce in technology-related skills development, too.

"Quite often it's assumed in companies that more experienced personnel don't want to be trained on stuff. Yeah that's not true, that's just wrong. But sometimes the assumption is Willie is nearly 60, he doesn't want to learn. Maybe he doesn't. But you know, don't assume, don't take away the opportunity. He may, he may not. But sure as hell he will feel aggrieved if you don't even give him the chance"

(Stakeholder 3)

This is particularly important for bridging the above-mentioned generational skills divide in the sector, and to engage older workers in the digital transformation, too. Indeed, multiple stakeholder interviewees highlighted the importance of collaboration between younger workers, who are well-equipped with digital skills and can be the frontrunners of innovation, and older workers, who have vast experience and practical knowledge.

"*Don't turn to the 60-year-old mechanical engineer and try and make him a programmer. But the guy who is 24 and doesn't know anything about machining, get him to work with the older guy." (Stakeholder 3)*

Pairing younger workers with older colleagues was suggested as a solution for combining years of experience and accumulated knowledge with young individuals' knowledge on newer engineering practices and technological skills. According to the research participants, by combining the strengths of older, experienced workers with younger generation's knowledge on new technologies and processes, companies can reduce their reliance on their ageing workforce and become more prepared for the future of manufacturing.

4.4 Technology uptake in Scottish SMEs

Scotland has a significant heritage in manufacturing, which can act as a double-edged sword, according to research participants. On the one hand, the prosperous past of the sector is a source of great pride of many small family-businesses. On the other hand, some research participants believe that this sentimental pride around old technologies and equipment holds the sector back, using old equipment based on the principles of mechanic engineering at the level of Industry 2.0. This finding is in line with the TOE framework, which argues that organisations' technological context – both internal and external, influences technology adoption in organisations (Hsu *et. al*., 2006).

As section 2.4.1 in Chapter Two has discussed, there is an array of organisational-level factors that influence the success of technology adoption. Damanpour (1991) claims that the type of organisation should be a primary variable when studying technology adoption; whilst Berger *et al*. (2021) and Lee and Xia (2006) found that organisational size is an important variable in technology adoption outcomes. This research focuses on technology adoption in small and medium enterprises. As introduced in Chapter Two, SMEs are characterised by informal, ad hoc practices and they often lack strategic planning. Therefore, changes in these organisations are often made as a response to immediate business needs. Whilst this shows the benefits of SMEs' flexibility, it can often hinder long-term planning of innovation and skills development (Nolan and Garavan, 2016; Muller *et al*., 2019; Idris *et al*., 2020; Harney and Alkhalaf, 2021).

According to the stakeholders, technology uptake is polarized amongst SMEs in the sector. Some companies embrace technological innovation and make a conscious effort to take their workforce on the journey with them, too. Whilst other companies are hesitant to engage with Industry 4.0.

One of the commonly mentioned reasons that stakeholders gave was a misconception amongst SMEs around new technologies in relation to their complexity and potential labour replacement effects. According to Stakeholder 9, technology tends to get a bad reputation as a threat to jobs and companies. However, in his opinion, which is supported by the Scottish government's statistics (Scottish Government, 2018; Digital Scotland, 2019), new technology adoption rarely results in decreased employment within the organisation overall. As for complexity, stakeholders believe that organisations do not recognise that taking small steps in their technology journey also counts as moving towards Industry 4.0. This suggests that there's a need for clearer communication from public sector organisations when approaching small manufacturing companies with the intention of helping them to get started on their technological journey.

Moreover, stakeholders reported that some subsectors within manufacturing that use older manufacturing processes and heavily based on mechanic engineering-types of equipment believe that their '*sector doesn't do technology*' (Stakeholder 3). One of the stakeholders illustrated this attitude with the example of companies that differentiated themselves on the market by making hand-made, traditional products, such as Harris Tweed or Glenmorangie whisky. The stakeholder explained that some companies do not understand that not all technologies are the same, and organisations often believe that engaging in Industry 4.0 means fully automating manufacturing processes. This misconception also supports one of the core motives behind doing case studies on two different types of technologies in this research. By highlighting the differences between the effects of two technologies, the study hopes to draw attention to the inadequacy of discussing different technologies as having homogenous effects. Therefore, the research will contribute to the effort of erasing the misconception in the industry, which was highlighted above.

Finally, stakeholders add that financial difficulties could also act as a barrier to technology adoption amongst SMEs. This finding is in line with literature and statistics (Nguyen, 2009; Muller *et al.*, 2019; Cannas, 2021), which show that the number one barrier to technology adoption for SMEs is the lack of financial resources, closely followed by the lack of appropriate skills. As discussed in section 4.2, disruptions caused by the Covid-19 pandemic have also created financial challenges for SMEs in the sector, which could further hinder technology adoption for some organisations.

As several research participants noted, there are various small pockets of funding available for SMEs in Scotland to start their technology journey. However, a couple of stakeholders highlighted that the funding landscape in the sector is disjointed, missing flexible funding offerings and intermediate funding opportunities for the exploratory phase of technology adoption. In addition, one of the respondents highlighted the need for simplifying the administrative procedures in funding applications, because SME's limited time capacity often restricts them from applying.

> *"Many of the public funding, it's maybe a 15- or 20- or 40-page document the SMEs have got to fill in and before they get to the end of it, they've lost the will to live and they don't even bother applying."* *(Stakeholder 1)*

This above argument shows that in spite of available opportunities offered by public sector or industry bodies, small and medium enterprises are oftentimes restricted by their own organisational capacity to harvest these opportunities. This suggests that technology uptake and related skills development are influenced by other factors, both internal and external to organisations that can make it difficult for organisations to adopt new technologies. In order to better understand these factors and to best support SMEs, support must be suitable for SMEs, of which a key prerequisite is to understand these organisations. This research aims to contribute to this understanding by providing insight into four SMEs' technology adoption journey.

4.5 Scottish manufacturing SMEs

Overall, the interviewed stakeholders argued that they had limited views on the sector's SMEs, as they have found it difficult to engage with the majority of them. During the interviews, a few reasons could be identified that caused challenges when it came to stakeholder and SME engagement. First, the interviewed stakeholders believed that there was a lack of trust from the SMEs towards the public sector, which undermined cooperation. Second, a lack of shared language around innovation and skills development was also mentioned as a hindrance to successful communication. Finally, SME owners' lack of time and hectic schedule was also named as a challenge in SME and public sector collaboration. However, despite these challenges, the interviewed stakeholders also had positive experiences and great partnership with some SMEs in the sector, which they shared during the interviews.

In general, stakeholders view SMEs as being reactive when it comes to innovation and only taking action when their customers request so. This is in line with Iacovou *et al*. (1995)'s findings on the drivers of technology adoption in SMEs, stating that the most influential external pressure for SME's technology adoption comes from customers and trading partners. However, the stakeholders did not name the lack of funding as the number one cause for such behaviour, as European Commission data would suggest (Muller *et al.*, 2019). Rather, they believe that the root cause of the problem is an overall short-termist view, which stems from a lack of time and human resources in the companies. As Stakeholder 12 put it:

"People are often very busy working in their business, but they don't necessarily have the time working on their business. They're not necessarily thinking about strategy." *(Stakeholder 12)*

A couple of stakeholders phrased it as SMEs tend to live a hand-to-mouth, month-to-month existence, where they are under so much pressure from day-to-day activities that they do not have time for strategic planning that is required for technology adoption and skills development. This finding is also in line with the literature (Nolan and Garavan, 2016; Kurochkina *et al.*, 2019; Idris, *et al.*, 2020; Harney and Alkhalaf, 2021), which argues that one of the most common barriers to both technology adoption and skills development in SMEs is the lack of strategic planning, which originates from the lack of time resources on the owner-managers' part.

Another barrier to skills development that was mentioned during the stakeholder interviews was related to work organisation. As Stakeholder 3 argues, organisations have become leaner over the last couple of decades, which resulted in a reduced number of workers in organisations. This led to a situation, where companies are unable to send their staff away on to training due to a lack of temporary cover for them.

"What we've seen over the past decade is as organisations have become leaner and leaner in terms of less and less people. There is less and less flexibility in the system to actually spend time upskilling, reskilling, or learning about new things. And when you put that then together with the rate of change that is happening, it's very difficult for people to spend the little time they have on some things that are actually meaningful." *(Stakeholder 1)*

This above quote illustrates how much influence work organisation can have on skills development in SMEs. Due to the small number of employees in SMEs, individual workers often have multiple roles and responsibilities in these organisations, which makes substitution challenging, which can hinder skills development activities (Nolan and Garavan, 2016; Kindström *et al*., 2020). The lack of skills has also been named as one of the key barriers to technology adoption by some stakeholders during the interviews, which shows the complex interplay between skills, technology and work organisation. In this above example, the work organisation leads to a lack of skills development, which consequently can impede successful technology adoption chances in companies.

The interviewed stakeholders also claimed that a lack of knowledge about new technological capabilities and innovations can make SMEs less likely to engage in technological innovations. This issue is related to the limited time capacity that SME's owner-managers often struggle with.

4.6 Conclusion

To summarise, this chapter introduced Scottish manufacturing sector, which is the context of the four case study organisations. First, the chapter discussed the various global and national level factors that shape the sector's skill landscape and organisations' opportunities and decisions around skills utilisation and technology adoption. As section 4.2 discussed, the key factors included the ageing demographic, which along with historical underfunding, created a skill gap in the sector, which was further deepened during the Covid-19 pandemic. However, despite the challenges that the sector faces due to the ageing demographic, Covid-19 and Brexit, the participating stakeholders were optimistic about the sector's future.

Section 4.3 discussed the participants' views on the sector's future skills requirements. From a skills level perspective, they believed that a general upskilling will be observable in the future, where workers will require transferable skills, such as logical order-thinking, problem-solving, adaptability, flexibility and creativity. As the next chapters of the case study findings show, this was in line with the case organisations' experience. In addition, stakeholder participants also believed that digital skills will play a key role in the sector's future due to the ever-increasing technological advancements.

As for the technology uptake amongst the sector's SMEs, stakeholders believed that technology uptake was polarised amongst SMEs. Misconception around the complexity of technologies and potential labour replacement effects, resistant attitude due to sectoral heritage, and lack of financial resources were claimed to be the most significant barrier to technology adoption in the hesitant SMEs. As section 4.5 showed, the research participants believed that SME's organisational characteristics, for example the lack of strategic planning and limited resources, have the potential to create challenges to these organisations when it comes to technology adoption and skills development in general. However, some SME characteristics, such as the organisations' flexibility and adaptability, are beneficial when it comes to adopting to changes. To better understand the interplay of technologies and skills at an organisation-level, this research explores technology adoption and related skills utilisation changes in four manufacturing SMEs. The next chapters discuss the findings of these case studies.

CHAPTER 5: CASE STUDY - MotorCo

5.1 Introduction

The fifth chapter introduces the findings from the case organisation MotorCo. This case study represents the adoption of a management system that transformed the way production is organised in the company.

The chapter starts with a brief introduction of the new management system technology and discusses its current use in the organisation. Section 5.3 outlines the mutually reinforcing relationship between the management system and the management, work organisation, roles and responsibilities in the company. Section 5.4 then moves onto discussing the skills implications of the changes that the new technology brought to MotorCo. Finally, section 5.5 summarises the main findings from the case study.

5.2 Technology adopted

5.2.1 Enterprise Resources Planning system

MotorCo adopted an Enterprise Resource Planning (ERP) system in 2015, which is a management software system that integrates several data sources and processes into one unified system. The ERP system helps to store, retrieve and share information on any aspects of an organisation's operation in real time. ERP systems have been in use for around two decades in the manufacturing sector, and therefore, may not be classed as 'new' technology. However, for small and medium enterprises, who are at the beginning of their technology journey, ERP systems are often the first significant technology investment that can transform tasks, work organisation and skills in the organisation. Indeed, the ERP system brought a significant change to most aspects of MotorCo – it transformed its management, rearranged roles and tasks in the company, and changed the organisation of production processes. The next section outlines the technology's current use in the organisation, which helps to answer the first research question of the research – how the new technology adoption affects job tasks, and consequently their skill requirements, in the organisation.

5.2.2 Technology journey

Customer enquiries

The use of the ERP system starts at the stage of customer enquiries in MotorCo's office. The first step of the process is an administrative task, where the Administration Lead of the company needs to key customer enquiries into the system. Prior to the implementation of the ERP system, this routine cognitive task was carried out on paper, which was more time-consuming and produced only paper copies of data. From the Admin Lead's perspective, the nature of the task itself and the responsibility of the task did not change with the implementation. As illustrated by the participant:

> *"I would say it's* [the job] *pretty much the same, just a different format."*
>
> *(Admin Lead)*

This information processing is followed by a decision-making process executed by the directors of the company – to decide whether the customer enquiries will be quoted or not. In this process technology is only used for retrieving information on the customer enquiries. Based on the information, the directors make their decisions whether to proceed with the enquiry further. In this decision-making process, the human element is dominant, and technology only plays a complementing role by retrieving information on the given enquiry.

Quoting and pricing

The next steps in the customer enquiry process are quoting and pricing. The efforts going into the quoting process vary depending on the nature of the job. The quoting and the pricing processes both heavily rely on the use of the ERP system. Both of these processes required initial set-up before the ERP implementation – the work centres, processes, materials and subcontractors used by the company had to be added to the system. After this initial set-up, however, the ERP system significantly sped up these processes.

For the quoting, the engineering team produces a general job routing by adding the materials, work processes and any potential subcontract jobs that the job may require. Based on the research participants' detailed accounts, this quoting process can be classed as a non-routine cognitive task, which requires an understanding of basic engineering principles, technical skills, the knowledge of work processes in the company, and some computer skills to carry out the process in the ERP system. Prior to the ERP implementation, the quoting process was paper-based and contained less detailed instructions concerning the production processes, but it followed the same principles.

The pricing process also changed with the introduction of the ERP system. As above mentioned, all of the work processes and materials are saved onto the system. Their associated costs were also added to the ERP system. Based on the quoted processes and materials, the ERP system automatically generates an estimated price to the quote. Engineers can override this suggested price if they see fit or if their experience suggest otherwise. But in general, the costing of jobs is automated in the company. According to the Managing Director, job costing is an area of the business that has seen a highly significant changes over the years, since there used to be a designated price estimator in the company, whose job solely consisted of estimating the price of jobs based on experience. This information processing task is now almost fully automated in the company, which illustrates the gradual disappearance of jobs mostly consisting of middle-skilled routine tasks that can be easily automated with enough information fed into a computer programme. Furthermore, as it will be discussed later, the ERP system allows the monitoring of how jobs perform financially, which helps the company to continually review their costing and job hours added at the quoting stage. This helps the company to closely monitor its financial performance in real-time and ensure accurate pricing at the customer enquiry stage, which is one of the main benefits of the new ERP system according to the Managing Director of the company.

Sales order

If the customer accepts the quote and orders the job from the company, the Admin Lead creates a sales order for the job on the ERP system. This sales order includes a sales number for identification purposes, the quote created by MotorCo and customer's details. The creation of the sales order can also be classed as a routine cognitive task, similarly to the customer enquiry stage detailed above, performed by the Admin Lead. Moreover, this sales order pack demonstrates a more standardized way of information recording and storing in the company, which shows that change in work organization also happened in the company simultaneously to the ERP implementation. This is discussed in more details later in the chapter.

Contract review

Once the sales order is created, it moves onto contract review. The purpose of the contract review is to prepare the jobs for going out to the workshop by creating a routing for the part including details on the production, assigned work processes, machines, methods of manufacture, materials with preferred suppliers, planned timescale for production, subcontractor processes, drawings and any special requirements that the engineer team might want to add for the machine operators in the workshop. Some of this routing is built at the quoting stage, but it gets finalised and more detailed during the contract review process. All of the above-mentioned stages of production are recorded on the ERP system. Once this contract review is carried out, a work order gets created with the above information, which then gets printed out and handed to the workers in the workshop with any additional documents such as drawings and notes.

This contract review is carried out by the engineering team in the company and according to the engineering director, it requires the following skills and capabilities: *technical skills* - including a basic understanding of engineering principles, gear geometry, machine knowledge; *sense-making;* and *common-sense*. On top of these cognitive skills, the need for *communication skills*, attention to detail, being organised and accurate were highlighted as well, along with *cooperation* and the importance of personality when it comes to working in a small engineering team. Finally, the engineering director claimed that experience is imperative when it comes to contract review, which suggests a preference for work-based learning in the company. He stated:

> *"We can't just employ somebody, even with an engineering degree, to come in and expect them to have the amount of knowledge into gear manufacturing."*
>
> *(Engineering Director)*

As for the human and technology interaction in the process, the ERP system is used for recording all the important data and information listed above; but the technology does not make decisions in the contract review process, it only complements engineers in the non-routine cognitive tasks that contract review entails. The software aids the process by storing all the relevant data in one place, and integrates all the stages of contract review on one dashboard, including subcontracting, material ordering, drawings, etc. This makes the contract review more efficient, transparent, and accurate, according to the directors of the company and the research participant from the engineering team. Prior to the implementation of the software, contract review was paper-based, did not involve the creation of a route card, and resulted in cluttered paper files of instructions. The introduction of route-cards, which happened simultaneously to the ERP adoption, further illustrates the changes in work organisation in the company towards a more standardized way of working.

Production

Once the full work order has been created through the contract review, the work order gets printed and handed over to the Production Controller. The production controller's responsibilities include administering goods coming in and out of the workshop, managing customer queries around production, dealing with purchase orders for materials and subcontractors, and monitoring production processes and workers' workload, and ensuring that the work centres in the workshop are set up properly. The ERP system forms an integral part in the production controller's job, as he organises his tasks by using the real-time information and the various reports on the system. In this job role, technology plays a complementary role to the various non-routine cognitive and manual tasks by providing relevant information for every step of the production process. While the technology could create job lists based on real-time information, the software does not take into consideration workers' workload and work-space set up. Therefore, it still requires some human regulation.

As for the workers in the workshop, their main tasks did not change with the introduction of the new technology, as they are still machine operators carrying out routine and non-routine manual tasks. Their interaction with the ERP system is, however, important from an administrative point of view. Workers record their working hours on the system by logging on at the start of working and logging off once they are finished with the given job. This shopfloor data capture allows directors of the company to monitor the time spent on each job, which helps them in financial planning; but it also gives them the opportunity to monitor workers' performance. This latter was not reported by any of the participants of this research that the ERP system would be used for this purpose in MotorCo, but the technology gives the opportunity to directors to do if they wish to. The shopfloor data capture is also used for recording time and attendance in the company.

As the above discussion shows, the ERP underpins every business function in the organisation with the exception of accounting. The company uses a separate finance software for accounting purposes, which is linked to the ERP system, but it is not part of it. According to the Managing Director, this set up suits the company and they are not planning to change it in the near future. Their External Consultant, however, pointed out some weaknesses of this arrangement when it came to integrating financial projections and financial data.

5.3 Technology and Work Organisation

The previous section showed how the new ERP system changed some of the tasks in MotorCo. The software, however, not only transformed tasks in the company, but the way work is organised, too. This section discusses the ERP system's effects on work organisation in the company. As one of the directors said:

> *"*[The ERP software] *is a package basically off the shelf, it kind of forced us to adopt a little bit in certain ways of doing things"* *(Engineering Director)*

One of the most striking differences that the ERP system made was in the way production is managed in the company. Prior to the management system adoption, directors were heavily involved in production control. There used to be a daily meeting, lasting one to two hours, where all the ongoing projects were discussed, daily tasks were decided on and got delegated. This was not only time consuming, but also inefficient. Plans and production priorities tend to change at a relatively short space of time in the company; therefore, the action points set during the daily meetings oftentimes became redundant within a matter of hours. Another issue with the management prior to the ERP system was a conflict of interest regarding production priorities. Each director had assigned customers to them, and each prioritized their own. This meant that workers in the workshop often got conflicting instructions about which job to work on. As one participant stated:

> *"What would happen was, you would come into the office and you would ask basically one of the directors to ask what job you should be working on next. So for example, you could go to one director and say 'what job should be doing?' and he would say 'do this' for example. Turn that shaft. And then one of the other directors would come in and say 'why are you doing that? You should be doing this.' So there was that conflict. I suppose it depended on what customers on the phone shout the loudest."* *(Engineer, MotorCo)*

This above quote clearly illustrates the inconsistency that used to characterize production management in MotorCo. According to the respondents, this inconsistency created a stressful atmosphere in the workshop and often left workers confused. Overall, this old system was disadvantageous not only for managers, whose time was mostly spent on the running of production as opposed to more strategic activities; but it also created an unpleasant working environment for workers in the workshop. Changing the inconsistency in production management was a key driver for adopting the ERP system.

The introduction of the ERP system meant that all customer orders were managed in one unified system in a consistent manner. Similarly to the use of route cards and improved record keeping, colleting all the jobs in one system also points toward a more standardized way of working in MotorCo. As the software keeps live information on all the jobs in the company and shows deadlines, next steps, designated work centres and progress on them, there is no need for managers to micromanage productions. The daily meetings are not required anymore, and the majority of the day-to-day running of the workshop is now in the hand of the Production Controller. By helping streamlining the organisation of production processes in the company and drawing clear boundaries around responsibilities and control, the new ERP system enabled MotorCo to reorganise its organisational structure. However, the new technology was not the sole driver for these changes, rather an enabler in the process.

The transformation of the Production Controller's job role also demonstrates the changes that the ERP implementation brought to work organisation in MotorCo. Prior to the implementation, his job role was moving materials from one work-station to another either manually or by using the forklift machine. He received his daily job list at the daily meetings, where he wrote a list in his notepad. If he had any questions regarding the jobs, or deliveries and deadlines, he needed to go into the office and ask one of the directors or the Admin Lead, who was in charge of handling the deliveries. The drawback of this set-up was that production activities were not a priority to office staff; therefore, he often could not solve small arising issues in a timely manner.

With the introduction of the new technology, the workshop labourer had his responsibilities significantly expanded, and he got promoted a Production Controller. His new role still included moving materials between work-stations; but he was now also responsible for delegating tasks in the workshop based on the information provided by the ERP system; dealing with customers enquiries and subcontractors; and managing deliveries. The creation of a Production Controller role meant that all the production-related activities in the company were brought together into one unified role, physically based in the workshop. All of these production activities, such as customer service, subcontractor and delivery management, were all present in the organisation prior to the ERP introduction, but the tasks were carried out by others in the company. For example, directors used to keep in contact with customers, while the Admin Lead used to be responsible for arranging deliveries. As the Production Controller noted, he felt guilty in the beginning that he was taking away the Admin Lead's job:

> *"So at the beginning it was 'oh no, I'm taking a lot of work away from* [Admin Lead]*"*
>
> *(Production Controller, MotorCo)*

This initial worry represents the fear of job replacement due to the introduction of a new technology. This particular replacement would have happened due to work reorganisation thanks to technology introduction, therefore it would be classed as an indirect technology-driven change. However, the transfer of responsibilities did not lead to job obsolescence. Each relevant participants of this study, whose job role was affected by the reorganisation of roles and responsibilities reported that at first the changes were somewhat challenging, but once they had some experience with the new set up, the new roles made more sense, and it led to a more efficient way of running the business. Overall, these changes meant that the day-to-day decision-making regarding production has been moved down from directors towards the workers in the organisation.

By not having directors micromanaging the production, workers in the workshop had more autonomy over their job lists. With the help of the new ERP system, they were able to see two or three of their upcoming jobs on the screen and based on their own judgement and set up at their workstation, they could decide, to some extent, the order of the jobs they will be working on. Compared to being used to told what to do, this increased level of autonomy required some adjustments from the workers, especially from the older workers. However, they admittedly enjoyed the increased control over their job lists, and they said that by seeing all the information on the screens, they felt more involved in the organisation. As this shows, the transformation of management in the company, which resulted in increased worker autonomy, shifted the company culture towards a more organised and empowered model as opposed to the previous top-down culture with low levels of worker autonomy.

As a result of pushing down more autonomy and decision-making towards workers and letting go of the everyday running of production, the managers in the company had more time to engage in strategic activities in the company. As the External Consultant and the Managing Director of MotorCo stated during the interviews, the ERP system was imperative to these activities. By capturing data on labour hours, production activities and monitoring real-time performance of the company, the software helped directors in the company with financial planning and identifying bottlenecks in the production system and finding solutions to them. MotorCo's commitment to ongoing development was also reflected it their continuing collaboration with the External Consultant that helped them in the initial ERP adoption. Moreover, the software itself was also under constant revision to see if it still fits the company's needs. At the time of the study, MotorCo was planning an update to their ERP system to unlock even more potentials of this form of technology by moving to a newer version of the software.

Overall, the ERP system's introduction influenced the way work was organised in the company. Job roles needed to be revisited and updated to best align the business processes with the new software, and to be able to harvest its efficiency benefits. Considering the changes to job tasks introduced in section 5.2, and the changes to work organisation discussed in section 5.3, the skills utilisation of some workers in the company changed after the adoption of the new technology. These skills changes are discussed in the next section.

5.4 Skills changes

5.4.1 Directors

The directors of MotorCo were highly involved in the day-to-day running of the company before the implementation of the ERP system. They delegated tasks amongst workers in the workshop and kept in contact with the customers. This meant that they did not have enough headroom for more strategic activities that would drive continuous improvement in the company. For this change, the directors needed to trust their workers to take on the additional responsibilities. From a skills perspective, this shift led to more engagement in non-routine cognitive tasks for more strategic activities, as opposed to the mundane, routine cognitive tasks that the everyday running of the company demanded. According to research participants, the directors' role included strategic activities prior to the software adoption too, but they did not have the opportunity to engage in them often due to the time constraints of micro-managing everyday production. With the introduction of the new ERP system, therefore, the skill requirements of the directors' job role did not change, but the extent to which they utilised their pre-existing skills did.

The External Consultant of the company added that ERP systems merely facilitate people to be as good as they are, meaning that if they had poor management and planning skills, the technology would only highlight that, not change it. He also emphasized the importance of robust leadership skills needed for successful technology adoption and further continuous development in any organisations. These claims were evident in the case study of MotorCo, where the Managing Director played a key role during the adoption of the technology and was crucial to the implementation process and the upskilling of the employees.

> *"If you take the* [Managing Director] *out of* [MotorCo]*, I'm not sure what they would have achieved. The ERP system is merely there as a facilitator for* [Managing Director]*. Without the ERP system, the* [Managing Director] *wouldn't have achieved*

what he's achieved. Without [Managing Director]*, the ERP system wouldn't have achieved what it's achieved. Both are as important as the other. And without either one, you're not going to succeed."* *(External Consultant, MotorCo)*

This above quote illustrates the importance of good leadership during technology adoption. Furthermore, it also highlights how imperative humans are to the success of any companies. As discussed in the Literature Review chapter, technological determinism theory can often over-emphasize the role of technology in workplaces and argues that humans have limited influence over changes to their jobs. The evidence from this case study, however, is more in line with the social shaping of technology approach, which recognizes the imperative role that humans play in organisations, even in the face of technology adoption. This was strongly evident in this case study, where multiple participants agreed on the importance of the new technology but claimed that it is the interaction of humans and technology what makes a real difference, as opposed to the software alone.

> *"I've always said, it doesn't run the business for you. It's a tool that enables you to run the business better. So you still need people performing the key functions, but performing those functions with the ability to take advantage of the benefits of the ERP system."* *(Managing Director, MotorCo)*

> *"I think we've got balance between the technology side of things and then the people side of things. We can benefit from both, so yeah, it's a success, it's a good tool. It's just not the complete answer. You still need to have that human input. […] So we've got staff who are familiar with the older approach and then we've got guys, who are very good at the software, so the two we've got together to combine our skills, to come up with our approach, it works for us."*
> *(Engineering Director, MotorCo)*

Following on from the last quote, only the effective combination of human and technology skills can unlock the benefits of technology implementation,

> *"Because with anything like that, the quality of the output pretty much depending on the quality of the input."* *(Managing Director, MotorCo)*

5.4.2 Administrative staff

For the administrative staff in the office, harvesting the benefits of the new management system did not require additional new skills. As described in Section 5.2.2, the office staff's interaction with the technology is limited to routine cognitive tasks, similar to the same skills they needed for carrying out the same processes on paper. According to the Admin Lead, the shift from paper-based system to a computer-one did not change the skill requirements of job, but the extent to which the administrative staff utilised their pre-existing skills did. The change of platform in these tasks increased the extent to which admin staff utilised their basic computer skills, such as data entry, which was already part of their roles before the implementation.

5.4.3 Engineering team

The engineering team also experienced some skills changes to their roles due to the technology adoption. As outlined above, the ERP system is used for data recording and information sharing purposes throughout the contract review process. Here, the technology complements human input into the non-routine cognitive tasks, where basic engineering principles and technical skills are still paramount. The introduction of the ERP system required additional software knowledge from engineers, and some basic computer skills. The team, however, uses a range of other engineering software, so they already had and used basic computing skills as part of their everyday job, prior to the ERP implementation.

The changes to their tasks and consequently, skills utilisation, came from the reorganisation of tasks in the department due to the new technology. The introduction of the ERP system led to more distinct roles in the engineering department. One engineer specialized in project engineering, one in wielding, one in programming and the fourth one in coating. Prior to the software adoption, *"it was more the case of you did a bit of everything"* (Engineering Director). However, before the technology implementation, the directors in the business conducted a review of the main functions and processes in the business and came to the conclusion that:

> *"We then realized to make the best use of the ERP system, it would be more efficient to have people with more defined roles within the business. Because it wasn't realistic to expect everyone to be able to use the whole of this ERP system. It was much more realistic to expect people to have specific things to learn very well how to use one part of that. So what you find is, depending on what the guys' role is, they become very very good at making use of one aspect of the ERP system to help them with their jobs."* *(Engineering Director, MotorCo)*

This example is in line with the literature on management systems, which argues that these technologies have a specialising effect. With the creation of these clearly defined roles, workers' tasks might get narrower and more standardized. Considering the deskilling theory, this means that workers will end up using less skills as a result of having more strictly defined roles. In MotorCo's engineering team, however, this task specialization did not result in deskilling. By moving from more generalised roles, the specialization meant that workers had to master more specific, more technical skills than before. Therefore, it can be argued that tasks specialisation led to the development of skills in this case.

5.4.4 Production team

The production team in the company also experienced skills utilisation changes after the introduction of the new technology. From a skills perspective, the technology-driven changes required the most adjustment from the Production Controller. Prior to the technology adoption, his job included non-routine manual tasks, which required some technical skills, for using the forklift and moving materials in the workshop. The expansion of his role into a Production Controller meant that his job now includes non-routine cognitive tasks, too, and therefore serves as an example for upskilling of the job. For the new tasks, the Production Controller needed to gain computer skills to use the ERP system; written and verbal communication skills to manage customer queries; leadership skills to delegate production tasks amongst machine operators; and decision-making to successfully organise production schedules. The production controller's personal journey clearly illustrates a significant upskilling effect, both upskilling of the job and the person. However, it is important to highlight that these tasks and the required skills were not a direct consequence of the technology adoption, as they were present in the company before the ERP introduction. Rather, they were the outcome of the change in work organisation in the company, which came hand in hand with the implementation of the new management system.

The workshop workers needed to gain computer skills, as they did not use computers as part of their duties prior to the ERP adoption. According to the research participants, the workers had these skills before, since they needed them in their everyday life. Therefore, it can be argued that the extent to which they utilised their pre-existing skills has changed, not their skills set. However, because their job roles did not require these skills before, it can be argued that these changes led to an upskilling effect on the job, but not on the individuals. The way workers are managed, and consequently, their level of autonomy has also changed with the introduction of this technology. By having some control over the order in which they complete their tasks, workshop workers now exercise decision-making using judgement based on their work experience. Therefore, overall, the adoption of the management system changed the machine operators' skills utilisation in the workshop and it enabled them to have more ownership over their tasks.

To summarise, various skills changes could be observed in MotorCo due to the ERP system implementation. Some skill changes were technical, where employees of the company needed to gain more specialist skills. For example, workshop workers had to develop basic computer skills. Other type of skills changes were more closely related to organisational issues and were imperative to the successful implementation of the ERP system, such as good leadership skills from management. Finally, some workers needed to adjust their skill sets to respond to changes in the work organisation caused by the new technology. For instance, the Production Controller's new job role included customer interaction, for which he needed to develop good communication skills; whilst machine operators needed to develop decision-making skills due to their increased authority. Overall, this case study showed that new technologies can change skills utilisation of employees in order to use the new technology, or to adjust to the work organisation changes that could be observed in the company after technology adoption. Therefore, the understanding of the skills changes caused by new technology adoption requires an in-depth view on organisations, which takes into consideration the organisational context and changes within it.

5.5 Conclusion

The case study of MotorCo illustrated the adoption of a management system technology, which had significant effects on work organisation in the company. The software reshuffled some roles and responsibilities in the company - it enabled directors to step away from the day-to-day running of the production and pushed more responsibilities onto workers. The reorganisation resulted in the creation of the Production Controller role, bringing together all the production related activities into one unified role. The ERP adoption also led to a more standardized way of working, improved record keeping and better transparency across the organisation. From a task perspective, the new software did not reduce the importance of human input; rather complementing workers in the execution of their tasks, not replacing them. From a skills perspective, the new technology brought three types of skills changes to MotorCo – skills changes related to the use of the new technology; skills changes required for the successful implementation of the technology; and skills changes needed for adopting to the change in roles thanks to the technology-driven work reorganisation in the company. Overall, this case study highlighted that the adoption of a new management system did not only change employees' skills utilisation by changing job tasks; but also by transforming work organisation and rearranging roles and responsibilities in the company.

CHAPTER 6: CASE STUDY - FixShop

6.1 Introduction

This chapter introduces findings from the second case study of the research, carried out in the case organisation FixShop. FixShop is an engineering workshop with ten employees in total. The case study involved interviews with the Owner-manager of the company, and two workshop employees. This case represents the adoption of a job recording tool, which can be classed as an embryonic management system, designed to suit the needs of micro-organisations that are taking their first step on their digital journey. The uniqueness of this case lies in its insight into the technology development process, as the adopted technology was designed by the Owner-manager of FixShop.

The chapter starts with a brief introduction to the adopted technology, its use in the organisation, and its main benefits in section 6.2. Section 6.3 then outlines the way the new technology and work organisation interact with each other in the company, and the consequent changes on management and responsibilities. The penultimate section discusses findings relating to skill utilisation in FixShop. Finally, section 6.5 concludes the main findings from the case study.

6.2 Technology adopted

6.2.1 Job recording tool

FixShop adopted a job recording application, which captures, stores and organises pictures and notes of jobs in the company. The visual recording of the jobs and the attached notes create a searchable, shareable real-time data base on ongoing projects in the organisation, which improves traceability across the organisation and visibility for every employee. The technology itself is based on the idea of providing a '*photo album for work'* (Owner-manager/Technology developer, FixShop), and purposefully keeping a simple design as its main appeal to other non-tech savvy micro businesses. As the Technology developer/Owner manager of FixShop explained:

> *"So we've got this huge market that is using email, paper notes, WhatsApp text message and 'who said what' being memorized, and photo albums. And we're*

> *taking all the things they do there, shoving it to one solution and packaging it up so that it's self-serving."* (Technology Developer, FixShop)

The basic premise of the technology admittedly resembles management systems, but by stripping away the inherent complexities of management system software, this application was designed and developed around micro businesses' needs in a bottom-up approach. This contrasts with management system solutions, where the software solution is designed first and then the implementing business later aligned at adoption. As illustrated below:

> *"[Bought-in job management software] says it will do everything for you and you have to do it in that way for everything to work. So you've got to make the conscious decision that you're going to tell everyone in your organisation 'Look, stop everyone. From today, all that's in the bin. We are using this and that's the way it is. And if it's a pain, we're going to work through it. But it'll be better in the long run."*
> (Technology developer, FixShop)

Whilst companies with more than 20 employees may benefit from the numerous features of management software, as seen in the case of MotorCo; smaller organisations, who are at the beginning of their technology journey, might be discouraged by the complexities of such software solutions, as the example of FixShop shows. This application adopted by FixShop offers a bridge for smaller companies to leave the '*tech-less Stone Age to become reasonably techy*' (Owner-manager/Technology developer at FixShop).

> *"So if we are going to succeed, we have to move to a complete opposite direction from job management as it exists right now. […] We want to take all the features out, because for people in* [FixShop] *or sole traders or whoever, what they want is just to be able to record their jobs in a searchable way."*
> (Technology developer, FixShop)

The above discussion suggests that organisational size and the pre-existing technological context of the business can have an impact on organisation - technology fit, which illustrates the influential role of the organisational context in technology adoption. This is discussed in more detail in Chapter Nine.

6.2.2 Technology journey

Administration

The interaction with the job recording application starts at the beginning of the repair journey. When the customers come into the workshop and hand over the mendable part, a job order gets created. This administrative task involves recording the customer's details, and notes on the particular part – dimensions, what needs to be fixed and instructions. The recording of these details happens on paper in a traditional job book, located at the customer service desk at the entrance, and on colour- coded T-cards (index cards that include the details and instructions of a given job) (see Figure 6.1. below).

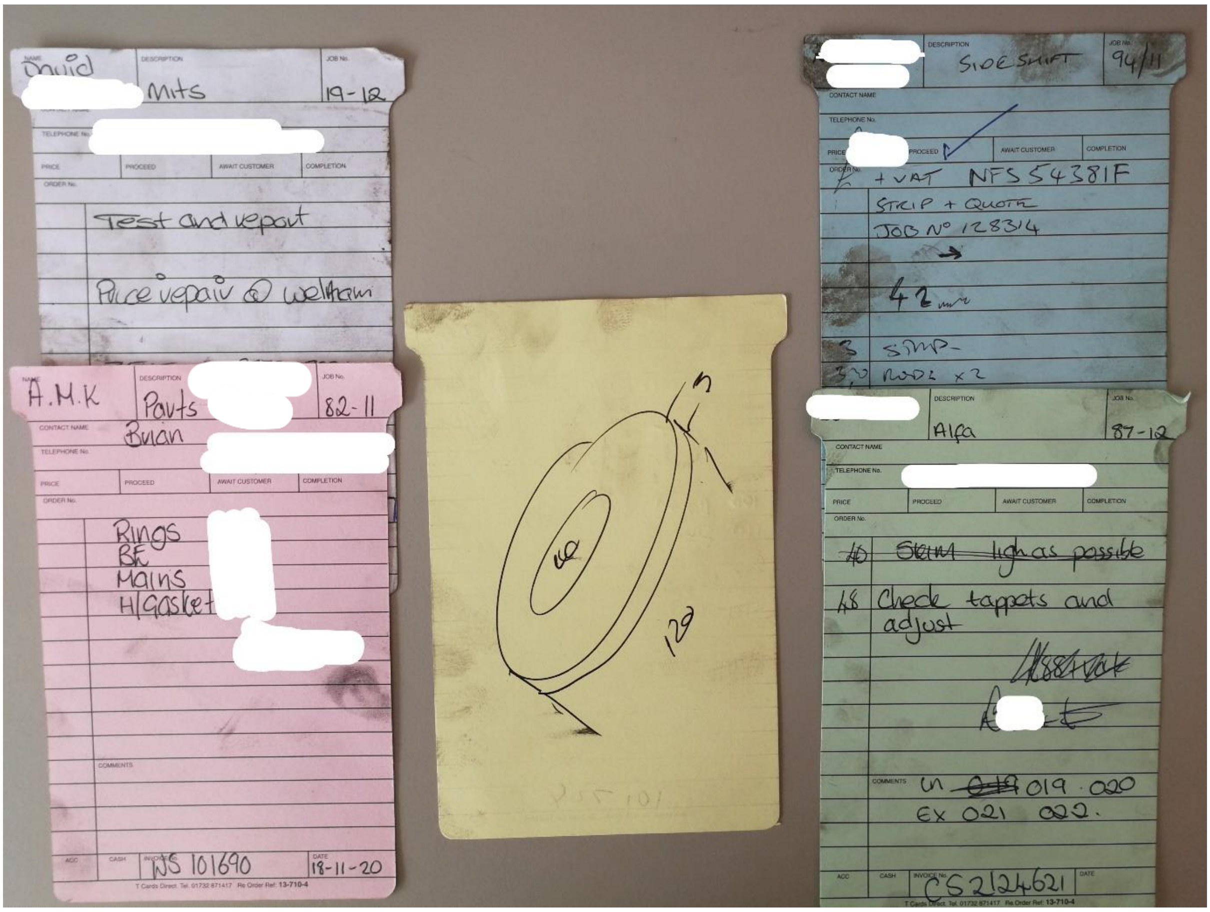


Figure 6.1: T-cards

As Figure 6.1 above shows, the T-cards occasionally include drawings with dimensions of the parts. However, as participants noted during the interviews, these hand-written notes and drawings are often open to misinterpretation, which can lead to confusion in the workshop. As well as recording the details on paper, employees create a job profile on the app too, using their mobile phones. The main benefit of using this app is that it allows taking pictures of the parts and adding notes to them. According to the research participants, the visual recording of jobs is incredibly useful for engineering companies, as it eliminates the misunderstanding stemming from misinterpretation of drawings and handwritten notes; and it also helps with customer relations, which are discussed later in this section. As one of the employees described it:

> *"We get a lot of different things that people may haven't seen before so we take pictures and we upload them onto the* [app] *and then we can use it as a reference if we're going to build something back together. We go 'oh where did this bit go?'. We can look at the picture there in the* [app]*. We can go back and look over. It also helps, everybody knows when jobs are finished and what jobs are not finished. You can just open up the app and say 'ok that job's finished'. So when there's a customer in, looking for this job and then you can go say 'OK, it's finished' and then you can go and look up the job and give it to them. It's really, really handy for backing the things and the fact it's got all the pictures, all the bits and bobs you can look at as well for the jobs. It's good."* *(Employee 1, FixShop)*

Overall, the nature of the routine administrative task of recording job details has stayed the same with the introduction of the app, as it still requires workers to document measurements of parts and instructions for repair tasks, albeit in a digital format. However, since the app enables and encourages more detailed record keeping complemented by visual data, it can be argued that the implementation of the app increased the extent to which workers utilise their information processing skills, where they translate measurements and instructions into written format.

Task delegation

Once the paper T-cards are created, they get transferred to the job board in the workshop (see Figure 6.2 below). This job board is used to track the progress of each job is in the workshop. The tasks get allocated using this board, where each employee has a designated slot. Every piece of information that is on the board is also updated onto the mobile app. The board, however, acts as a visual tool for the Owner-manager and the workers of the company to give an instant update of how busy the workshop is and at what stage each job is at.

> *"It's* [job board] *just a very, very easy way to provide even subconsciously a lot of information about what's going on at any given moment. I can literally glance at that and know what's going on, generally speaking. There is a point where you have to say that pen and paper will always be the most sensible solution to a problem."* *(Owner-manager, FixShop)*

Figure 6.2: Job board

The Owner-manager of the company admittedly considered designing the job recording app in a way that it can visualize this job board. However, there was no solution found for this, and it is where the line had to be drawn at which digitalisation provided no further benefit to the company. As the Owner-manager said:

> *"And there is no need for everything to be digitised. […] And people do see job management* [software] *trying to get rid of these boards and get rid of the paper book on the desk and get rid of the notes on your desk and all the rest of it. But the truth is that it won't disappear. And it should only disappear if you can find something that is a multiple better. You know, don't just change it for the sake of it."* *(Owner-manager, FixShop)*

Whilst the use of the old job board for task delegation and providing updates on the workshop's workload is effective in FixShop, this might not be the case for slightly bigger organisations. This reinforces the point that micro businesses and small and medium sized businesses may have different levels of complexity when it comes to job management, therefore, different technology requirements, too. This illustrates the influential role that organisational size can play in technology adoption.

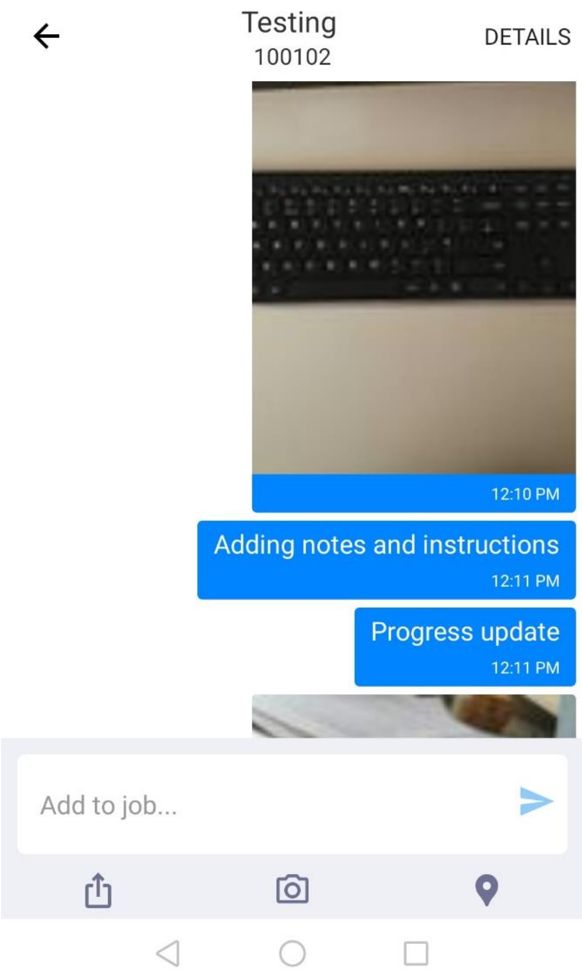
The example of the use of the new app and the old job board illustrates the parallel use of traditional paper-based methods and digitalised technological solutions. Here, whilst technology has been introduced into the process by complementing the information on the physical job cards with visual data and more detailed instructions, task delegation is still predominantly paper-based in the company, and the decisions around task delegation are made based on the information given by the job board.

> *"What order they'll do it* [jobs] *in is based still on the old system of T-cards going in their board. We can say anything we like in [the app], but the cards going in their slot dictates that they're their jobs, and ideally in order on the board of what to do."*
>
> *(Owner-manager, FixShop)*

Workshop activities

Workers in the workshop argued that they rely more on the information given by the job recording app, than the T-cards on the job board. Whilst the main tasks of the workers, which are still repairing and reconditioning parts, did not change with the introduction of the new app; they use the recording app in a complementary way during their work in the following way: they take regular photos of their progress, and they add notes and updates on what they have done to the part, including various measurements and dimensions (for the app layout, see Figure 6.3 and 6.4 below). As one of the workshop employees stated, they use the photos on the app as reference points during their work for building parts back together. Therefore, the app helps employees by providing visual information to them during the repair process, which was not available to them prior to the technology adoption.

As Figure 6.4 shows, the app also aids teamworking in the workshop. Multiple team members can be added to a given job, and they can see each others' update and notes along the way. Moreover, subcontractors can also be added to each job books, which makes communication with them easier. Here, the app serves as a platform for communication across the workshop, which complements the dominant verbal communication in the company with more written communication amongst staff.



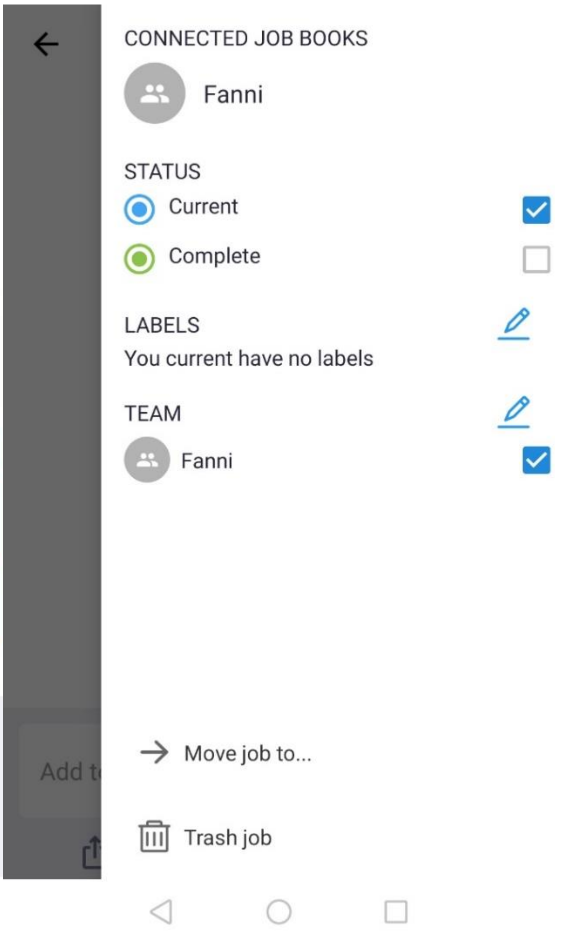


Figure 6. 3: Job recording app 1

Figure 6.4: Job recording app 2

The job recording app also helps workers in contacting customers, as it provides a direct line to them, and workers can contact customers or answer customer queries without involving their manager in the process.

> *"It's ideal, because you can send a message to a customer, keep the customer noticed all the time. So that was a great help in the organisation and doing the whole jobs, too. Because sometimes you were doing things and then you would have to phone the customer, wait for them to phone you back, because you usually couldn't get them. Now there's that direct line. Everybody's got a mobile phone, that's the thing. If they have the phone, it's great that way. It's ideal. It has solved a lot of the organisational problems."* *(Employee 2, FixShop)*

Prior to the introduction of the app, workers did not have access to customer communication channels, therefore, customers had to be contacted with the help of the manager. The move from the old system to the new one has significant efficiency benefits for workers and customers – as they can resolve arising issues more quickly and efficiently with the help of visual evidence; and for the manager, too, since he does not need to be as closely involved in the day-to-day queries of the workshop. As participants described the benefits of the change:

> *"It used to be where jobs were basically put aside, because you couldn't speak to a customer. So the job could sit for a week or two and then the customer goes on saying 'why didn't you contact?'. But if you're busy, it's not the easiest thing just to go and contact a customer. But now, if you're going to the next job, you're going on to the* [app]*, just drop them the job and contact the customer if you got a problem with the job. So it's easier that way. And you also don't have to go to [the manager] and say 'could you go and contact this customer?'. You just do it yourself."*
>
> *(Employee 2, FixShop)*

Overall, the new technology complements the workers' job, by providing them with the necessary information to aid their engineering tasks and helps them to accurately record their progress and the details of their jobs.

Customer after-care

Once the job is finished, workers can mark the job on the app as 'complete' (see Figure 6.4), and a job report gets created, which will then be sent to the customers. This job report includes all the pictures and notes that the workers took during the repair process, so the customers can see the details and even download the pictures for reference for future repair queries. Some details are removed from the job reports, such as the employees' names and the time stamps of the various entries. The creation of the job report happens automatically and therefore does not require additional human input, but it is based on information provided by the workers in the workshop. The job report allows improved information sharing with, and transparency towards, customers. It serves as an additional benefit for the business, as this level of information sharing was not characteristic of FixShop prior to the introduction of the new technology.

The job recording app also supports workers in customer interactions when the customers collect their finished parts. As one employee described the app's benefit:

> *"It's handy as well in giving customer back something, they'll say 'oh there's meant to be a… we gave it with a valve on' and we go we took a picture of it when it first*

arrived and it doesn't have it in the picture, so it's obviously your guys who list it'. It really helps with that. It covers you." *(Employee 1, FixShop)*

Overall, as *section 6.2* shows, the production process of the company did not change significantly with the introduction of the new technology, and this was purposeful from the very beginning of the technology design journey. As the Owner-manager/Tech developer stated, technology touches every stage of the business, but in a complementary way:

> *"So it totally sits on top of what they've already did. So for example, we still use a paper job book in the front desk. We still use these paper T-Cards. We still have T-cards on the board in the workshop, we still shout to each other, we still get things wrong… But everything is complemented."* *(Owner-manager, Fixshop)*

6.3 Technology and work organisation

The above section outlines how the new job recording app is used by most workers in the company. The new job recording app not only complements workers in executing their core tasks of repairing parts and engines; but it also supports the process of evolving work organisation in the company. This section outlines the way technology helps the transformation of the way work is managed in FixShop.

The job roles and main responsibilities of the ten employees in the workshop has largely remained unchanged over the years, however, the company culture has shifted significantly, which in turn had an impact on management and workers' experience. The shift in the management culture in the company reduced the need for management's involvement in the day-to-day running of the workshop. According to the employees, in the 'old days', everything had to go through the now-retired previous manager, such as customer queries, task delegation and monitoring work progress in the workshop. This meant that the previous manager's physical presence was essential to the smooth running of the workshop. The managerial style reflected the male-dominated 'norms' in the repair industry and was described as an aggressive 'shouting match' during the interviews. This created a company culture with a hard division between workers and management – them and us, where workers preferred to keep their head down to avoid confrontations.

The current owner-manager of the business has changed the above-described culture significantly. The atmosphere in the workshop reportedly calmed down, which is due to the increased accountability. By everyone having access to the information provided on the app, visibility and transparency also improved in the company, which empowered workers to have more control over the execution of their tasks and seek the manager's assistance less. Since the manager's approval is no longer required before contacting the customers, workers in the workshop can now take matters into their own hands and deal with customer queries directly. The division of 'them and us' has also been reduced, since the new manager is more supportive towards the workers than his predecessors. As he stated:

> *"if you are reasonably consistent about how and how much you help people, then the whole system works because everyone works for the purpose of doing their jobs and getting out doing right. So if you give them the right tools, and* [the app] *is part of that, and you give them the right support, then you end up with a good team."* *(Owner-manager, FixShop)*

As the above quote illustrates, the job recording app helps in this culture shift in the company. First, by enabling remote management, as the manager can monitor job progress through his mobile phone and does not have to be in the workshop for long hours. This means that workers, whilst being monitored to a certain extent, can get on with their job on their own, as illustrated by an employee's quote in section 6.2.2. This shows the second way technology helps the culture shift, as it empowers workers by providing them information on the jobs, which means that they can make well-informed decisions, and they can also deal with customer queries themselves.

While the changes in the previous paragraph illustrate the positive effects of the new app on the management culture in the company, it also needs to be noted, that the technology could be used differently. As above mentioned, the app allows the close monitoring of employees' progress on each job. This information could be used for performance management purposes and punitive measures could be introduced if workers fall short of expectations. This example illustrates that technology is not predetermined to bring certain organisational outcomes; rather it is the use of the technology, which rests on multiple managerial decisions, that determines the technology's impact in an organisation.

Overall, this shift in the company culture created a more open environment, where the technology helped to improve transparency and accountability. This culture shift meant that FixShop became slightly more formally managed and organised, which was admittedly a welcomed change not only for the manager, but the employees of the business, too. However, the technology implementation did not require an extensive work-reorganisation in the company, and the core tasks and responsibilities did not change with the introduction of the new app.

6.4 Skills changes

The overarching aim of this research is to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing small and medium enterprises. FixShop has adopted a job recording app, which was purposefully designed around the organisation's needs and format, to keep the technology-driven changes minimal. Nevertheless, the introduction of the new technology still brought changes to the organisation, which had implications for skills utilisation.

6.4.1 Owner-manager

As section 6.3 outlined, the implementation of the new job recording tool has helped the transformation of management in FixShop, which influenced the owner-manager's job role. Since taking over the company, he has gradually stepped away from the workshop and let go of the day-to-day running of workshop activities and micromanaging workers. By giving more information to workers through the app and allowing them to contact the customers directly, the Owner-manager no longer deals with the same volume of customer enquiries. From a skills perspective, these changes did not require the manager to pick up new skills or stop using other ones. Rather, the extent to which he uses his already existing skills has changed, along with the channel through which he uses them. For example, before using the app, he gave instructions to his workers face-to-face, whereas now a lot of communication towards his staff happens through the mobile app.

The technology adoption process has highlighted the importance of the manager's leadership skills and change management skills. It was his responsibility to convince the workers in the company of the benefits of the new technology, to onboard them and to show them how to use the app initially. He also supported the workers during implementation and collected feedback from them on a regular basis.

Additionally, uniquely to this case, the Owner-manager decided to design the new technology himself, as he did not find a suitable solution on the market for FixShop. This meant that he gained an array of skills and knowledge in the field of technology development and entrepreneurship. This is a significant area of skills development, which had a considerable upskilling effect on the Owner-manager as an individual. Whilst these skills were crucial for the design of the new job recording tool, this upskilling is not directly related to the Owner-manager job role in FixShop. In other words, a distinction can be made, where the skill development meant upskilling for the individual, but not the managerial job role.

6.4.2 Workshop employees

As for the workers in the workshop, the introduction of the new app did not change the way they carried out their main engineering tasks. It rather changed the way they recorded and accessed information on their jobs' progress. According to the workers, the mobile app did not require new computer literacy skills, as the use of the app is similar to any other mobile apps they would use outside of work. However, it is important to note that whilst workers had basic computer literacy skills prior to the introduction of the app, and therefore needed no digital skills training, the skill requirements of their jobs still changed. Therefore, this example illustrates an upskilling effect for the job role, but not the individual.

Due to the workers pre-existing basic computer literacy skills, there was no formal training during the implementation. The Owner-manager, who designed the app, showed each worker once how the app works in the form of informal 'on the job training'. The workers then familiarised themselves with the layout and the various features and shortly became confident using it. One of the older workers reported that he gained confidence in using the app more slowly than the others, as he did not use his mobile phone a lot before. But his colleagues and the Owner-manager were there to support him, and he is now comfortable with recording his jobs on the app and enjoys the benefits it has brought to the way work is organised in the company. This example also provides evidence for increased collaboration in the workshop, as the workers reportedly supported each other during the technology implementation process.

As the new app gives access to information about jobs to workers, they now need to utilise their information processing skills to a larger extent. Since they can now directly contact customers, workers also said that they utilize their communication and customer service skills more often than prior to the tech adoption. Moreover, the manager of FixShop spends less time in the workshop, which means that workers needed to learn working independently to a greater extent. This is not a direct consequence of the technology adoption, but since the technology facilitates remote management, it acts as an enabler in the process.

6.5 Conclusion

The case study of FixShop illustrated a micro-business' technology adoption journey, implementing a job recording tool, which can be classed as an embryonic management system. Since the organisation did not use any digital technology for job management prior to the implementation of this app, this technology adoption represents their first step on their digitalisation journey.

Since the leap from using a fully paper-based administration system to using some technology was considered a significant change in the organisation, the Owner-manager of the company sought to find a technology solution that brought the least disruption to the organisation. As he did not find a solution with a sufficiently low level of complexity that would suit his micro-business, the Owner-manager developed the job recording tool for FixShop. This shows that in this case, the existing work organisation did not simply influence the organisation's choice of technology, the technology was designed around the company's existing work organisation and its needs.

Overall, the implementation of the technology did not bring changes to the employment levels in the company and the roles and responsibilities remained mostly unchanged in FixShop. The benefits of the use of the new app include increased efficiency, improved customer relations and better transparency across the organisation. Furthermore, the job recording tool aided the company's culture shift and improved management system, which resulted in a more formal, better work organisation in general.

Whilst the roles and responsibilities did not change with the introduction of the new technology, skills utilisation changes could still be observed in the company after technology adoption, and the implementation of the app highlighted the importance of certain skills. First, the successful implementation of the technology required good leadership skills from the Owner-manager in the company, and increased collaboration of staff members. Second, to harvest the benefits of using the new technology, the extent to which workers had to utilise their data processing skills and customer service skills increased, along with the need for working more independently.

To conclude, the case of FixShop highlighted that the micro-organisation's first step on their digitalisation journey is highly restricted by their pre-existing work organisation. Therefore, to bridge the wide gap between not using technology at all to start using some technology, micro businesses require simple technological solutions that keep the technology-driven disruption at low levels, in order to reduce micro-organisations' reluctance to technology adoption and encourage engagement in Industry 4.0.

CHAPTER 7: CASE STUDY - BrewCo

7.1 Introduction

This chapter introduces findings from the third case study of the research, carried out in the case organisation, BrewCo, a family-owned brewery located in rural Scotland. The brewery has 22 employees in total. The case study involved interviews with the Head Brewer of the company, and the Lead Brewer of the old brewing kit. The case represents the brewery's automation journey, where the adoption of a new, automated brewing kit enabled the company to meet its growing demand from its customers and expand their product offerings. The case study serves as an example of hard automation of production in a micro business and offers an insight into the growing skill requirements in the company due to the technology-driven expansion of production capabilities.

This chapter starts with a brief introduction to the brewery's production processes on the company's old brewing kit prior to the building of the automated brewery in section 7.2.1, followed by a discussion on the use of the new brewing kit and the changes it brought to the production in the organisation (section 7.2.2). With the introduction of the new kit, the company decided not to dispose of their old brewing kit, rather they repurposed it for the production of more experimental beers, unique to the location – this new brewing project is discussed in section 7.2.3. The chapter then moves onto discussing how the expansion of production affected work organisation in the brewery in section 7.3. The penultimate section of the chapter, section 7.4, discusses how the implementation of the new technology and the organisational context influenced skills utilisation in the brewery. Section 7.5 concludes the main findings of the case study.

7.2 Technology adopted

7.2.1 Old brewing kit

BrewCo brewery was established in the early 2000s, when the founders purchased a second-hand, manual brewing kit (later referred to as the 'old kit') and started their operations in a former dairy building (Figure 7.1) on the owner-family's estate.

Figure 7.1: Old brewery

As Figure 7.1 above shows, the old brewery building is a rustic style barn with exposed beams (pictured on Figure 7.2) and during one of the research interviews, a bird flew into the building and stayed there for the remainder of the interview.

Figure 7.2: Old brewing kit

Brewing process on the old kit

The old brewing kit is a two-vessel system with the brewing capacity of 1600 litres. As the interview participants described it, brewing on the old kit is a highly manual endeavour.

A creative process precedes the physical brewing at the recipe creation stage. This process requires knowledge of flavours, ingredients, an in-depth understanding of the different stages of the brewing process and their effects on flavours. As well as following the well-established recipes of the brewery's core beers, BrewCo also regularly experiments with new brews and flavours.

Once the recipe is determined, the physical brewing process starts with filling tanks with water to boil, pouring malt into the vessels from 24 kg sacks, and attaching pipes to transfer wort and excess water throughout the process. After the initial mashing is done, the spent grain needs to be disposed of by shovelling it out of the containers, and tanks must be washed out manually, too. As the Lead Brewer in the old brewery described it:

> *"Everything is quite manual. You are hooking up the hoses, and then grinding the hobs. Probably the most physical part is discharging the spent grain. When we have to dump it and shovel it. You need to be fit for that. I had some back problems, but it's part of it."* *(Lead Brewer of the old kit, BrewCo)*

These manual processes are complemented by routine record-keeping tasks. The paper-based brew sheets must be filled out with information on the process - including data on temperature levels, volume, gravity, densities, alcohol levels - to meet legal requirements. Once the brewing ended, the final product is sent to be bottled and the kit has to be washed manually. As the brewers highlighted during the interviews, the cleaning of the kit must be completed before a new brewing process could start on the old kit.

As BrewCo gained popularity and won numerous beer awards over the years, the demand for their products grew significantly. To meet this growing demand, the brewery was operating at its maximum capacity using the old brewing kit, doing nine brews a week. This required the brewing staff, at the time consisting of two brewers only, to work in two shifts, one of them started mashing the first brew of the day at six in the morning, whilst the other brewer finished at eight in the evening. Two brews a day meant that the kit often had to be cleaned before it had time to cool down, and the brewers had to clean the spent grains out in a hot environment, which made the process physically more demanding. The current Head Brewer of BrewCo was one of those brewers, and remembered those years in the following way:

"What we were doing in there with nine brews a week, everything had to be finished, cleaned, ready… You know, we had to empty the tank, into the conditioner room to move the fermenter in… It was constant. I don't want to say it was like a runaway train, but it did kind of feel like a thing where we were just hanging on to dear life. We did that for two years and it wasn't a lot of fun [laughs]. I mean we did it, but it was hard work." *(Head Brewer, BrewCo)*

Drivers for technology adoption

Despite working at its full capacity, the brewery could hardly meet the growing demand, which meant that they had no capacity to brew anything else apart from its core beers. This led to a decrease in using creativity for coming up with new recipes and experimenting with flavours. Moreover, the company ended up turning away customers, which was not beneficial for the business.

"It was literally the case of we ended up turning away customers, because we didn't have the capacity. But you never really want to turn away customers, because someone can end up being a really big, really important customer in the future. But if you can supply them now… You don't want to take them on and upset them. If you can supply them this week, but then can't supply them next week… It was pretty hard times, to be honest. " *(Head Brewer, BrewCo)*

Considering the above outlined, the main drivers for the building of a bigger, automated brewing kit were to increase the production capabilities to meet the growing customer demands; and to improve the cleaning process during brewing, which had implications for both production efficiency and employee well-being. The next section introduces the new brewing kit.

7.2.2 New brewing kit

The new brewing kit was commissioned to be built in a converted sheep shed on the owner-family's estate next to the old brewery. As Figure 7.3 shows, the building of the new brewery is bigger than the old one's, to house the new, three-vessel system 6500 litre brew kit.

Figure 7. 3: New brewery building

As opposed to the old brewery, the new building is a light, clean, stainless-steel dominated building with considerable amounts of pipework and cables (see on Figures 7.4 and 7.5).

> *"When they were building it, I remember I was looking up all the pipes and cabling and go* [sighs] *'ok, this is a different world!'. Whereas in* [the old brewery] *that's completely manual. There are elements of manual operations over here, but it's much more automated and you can leave things just to get on with it."*
>
> *(Head Brewer, BrewCo)*

Figure 7.4: New brewing kit part 1

Figure 7.5: New brewing kit part 2

The new brewing kit expanded BrewCo's capacity significantly, going from 14,000 litre capacity per week to 100,000. As it was pointed out during the interviews, the steps of the brewing process remained the same in the new brewery too, but the volume significantly increased, and the manual processes described in section 7.2.1 became automated.

The increased brewing capability allowed the company to meet their customers' demand for of their core beers, but also has given space to experiment with new recipes and create new beers. According to the research participants, this has brought back the creative process that precedes the physical brewing, which was a welcomed change for the brewers.

Brewing process on the new kit

On the new kit, the brewing process starts by downloading the master recipe, within which brewers can alter how the plant operates by changing temperature levels for boiling, mashing, increasing or decreasing standing time, regulating liquid movement. Once the recipe is downloaded and the right settings for the brew are finalized, the brewers start the process by selecting 'start' on the screen pictured below on Figure 7.6.

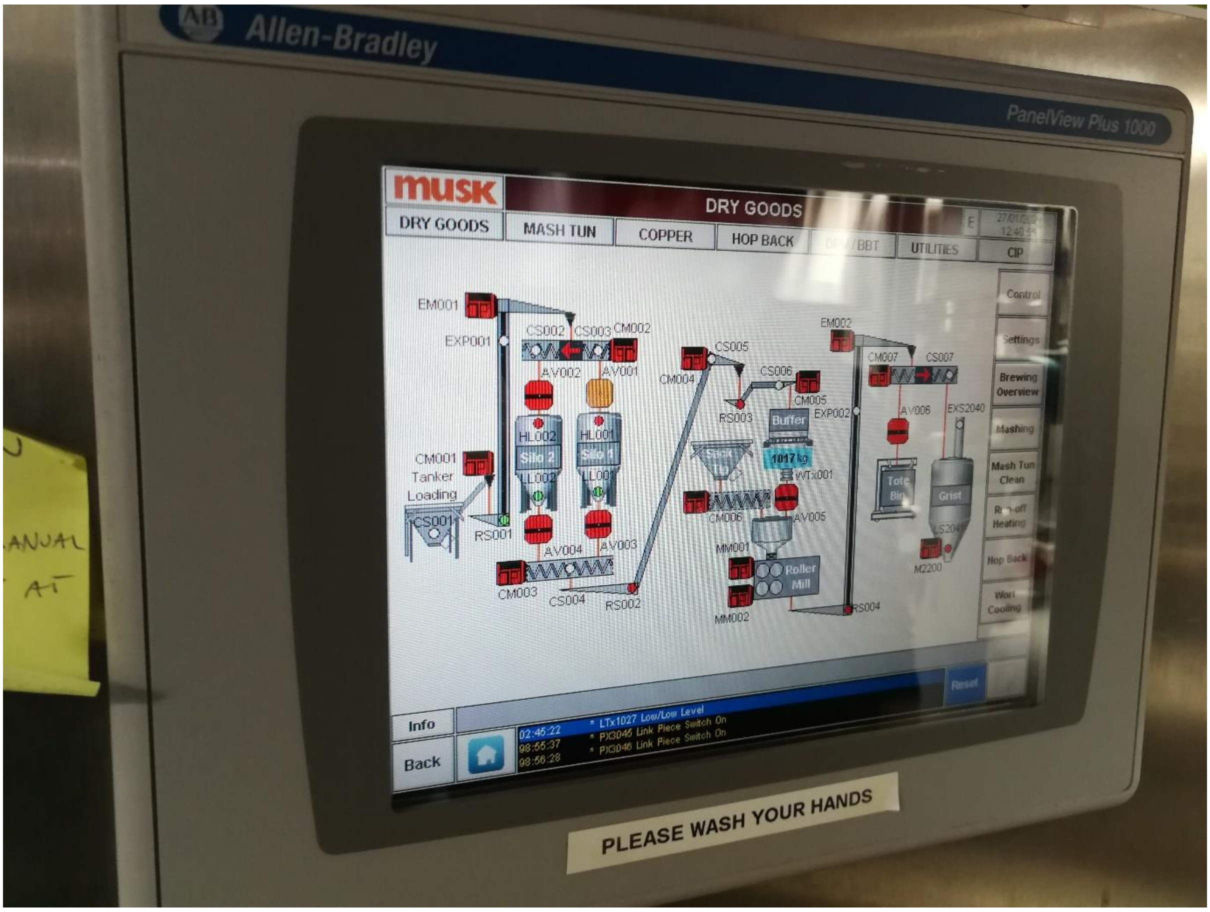


Figure 7.6: New brewing kit control panel

The hob is loaded by a machine, and the vast majority of the physical brewing happens automatically under the brewers' supervision and occasional intervention. The Lead Brewer of the old brewery also brews on the new kit regularly, and he described the manual process as follows:

> *"It's quite easy to brew over there, because everything is automated. It's pressing buttons, sometimes you need to load a few bags of malt, that's it."*
>
> *(Lead Brewer of the old brewery, BrewCo)*

Whilst the above quote shows that the automation of the brewing process significantly reduced the amount of manual tasks required for the brewing in the new brewery, human input is still crucial in the brewing process. As the Head Brewer said:

> *"But there are still sort of critical points, you've got to physically break pipework, shut vaults, so you can't cross-contaminate things. And it prompted on the screen, go and do it, acknowledge, so you know it's done. It's just, it's back up basically. […] so much happens, you step on. So much happens, you step on, put a value in. You know, you've got to put a pH value in, a cavity sample, temperature, whatever.*

Step on. If you're running it, it's on you to run it. It doesn't do anything for itself."
(Head Brewer BrewCo)

This sense of responsibility, which illustrates how imperative human intervention is to the brewing process, was highlighted by the Lead Brewer, too.

> *"You always kind of have it at the back of your head that responsibility that if you leave that vault open, the whole batch will go to the drain. There is some pressure. I always try not to think about it. But usually at the end of the day, I can feel that stress in my legs." (Lead Brewer in the old brewery, BrewCo)*

Therefore, whilst much of the manual tasks are automated, the brewing process still requires the presence of qualified brewers in the new breweries to oversee the production and monitor the brewing process. As the Head Brewer of the company stated:

> *"This* [points at the screen on Figure 7.6, representing the automated technology system] *is a means to an end. We know what we want to do, how we do it. And this is how we're going to do it." (Head Brewer, BrewCo)*

Once the brewing process is finished, the final product then gets loaded into tanks and gets taken away to a bottling site. Currently the bottling is outsourced in the company due to space limitations.

In addition to the brewing activities, the brewer team has a weekly tasting session, where the team tastes and evaluates the brewery's core beers. This involves identifying and discussing tasting notes and off-flavours and finding solutions for any issues with the brewing process they might find. These tasting sessions require an in-depth knowledge of flavours and a good tasting palate, which is unique to everyone. The skill implications of these tasting sessions are discussed in section 7.4.

Overall, brewing in the new, automated brewery changed production in BrewCo significantly, and it had numerous benefits for the company. The introduction of the new brewing kit meant that the brewery's core beers can now be produced with higher level of consistency and repeatability. The new automated brewing kit also provided more stability and control over the brewing process, according to the Head Brewer. Since the demanding manual tasks got automated, the new brewery kit also freed up time for brewers to engage in creating new recipes and experimenting with flavours. The owners of BrewCo also made the conscious decision of keeping the old brewing kit as well and started an experimental brewing project on the old kit. This is discussed in the next section.

7.2.3 New project on the old kit

The introduction of the new brewing kit transferred the production of the company's core beers to the new brewery, leaving the old, rustic brewing kit free to experiment on. BrewCo launched a barrel-aging project on the old kit, brewing spontaneously fermented craft beers with the intention of market diversification. The motivation behind this project is to produce unique farmhouse beers that reflect the local area. Spontaneous fermentation means that no brewer's yeast is used for the brewing process, rather, a naturally occurring wild yeast is gathered from the air and used for fermentation. Whilst this produces a unique taste, the brewing process is significantly longer than in the new brewery. As the Head Brewer said during the interviews, the brewery's core beer might take three or four days to ferment, whereas the beers that are spontaneously fermented can take six to nine months, and then an additional couple of years for barrel ageing. The volume of production is also vastly different from brewing in the new brewery. In the old brewery, the beers cannot be replicated and therefore, production is limited. One edition might means producing eleven to twelve hundreds of bottles, and no more. As the Head Brewer described:

> *"… what we produce is what we produce. It's ready when it's ready. There's no kind of 'This is got to be done'. […] Now, it's a case of 'Right. It happens when it happens.'" (Head Brewer, BrewCo)*

Since the old brewing kit depends on manual operation, brewing the spontaneously fermented craft beers include manual tasks described in section 7.2.1. In addition, the new project also requires experience in barrel ageing and blending. Both of these depend on in-depth knowledge of flavours, ingredients and materials. To launch this project, the brewery recruited a brewer, who is specialized in barrel ageing. The skills implications of this brewing style are discussed in more details in section 7.4.

Overall, the discussion in section 7.2 introduces the automation journey of production in BrewCo – moving production from the old, traditional manual brewing kit to a new, automated brewery; and launching a special, experimental brewing project on the old brewing kit. These changes did not only influence the task requirements of brewing, they also vastly increased the volume of production in the company. As a consequence of that, the business also had to evolve to be able to serve the increased market demand and handle the higher levels of production. The changes on work organisation and job roles are discussed next.

7.3 Technology and work organisation

The original concept of opening BrewCo was based on the intention to bring back employment into the rural area where the brewery is located. In the beginning, three employees worked in the brewery, and two worked in the office. The company has gradually expanded over the years, the biggest driver being the growth of production to meet increasing demand.

7.3.1 Overall employment

Initially, when the new brewery was built, the team did not expand, as the operation of the new kit was easily overseen by the existing two brewers. However, despite the automation of the brewing process not needing more technical staff, the increased volume of production required more material handling labourers.

> "[Did you recruit additional staff when you built the new kit?] *Yes, to do more of the packaging side of things, because the brewing side of things is easy, a lot less involved. But each time you brew, you produce four time as much. So you've got to handle four times as many casks or kegs, It takes longer to package, it takes longer to put them away, that side of things. The production side is a lot quicker. But it takes longer because of the volume of things, not necessarily the nature of things." (Head Brewer, BrewCo)*

This example shows that in BrewCo, automation reduced the manual tasks related to the brewing process, but the improved production efficiency reclaimed the need for manual tasks in material handling and packaging. Based on this, the new technology, whilst reducing the need for human input in one part of the organisation, increased the need for human workers in other parts. Therefore, overall, it still led to increased levels of employment.

Furthermore, as the production volume grew, the company also expanded with a new tap room that sells the brewery's products, it started delivering bigger volumes, extended its commercial team and also launched its new brewing project in the old brewery. All these changes gradually increased employment in the company, growing from five employees before the technology adoption to twenty-two employees at the time of the research. Whilst the technology is not directly linked to all of these additional roles, the increased production financially enabled the company to expand. As the Head Brewer reflects on this:

> "*It just happened kind of gradually, getting bigger. It was like 'we need somebody to … We've got a tap room, we need staff for that. We need more salesmen.' As you get bigger, you discover that you can't physically do everything. So what do*

we need? We need somebody to do that, so get the job advertised."

(Head Brewer, BrewCo)

As the above quote shows, recruitment in the company tends to be reactive to emerging business needs, as opposed to being a result of a long-term strategic planning. This is often characteristic of small and medium enterprises, illustrating how internal organisation context influences human resource management in companies.

7.3.2 Brewing team

As a result of increased production caused by automation, more specialised responsibilities were required in the brewing team, which grew from two to four people. All four brewers engage in brewing in the new brewery. In addition, one brewer is responsible for quality control, whilst another one is responsible for engineering supervision. These two brewers tend to work in the new brewery for the majority of their time.

Quality control involves monitoring the product quality of the different stages of production and having the power to stop production at any time in case the product quality drops. Quality control can be classed as a non-routine cognitive task, which requires high levels of technical knowledge and involves decision-making.

The engineering supervision is carried out by a qualified mechanic engineer in BrewCo, and his task is to oversee the production process from a technical point of view. According to the interviews, this role requires trouble-shooting and extensive knowledge of the automated brewing process and the new brewing kit. This role is reported to be key in harvesting the benefits of the new brewing kit.

The launch of the new brewing project on the old kit also meant that the brewery needed someone with experience in experimental brewing and barrel ageing, who then became the Lead Brewer in the old brewery. His work time is split between the old and the new brewery.

Finally, the Head Brewer in the company oversees production in the company as a whole and manages the brewing team. As previously mentioned, the Head Brewer was one of the brewers working in the old brewery before the new technology was introduced. He joined the company in 2005 as a brewer, and his role evolved significantly over the years. As the brewing team and production expanded, the Head Brewer got additional responsibilities including organising and managing brewing activities and brewers in the company. Moreover, the increased production also meant that the company had a greater impact on the environment, which brought up additional sustainability issues in the company. The management of these production related environmental issues, for example the cleaning of the wastewater going into the local loch, also fell on the Head Brewer. Having multiple roles and responsibilities overseen by one employee is often a characteristic of small and medium enterprises, according to the literature. The additional responsibilities also had skills implications, which are discussed in section 7.4. The Head Brewer's example shows that not only the employment levels changed over time with the creation of new roles and responsibilities, but the existing roles in the company also evolved as the business grew, thanks to the technology-driven expansion of production.

Overall, section 7.3 showed that the increased volume of production allowed the brewery to expand over time, which mean that new job roles were created in the organisation – first in material handling, and later the brewing team also grew. Each member of the brewing team's main responsibility is brewing, but the direction of change in the team points towards more specialisation than before. Brewers specialise in quality control, engineering supervision, barrel ageing and overall production management. Additionally, the growing production did not only create new roles, but it also expanded existing job roles in the company. The changes in roles and responsibilities impacted skills utilisation, which are discussed next.

7.4 Skills changes

Prior to the technology implementation, the brewers had to carry out a lot of physically demanding manual tasks during the brewing process, as section 7.2.1 outlined. This required high levels of physical strength. With the building of the new brewery, most of these manual tasks got automated, which reduced the need for physical labour to some extent. For the use of the new equipment, brewers had to familiarize themselves with the new brewing kit and develop software knowledge of the particular machine. According to the research participants, the key to this is to have a good understanding of the general brewing process and its different stages – since the new technology follows the basic brewing principles, its use is fairly intuitive and user-friendly.

As the automation of the manual tasks freed up time for the brewers, it enabled them to re-engage in recipe creation for new beers, which requires high levels of creativity, knowledge of ingredients and flavours, and a sense of curiosity, according to the research participants. The brewers in the company had these skills prior to the new brewing kit, despite them not being able to utilise them to a large extent due to lack of time and capacity. Therefore, according to the interviews, the brewers did not need to develop new skills, they rather utilised pre-existing skills to a greater extent.

A further key skill that brewers need for ensuring good quality products is having an extensive tasting palate. As the Lead Brewer of the old brewery stated, everyone’s taste palate is individual:

> *“Usually each person will say something different. Or similar, but different. For example we are tasting some fruity IPA, and some might say ‘it’s pineapple’, while someone else says ‘it’s mango’. It’s different. It’s an individual thing. So it doesn’t mean that if someone can smell something and the other can’t, it doesn’t mean that it’s not there. Some people are more sensitive to smells, some aren’t.”*
>
> *(Lead brewer in old brewery, BrewCo)*

This above quote illustrates how subjective the tasting process is. Whilst the skills required for tasting and evaluating flavours can reportedly be improved through training and experience, it is not something that is likely to be automated in the future. As the Head Brewer argued:

> *“You can get machines that will tell you what’s going on, like you run it through a gas check and it will tell you it’s got these chemicals in at that levels… But how do you know what it tastes like? You need somebody with a nose, a mouth and the ability to experience that’s what it tastes like ‘oh yeah, that’s what we get…’ And the ability to translate that into something that will get others enthusiastic about it.”*
>
> *(Head Brewer, BrewCo)*

Again, the adoption of the new technology itself did not require an improved tasting palate, but by expanding production and enabling the widening of the brewery’s product range, brewers now utilise their tasting skills to a greater extent than before. The weekly tasting sessions and the new brewing project in the old brewery serve as an example to this.

As mentioned previously, as the brewing team grew over time, more specialized responsibilities were assigned to each brewer. The brewers’ past experience and qualifications shaped these responsibilities.

The brewer responsible for quality control in the new brewery has professional qualifications from abroad, which equipped them with knowledge on microbiology and biochemistry. This knowledge is necessary for inspecting product quality at different stages of brewing and ensuring that the products will not only taste good, but they also meet health and safety requirements. For this role, the brewer requires in-depth knowledge on the brewing process from a biochemistry perspective to guide their decision-making during monitoring the brewing process.

Another brewer in the new brewery is responsible for the engineering supervision of the brewing process. The brewer responsible for this has a mechanical engineering background, which provided highly useful for managing the new automated brewing kit. It is his main responsibility to monitor the technical sides of production and trouble-shoot in case any technical issues arise. He is also in charge of training new staff members on the use of the new technology, as he has the best understanding of the new kit in the company. To complement his mechanical engineering qualifications, the brewer was attending a one-year technical professional course by the Institute of Brewing and Distillery at the time of the research.

The Lead Brewer in the old brewery works in the old and the new brewery, too. He is fully responsible for the new brewing project in the old brewery. He was employed for this role due to his past experience in barrel ageing. He has no professional qualifications; he is a self-taught brewer. He started his journey with home brewing, educating himself through YouTube videos and reading relevant materials. He later undertook an internship, where he learned from his mentor and attended professional conferences as a member of the public. Despite lacking professional qualifications, his vast experience in barrel ageing and experimental brewing prepared him for the role he currently works in. Working on the new brewing project requires manual skills to operate the old brewing kit, and a good understanding of the brewing process, spontaneous fermentation and blending. Blending, similarly to new recipe creation, requires in-depth knowledge of ingredients, flavours and a good tasting palate. To further develop the project, the Lead Brewer decided to plant a fruit farm next to the old brewery to grow ingredients locally – for this, he had to gain knowledge on planting and growing fruit in a sustainable way. Attending to the fruit farm also requires manual tasks for garden maintenance. When joining the BrewCo in 2019, he also had to learn how to brew on the new brewing kit. He had no previous experience in using automated brewing kits, and admittedly, it took him a year to become comfortable with brewing in the new brewery. He was taught by his brewer colleague with the engineering background.

Finally, the Head Brewer in the company oversees the production in the brewery and he manages the brewing team. He is a professional brewer with a masters and an honours degree in brewing and distillery. He joined BrewCo as one of the two brewers shortly after the brewery opened, and his role expanded over time. In addition to brewing, he now needs to fulfil management tasks, which requires leadership and communication skills. He received no training in management skills, this responsibility grew gradually. Similarly, dealing with sustainability related production issues also gradually became his responsibility, which requires creativity, problem-solving skills and flexibility. All these skills, according to the Head Brewer, were developed on the job.

Overall, some of these above discussed specialized skills in the brewery were related to the use of the new technology, such as the engineering monitoring, and the formal quality control; whilst others, such as barrel ageing or the managerial skills, were introduced due to the growth of the company, which was enabled by improved production efficiency thanks to the new brewing technology. Despite each brewer specializing in different areas, each of their main responsibility is brewing. Two brewers are based in the big brewery, one of them is based in the old brewery, whilst the Head Brewer oversees the overall production. However, brewers work flexibly, wherever they are needed at the time. This informal way of task delegation suits this small organisation, as the Head Brewer argues:

> *"If [Lead Brewer in old brewery] needs folk to help him, with bottling and things like that, people will help. Likewise, if we need something with the brewing over there *pointing at new brewery*, we can have [Lead Brewer] helping with that. […] It's just kind of the nature of the beast. There's a body there 'you're doing this, you're doing this'. It's just a small company."* (Head Brewer, BrewCo)

This illustrates how the internal organisational context influences skills requirements in the company, where multiskilling and flexibility in working are required to be part of the team. In addition, not only the internal context has an impact on skills, but the external location of the company also influences skills needs. Due to the rural location of the brewery, the brewing team needs to be flexible, inventive and self-reliant. For example, when an equipment breaks or there are faults in the electricity supply, the brewery cannot rely on immediate help from service companies due to its remote location. Therefore, brewers need to be flexible with production to find temporary solutions, which requires problem-solving skills and a good knowledge on brewing process to find alternative solutions.

Overall, section 7.4 illustrated how skills requirements for brewing have changed over time in BrewCo. Whilst some of these changes were directly linked to the use of the new technology, others were more closely related to the growth of the business over the years, which was enabled by the technology-driven production growth. This illustrates how technology implementation can directly bring new skill requirements and can also lead to skills utilisation changes by transforming the way work is organised.

7.5 Conclusion

The case study of BrewCo illustrated a family-owned farm brewery's automation journey, where the company moved from a fully manual brewing kit to a new, automated brewing equipment, which was built to meet the company's growing customer demand. The new brewing kit significantly increased production capabilities in the company. By automating the manual tasks in the brewing process, the new technology also freed up time for brewers to widen the brewery's product range by creating new beers, and to launch a new brewing project in the old brewery.

As for the work organisation, three major changes could be observed in the brewery after the implementation of the new brewing kit – increased levels of employment, specialisation within the brewing team, and the expansion of existing roles in the company. Whilst some of these changes can be directly linked to the use of the new technology, such as the creation of the engineering supervision role in the brewing team, other changes are more closely linked to the business growth enabled by the increased production capabilities. Here, technology is not the direct cause of the changes, it rather acts as an enabler in the process. This point is illustrated by appearance of the barrel ageing specialisation within the brewing team, where the barrel ageing project is performed in the old brewery, which was freed up by the introduction of the new brewing kit.

The adoption of the new technology also had skills implications for the brewing process. Directly, brewers in the company had to learn to use the new equipment. The brewing team also expanded with a mechanical engineer, whose engineering knowledge proved to be highly beneficial for the company. The automation of the manual tasks also freed up time for the brewers, which meant that they could engage more in the creative processes of experimenting with new flavours and creating new recipes. Since the brewers already had the skills required for these non-routine activities, their skill levels did not change, but the extent to which they utilised their already existing skills did. Finally, the new technology also changed skills utilisation in the brewery through changing work organisation. As an example, the growing brewing team needed to be managed, therefore, the Head Brewer had to develop managerial and leadership skills.

Overall, the case study provided an example for hard automation, where the new technology replaced certain tasks in the production process, such as the manual tasks of cleaning the brewing kit; but it also highlighted the importance of human input in other areas of the brewing process, for example in quality control. This illustrates the double nature of automation – while it replaces tasks, it also creates others. Furthermore, the case study illustrated how the external and internal organisational context influences skills utilisation and recruitment activities, which emphasizes the need to take into consideration the organisational context in skills research.

CHAPTER 8: CASE STUDY - PartLtd

8.1 Introduction

This chapter introduces findings from the fourth case study, carried out in the case organisation PartLtd, a precision engineering company that has 250 employees in Scotland. The case study involved interviews with PartLtd's Managing Director, Head of Development and a manufacturing engineer; and further data were also collected by observing the work of an inspector and a machine operator during the site visits. This case study introduces the roll out of an automatic tool-setter across the business with the intention to enhance production efficiency. The case represents an example of classic hard automation, where a new automatic tool takes over tasks that were previously performed by humans. The implementation of the new technology affects production processes in the company, as well as the skills utilisation of machine operators.

The chapter starts with a brief introduction of the adopted technology in section 8.2, including its use in the company, along with the benefits it brought to PartLtd and the implications of its implementation for the human-technology interaction. The chapter then moves onto discussing the impact that the technology had on work organisation in section 8.3, and the skills implications of the technology adoption in section 8.4. The final section of the chapter (8.5) concludes the main findings from the case study.

8.2 Technology adopted

8.2.1 Automatic tool setter

PartLtd started the implementation of an automated probing and tool setter (pictured below Figure 8.1) across its Scottish site in 2021. The company has used this technology in smaller pockets of the business before, but a decision was made to install it across the whole site to improve the company's production efficiency and product quality.

Figure 8.1: New automatic tool-setter

The technology is used for machine tool setting during the manufacturing of highly complex and unique parts. In order to manufacture the individual parts, machines have tools loaded into them with the right measurements to achieve high levels of accuracy. The Head of Development in PartLtd explained the process in the following way:

> *"Tool-setting – if we go right back to, taking all the technology out, say there's 50 tools we use to machine those parts and assemble them. Somebody would be in there, loading 50 tools in, and setting manually different tools to set the machine. Then it will be one step further with the off-line tool setter, where we would take the tools to a room round the corner, load the tool in and say 'OK, it's 100mms, that one is 200, that one is 150'. Round it in, load. The tools need changed out of the machine, park round, measure, park round gear, go back in, tell the machine 'that's that'."* (Head of Development, PartLtd)

As the above explanation shows, prior to automation, the tool-setting process relied heavily on workers measuring tools individually, noting down dimensions and then setting up the machines accordingly. This left the setting up process vulnerable to manual errors at multiple stages – at the initial measuring, the loading, and at feeding numbers into the machine (machine pictured below on Figure 8.2). According to the interviews, manual errors used to occur on a regular basis prior to automation, which led to high levels of scrap production and inefficiencies in the production.

Figure 8.2: Old tool-setting screen

With the introduction of the new automatic tool setter, the human input declined in the tool-setting process. As the interviewees explained:

> *"So where we are now, the tools are just loaded into the machine, and then there's codes put into the programme to say 'use the laser', so then the tool comes into the machine, before it starts cutting anything, it comes down, measure, update the machine, and then carry on."* *(Head of Development, PartLtd)*

> *"In the past for tool-setting, we used an offline pre-setter. Basically just measuring the length of the tool. But with the new tool setter, the benefit of it is that it's constantly resetting the tool. At every cycle. So it's not just once at the beginning, it's all throughout the process, rather than just at the start, if you like. So it's constantly updating all through the batch of the products."*
> *(Manufacturing Engineer, PartLtd)*

Machine operators no longer need to measure the tools, it is done automatically by the built-in laser. According to the interviewees, the levels of manual errors declined, along with the amount of scrap materials produced in the workshop. Moreover, the new tool automatically remeasures parts during the production process, which means that consistency, accuracy and repeatability also significantly improved during production. Finally, automation also brought time-efficiency for the company, as the tool-setting process' duration decreased to a matter of minutes, as opposed to hours it took prior to automation. These examples show that the introduction of the new tool setter has resulted in considerable productivity and quality benefits for PartLtd.

8.2.2 Human-technology interaction

The automation of tool-setting, whilst reducing the need for human input, did not fully remove workers' roles in the process. First of all, the new tool setter relies on programmes that need to be written for each production process. The writing and the testing of these programmes are carried out by engineers in the business. This is part of the initial technology implementation, and once the programmes are written and tested, there is no need to revisit them. Therefore, the tasks of writing and testing the programmes will significantly reduce after the initial setting up period and will only need to be performed occasionally in the future.

The most significant change in human-machine interaction can be observed in the machine operators' role. Prior to the technology adoption, machine operators had to measure the tools themselves and feed the information into the machines manually. With the introduction of the automatic tool setter, this aspect of their job disappeared. The transfer of tool-setting from human to a machine means that the responsibility of decision-making regarding tool-setting now sits with the technology, rather than machine operators.

According to the Managing Director of the business, trust played a highly important role in this transition. At the beginning of the technology implementation process, the machine operators reportedly had scepticism towards the new technology, fearing their own replacement and doubting the technology's capabilities. This scepticism, however, was eased by involving the machine operators in the implementation process as much as possible through asking for their feedback on the new machine. As the Head of Development said:

> *"So feedback from what works well, what doesn't work well, what could be done better…. It's paramount."* *(Head of Development, PartLtd)*

This highlights the importance of humans in the technology adoption process, which was further echoed by the Manufacturing Engineer who is responsible for the smooth implementation in the shopfloor.

> *"The reaction is pretty positive on the whole. People understand the benefits of it and why we are going down on this route. So for me, the reaction has been pretty good. So for now it's about training them. They are now being aware if there are any problems, how to solve the problems. It's been good so far."*
> *(Manufacturing Engineer, PartLtd)*

These quotes show an overall positive view on the skill changes related to the adoption of new technology. However, it is important to note, that the employees' attitude towards these changes were mostly reported by management, and therefore, might be biased. Unfortunately, the research sample did not expand to machine operators in the company, and therefore, the findings relating to employees' attitudes need to be considered with caution.

Moreover, even though the new tool setter freed up time for machine operators by overtaking physical tool setting, machine operators still have a role to play in monitoring the process and supervising the new technology. According to the Head of Development, whilst the automation did not result in additional physical tasks for the machine operators, it required a more extensive process understanding from the workers than they had before.

> *"One of the first things is understanding the system. Understanding what it's doing, why it is doing it, what it's replacing? So there are still things in there that need to be done. In the eventualities of something breaking or whatever, recalibrating, rechecking. In the very first instances, understanding what it's doing, why it is doing it, how it's doing it and what it is actually replacing. […] Yeah it frees up time and*

tasks, it doesn't give them more to do. No more tasks. I believe it gives them something new to think about and understanding, but not any more physical tasks."

(Head of Development, PartLtd)

This process understanding, which was not required of machine operators previously, is key to the operators' new responsibilities, which are to discover any problems or issues during the machining process, and to find solutions for those issues.

"They [machine operators] *are now being aware if there are any problems, and how to solve the problems."*

(Manufacturing Engineer, PartLtd)

These new non-routine cognitive tasks of process monitoring and troubleshooting often do not require physical intervention, therefore can easily go unnoticed and unreported. However, they illustrate how the machine operators' role expanded with the introduction of the new technology, even if this is not as easily noticeable as the physical tasks of tool-measuring and setting-up, that were overtaken by the new technology. The skills implications of this change are discussed in section 8.4.

The new tool-setting technology also has implications for the inspection process in the company. Upon production, the manufactured parts go into the inspection area, where the parts are measured against customers' drawings by an inspector. This is to ensure accuracy and maintain high quality of production. With the new tool-setting technology, despite the parts are still being checked, the inspectors reported to have more confidence at the first checking than they had before with manual tool setting. According to the Inspector, who was observed during the site visit, the initial probing of batches of produced parts are not expected to disappear, but the rate of probing might relax, as the confidence in the new tool-setter improves. The Inspector gave the example of probing one part in five might change to the rate of probing one in ten, or twenty in the future (*based on the researcher's field notes*). This example shows an increasing sense of confidence in production accuracy thanks to the new technology and implies potential time saving benefits to the company in the future.

Overall, the interaction between the workers of PartLtd and the new automatic tool setter demonstrates that whilst automation can lead to the replacement of certain tasks, the need for human input does not necessarily disappear from the process, it rather transforms. Therefore, it can be argued that despite the new technology becoming increasingly important in PartLtd's production, humans still remain essential for the smooth running of manufacturing processes. As the Head of Development summarised: *“The machine will never do it all“.*

8.3 Technology and work organisation

According to the Director of Operations, the two main drivers of the new tool setter’s adoption were to simplify the tool-setting process, and to standardise the used technologies across the business. The simplification of the tool-setting process was described above in section 8.2. This section discusses the implication of standardisation in the business.

The standardisation of tool-setting during production has two organisational implications. First, the new technology allows the standardisation of production, where the same tool-setting technology is used for all the machines across the workshop. This ensures consistency during production, which is one of the aforementioned benefits of the new technology. Furthermore, PartLtd made a conscious decision to use the same brand of tool setter across all the business, to build up an efficient and convenient partnership with the supplier.

> *“That’s why we chose to have one supplier across the board. We could have different systems on different machines, because might slightly be better for that type of equipment, or that type of machine… But we wanted it to be standardized across the whole business, because then we can have a partnership with that supplier, to be able to solve the problems quickly.”*
>
> *(Head of Development, PartLtd)*

The move to the use of one uniform system meant that PartLtd removed the alternative brand of technologies from their existing machines, to replace them with the new tool setter, which they used in certain pockets of the business previously. This example shows that the pre-existing technological context and prior experience with brands influenced the company’s choice of technology, demonstrating the influence that the organisational context can have on new technology adoption in businesses.

The second implication of the new technology is related to the standardisation of the workforce requirement in the company. Standardising the technologies across the business meant that the skill requirements and training required for the workforce also became uniform for machine operators on the shopfloor. Consequently, employees are able to work flexibly across the machines in the shopfloor, which is beneficial for covering for absent colleagues. The skills implications of this are discussed in the next section.

Overall, this section showed how the automation of the tool-setting process led to the standardisation of production, as well as the standardisation of workforce requirements in PartLtd. This is in contrast with the findings from the case study on BrewCo, where automation led to the standardisation of production, but specialisation within the brewing team. This comparison will be discussed in more detail in the next chapter.

8.4 Skills changes

As section 8.2 discussed, the introduction of the new automatic tool setter has taken away the manual tasks of tool-setting from workers on the shop floor, including measuring the tools and typing the dimensions into the machine. By automating the process, machine operators no longer needed to perform these tasks, which suggests that they have been replaced by automation in these particular tasks. This is line with the general discourse on automation's deskilling and replacement effect, and the workers' initial scepticism also supported this view. However, the example of PartLtd shows that ultimately, automation did not have a replacement effect on machine operators and their jobs, it rather demanded them to gain new skills. As the Head of Development argued:

> *"That is a discussion I have with the guys fairly regularly about the comments of… I guess that we as a company deskilling them by putting in these processes. I'll look at it differently and say that we are changing the skill set that the guys need to have, rather than deskilling. Having these discussions with the guys helps to take the scepticism away. I see it as something positive. There are of course guys that haven't been involved in it up until now, maybe still have some of that scepticism because they have not been involved but once they do, from my point of view* [puts hands up], *they see it as a positive."*
>
> *(Head of Development, PartLtd)*

With the introduction of the new tool setter, machine operators had to gain an overarching process understanding, to comprehend the tool setting system's working. According to the Director of Operations, PartLtd had suffered from people constrains on the shop floor in the past, where only a few individuals had process knowledge, and therefore, they were responsible for problem-solving. With the introduction of the new tool setter and equipping machine operators with process knowledge, this skills bottleneck ceased to exist in the organisation.

Having an overarching understanding of the production process not only empowers machine operators, but this knowledge is also vital for them to be able to fulfil their new responsibilities, which are monitoring the tool-setting machine, spotting problems in the system and finding solutions for trouble shooting purposes. These new tasks require process knowledge, problem-solving skills and creativity. These three new skills requirements are more technical and cognitive in nature, than the previous physical tool-setting required of workers. Therefore, it can be argued, that overall, the automation of tool-setting led to upskilling for machine operators in the workshop.

Additionally, the use of the new automatic tool setter also requires workers to collaborate with automated decision-making, which demands trust and an openness to technology from the workers. Since PartLtd has always had a technology-heavy production site, workers were used to working alongside machines before. However, workers were reportedly hesitant in placing trust in the decisions made by the technology; and at the time of the research, they have not reached full confidence.

Overall, this section showed that the introduction of the new automatic tool setter led to positive skills utilisation changes for machine operators, who gained an overall process knowledge of production, and now engage in more cognitive tasks than before the automation. This example shows upskilling effects for individuals, as well as, job roles. The introduction of the new technology increased the demand for higher-level, more technical and cognitive skills for machine operators, such as process understanding and problem-solving skills. Whilst this positive skills change is in contracts with the traditional narrative on the replacement effects of automation, it is in line with the findings from the case study on BrewCo, where automation also reduced manual tasks but encouraged more complex, non-routine activities. The comparison of the two cases are discussed in more detail in the next chapter.

8.5 Conclusion

The case study of PartLtd demonstrated an impactful step in a medium-sized engineering company's automation journey – the rollout of an automatic tool setter across the company's Scottish site. The introduction of this technology reduced the manual errors made during the tool-setting process, decreased waste in the company, and led to improvements in accuracy, repeatability and consistency across production.

Whilst the automatic tool setter made the manual tool-setting tasks of machine operators redundant, the importance of human input did not disappear from the process, it rather shifted towards more of a monitoring and problem-solving role. This highlights the continuing relevance of human input despite increasing automation in the company.

As for work organisation, the introduction of the new tool setter led to two forms of standardisation: the standardisation of production, and the standardisation of skills requirements in the workshop. The former meant that one brand of tool setter technology was rolled out across the whole site, achieving technological uniformity in tool-setting. This led to the standardisation of skills requirements amongst machine operators, who now have the capability to operate machines flexibly across the workshop.

The automation of tool-setting resulted in a significant change of skill requirements for machine operators. The new technology removed the need for the previously fully manual tool-setting, but expanded machine operators' skills with the cognitive skills of process knowledge, problem solving and creativity. Therefore, it can be argued that the introduction of the new technology ultimately resulted in positive skills utilisation for machine operators.

Overall, this case illustrated automation's standardising effects on work organisation and demonstrated the double-nature of automation in replacing manual tasks in tool-setting but also creating new responsibilities and demand for human input elsewhere in the process. Furthermore, the case study highlighted the effect of the organisation's pre-existing technological context on the choice of technology, which emphasizes role of organisational context in technology adoption.

CHAPTER 9: COMPARATIVE ANALYSIS

9.1 Introduction

This research explores organisational-level changes to skills utilisation of different groups of workers after the adoption of two types of technologies – management systems technologies and automation, in Scottish manufacturing SMEs. The previous five chapters outlined the key findings from the case studies and the stakeholder interviews. This chapter compares and discusses the key findings from the case studies in relation to each other, outlining differences and similarities between the organisations' experience with technology adoption and consequent changes. The data analysis was led by the conceptual framework that was summarised in section 2.6, in Chapter Two. The research followed the principles of the social shaping of technology approach, which recognizes that the technical and the social are mutually constitutive, and they influence each other interdependently in multifaceted ways (Howcroft and Taylor, 2022). At the organisational-level, technology and work organisation are mutually constitutive. Therefore, technology-driven changes in organisations are not pre-determined, and the use of technologies and their consequent effects of workers are impacted by a range of organisational-level factors (Howcroft and Taylor, 2022). To capture the changes that new technology adoption brought to organisations, and consequently to skills utilisation, the changes in the case organisations were examined with consideration of the three domains of technology, people and organisation. The next sections of this chapter outline the changes to skills utilisation in the case organisations after technology adoption and discuss and compare the various factors that might have changed in the three domains (see Figure 9.1) that led to the skills changes in the case organisations. Finally, the chapter concludes by discussing the findings in relation to the research questions that this study has set out to answer.

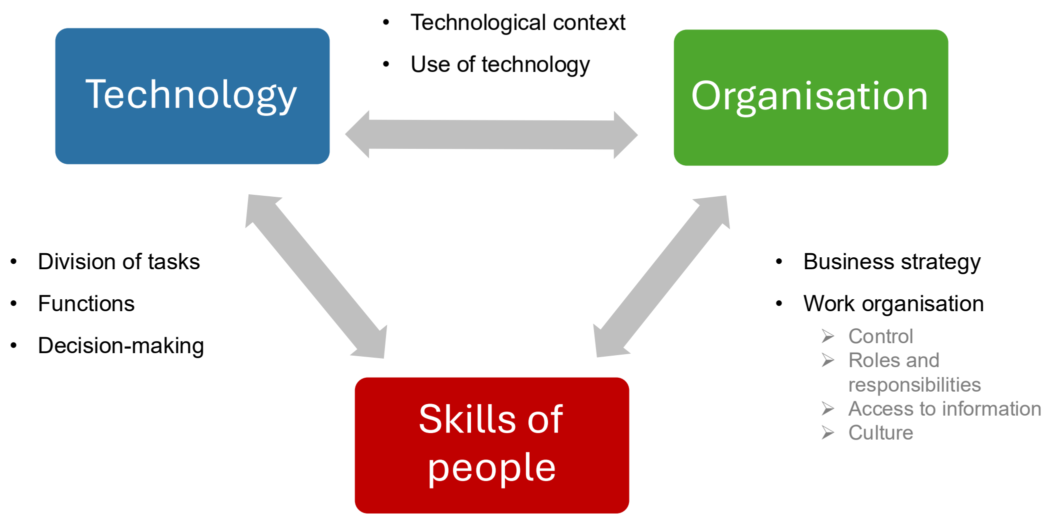


Figure 9.1: Conceptual framework

9.2 People and organisation

9.2.1 Goals of the organisation

The overall goals and business strategy of an organisation can influence the skills that are valued in a company, the way in which people are managed, and the skills that workers utilise. Changes to the business strategy could be observed in one case organisation, BrewCo. The automation of the brewing process has allowed the brewery to meet its customers' demand in their core products; and by freeing up space and production capacity, the brewery could start experimenting with spontaneous fermentation on the old brewery kit, which allowed the company to enter a specialist, more niche competitive market that focuses on innovation. In this example, the new technology adoption did not directly change the business strategy of the organisation, but by improving production capacity in the company, it enabled the expansion of its product offerings and competitive potential (Sung and Ashton, 2016; Knox and Warhurst, 2018). The start of the new barrel-ageing brewing project required a specialist skill set that the company needed to hire externally. As the production grew and the brewing team expanded, specialist roles were created in the company, which meant that brewers had to utilise more specialist skills besides their core brewing activities.

The building of the new automated brewing kit significantly expanded production in BrewCo, which led to considerable organisational growth. This example provides contradictory evidence to the deterministic narratives on technological change and forecasts claiming that new technologies, in particular automation, will replace lower-skilled workers (Gallie, *et al.*, 2004; Autor, 2013; Autor and Dorn, 2013). In BrewCo, automation led to increased employment, which shows the ways in which new technologies create additional labour demands. From a social shaping of technology perspective, this example shows that the adoption of new technologies is not pre-determined by technological capabilities but rather influenced by the priorities of an organisation (Howcroft and Taylor, 2022). Focusing solely on technological capabilities, the automated brewing kit was able to replace the routine, low-skilled manual tasks of brewing. However, widening the deterministic perspective, the example of BrewCo shows here that the main driver for automating the brewing process was to meet the brewery's customers' demand by significantly improving production efficiency. This increased production then had a positive impact on the employment levels of the company. The implications of this organisational growth on job roles in the company are discussed in a later section.

9.2.2 Work organisation

The next factor that shapes skills utilisation is work organisation. The most significant changes to work organisation could be observed in the case studies of MotorCo and FixSHop, the two companies that adopted management systems technologies (see Figure 9.2 and Figure 9.3 below). In the case organisations that adopted automation technologies, the changes were more observable at job role level, which are discussed in the next subsection of this chapter. In both MotorCo and Fixshop, the adoption of the new technology resulted in the reduction of micro-management. The decreasing managerial presence on the shopfloor meant that workers enjoyed more authority compared to prior to the changes. However, these changes differed in the two case organisations.

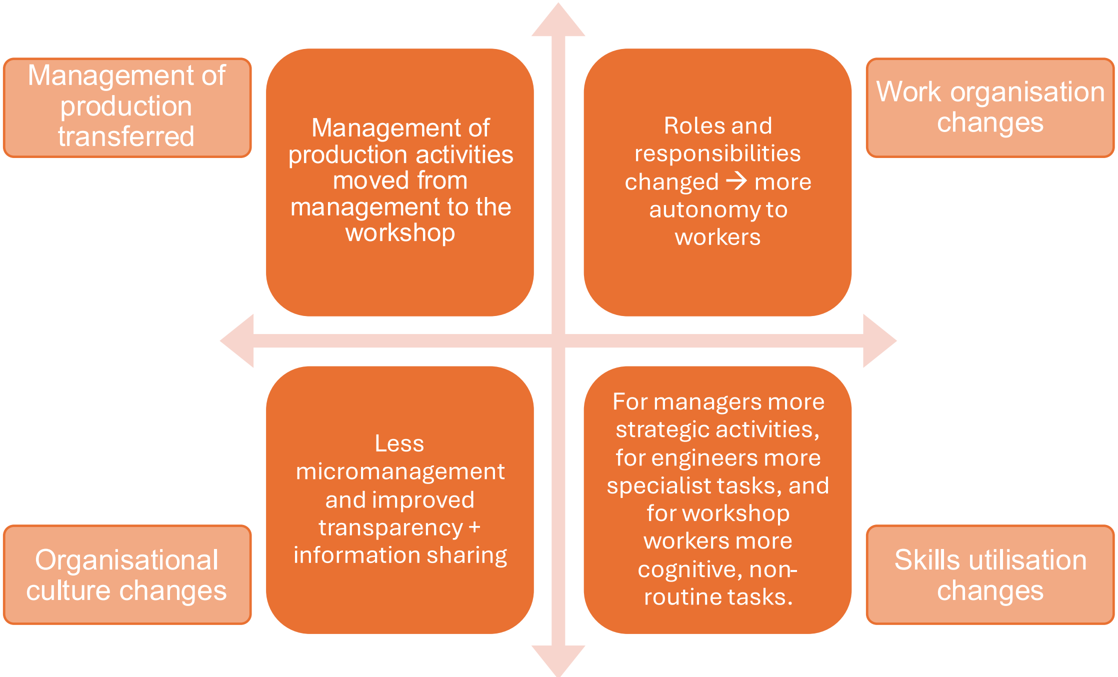


Figure 9.2: Summary of changes in MotorCo

MotorCo, which is a small sized company, is a more structured organisation in comparison to FixShop. Here the technology was adopted with the intention of improving work organisation in the company. The new technology had a significant impact on the way production was organised, and jobs related to production management saw significant changes. Whereas the administrative team and the engineering teams' work processes were complemented by the new technologies, but their main tasks did not change upon technology adoption. With the introduction of the new ERP system, the organisation of the production activities has become more streamlined, and the responsibility of task delegation was transferred to the shopfloor with the creation of the Production Controller job role. This not only allowed the company to stop having a two to three hours long production meeting each day, which significantly improved efficiency; but it also had an important impact on the work environment and organisational culture, which reportedly became calmer and better organised with less conflicting instructions from management.

From a roles and responsibilities perspective, the changes have freed up time for the management of the organisation, which meant that they could engage in more strategic activities that encouraged organisational development. According to research participants, the directors' role included strategic activities prior to the software adoption too, but they did not have the opportunity to engage in them often due to the time constraints of micro-managing everyday production. Therefore, from a skills utilisation perspective, the technology did not change the skills requirements of the directors' job role, but it did increase the extent to which they utilised their pre-existing cognitive skills. This example is in line with the skills biased technological change view, which argues that by taking over more mundane tasks, new technologies free up time for workers to engage in higher-skilled, more complex activities in the workplace (Hirsch-Kreinsen, 2016). However, in this example, the tasks of everyday production management did not disappear with the introduction of the new technology, they were rather transferred in the organisation. Therefore, the skills biased technological change only explains part of the skills changes that refer to high-skilled individuals in the company. Moreover, the use of the new ERP system also required some technology-specific digital skills from the directors of the company, as well as some data literacy skills to be able to benefit from the performance data that the new ERP system recorded. Here, the introduction of new technology has led to the development of additional technical skills that the job role did not require prior to the changes and the directors did not possess before either, serving as an example for upskilling both of the job and on the person.

With the reduction of the directors' micromanagement, the majority of production management activities were transferred to a newly created Production Controller (PC) job role in the company. The Production Controller job role was taken on by an employee, who was a manual labourer prior to the technology adoption. With the creation of the Production Controller job role, the production-related tasks moved closer to the workshop, which reportedly helped efficiency in the organisation. For these new tasks, the PC had to gain new skills, such as computer skills to use the ERP system; written and verbal communication skills to manage customer queries; leadership skills to delegate production tasks amongst machine operators; and decision-making to successfully organise production schedules. The Production Controller's personal journey clearly illustrates a significant upskilling effect, both upskilling of the job and the person. From a skills utilisation perspective, the PC had to utilise higher level of skills (for instance, improved communication skills) and different function of skills (such as more social skills for task delegation in the company, or customer service skills). However, these tasks were present in the organisation prior to the new technology adoption; therefore, the skills changes were not necessarily a result of the introduction of the ERP system, but rather the rearrangement of roles and responsibilities in the company.

The core tasks and responsibilities of workshop workers did not change significantly after the technology adoption in MotorCo. However, due to the reduced micromanagement and increased access to real-time information, workers gained more freedom in choosing the order in which they carry out their tasks, which represents a slight increase in workshop employees' authority. From a skills perspective, workshop workers had to utilise digital skills to record their jobs on the new ERP system, which was not a skill requirement of their job role prior to the ERP adoption. In addition, since the new system allowed them to plan the order in which they carried out their jobs, the workshop workers also got to utilise their decision-making skills to a higher extent than they did prior to technology adoption. Based on the research findings, the increase in utilising digital skills and decision-making skills meant an upskilling effect on the job, but not on the individuals, as workshop employees possessed these skills prior to the technology adoption too, but they did not need them in their jobs.

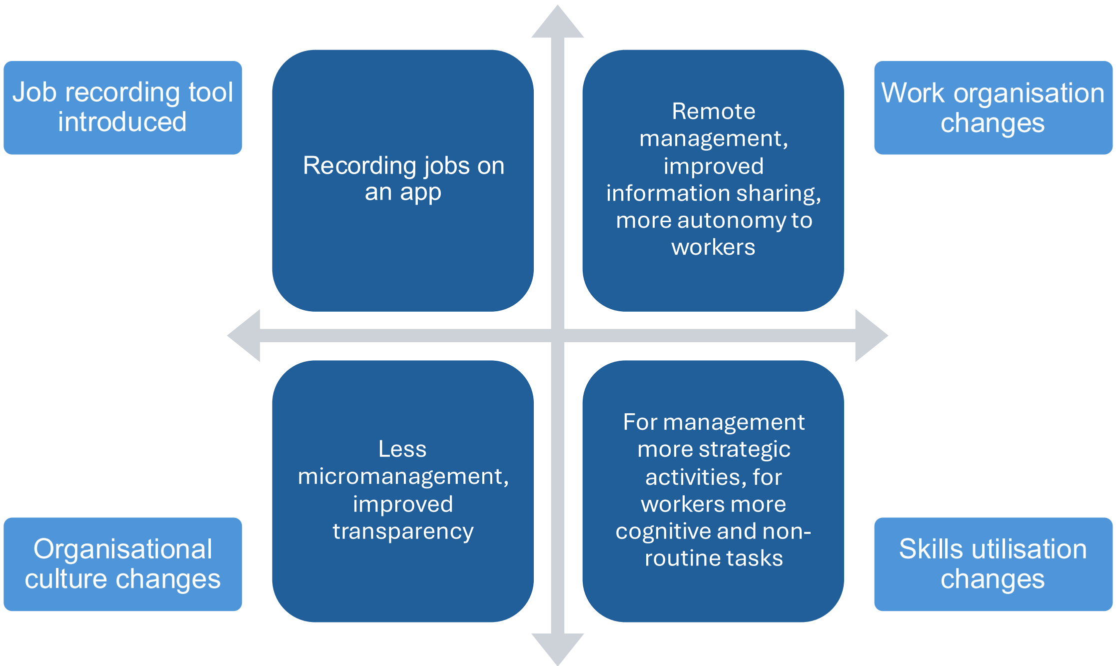


Figure 9.3: Summary of changes in FixShop

Work organisation changes could also be observed in the case study on FixShop. However, these changes manifested differently in FixShop than they did in MotorCo. Whilst in MotorCo the new technology was adopted with the intention of improving work organisation and it rearranged some roles and responsibilities in the organisation; in FixShop, the technology was designed to fit the pre-existing structure of the company.

Here, technology was adopted to improve the company's record keeping and storing and accessing data on the jobs.

Similarly to MotorCo, the new technology also allowed the Owner-manager of the business to step away from the shopfloor, which reflects the new management style and culture in the company. However, it is important to point out that whilst this could suggest reduced monitoring of workers' performance from the Owner-manager on the shopfloor, the new technology enabled the monitoring of workers' progress via the app. The Owner-manager of the company did not choose to utilise that aspect of the new technology, but the option was available to him. This highlights the social shaping of technology approach's argument that technological outcomes are not pre-determined, and people have a choice over how technologies are utilised in organisations (Howcroft and Taylor, 2022). The adoption of the new technology, however, was not the driver of these management and culture changes, but it enabled the process.

As for the roles and responsibilities of workers in the organisation, the owner-managers had more time freed up due to stepping away from the workshop, which allowed him to focus on developing the new technology, and take on a role that was not directly related to FixShop. The introduction of the new app did not just allow the Owner-manager to reduce his shopfloor presence, but it also allowed the transfer of customer service activities to the shopfloor workers in the company. From a skills utilisation perspective, these changes allowed the Owner-manager to increase the utilisation of his cognitive skills in his new technology-developer role. This, however, did not mean that he did not continue to utilise his leadership skills at FixShop. As the new app facilitated remote management, the Owner-manager continued to monitor workshop activities, albeit remotely through a different channel.

The workshop employees' core tasks and responsibilities still focused on repairing parts. In addition, similarly to MotorCo, the new technology improved information sharing across the organisation, which enabled better cooperation in the workshop and better customer service. The introduction of the new job recording app expanded the skill requirement of the workshop employees' jobs. The new app changed the way workers recorded their progress on jobs and the way they collaborated with each other. As a result of this, their job role required more information processing skills and written communication skills. In addition, due to the reduced managerial presence on the shopfloor after the introduction of the new app, workshop employees were required to work more independently, which meant that they utilised their decision-making skills to a larger extent than they did prior to the technology adoption.

Overall, work organisation changes could be observed in both MotorCo and FixShop upon the adoption the new management system technologies. However, different aspects of work organisation had the higher relevance in these changes in the two case organsiations. In MotorCo, the most significant transformation was around the production roles and responsibilities, where some tasks and responsibilities were rearranged and a new job role was created. In addition, the reduced managerial presence on the shop floor also reportedly changed the culture of the shopfloor. However, the change in organisational culture was not mentioned during the interviews of employees working in different parts of the business. Therefore, the findings of this research in relation to change in organisational culture are limited to the workshop. In FixShop, the most significant changes could be observed in the culture of the organisation, which was supported by the improved information sharing across the organisation and the management style of the new Owner-manager. Whilst these changes were not directly driven by the new technology, they were enabled by it.

The differences in work organisation changes could be explained by the differences in MotorCo and FixShop's organisational characteristics, such as organisational size (Nolan and Garavan, 2016). At the time of the research, MotorCo had 37 employees and classed as a small sized organisation. Whereas FixShop was a micro sized business with 10 employees in total at the time of the research. In MotorCo, the company was divided into separate business units and teams, such as the directory team, the admin staff, engineers and production workers. As discussed above, the most significant work organisation changes that followed the technology adoption were mostly limited to the production side of the business. Whilst these changes were considerable in regard to how work was organised in the workshop, the contrasts between before and after the technology adoption were significant for only the affected workers in the business, such as the Production Controller and the directors of the business. In FixShop on the other hand, eight out of ten employees used the new technology for their work. In addition, the culture change in the workshop has affected eighty per cent of the business' workers, as opposed to only certain groups of workers.

The above discussion shows that technology and work organisation are mutually constitutive, as the social shaping of technology approach argues (Howcroft and Taylor, 2022), and new technology adoption can alter the interplay of people and work organisation in a variety of ways. Differences can be observed even when adopting the same type of technology, management systems technology in these cases, due to various organisational characteristics (Howcroft and Taylor, 2022). Whilst the studied management system technologies influenced most jobs in both MotorCo and FixShop, and the adoption of the technologies changed the way work was organised; automation that was adopted in BrewCo and PartLtd, was more focused on production activities, and in these organisations, the changes to the interaction of humans and organisation due to technology adoption could be more observable at the job design level.

9.2.3 Job roles

At the job role level, the new technologies either had a standardising or a specialising effect on jobs' overall skills requirement. In MotorCo, the introduction of the new software impacted the engineering team's skills by rearranging the tasks in the department. The introduction of the new ERP system has resulted in more specialised and distinctive roles in the engineering team. One engineer specialized in project engineering, one in wielding, one in programming and the fourth one in coating. For these new specialised roles, the engineers had to gain and utilise specific technical skills. However, similarly to some of the changes to the PC's job role, these skills changes were not due to using the new technology, but rather due to work reorganisation in the engineering team.

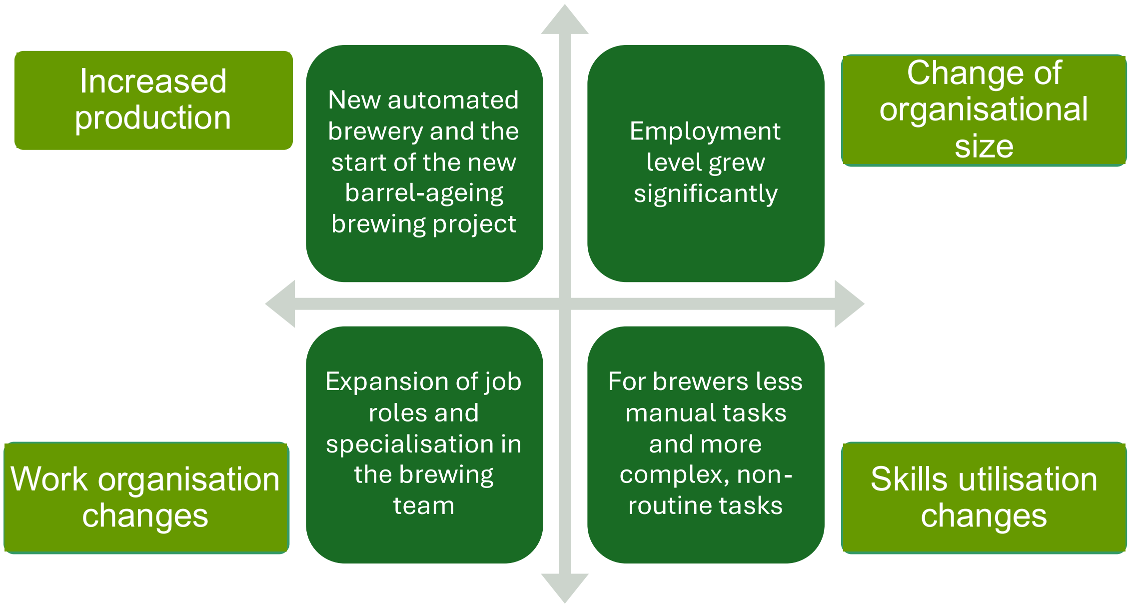


Figure 9.4: Summary of changes in BrewCo

A similar skills specialisation could be observed in BrewCo, too (Figure 9.4). As the production and brewing team grew, more specialised brewer roles were created in the company, where designated individuals were responsible for quality management, engineering supervision, barrel ageing, and the aforementioned managerial activities. This is in line with the experience of MotorCo's engineering team as well. However, in both of these cases, except for the engineering supervisor in BrewCo, the skills changes happened due to work reorganisation, rather than use of the new technology.

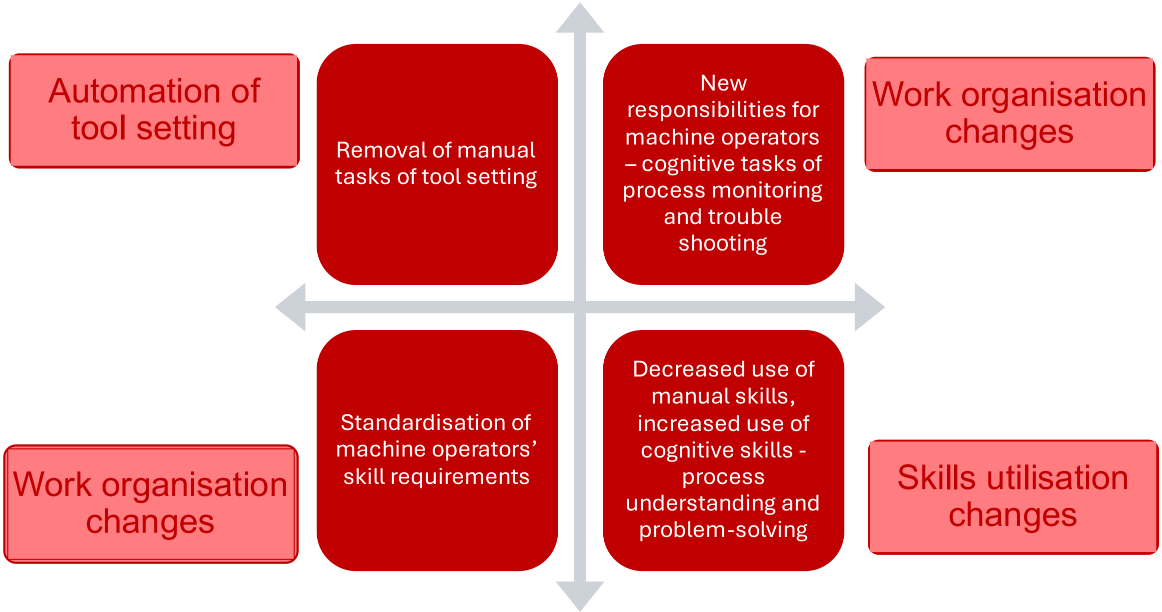


Figure 9.5: Summary of changes in PartLtd

In PartLtd, the machine operators became responsible for monitoring the performance of the new tool, which is a more cognitively demanding activity than the tool setting was prior to automation (see Figure 9.5 above). This new responsibility required machine operators to have an overall process understanding, which they did not have before the technology adoption. This process understanding was pivotal for the tool-setting monitoring and the occasional trouble-shooting, which required further problem-solving skills and creativity from workers. This example is supportive of the upskilling view. However, since these new responsibilities often do not require physical intervention, they can easily go unnoticed or unreported. This example, therefore, highlights the importance of studying the effects of technological change at the micro-level, to be able to capture the nuanced changes that technology adoption brings. Whilst the machine operators in PartLtd experienced a general upskilling as a result of tool setting automation, the standardisation of production did not result in specialisation of skills, as it did amongst engineers and brewers in MotorCo and BrewCo. Indeed, in PartLtd, the standardisation of the tool setting stage of production led to the standardisation of skill requirements amongst machine operators in the workshop.

The small sample does not provide conclusive explanations for the reason behind the different effects on skills demand. However, one possible explanation based on the findings might be the differences in the skill level of workers involved. The standardisation of production has led to skill specialising amongst skilled professionals in MotorCo and BrewCo. Considering the value we attach to skills, it can be argued that individuals, whose jobs' require higher-level specialist skills, are in a more favourable position compared to their lower-skilled colleagues, because they are harder to replace in the workplace. If we position this argument in the technological change debate, it is in line with the skills-biased technological view, which argues that new technologies will benefit workers in higher-skilled positions due to their lower levels of vulnerability to replacement. If we study the changes at a qualification or other easily observable levels, the findings from the PartLtd case study support this view. However, considering the additional process understanding that the workshop workers had to gain in PartLtd as a result of the automation of tool-setting, it can be argued that these workers experienced upskilling and therefore, their work experience has also improved due to the introduction of hard automation in the tool setting process. Nevertheless, despite this positive effect on the lower-skilled workshop workers, it cannot be denied that the standardisation of their skills requirements when using the new technology has made them more susceptible to replacement, either by machines or fellow workers. Therefore, whilst the findings of the case study show a positive upskilling result for these workers in the timeframe when the study was conducted, it cannot guarantee and conclude that these machine operators will not be disadvantaged by these skills changes in the long-run.

Beyond the standardising or specialising effect, the new technologies also expanded some pre-existing job roles in the case studies. As discussed above, the most significant skills changes could be observed in MotorCo's Production Controller's job role. However, the PC was a newly created role. In the other case organisations, the new technologies did not create new job roles, but they expanded pre-existing roles.

In FixShop, the adoption of the new app enabled the transfer of customer service tasks from the Owner-manager to workshop employees. Since the new app allowed the workers to directly communicate with customers, they also needed to utilise customer service skills after the introduction of the new technology. This was not part of their job role before, and therefore, workers had to develop these skills.

In BrewCo, automation led to increased employment. As the company grew from a micro business to a small sized organisation, the Head Brewer's job role has expanded with an array of managerial responsibilities, that required the development of leadership skills, communication skills and problem-solving skills. According to the Head Brewer, these skills were developed organically through experience, which confirms the prevalence of informational learning in SMEs (Wapshott and Mallett, 2015; Harney and Alkhalaf, 2021). In addition, the new automated brewing kit technology took over the majority of physical tasks related to brewing, which meant that the brewers had to perform physically demanding tasks to a significantly lesser extent than previously. By removing these tasks, the new technology also freed up time for the brewers to return to more complex tasks, such as recipe creation that required high levels of creativity, and personal abilities such as their taste pallets. This example also supports skills biased technological change and shows that even if technology replaces certain tasks, humans will not lose relevance in the workplace (Hirsch-Kreinsen, 2016). In this example, the adoption of the new technology allowed workers to utilise their pre-existing skills that were dormant for the period of time when the brewery was struggling to meet customers' demand. Here, similarly to the management of MotorCo and FixShop, the introduction of the new technology allowed high-skilled employees to engage in more strategic activities that encourages strategic business development on the longer run. This is a particularly important development for small and medium sized enterprises, since these organisations often face challenges due to the lack of time resources designated to strategic activities (Muller *et al.*, 2019; Idris, *et al.*, 2020; Harney and Alkhalaf, 2021).

In PartLtd, the automation of tool setting only impacted the machine operators' skills utilisation in the organisation. By replacing the routine manual task of tool setting, the machine operators' responsibilities seemingly decreased. However, as the research participants reported, the machine operators had to take on more cognitive tasks instead – process monitoring and troubleshooting. For this, the machine operators had to develop an overall process understanding, which they did not possess prior to the technology adoption; as well as utilising problem-solving skills as and when the need arose. This example shows that even though automation replaced machine operators' tool setting tasks, it did not replace human input entirely in the process. In fact, it gave machine operators more cognitive tasks, albeit less visible on the surface. This skills change is similar to the Production Controller's in MotorCo, since the adoption of new technology required the development of different function of skills, cognitive skills, that workers did not require prior to the adoption.

9.3 People and technology

Regarding how people interact with technologies, the division of tasks between technologies and people differed based on the type of technology the case organisations adopted. In MotorCo, the new management system technology complemented people's work in the organisation. It aided the directors in their more strategic activities, such as financial planning, by providing real-time information on production activities and sales. Similarly, the new ERP system helped engineers in the contract review process and provided crucial production information for the new Production Controller for production management. In FixShop the new app enabled the transfer of preexisting customer service tasks from the Owner-manager to workers; and it enabled improved information sharing and data recording across the organisation. In both of these cases, the new technology enabled these changes and complemented human input into the various work processes.

As the literature argues, automation technologies have the capabilities to replace human input in work processes (Levy and Murnane, 2005; Peng, *et al*., 2018). The two case studies that adopted automation technologies demonstrated this replacement effect of new technologies. In BrewCo, the new technology has replaced the manual tasks of brewing; whilst in PartLtd, the new automatic tool setter replaced the need for manual tool setting. However, the findings of both of these case studies showed that automation did not replace the need for human input. In BrewCo, the automation of the brewing process allowed the brewers to engage in more complex tasks, such as recipe creations. In addition, even though the new automation replaced the need for manual tasks in brewing, it created increased demand for manual tasks in packaging and stock management. Therefore, one the one hand, automation allowed high-skilled individuals to engage in high-skilled activities, as the upskilling view argues. On the other hand, it also created need for manual tasks elsewhere in the organisation. Hence, the case of BrewCo does not fully support the skills biased technological change view, because the demand for low-skilled, manual work also grew with the introduction of the new technology, albeit at a different part of the company. More broadly, these examples highlight the need to move away from the limited focus on technologies and separate job tasks, and to broaden the focus of enquiry to organisational-level changes in order to best capture the holistic effects of new technologies in the workplace.

In PartLtd, the automation of tool setting replaced the manual tasks related to tool setting. However, as research participants argued, whilst the routine manual tasks disappeared, machine operators were required to engage in the more cognitive activities of process monitoring and trouble-shooting. Whilst these cognitive activities were less visible on the surface, they still required new skills from machine operators, such as process-understanding and problem-solving. This example contrasts the deskilling view, which argues that automation results in a narrowing of work tasks (Kunst, 2019; Nikolova, *et. al*., 2023), and workers become specialised in repetitive activities, whilst the need for their technical skills and their ability to exercise authority decreases (Green, 2013).

Another aspect of the human-technology interaction is related to decision-making. This was the most relevant in case studies that adopted automation technologies. In PartLtd, the automatic tool setter took over the measurement tasks of tool settings. As research participants argued, one of the most challenging parts of the technology adoption process for the machine operators was building trust with the technology's decision-making. In BrewCo, even after the automation of the brewing process, the responsibility of decision-making stayed with workers.

9.4 Technology and organisation

As for technologies and organisation, this section focuses on organisations' technological context, the type of technology that organisations adopt and the way in which employers choose to utilise the adopted technologies.

The technological maturity and the organisational characteristics of the business were both reflected in the choices that the case organisations made in relation to the complexity of the adopted technology. An important organisational characteristic that influenced the choice of technology in the two case studies adopting management systems technologies was the structure of the organisation. Due to its size, MotorCo is a more structured organisation with defined, separated business functions, such as the director team, the administrative function, the engineering team and the production team. Having already defined, separate business functions enabled the organisation to adopt an off-the shelf technological solution that even further improved the structure of the organisation and streamlined the cooperation across the different business functions. FixShop, as a micro sized business, did not have separate teams for the different business functions, and the majority of their employees worked in a workshop on repair activities. As the Owner-manager of the organisation argued, a complex off-the-shelf management system solution would have not suited the organisation's needs, and therefore, they chose a technology that followed the company's pre-existing organisational structure.

Besides the organisational size and consequent organisational structure, the preexisting technological maturity of the case organisations also differed. On the one hand, MotorCo was able to adopt an off-the-shelf management system technology and organised its production processes accordingly. The adopted software underpinned every organisational function, except for finance and accounting. On the other hand, FixShop could not find a technological solution that suited the company's needs, organisational structure and its underdeveloped technological infrastructure. Therefore, the Owner-manager has developed a simple solution that suited the micro-business' need. This example shows that the businesses' technological maturity influenced their choice of the technology. Before adopting the new embryonic management system technology, FixShop did not use digital technologies for the core activities in the company. Therefore, the adoption of this new technology represented the first step of the organisation's technological journey. Whereas in MotorCo, technology might not had been used for production management purposes prior to the adoption of the ERP system, but the company had certain level of technology use before. Whilst it cannot be measured whether the change from using no technology at all to some technology, or the change from some technology to more technology have brought more transformative changes to the case organisations, these two case studies still demonstrate that the preexisting technological maturity of the business impacts the level of changes that could be observed in organisations after technology adoption (Dhondt *et al.*, 2019).

In the case studies that adopted automation technologies, the new technologies predominantly focused on their production activities. Therefore, the overall structure of the organisation was not a key determinant factor in the companies' decision about the specific technology they would adopt. In BrewCo, the brewing processes were not automated at all prior to the new brewing kit, and the new automated kit was designed and built for BrewCo specifically. Similarly, in PartLtd, the structure of the organisation was not the most influential factor in choosing the new technology. Here, the choice of technology reflected PartLtd's technological maturity, because the company chose the adopted technology based on their previous experience with the brand and with the intention to unify the brand of technology across its production. PartLtd's technological maturity is in stark contrast with FixShop's early steps of their technology journey. PartLtd did not only show the most technological maturity as a business out of all the case studies, but it was also the only company where the technology was adopted to standardise the skill requirements of its machine operators across the workshop, which potentially, can make these workers more susceptible to replacement on the long run. The collected data for this research does not provide sufficient evidence to claim that higher levels of technological maturity in a business might result in an overall more negative effect on workers, future research is needed for the exploration of this potential link.

The second factor focuses on the choices that employers make regarding the utilisation of technologies in their organisations. The most outstanding case study example on the importance of managerial choice could be observed in FixShop. As discussed in Chapter Six, the new job recording app allowed the remote monitoring of employees' progress on their jobs, and could have facilitated an increase in managerial control over employees' work (Thompson and Newsome, 2004; Smith, 2015). However, as the Owner-manager of the company claimed, despite having the opportunity to remotely monitor workshop workers, he chose not to utilise that aspect of the technology. This is an important example of how technological outcomes are not pre-determined in organisations, and how managerial choices on what aspects of technologies will be used can determine technology-driven outcomes (Howcroft and Taylor, 2022).

9.5 Conclusion

The first research question that this study has set out to answer was: *how does the adoption of new technologies change skills utilisation in Scottish manufacturing SMEs*? In this study, new technology adoption in Scottish manufacturing SMEs have affected skills utilisation in a number of ways.

Looking at changes to people's roles in organisations, the most notable changes include changes to organisational strategy (e.g., opening up opportunities for niche product development), work organisation (e.g., devolving responsibility of management and decision-making to shop floor) and job role requirements (e.g., expanding roles with additional responsibilities). These changes resulted in workers utilising their pre-existing skills to a greater extent, developing more specialised skills, or utilising new/different functions of skills, such as social skills that were not required prior to the changes.

Focusing the divisions of tasks between people and technologies, crucially, the findings show that how technology affected skill use partly depends on the technology adopted. Management system technologies were instrumental in changing work organisation and affording shop floor workers more involvement and autonomy, that required more cognitive skills than they would previously utilise. Automation technologies replaced manual tasks, allowing the company to redirect production efforts to niche products, thereby requiring more cognitive input from workers.

Overall, the research findings showed a wide range of skills utilisation changes in the case organisations. The most common skills utilisation change was the higher extent use of pre-existing skills, as opposed to developing new skills, or stop using certain skills. The qualitative case study research design enabled the exploration of these skills changes at the job- and the organisational-level, which offered an insight into the nuances of skills utilisation changes within jobs, and the complexity of the interplay of people, technology and organisation in the case organisations.

To explore the role of the organisational context in these changes, the second research question was: *in what ways do organisational factors interact with the interplay of technologies and skills in the case organisations?*

The research has found that the organisational context and consequent organisational factors were key determinants in skills utilisation outcomes. The most influential factors were the organisations' technological context, which influenced the choice of technology, and the managerial decision-making regarding the use of the technologies. The reported positive overall effects of technologies on management and employee skills were facilitated by the decisions owner-managers have taken to use technologies to involve workers in the production process and affording decision-making autonomy.

Technological context and managerial decision-making as the two most influential organisational factors in technology adoption outcomes demonstrate the crucial role of both the technical and social spheres in technology-driven organisational changes. This study provides empirical evidence of how technology is influenced by the social aspects of organisations as much as those social entities are influenced by the technology. This mutual interdependence is a key finding of this research and the theoretical implications of this are discussed in the next chapter.

CHAPTER 10: DISCUSSION

10.1 Introduction

The overall aim of the research was to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing small and medium enterprises (SMEs). Through exploring skills utilisation changes upon technology adoption, the research demonstrated the mutual interdependency and shaping of technical and social spheres of an organisation. The previous chapter analysed the overall findings of this research. This chapter discusses the findings in relation to the relevant academic literature and outlines the key theoretical contributions of the study.

The chapter starts by discussing the overall positive skills changes that could be observed in the case organisations. Section 10.2 outlines how this finding differs from the dominant, techno-deterministic narrative in current debates on the future of work, and how it can be explained by the social shaping of technology approach, which focuses on the crucial role of context and choices in technology adoption. Whilst the majority of the findings of the research supports the SST approach, the key motivation behind technology adoption in the case organisations is not in line with SST scholars' narrative. Section 10.3 outlines the potential reasons for this divergence, namely the context in which the case studies were carried out - the Scottish manufacturing sector with a tight labour market and the SME context. This analysis shows how SST literature should widen its horizon beyond focusing on control as a key mechanism behind technological change. In the empirical data of this research, changes to organisational culture were amongst the most notable mechanisms through which the new technologies impacted skills utilisation of workers. Section 10.4, therefore, discusses how skills literature should take into consideration organisational level factors when studying technologies' impact on work, and look beyond the narrow, job-level changes in the division of tasks between people and technologies.

10.2 Positive employee outcomes

Contributing to the debate on the direction of skills changes associated with the current wave of technological change, the study showed no evidence of employees being disadvantaged as a result of new technology adoption. Technology adoption led to overall positive skills outcomes for employees in the studied case organisations. Skills utilisation took the form of either increased utilisation of employees' preexisting skills or developing new technical or cognitive skills for new tasks, as well as increased autonomy and decision making.

These positive employee outcomes contradict the negative narratives on technological change and their threat to human relevance in the workplace, as suggested by Frey and Osborne (2017)'s forecast. As Chapter Two discussed, much of the recent mainstream scholarship treat technological change as a deterministic, exogenous variable (Joyce *et al.*, 2023), where technological innovations act as autonomous entities and advancements in technological capabilities automatically lead to the implementations of technologies, neglecting the array of decisions that stakeholders make in relation to technology adoption (Hayton, 2023; Joyce *et al.*, 2023). Additionally, this view also argues that new technologies cause social and organisational outcomes in a linear, deterministic manner. The forecasts that follow these assumptions either predict a negative future, where new technologies make human input obsolete in the workplace, resulting in mass technological unemployment (Ford, 2015; Frey and Osbourne, 2017); or a positive, utopian future, where workers are released from work and are able to enjoy a leisure society without the productivity pressures of capitalism (Srnicek and Williams, 2015). Both of these images on future possibilities rest on the assumption that new technologies will take over humans' tasks and jobs. Whilst these deterministic narratives are widespread even outside of academia (Morgan, 2019); their predictions have not materialised, and as Howcroft and Taylor (2022) argue, and as the results of this study further supported, they are unlikely to do so in the foreseeable future. The reason behind this is that deterministic narratives fail to recognise technological change as a socioeconomic transformation, where social processes at work and economies at large shape the transformation as much as technological advancements do (MacKenzie and Wajcman, 1999).

The exploration of the skills utilisation changes upon technological adoption in Scottish manufacturing SMEs through the lenses of the social shaping of technology (SST) approach allowed the research to capture and explain a wide range of organisational-level changes that occurred in the case organisations. The social shaping of technology approach recognizes the equal importance of both social processes and technologies in technological change (Williams and Edge, 1996; Howcroft and Taylor, 2022).

By offering an insight into the influence that managerial decision-making had over the type of adopted technology, the use of technology and in one case, even the design of the technology, this research highlighted one of the key arguments of the SST approach, the role of choice in technology development, adoption and utilisation. As the research findings showed, this decision-making was influenced by a range of contextual factors, which are discussed in more details in section 10.3. In line with the SST approach, this research demonstrated that the process by which technologies are adopted and utilised in organisations, and their consequent outcomes, are not pre-determined, nor inevitable (Williams and Edge, 1996; Grant *et al.*, 2006; Gobena, 2024).

What is more, not only the organisational level factors influence over the choice and use of technologies were evident in the research, but the study also demonstrated that material characteristics of technology do matter, as much as the social process that shapes its design and adoption (Howcroft and Taylor, 2014; MacKenzie and Wajcman, 1999; Williams and Edge, 1996). The research showed the significant impact that different types of technologies can have on organisations, and within that, organisational culture and work organisation. Whilst this could be expected from management systems technologies that empowered workers in this study, the case studies on automation also demonstrated organisational-level changes where roles and responsibilities were transferred as a result of technology adoption, for the benefits of not only management, but also workers of the organisation. This mutual interdependency of the technical and social spheres within an organisation supports the core argument of the social shaping of technology approach, which argues that technologies and work organisation are mutually constitutive in organisations (Howcroft and Taylor, 2014).

As a result of the mutual interdependency, SST scholars argue that technologies are not neutral entities, since their design and consequent material characteristics inherently carry the power relations and class interests that benefit from their introduction (Howcroft and Taylor, 2022; Thompson, 2019). As Joyce *et al*. (2023) point out, much of the recent research on new technology approaches this from a political stance within the SST scholarship, focusing on control as the core purpose of technology development and adoption. This view stems from the Labour Process Theory school of thought that views the employment relationship's power relations inherently unequal, where the key motivation of employers is to derive labour from workers through the mechanism of control (Thompson and Newsome, 2004). From this perspective, the aim of the new technologies is to enable employers to exercise control over workers' labour process, which ultimately, leads to negative outcomes for workers.

Considering the technological capabilities of the two studied technologies in this research, management system technologies and automation, both had the potential to be utilised in a way where employers increasingly monitor employees' performance or substitute the need for their input and consequently make them obsolete in the work processes. However, a key emerging finding of the research was that employers of the studied organisations did not utilise the adopted technologies in a way that would restrict their workers' work processes, even in cases where the technology enabled closer monitoring of performance. In this study, the new technologies were introduced with the intention to improve performance, but not at the expense of workers. In fact, as earlier argued, the changes benefitted workers, rather than disadvantaged them. This research, therefore, supports and reinforces Joyce *et al.* (2023)'s call for looking beyond managerial control as the main driver behind the design and adoption of new digital technologies; and shows that there are "*more interesting stories to tell about how, when, and why*" technologies are adopted and how the organisational processes play out in various settings and with different technologies (Joyce *et al*., 2023, pg. 154). The next section discusses the story that this research told about the key driver of technology adoption in the context of Scottish manufacturing SMEs, and how this research finding might inform future research on technology adoption.

10.3 Influence of context

In line with the control focused narratives, the overall objective of adopting new technologies was to improve organisational performance and production efficiency in this research's case studies, too. The difference, however, lies in the motivation for the improvement. In this research, the key motivator for improvement and related technology adoption for the case organisations was to make the most of their resources that they have already had. The external context of the case organisations can offer some explanations for the motivation behind the managerial decision-making regarding technology adoption, whilst the organisations' internal context can further explain the decisions regarding the utilisation of the adopted technologies.

The research was carried out in Scottish manufacturing small and medium enterprises. As Chapter Four showed, this sectoral context is characterised by a tight labour market, where the sectoral skills challenges are heightened by the ageing demographic of the sector, the pandemic-related skills development shortages, and the reduced mobility of international workers due to Brexit (Scottish Government, 2021). In face of these skills shortages in the tight labour market, employers can find it difficult to source skills and additional human resources from outside of the organisation and might turn to technology adoption to reduce their reliance on human labour and to seek automated substitutes. However, as some of the stakeholders of this research and owner-managers of the case studies argued, taking into consideration the value of the vast organisational and technical knowledge that experienced workers have, employers would rather seek solutions that work with their employees, rather than replace them. As a consequence, in this research, the adopted technological solutions aided workers' input and enabled employees to focus on activities where they created the most value, such as more strategic and/or creative activities. This resulted in the above discussed positive employee outcomes.

Making the most of existing resources is also characteristic of small and medium enterprises, considering that these organisations often rely on limited resources, compared to their larger counterparts (Nolan and Garavan, 2016; Muller *et al.*, 2019). As the literature argues, SMEs have less financial, human and time resources than larger organisations do, which can create challenges, leading to lack of strategic planning in the organisation and short-termist attitude to management (Idris *et al.*, 2020; Harney and Alkhalaf, 2021). These issues were evident in the study's case organisations, too, prior to new technology adoption. Part of the motivation to adopt the new technologies were not only to improve production efficiency, but also to create changes to organisational culture. As a result of this, the work organisation changes that could be observed in the case organisations upon technology adoption included the transfer of responsibilities, moving authority downwards in the hierarchy of the organisation, and freeing up more space to strategic planning in the case organisations. This mutual shaping of work organisation and new technologies is in line with the social shaping of technology approach, which recognizes that technology, work organisation and the people in the organisation shape each other interdependently in various ways, rather than linearly as the techno-deterministic views argue (Mackenzie and Wajcman, 1999; Howcroft and Taylor, 2022). This means that technologies, people and work organisation are mutually constitutive in an organisation, where technologies are prefigured by pre-existing forms of work organisation and embody divisions of labour and expertise, whilst at the same time, technologies are often adopted with the intention to change, improve and transform work organisation (Howcroft and Taylor, 2022). The research overall demonstrated that the social and technical spheres of an organisation mutually shape each other, and the organisations' external context and the organisational characteristics shaped employers' decisions regarding technology adoption.

As mentioned above, the key driver for technology adoption in the case organisations was not to exercise increased power over employees' work, but to make most of the available resources in the organisations. This ultimately not only benefitted the owner-managers of the case organisations, but the workers as well, since they experienced positive skills utilisation changes. Findings from the research showed that the changes that could be observed in most case organisations were achieved through the mechanism of improving organisational culture, rather than increasing managerial control. Even in cases, where the new technology had the capacity to be utilised for enhanced monitoring. This demonstrated how employers' choice shaped the utilisation of technologies in the case organisations, which is in line with the SST approach. What is more, the research findings offered a new area of enquiry for future research to further explore the drivers and processes by which contextual factors shape the adoption and utilisation of technologies, and the consequent skills changes.

10.4 Beyond upskilling and deskilling

As section 2.5 in Chapter Two discussed, research that studies the effects of technological change on skill requirements tend to fall into two main categories – supporting the upskilling view or the deskilling view. Empirical support can be found for both directions of skills changes in existing research, depending on the group of workers examined (Hötte *et al*., 2023; Hirsch-Kreinsen, 2016; Anton *et al*., 2020). The findings of this study, however, showed positive skills utilisation changes to all groups of workers across the four case studies. One explanation for the divergence between these findings and the existing literature on technological change and skills is the unit of analysis used in the research. The studies examining the changes to skill requirements of jobs tend to be limited by its narrow focus on the division of work between technologies and humans, more specifically the interplay of tasks and technologies. From this perspective, technologies can either replace or complement human input. This binary view on the potential effects of technologies on skill requirements results in quantitative measurements and predictions on whether there will be less or more jobs available for workers after technology adoption.

The findings of this research, however, demonstrated that the skills utilisation changes in the case organisations pointed beyond the quantitative changes to work. Even in cases where certain manual tasks were eliminated, they were replaced by more cognitive activities that could go unnoticed in quantitative studies. Indeed, in all case organisations positive, qualitative changes could be observed after technology adoption, through changes to work organisation or organisational culture, as above discussed. In managerial roles, for example, the new technologies enabled managers to engage in more strategic activities, which had a positive organisational outcome for the studied SMEs. These changes did not mean that managers had to develop new skills, or that their jobs required new skills for these activities, but they could utilise their pre-existing skills to a higher extent. Further skills changes could also be observed due to the expansion of employment in one case organisation, and worker empowerment in other cases. These changes, however, could only be observed by taking into account wider, organisational-level changes, beyond the narrow, job-level changes. It is also important to note that as the previous sections of the chapter discussed, the organisational-level changes upon technology adoptions are also highly influenced by an array of contextual factors. These findings provide further evidence for Hötte *et al*. (2023)'s argument that empirical support can be found for all directions of skills changes upon technology adoption, due to the variety of contexts in which the changes are studied. In this research that studied changes to skills utilisation upon technology adoption in Scottish manufacturing SMEs, the skills changes were beneficial for all group of workers.

Overall, the research demonstrated that studying skills utilisation changes at the organisational level resulted in richer, more holistic data and better understanding of the potential effects of technologies on skills utilisation in the case organisations. In light of this, future research should expand its focus from job-level task and skills changes when studying the effects of new technologies and take into consideration the contextual factors that shape the technology-driven skills outcomes in organisations.

10.5 Conclusion

The two research questions that the study has set out to answer focused on how skills utilisation changes after technology adoption in Scottish manufacturing SMEs; and what role do organisational factors play in the interplay of skills and technologies. The research analysed organisational-level changes at the intersections of technology, skills and organisation to examine the changes after the adoption of two types of technologies, management system technologies and automation, in two SME case organisations each.

Overall, the research has found that technology adoption can enhance skills utilisation. Across the four case organisations, all group of workers experienced positive skills changes. This finding contradicts the negative narratives on technological change that portray technologies as a potential threat to human relevance in the workplace. In support of the social shaping of technology approach, the research showed that technology-driven outcomes are not pre-determined, since technologies, organisations and people are mutually interdependent entities that shape each other in various ways. This highlights the crucial role of context in technology adoption and related skills changes, which was the focus of the second research question.

The exploration of the role of organisational context in the interplay of technologies and skills demonstrated the intricate ways in which contextual factors shape employers' decisions relating to technology adoption and skills utilisation in organisations. The SST approach argues that the key motivation behind technology adoption is often to increase control in the workplace to enhance organisational performance. In the context of this research, which is characterised by a tight external labour market and limited available human resources in the Scottish manufacturing sector, employers adopted technologies with the intention to improve work organisation and production in the companies. As a result, technology adoption led to workers' empowerment, rather than increased control. By proposing an alternative explanation for the motivation behind employers' choices regarding technology adoption, the research further developed the social shaping of technology approach.

In addition, the study demonstrated the value of expanding the research focus beyond the narrow job-level analysis that is characteristic of the dominant upskilling and deskilling debates on technological change. As the above discussion showed, the organisational-level analysis allowed the exploration of qualitative skills changes in organisations after technology adoption, which resulted in a more holistic understanding of skills utilisation changes beyond the binary view of upskilling or deskilling debates.

Overall, as this chapter showed, the research contributes to the evidence base on how technological change can enhance skills utilisation in the workplace. The findings of the research support the social shaping of technology approach by demonstrating the mutual interdependency of technology, people and organisation; and it further develops the approach by offering an alternative, more positive explanation for possible employers' motivation behind technology adoption. For future skills research, the study suggests the widening of the research focus from job-level analysis to organisation-level analysis to better understand the complexity of skills changes after technology adoption.

CHAPTER 11: CONCLUSION

11.1 Introduction

The previous chapter discussed the key theoretical contributions of the research. The eleventh and final chapter of the thesis concludes the research by offering a brief summary of the research and outlining its recommendations for future research in section 11.2. This is followed by the study's contributions to policy and practice in section 11.3, and some recommendations on how to better support Scottish manufacturing small and medium enterprises in technology adoption and related skills development. Finally, the chapter concludes with the researcher's reflection on her PhD journey in section 11.4.

11.2 Research summary

The overall aim of this research was to explore and analyse ways in which new technology adoption changes skills utilisation in Scottish manufacturing SMEs. The research has set out to answer two research questions. The first research question explored the question of *how does the adoption of new technologies change skills utilisation in Scottish manufacturing SMEs*; whilst the second research question examined *how organisational factors interact with the interplay of technologies and skills in the case organisations.*

The conceptual framework of the research (as outlined in section 2.6) was based on the principles of the social shaping of technology approach (SST) (Howcroft and Taylor, 2014), which highlights mutual interdependency of technology, people and organisation. The research, therefore, analysed organisational-level changes at the intersections of technology, skills and organisation to examine the changes after the adoption of two types of technologies, management system technologies and automation, in two SME case organisations each.

For this, the research adopted a qualitative research method, collecting data from sectoral stakeholders from Scottish manufacturing, and conducting case studies in four Scottish manufacturing SMEs. The data collection methods included semi-structured interviews and field notes from site visits in the case organisations. This methodology allowed the in-depth exploration of the case organisations' external and internal context and provided rich qualitative data on technology adoption and related skills utilisation changes in an

SME context. The data analysis process included a reflexive thematic analysis and was guided by the conceptual framework of the research.

Overall, the research has found that technology adoption can enhance skills utilisation. Across the four case organisations, all group of workers experienced positive skills changes, with the most common skills utilisation change being the higher extent use of pre-existing skills, as opposed to developing new skills, and stopping the use of certain skills. These positive employee outcomes counter the negative narratives on technological change and their threat to human relevance in the workplace, as suggested by Frey and Osborne (2017)'s forecast. In support of the social shaping of technology approach (Howcroft and Taylor, 2014; Joyce *et al.*, 2023), the research showed that technology-driven outcomes are not pre-determined, and the choices that employers make regarding technology adoption and skills utilisation in the organisation are influenced by an array of contextual factors.

In the context of this research, which is characterised by a tight labour market and limited human resources, employers adopted technologies with the intention to improve work organisation and production in the companies. As a result, technology adoption led to workers' empowerment, rather than increased control over their work, which is often argued to be the key driver for technology adoption amongst SST scholars. By demonstrating an alternative explanation for the motivation behind employers' choices regarding technology adoption, the research further developed the social shaping of technology approach and supported Joyce *et al.* (2023)'s call for future SST research to look beyond its focus on the role of managerial control in technology adoption and explore technology adoption and related organisational change in various settings.

As for skills research, the study highlighted various ways in which skills utilisation can change in organisations that go beyond the job-level changes in the division of work between technology and people. Widening the scope of analysis to the organisational level, the research demonstrated that the binary view of the upskilling and deskilling debates on technology adoption can miss crucial qualitative changes to jobs and consequent skills utilisation in organisations. Therefore, the research proposes that future research on technological change and skills should incorporate the organisational level analysis more to better capture the impact of new technologies on skills use.

Overall, the research has contributed to the evidence base on the impact of technology adoption on skills utilisation. By demonstrating the mutual interdependency of technology, people and organisation, the research supported the social shaping of technology literature and further developed the approach by offering an alternative explanation for the key driver behind managerial choices in relation to technology adoption and consequent skills utilisation. In addition, the study also contributed to skills research on the effect of technological change. By exploring the effects of technology adoption at the organisational level, the research highlighted the influential role of contextual factors in the interplay of technology and skills and demonstrated nuanced skills utilisation changes in the case organisations that go beyond the quantitative changes in the division of work between technology and people.

11.3 Contributions to practice and policy

As this research studied the interplay of technology, skills and organisation exclusively amongst Scottish manufacturing SMEs, its implications for practice and policy are context specific to Scotland's manufacturing sector.

The research highlighted that the lack of investments in the sector due to deindustrialisation from the 1980s has created barriers to current technological advancements. The majority of SMEs in the sector use out-dated, legacy technologies, which not only heightens the companies' reliance on older workers' skills, but also creates underdeveloped technological context in the companies. As the case studies of FixShop and PartLtd demonstrated, the technological context of the organisations played an important role in technology adoption decisions. Therefore, to support SMEs, the sectoral technological infrastructure amongst these organisations should be improved and its improvement must also be financially supported through grants.

The lack of past investment was also evident in the sector's skills supply, which created a currently ageing demographic in the sector with significant middle career skill gaps. As a result of this, the sector heavily relies on younger workforce to fill this gap. However, there is a mismatch between skill supply and demand in the sector, as the Small Business Survey Scotland also reflects (Scottish Government, 2022). A potential explanation for this could be that young people are equipped with digital skills that suit Industry 4.0 innovations, which do not match the outdated technological context of companies. In turn, young workers lack the work experience and knowledge that comes from it, which is reportedly a key requirement of employers.

In terms of the expected future direction of skills in the sector, the interviews with stakeholders and case study evidence showed that often it is not new technical engineering skills that are needed to adopt to new technologies, but rather more transferable skills, such as logical order-thinking, problem-solving and adaptability. Since these skills are not job specific, and workers can develop them outside of their job roles, much of the skills changes that can be observed after technology adoption are the increased utilisation of workers' pre-existing skills, which were either not needed for their jobs before the technology adoption, or not to the same extent.

Finally, the research has showed a mismatch between data collected from external stakeholders and SMEs. This suggests a detachment between the parties, which can hinder successful collaboration. The research has found that one of the key reasons for this detachment might be the differences in the parties' timeline and agenda. On the one hand, sectoral supporting agencies, industry bodies and policy makers work to ensure that the sector is well-equipped with a suitable skills pipeline for the future, and ready to tackle ongoing global and national challenges, such as the climate change, the Covid-19 pandemic or Brexit. This focus often leads to decades-long targets, aims and objectives. On the other hand, SMEs focus on their day-to-day survival, which takes priority over strategic, long-term planning. For support to be best, it is important that stakeholders meet SMEs in their everyday reality.

From a technology adoption perspective, the research emphasized the need to recognize the importance of context when designing support initiatives for SMEs. This study has shown that work organisation plays a crucial role in technology adoption in small and medium enterprises, and SMEs often need support in developing their companies from a business and management point of view, before they could take on new technologies. Areas that were reported to be key in helping adoption were strong leadership, and a supportive company culture. Practitioners and policy makers, therefore, are recommended to launch and coordinate business development initiatives for the sector's SMEs, which would strengthen these companies' stability, and would ultimately allow them to engage in more long-term innovation projects, once they stop fighting an ongoing battle for survival.

To get to know SMEs' context and the issues they are dealing with, the engagement between policy makers and support agencies and SMEs must improve. This study was an initial step in getting to learn about Scottish manufacturing SMEs' experiences on technology adoption and the related skills changes in their organisation. To encourage more engagement, the research suggests policy makers and industry bodies to improve communication and make sure it uses the same language as SMEs of the sector do, since the findings of this study have shown that the disconnect between SMEs and external stakeholders are caused by a lack of shared understanding around the topic.

11.4 Reflections on the research journey

Section 3.9 in the Methodology chapter summarised the researcher's reflection on collecting data for the research; covering the topics of finding research participants during the pandemic, interviewing online, and the influence that the researcher's personal characteristics might have on data collection. This section reflects on the researcher's overall research journey and the personal and professional development that she experienced during the research process.

The research started with the broad focus on the effects of technological change on skills and employment in Scotland. After reading a wide range of literature in the initial months of the research, I recognized that I was most interested in looking behind the statistics and the figures of large, quantitative studies on the topic in order to explore what happens at the organisational level when new technology gets introduced, and how the adoption and connected skills changes are influenced by contextual factors. To gain a rich insight into the companies' lived experiences, a case study research method was chosen.

Once the approach was identified, I had the opportunity to have informative discussions with various sectoral representatives from Skills Development Scotland. After these conversations and some further research, I decided to study technology adoption and related skills changes in Scottish manufacturing SMEs. The pandemic, however, changed my research plans, and made gaining access to SMEs increasingly difficult.

To stop delaying the start of data collection, I decided to expand my research sample, and interviewed sectoral stakeholders, who provided invaluable insight to the external context of my case study organisations and helped me to understand their point of view on technology adoption and sectoral skills development. Their insight later informed my above section on recommendations for practice and policy.

As I continued reading whilst I was trying to recruit case study organisations, I also developed a keen interest in exploring the adoption of different types of technologies, to investigate whether their adoption will influence skills differently or not. In the end, I recruited four SMEs for the research, which allowed me the comparison of two types of technologies – management system technologies and hard automation. The two research questions that guided my investigation focused on skills utilisation changes in the companies, and the organisational factors that influence the interplay of technologies and skills. As I was conducting my research interviews, it became apparent that work organisation played a crucial role in both technology adoption and skills changes. When I was visiting the case studies following the interviews, I made sure that my enquiry extends to the changes in work organisation in order to understand the complex changes that new technologies bring to companies. By highlighting the importance of the types of adopted technologies and the role of work organisation, I hope that this research provided valuable ideas to consider in future research projects to further develop theory on technology adoption and skills.

Finally, by comparing the data collected from external stakeholders and the case studies, I discovered an apparent disconnect between SMEs' needs and the supporting sectoral agencies' and industry bodies' offerings and views on how to best support SMEs in the sector. I hope this study offers valuable observations and recommendations for policy makers and practitioners, too, that may help them to bridge the gap between industry and policy.

From a personal development perspective, the last years have been immensely formative for me. As a reliable student, I have always been good at completing clearly defined tasks, writing assignments on specific questions and answering exam questions that I had months to prepare for. Looking back, I went into this PhD naively thinking that I can continue this well-tried strategy of working hard and following clearly defined directions, and all will be well. I was wrong, and this realisation has led me to the biggest lesson I have learned in the past years. When it came to refining my research focus, writing research questions and choosing a sector for data collection, I felt lost. This time, I had to be the one, who makes the decisions, and I did not enjoy that. It took me several months to make my decision, and even then, I felt insecure about it. I now see that there was never a right or wrong option - all I could do was making the most of the one I committed to. Another important personal lesson that I have learned during the PhD was how not to attach my self-worth to my research and my momentary performance. The feedback was always about my work, not me; and even though it sounds obvious, it took a minute to learn.

From a researcher perspective, this PhD provided me with exciting insights into technology adoption on the 'shopfloor', allowed me to make new connections and challenged me for countless hours of mental gymnastics. Doing doctoral research during a global pandemic was isolating and difficult at times, but it also made me very appreciative of any interaction I have got to enjoy during the years. I was lucky enough to meet with a wide range of people during the Medici summer school I attended in my first year; my PhD internship with Skills Development Scotland in second year, and all throughout my data collection that ended in the beginning of my third year. Meeting people from various research and work background have made me a better, well-rounded researcher and a more thoughtful person in general. I had many mentors over my academic years, who made a difference in my journey, and I look up them to greatly. I have also made valuable friendships, and I treasure them immensely.

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APPENDICES

Appendix 1: Interview guides

CASE STUDY QUESTIONS

Owner-Manager

As you know, ultimately my research is interested in the effects of new technologies on the skill requirements in your organisation. But first, I would like to ask a few questions to better understand your organisation/your job/skills development in your company.

Can you describe what your organisation does?

Prompts*:*

- *Main focus of the org*
- *Roles within the company*
- *Main stakeholders of the company*

What are the key skills in your company?

(HARD - basic IT skills, problem solving, writing/numerical skills, communication, manual dexterity, flexibility, cognitive skills, specialist skills, more specific IT skills?)

(SOFT – instructing/training others, sales skills, customer service, persuading others, team working, managing and motivating staff, time management, planning, emotional management, presentation skills, negotiation)

Prompts:

- *Qualifications*
- *Skills development*
- *Formal vs informal training*
- *External training providers*
- *Challenges to skills development*
- *Sectoral skills development opportunities*

What technology did you adopt recently?

Prompts:

- *Purpose of the tech*
- *Main drivers behind it – why?*
- *Employees skills assessment*
- *Other solutions*
- *Why this technology?*
- *Influences (external, internal) on the tech adoption process*
- *Challenges during adoption*
- *Jobs affected*

How did the new technology change work in your organisation?

Prompts:

- *Employment (redundancy, restructuring, outsourcing, in-house)*
- *What roles did it influence – job description, assessments prior to adoption*
- *Intended and unintended changes*

How did the new technology affect the skill requirements in your organisation?

Prompts:

- *Skill requirements (existing, new ones)*
- *Effects on key skills*
- *Change of skills composition*
- *Changes – expected or unexpected*
- *Training*
- *Training of new recruits*
- *Current skills policies and external training opportunities*

To what extent did Covid-19 have an effect on the technology adoption process and the relevant training activities?

- *Stage of adoption in March 2020*
- *External support during Covid-19*

Employees

As you know, ultimately my research is interested in the effects of new technologies on the skill requirements in your organisation. But first, I would like to ask a few questions to better understand your organisation/your job/skills development in your company.

Can you please describe your job role to me?

Prompts:

- *Tasks*

What are the most important skills or capabilities for your job?

Prompts:

- *Qualifications*
- *Skilled job*
- *Technologies*

Can you please describe how the new technology has changed your job?

Prompts:

- *Tasks*
- *Changes (Work organisation, tasks, new work teams)*
- *Incremental or significant way*
- *Attitude/Feelings*
- *Necessity of new tech*
- *Benefits and disadvantages of new technology*

Do you need different skills or capabilities for doing your job as a result of the new tech?

Prompts:

- *How did it change*
- *Skills –had to learn or had it before*
- *Other reasons for changes*

Did you receive any training related to the new technology?

Prompts:

- *Details of training*
- *Adequacy of training*

Did Covid-19 has any effect on the technology adoption in your opinion?

Prompts:

- *Speed of the process*
- *Guidance*

Technology Specialist

Can you please introduce this technology to me?

Prompts:

- *What is it used for?*
- *Who is it designed for?*
- *How does it work?*

What kind of skills does the use of the technology require?

STAKEHOLDER INTERVIEW QUESTIONS

SMEs + sector

What challenges do SMEs face currently in the sector?

- Tech adoption
- Skills development/training

How do you think Covid-19 impacted SMEs in the sector?

  - Investment
  - Planning
  - Skills development

Collaboration with SMEs

In what ways do you engage with SMEs?

What are the challenges in engaging with SMEs?

<u>**Appendix 2: Participant information sheet**</u>

Participant Information Sheet

I am Fanni Tamasi, a PhD candidate at the University of Stirling, sponsored by Skills Development Scotland. The current working title of my PhD research is:

Technology adoption and skills development in Scottish manufacturing SMEs

The purpose of this study is to examine the role that skills development plays in technology adoption in selected Scottish small and medium enterprises (SMEs). The research aims to understand how the implementation of new technologies might change the way work is carried out and how skills development can best support the process of adopting the technology.

The research involves interviews with a number of people to understand the changes that the new technologies bring to your organisation. You have been invited to take part in this research because I believe you can provide a valuable perspective on this topic.

Your participation would involve an interview with me, which should take **no longer than 40 minutes.**

- Taking part is **completely voluntary**. Everything you say will be **kept confidential and anonymous**. Every participant will be given a pseudonym and when I write up my thesis and any associated academic publication, only the pseudonyms will be used in order to avoid any kind of identification.
- If you agree to take part, you can **stop at any point**, or decline to answer any particular question that you are not comfortable with. The interview is unlikely to cover personally sensitive topics, but redundancy might come up during the conversation. If you feel uncomfortable discussing this sensitive topic, feel free not to answer the relevant questions.
- You can **withdraw** from the research at any point up to the stage your interview is analysed.

- I would like to **audio record the interview**, so that I can remember everything that you have told me. Recordings will be kept **securely**. The transcript will only include your pseudonym and can be deleted after the assessment of the dissertation upon request. Are you happy for me to record this interview or would you prefer me not to?
- The **collected data** will be analysed by me, and the findings will later be presented in my PhD thesis and possible future academic publications. Please note that no one apart from me will have access to the original data. My supervisors and mentors might see the analysed data - but that will only include pseudonyms, therefore cannot be traced back to individual participants.
- The collected data **may be reanalysed by the researcher** for potential academic publications in the future. Therefore, the transcript of this interview will be kept and stored securely for 10 years after the final assessment of my PhD thesis. In case you are not comfortable with this, I can destroy the transcript of your interview after my PhD is fully assessed.

Would you be happy for me to contact you in the future for further research on this topic? If so, please leave your contact details below.

____

Please note that the research project has been approved by the University of Stirling's General University Ethics Panel and adheres to GDPR guidelines. In case you have any concerns or comments regarding the ethics of this research, please contact the university's Data Protection Officer, Joanna Morrow (Deputy Secretary) at deputy.secretary@stir.ac.uk.

If you have any question, please email me at fanni.tamasi@stir.ac.uk. Alternatively, if you have further comments or queries, you can contact my supervisor Professor Ronald McQuaid at ronald.mcquaid@stir.ac.uk.

Appendix 3: Consent form

CONSENT FORM

Technology adoption and skills development in Scottish manufacturing SMEs

Please read the following statements, and delete any you are not happy with:

- I agree to take part in the above study.
- The aims of this research have been explained to me.
- I have had the opportunity to ask any questions and have had these answered satisfactorily.
- I understand that any information gathered will remain confidential and no information that identifies me will be made publicly available.
- I understand that my participation is voluntary and I may decline to answer any question or end the interview at any time.
- I understand that I can withdraw from the research up to the stage when my interview is analysed.
- I understand that the interview is unlikely to cover personally sensitive topics, but redundancy might be potentially discussed as part of the conversation.
- I agree to the audio recording of this interview.
- I understand that the transcripts will only be accessed by the researcher and examiners and will not be passed on to any third parties.
- I understand that the data collected in this interview will be used for the researcher's PhD thesis and be potentially reanalysed for further academic publications.

If you would like a copy of the summary of the findings of this research, please leave your email address below.

____

If you have any additional question before the interview, please email me at fanni.tamasi@stir.ac.uk.

Name of Participant: Date:

Signature:

Appendix 4: Recruitment poster

Skills Development Scotland

UNIVERSITY of STIRLING Management School

PARTICIPANTS NEEDED

…for research studying the effects of technology adoption on skills!

I am looking for **manufacturing SMEs**, who adopted any type of **technology** in the last four years.

For more information please contact:

Fanni Tamasi
PhD Researcher

Email: fanni.tamasi@stir.ac.uk
Twitter: @FanniTamasi
LinkedIn: https://uk.linkedin.com/in/fannitamasi

Appendix 5: Research summary

Technology adoption and skills development in Scottish manufacturing SMEs

Topic overview

The overarching aim of this research is to understand the role that skills development plays in technology adoption. New technologies - if they are adopted - cause significant changes within organisations and jobs; and consequently, often alter the skill requirements of jobs. For successful technology implementation, employees must possess or be able to develop the right skills.

My research studies technology adoption and skills development in Scottish manufacturing small and medium enterprises.

I'm looking to recruit organisations with **less than 250 employees** that adopted any kind of **new technology in the past 4 years**. Technology refers to, but not limited to:

- any new hard equipment,
- management systems,
- ERP systems,
- communication systems,
- information technology,
- new production system,
- human enhancement technology.

The research focuses on manufacturing SMEs that can be based in **any sectors**, for example, food and drink manufacturing, engineering, automotive industry, aerospace industry, energy industry, life and chemical sciences, or the textile industry.

Benefits of research participation

- The research offers a great opportunity for organisations to **evaluate, assess and reflect** on the effectiveness and progress of a recent change relating to the adoption of a new technology in the company.

- The research involves data collection with various stakeholders in the organisation. The findings of the study will offer a holistic view on the **different viewpoints** in the organisation, which offers a great feedback opportunity for organisations.
- The results of the study will be summarised in a **business report** along with some recommendations, which will be sent to the research participants.
- The findings of the study will be presented at a **knowledge exchange event**, where participating organisations can engage with various stakeholders in the sector and discuss technology adoption and skills development.
- The research is funded by Skills Development Scotland and it offers a great opportunity for SMEs to have their voice heard in the **national discussions** around skills development.

Data Collection

Data collection will involve semi-structured interviews, and focus group discussions with work teams. The data collection will be carried out online due to Covid-19 related restrictions. The data collection would only require an hour from each participant; or two, if they participate in any focus group discussions.

Each interview will last approximately 45 to 60 minutes. Interviews will be conducted with the owner-managers of the case organisations; workers, whose work tasks are directly affected by the implementation of the new technologies; employees, who are responsible for delivering training relevant to the new technology adoption; and if access allows, technology specialists, who were involved in the implementation of the new technologies.

Focus groups will be conducted on the decision making process around the implementation of the new technology; changes to the work process; and the training and skills development aspect of the implementation. These discussions will last approximately an hour each.

Dissemination

The results of this study will be presented in the PhD thesis of the researcher and in potential future academic publications. A policy brief will also be produced out of the findings of the study as a requirement of the collaborative sponsor, Skills Development Scotland. A summary report that the researcher will produce based on the findings of this study will be sent to the research participants via email.

Appendix 6: Business summary report

Technology adoption and skills changes in Scottish manufacturing small and medium enterprises (SMEs)

Research Summary Report

June 2023

Fanni Tamasi

fanni.tamasi@stir.ac.uk

Table of content

Please note that these page numbers relate to the thesis and are not in line with the original report's page numbering. The page numbers were merged due to editing consistency.

Executive Summary

The overarching aim of this research was to explore and analyse the ways in which new technology adoption changes skill requirements in Scottish manufacturing small and medium enterprises (SMEs). To investigate the relationship between technology adoption and skills changes, the research has adopted a qualitative research method, and collected data from sectoral stakeholders and carried out case studies in four Scottish manufacturing SMEs.

The first research question that the study has set out to answer was: *How does the adoption of two types of new technologies (management system software and hard automation) change the skill requirements in Scottish manufacturing SMEs?* First, the study explored sectoral stakeholders' views on skill changes in the sector that could be observed in relation to technology adoption. The interviewed stakeholders reported an overall positive, growing demand for upward skills formation in the sector. This upward skill trajectory could be observed in the sector due to technological innovations, as well as other influential factors, including demographical changes and ambitions to reach NetZero. In terms of the direction of skill specialisations, stakeholders argued that there is a growing demand for 'generalists' in the sector, who can flexibly develop specialised technical skills as and when required. This finding highlights the importance of agility and adaptability in skills development, which is key to successfully navigate the current wave of technological change and its effects on the world of work.

Findings from the stakeholder interviews were mostly supported by the four case studies of the research. The research studied the adoption of two types of technologies to explore whether the type of technology adopted influences the skills changes in the organisations. The two studied technologies, management system software and hard automation, indeed had differing skills effects in the case organisations. Additionally, the research findings also showed varied skills implications for different groups of workers. The adoption of hard automation technologies impacted workers directly involved in production processes, whereas management system technologies influenced most workers across the studied organisations. The degree of skills changes varied between the different groups of workers, but overall, the findings showed a general upskilling effect of the new technologies on job skills and individuals' skills. In terms of skill specialisation, automation had a skill specialisation effect on skilled professionals, who needed to develop further technical skills after the introduction of the new technologies; whilst machine operators experienced a standardisation effect on their skills due to the new technologies. Furthermore, not all skill changes were a direct result of the use of the new technologies.

In some of the studied skill changes new technology acted as an enabler, rather than a key driver. This suggests that there are various contributing factors that influence the relationship between skills and new technologies. These factors were the focus of the second research question.

The second research question asked: *What role do contextual factors play in the relationship between new technologies and related skills changes in Scottish manufacturing SMEs?* The stakeholder interviews provided an insight into the external contextual factors at play in the Scottish manufacturing sector. According to the stakeholder participants, the key factors influencing technology adoption and skills in manufacturing were the ageing demographic in the sector, climate change and drive for NetZero, the recent Covid-19 pandemic, and Brexit. Out of these external factors, the case study organisations have found the effects of Covid-19 on technology adoption and skills the most relevant. The pandemic not only disrupted production in all case studies, but it also delayed the adoption of the new technologies in two of them. Whereas in the first case study, the management system software enabled office-staff to work remotely, which proved to be a significant benefit for the business during lockdown.

As for the internal contextual factors, work organisations had a significant impact on technology adoption and related skills changes in the case organisations. The two studied technologies had differing effects on work organisation. The adoption of management system technologies, for example, impacted the distribution of roles and responsibilities in the two case organisations. In both cases, the new management system software reduced managerial presence on the shopfloor and encouraged more independent work from workers. In turn, managers of the companies had time to engage in more strategic activities. Hard automation impacted work organisation in the case organisations in a more indirect manner, for example, the increased production capabilities led to increased employment in one of the case organisations. Moreover, beside work organisation, organisational size and the companies' pre-existing technological environment also had an impact on technology adoption and related skill changes in the studied companies.

Stakeholder summary

Technology adoption and related skill changes

The findings from the stakeholder interviews showed that there is a wide range of issues that shape the skills landscape in the sector, namely an ageing demographic, lack of past investments, Covid-19, Brexit, climate change and the current wave of technological innovations. Overall, the stakeholders believe that the direction of skills changes in the sector will take the form of upskilling, with a minimal amount of deskilling in the areas of out-dated technical engineering skills. The stakeholders also highlighted some skills areas that will be increasingly important in the coming decades, including transferable skills, digital skills, and leadership skills. According to the interviewees, the sector offers a wide range of skills development opportunities, including traditional university courses, work-based apprenticeships programmes and additional training opportunities for individuals already employed in the sector. However, despite the array of skills development offerings, there still seems to be a mismatch between skills supply and demand in the sector, and innovation levels are not as widespread amongst smaller organisations as it would be desirable to be able to engage in Industry 4.0. This suggests that there are additional factors that influence technology uptake and skills development.

Key factors that shape the interaction of skills and technologies

The findings from the stakeholder interviews identified factors relevant to misconceptions around new technologies, their complexity and potential labour replacement effects. Moreover, factors, related to SMEs specifically, were also discussed during the interviews, such as the lack of SME leaders' time for strategic planning, which can have implications for skills development and consequently, can undermine technology adoption in these organisations. Lean work organisation was also named as a barrier to skills development in SMEs. Finally, the lack of time resources of SME owner-managers was also found to negatively impact the organisations' engagement with external stakeholders, according to research participants. The lack of engagement also means that stakeholders find it difficult to understand how to best support SMEs, as they lack organisational-level insight into these companies.

Case study 1

Case organisation

The first case organisation (CO1) is an engineering company that specializes in gear manufacturing. The organisation's customers are predominantly other manufacturing businesses from the oil and gas sector, steel industry, and the rubber and plastics industry. The company is located in a small town with developed infrastructure. CO1 is a family-owned business and currently has 37 employees, including 24 workers in the workshop, and 4 engineers in their engineering office. The rest of the employees are office-based.

Adopted technology

CO1 adopted an Enterprise Resource Planning (ERP) system, which is a management system technology that integrates several data sources and processes them into one unified system. The ERP system helps to store, retrieve and share information on any aspects of an organisation's operation in real time.

Skill changes

The new ERP software freed up managers' time that they previously spent on managing the day-to-day operational tasks, and allowed them to engage in more strategic, forward-facing activities to a greater extent. Whilst these changes did not require managers to gain new skills, the extent to which they utilised their already existing skills for non-routine cognitive tasks has increased. Additionally, the new ERP system provided live data on labour activities, financial performance and manufacturing processes. To maximise the benefits of the data, managers had to gain data literacy skills, which provides evidence for the upskilling effects of the adopted ERP system on managers' jobs. The delegation of daily production activities was transferred to and managed by the production controller in the company.

As for the engineering team, the adoption of the new management system led to the standardisation of the contract review process, and it also enabled work reorganisation in the engineering team. The work reorganisation meant that engineers moved away from generalised roles, and each of them specialised in different engineering areas, developing additional technical skills. This example supports the external policy stakeholders' view on the growing demand for generalist engineers with the ability to specialise in certain areas when the need arises. It is important to note that the skill specialisation in CO1 was not the direct result of the use of the new technology, but the result of the work reorganisation, which was enabled by the new technology. Therefore, similarly to the changes of managers' jobs, technology was not a key driver in this skills change, but rather an enabler.

As for the production activities, the workshop labourer took on a new job role, production controller (PC), which included a wider range of additional responsibilities compared to his previous role, such as the delegation of daily production tasks and customer service tasks. The production controller's personal journey clearly illustrates a significant upskilling effect – to take on his new role, he had to gain basic computer skills, verbal and written communication skills, and leadership skills, too. However, it is important to highlight that his new tasks and the required skills were not a direct consequence of the technology adoption, because they were not created by the new technology, as they were present in the company before the ERP introduction. Rather, they were the outcome of the change in work organisation in the company, which was enabled by the implementation of the new management system.

The core tasks of other machine operators (MO) in the workshop did not change, but the way they recorded their progress did. The new ERP system meant that production workers' job role now required basic computing skills for logging on to the system and record their working hours. Moreover, with the reduction of managerial presence from the workshop due to the use of ERP system, the production workers were encouraged to take more responsibility over their job lists and exercise decision-making over the order in which they carried out their tasks. These two changes are examples for direct and indirect upskilling effects of new technology adoption. The first one illustrates the need for upskilling to use a new piece of technology; whereas the second one shows the need for upskilling to adjust to the changes in work organisation that were enabled by the new technology adoption.

Case Study 2

Case organisation

The second case organisation (CO2) is an engineering workshop that specialises in repairing and maintenance services. The workshop offers hydraulic engineering, machine shop services, engine re-manufacturing, diesel workshop services and engine and machinery repairs and servicing. The business' customers include other businesses and individuals alike with bespoke machines and equipment. CO2 is a family-owned micro business with ten employees in total.

Adopted technology

CO2 adopted a job recording application, which was created by the company's owner-manager. The app captures, stores and organises pictures and notes of jobs in the business. The visual recording of the jobs and the attached notes create a searchable, shareable real-time data base on ongoing projects in the organisation, which improves traceability across the organisation and visibility for every employee. The technology itself is based on the idea of providing a '*photo album for work'*, and purposefully keeping a simple design as its main appeal to other non-tech savvy micro businesses. The basic premise of the technology admittedly resembles management systems, but by stripping away the inherent complexities of management system software, this application was designed and developed around micro businesses' needs in a bottom-up approach. This contrasts with management system solutions, where the software solution is designed first and then the implementing business later aligned at adoption.

Skill changes

The effects of the new technology in CO2 were similar to those on CO1's management team. By reducing the time that the manager spent on micromanaging in the workshop and contacting customers, the new technology created space for the manager to engage in more forward-facing, strategic activities outside of the workshop.

With the introduction of the app, the workshop employees needed basic computer literacy skills. This new job recording app was purposely designed highly user-friendly, and it only requires the competency of using a mobile-phone app platform to take photos. Most of the workforce has reportedly had the skills to navigate mobile phone apps by using it regularly in their private lives.

Since the new job recording tool decreased managerial presence in the workshop and enabled remote communication between workers and their manager, workers were encouraged to work more independently than before. This also led to a more open culture in the company, characterised by trust and accountability. Additionally, the new job recording app allowed workers to directly contact customers, which meant that they now engaged in customer service, too. Therefore, customer service and communication skills were new skill requirements from workers, further supporting the upskilling effects of the new job recording app in the case organisation.

Case Study 3

Case Organisation

The third case organisation, CO3, is a farm brewery, which operates two breweries on site: one manual, rustic brewery for farmhouse beers, and a new brewery using state-of-the-art technology. The brewery produces high-quality, core beers and some special releases in the new brewery. The company serves a wider audience with its core beers, and some niche, specialist audience through their farmhouse releases. The brewery is located in a rural area with limited infrastructure. Whilst its location offers a tourist attraction to the brewery's customers; the remote location requires high levels of self-dependence from an operational perspective. CO3 is a family-owned business with 22 employees – including four brewers, two warehouse and packaging assistants, three drivers, one farmer, three brewery tap shop workers, and seven office-based support staff.

Adopted technology

BrewCo commissioned the building of a new automated brewery kit to the site in 2014, which has significant contrasts to the original manual equipment. The automated system in the new brewery kit follows each step of the beer production – the loading of raw materials into the equipment; monitoring temperatures, pH levels and speed of movements across the brewing process; emptying the waste materials after production; monitoring the cleaning process; and dispatching the ready product for delivery.

The new brewing kit expanded the brewery's capacity significantly, going from 14,000 litre capacity per week to 100,000. As it was pointed out during the interviews, the steps of the brewing process remained the same in the new brewery too, but the volume significantly increased, and the manual processes became automated. The increased brewing capability allowed the company to meet their customers' demand for of their core beers, but also has given space to experiment with new recipes and create new beers.

Skill changes

The adoption of the new technology had skills implications for the brewing process. Directly, brewers in the company had to learn to use the new equipment. The automation of the manual tasks also freed up time for the brewers, which meant that they could engage more in the creative processes of experimenting with new flavours and creating new recipes. Since the brewers already had the skills required for these non-routine activities, their skill levels did not change, but the extent to which they used their already existing skills did. Finally, the new technology also changed skill requirements in the brewery through changing work organisation. As an example, the growing brewing team needed to be managed, therefore, the Head Brewer had to develop managerial and leadership skills. Taking on more specialised roles within the brewing team (focused on quality control, barrel ageing projects, engineering supervision and management) resulted in upskilling for brewers. This meant that overall, the automation of the brewing process had a standardising effect on the beer production in the brewery, but a specialising effect on the brewers.

Case Study 4

Case Organisation

The fourth case organisation (CO4) is an engineering company, that specializes in high-precision engineering. The company manufactures highly specialized, custom-made complex components for customers in the aerospace industry and the defence industry. CO4 is a privately-owned company with 250 employees in Scotland. At the site where the case study was conducted, 50 employees are working in the machine shop and are supported by a team of engineers and office-based staff. The majority of the employees in the workshop are machine operators, operating a wide range of equipment including automated and manual tools. The engineering team is responsible for planning production, programming automated equipment and supporting production processes.

Adopted Technology

At the time of the research, CO4 was in the process of rolling out an automated, high-accuracy laser tool setting system across its business to replace the manual tool setting, which was used in the organisation before. This technology got incorporated into existing machines in the engineering workshop. By replacing the offline tool setter, the new automatic non-contact tool setter enabled constant resetting on the machine tools at every cycle of the production. By replacing the manual tool setting process, the new automatic tool setter improved the accuracy and time-efficiency of the process.

Skills changes

With the introduction of the automatic tool setter, the machine operators no longer needed to perform the routine manual task of tool-setting, which was reportedly highly vulnerable to human errors prior to automation. On the one hand, this change removed a considerably time-consuming manual activity from machine operators. On the other hand, the machine operators became responsible for monitoring the performance of the new tool, which is a more cognitively demanding activity than the manual tool setting was prior to automation. This new responsibility required machine operators to have an overall process understanding, which they did not have before the technology adoption. This process understanding was pivotal for the tool-setting monitoring and the occasional troubleshooting that required further problem-solving skills and creativity from workers. This example supports the upskilling view on the skills effects of technology adoption.

As for work organisation, the introduction of the new tool setter led to two forms of standardization: the standardization of production, and the standardization of skills requirements in the workshop. The former meant that one brand of tool setter technology was rolled out across the whole site, achieving technological uniformity in tool-setting. This led to the standardization of skills requirements amongst machine operators, who now have the capability to operate machines flexibly across the workshop.

Recommendations

The first recommendation of this research for practice and policy is to continue encouraging work-based learning in the sector to bridge the gap between employers' skills demand and young workers' skill sets. The sector has already launched successful apprenticeship programmes with flexible micro-credential training to keep up with changes in demand, and sectoral skills development initiatives must continue to follow this example's agility in terms of content and modes of delivery.

To address the challenges created by the ageing demographic of the sector, research participants believed that pairing up young workers still in training with experienced older workers is a mutually beneficial, effective form of knowledge transfer, where workers can learn from one another. Pairing experience with new skills also allows progress in integrating new knowledge into organisations, whilst simultaneously respecting the companies' traditions.

From a technology adoption perspective, the research emphasized the need to recognize the importance of context when designing support initiatives for SMEs. This study has shown that work organisation plays an important role in technology adoption in small and medium enterprises, and SMEs often need support in developing their companies from a business and management point of view, before they could take on new technologies. Areas that were reported to be key in helping adoption were strong leadership, and a supportive company culture. Practitioners and policy makers, therefore, are recommended to launch and coordinate business development initiatives for the sector's SMEs, which would strengthen these companies' stability, and would ultimately allow them to engage in more long-term innovation projects, once they stop fighting an ongoing battle for survival.

To get to know SMEs' context and the issues they are dealing with, the engagement between policy makers and support agencies and SMEs must improve. This study was an initial step in getting to learn about Scottish manufacturing SMEs' experiences on technology adoption and the related skills changes in their organisation. To encourage more engagement, the research suggests policy makers and industry bodies to improve communication and make sure it uses the same language as SMEs of the sector do, since the findings of this study have shown that the disconnect between SMEs and external stakeholders are caused by a lack of shared understanding around the topic. One recommendation for overcoming this issue is to organise similar events to Scottish

Engineering and CeeD, where member companies allow fellow practitioners to visit their facilities and share their experiences around new innovations or ongoing projects. These events offer opportunities for networking within the sector, and also provide platform for benchmarking and sharing sectoral best practices. Moreover, it can be argued that SMEs would be more open to learn from fellow companies, and by attending these events, policy makers and other external stakeholders can also build relationships with SMEs and learn about the issues that these organisations face.