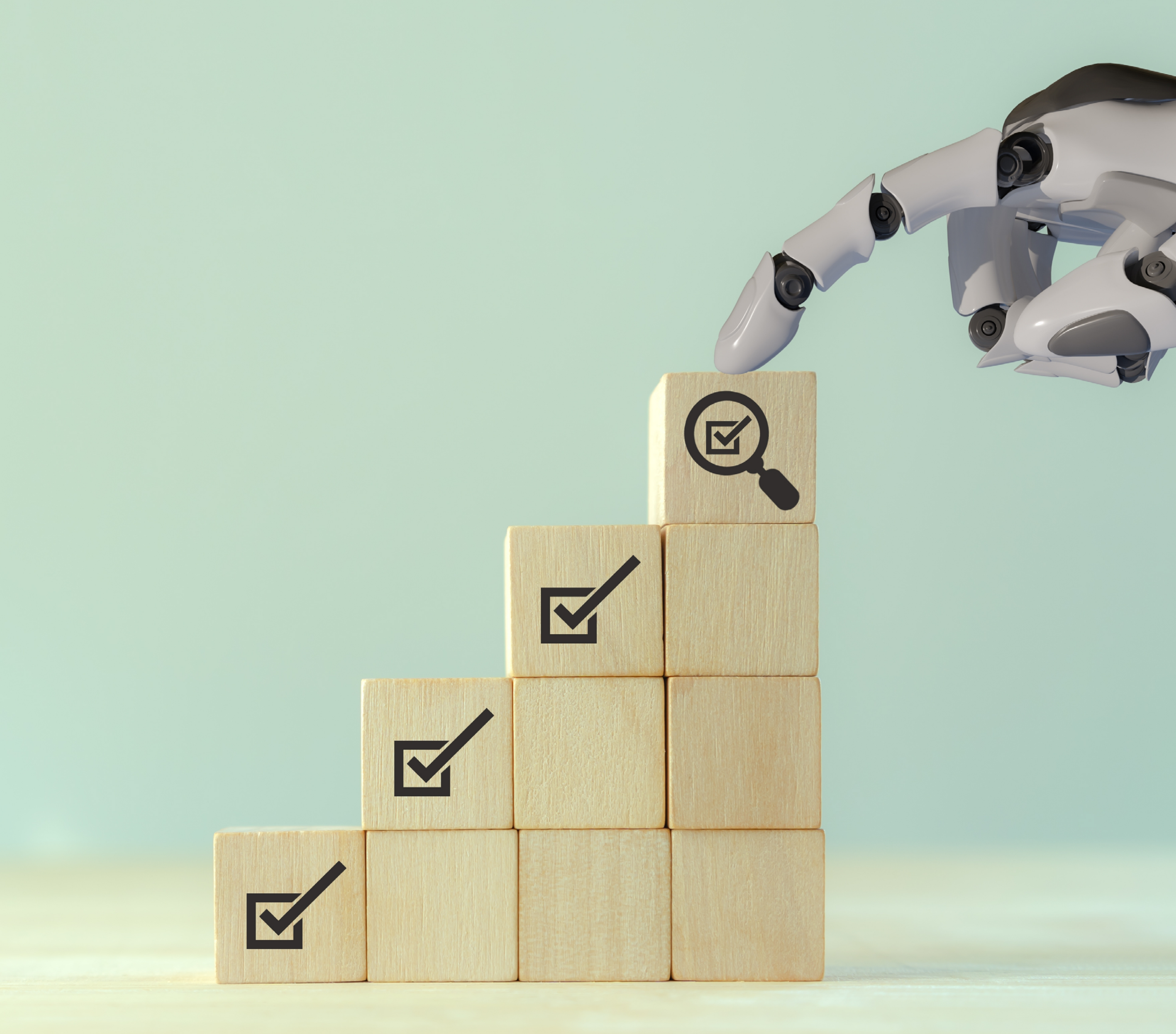

AI Catalyst: Cracking the code for MSME productivity

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Key words

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The Productivity Institute

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Be the Business

Be the Business is an independent charity that inspires greater productivity, by connecting leadership teams to the relevant expertise needed to answer today's challenges. Since our inception, our single focus has been to develop real-world, practical actions SME leaders can take to improve their business productivity. That is why our programmes are hands-on, pragmatic and backed by quantitative and qualitative data gathered from the UK's SME community. By combining peer-to-peer experience, the employee expertise found within our pioneering partners, independent business experts and our research and insights, we inspire leadership teams to create and deliver positive business change. Collectively we're transforming the UK's productivity, raising the value of businesses in our communities, safeguarding jobs and improving standards of living.

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Terminology Index

Abbreviation Glossary

AI	Artificial Intelligence
AR	Augmented Reality
B2B	Business to Business
BPE	Business Population Estimate
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CMI	Chartered Management Institute
CRM	Customer Relationship Management
C-TAM-TPB	Combined TAM and TPB
DBT	Department of Business and Trade
DL	Deep Learning
ERC	Enterprise Research Centre
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEM	Global Entrepreneurship Monitor
GFC	Global Financial Crisis
GNSS	Global Navigation Satellite System
GPT	General Purpose Technologies
GVA	Gross Value Added
HEI	Higher Education Institution
HR	Human Resources
IaaS	Infrastructure as a Service
ICO	Information Commissioners Office
IDT	Innovation Diffusion Theory
IoT	Internet of Things
IQ	Interview Questions
IT	Information Technology
KBV	Knowledge Based View
KPI	Key Performance Indicators
LLM	Large Language Model
LSBS	Longitudinal Small Business Survey
MCPU	The Model of PC Utilisation
MFP	Multi-factor Productivity
MGI	McKinsey Global Institute
ML	Machine Learning
MM	Motivation Model
MSME	Micro-, Small-, and Medium-Sized Enterprises
NEBIC	Net-Enabled Business Innovation Cycle Model
NGAI	Non-Generative AI systems
NLP	Natural Language Processing
OECD	Organisation for Economic Cooperation and Development

PaaS	Platform as a Service
PAR	Participatory Action Research
PAYE	Pay as You Earn
PNT	Positioning, Navigation, and Timing
PPE	Personal Protection Equipment
R&D	Research and Development
RBV	Resource-Based View
RCT	Randomised Control Trial
RFID	Radio Frequency Identification
ROI	Return on Investment
RPA	Robotic Process Automation
RQ	Research Question
SaaS	Software as a Service
SCT	Social Cognitive Theory
STEM	Science, Technology, Engineering, and Mathematics
TAM	Technology Acceptance Model
TFP	Total Factor Productivity
TOE	Technology Organisation Environment
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UK	United Kingdom
UKRI	UK Research and Innovation
UTAUT	Unified Theory of Acceptance and Use of Technology
VAT	Value Added Tax
VR	Virtual Reality
VRIN	Valuable, Rare, Inimitable, and Non-Substitutable

Executive Summary

Small-, Micro-, and Medium- Enterprises (MSMEs) form the backbone of private sector economy in the United Kingdom (UK). According to the Business Population Estimates published by the Department of Business and Trade, in October 2024, MSMEs account for **16.6 million jobs**, or **60%** of the employment and contribute to **52%**, or **£2.8 trillion** to the UK private sector turnover (Department of Business and Trade, 2024). Despite their crucial role, research undertaken by Hart and Bonner (2024) identified that during the period **2021-22**, only **8%** of MSMEs had managed to concurrently grow turnover, jobs, and productivity. These firms grew both their revenues and headcount, but their revenues at a faster rate thereby increasing their productivity.

Adopting technology, particularly digital technologies, amplifies productivity (Brynjolfsson & Hitt, 2000; Brynjolfsson & Yang, 1996; Hitt & Brynjolfsson, 1996; Pilat et al., 2003; Van Ark, 2016; Van Ark et al., 2013). The recent surge in Artificial Intelligence (AI) deemed a General-Purpose Technology has generated optimism about its potential to boost productivity. Early research indicates that Generative AI and Large Language models can substantially enhance labour productivity by a wide margin of estimates ranging from **10 to 56%** (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024). However, despite considerable media attention and the availability of numerous AI solutions, adoption rates of AI in the UK remain relatively sluggish (Be the Business, 2024a; Cunha et al., 2024; Goldman Sachs, 2024a; Microsoft & Public First, 2024).

The Project --***The AI Catalyst*** -- embarked on participatory action research to investigate the causal factors affecting productivity, assess digital readiness, and determine whether tailored, research-led 'Knowledge Exchange' sessions could facilitate AI adoption. Collaborating with **fifteen** MSME firms across the UK, the project spanned across **five** months, during which **100** hours of 'Knowledge Exchange' sessions were delivered. Each firm actively engaged in at least **six** sessions, held fortnightly. During the sessions both Generative AI and Non-Generative AI solutions were explored.

Several causal factors affecting productivity and digital technology adoption in MSMEs were identified. Broadly they can be categorised into access to resources and capabilities and their efficacy. But, most importantly, integrating digital technologies, particularly AI, into a firm, necessitates a **sociotechnical** approach (Brynjolfsson & McAfee, 2011, 2014; Butler et al., 2023), which involves developing a comprehensive understanding of the technology, firm, people, occupations, and tasks as components of a unified system (Brynjolfsson et al., 2018; Kraus et al., 2022; Prahalad, 1993; Sawyer & Tyworth, 2006; Venkatesh et al., 2003; Vial, 2019, 2021).

Twelve of the **fifteen** firms chose to adopt Generative AI solutions. Additionally, **three** firms-initiated trials on business process systems. **One** firm upgraded its accounting package to leverage AI capabilities, and few firms invested in upgrading their broadband infrastructure.

Collectively, these initiatives resulted in an estimated investment of more than **£100,000** to support more than **360** users, representing over **one-third** of the workforce employed by the **twelve** firms. Most importantly, the efforts led to an increase of **0.25** in the weighted score for technology diffusion, that was applied for the assessment.

1 Introduction

Micro, small, and medium enterprises (MSMEs) are crucial to the UK economy. They constitute to over **99%** of the UK's private sector business population and render substantial contributions to revenue and jobs (Department of Business and Trade, 2024).

Productivity is an inherently multifaceted and interdisciplinary phenomenon, shaped by a complex interplay of various factors. Extensive research by the 'Enterprise Research Centre' (Enterprise Research Centre, 2022a) and 'The Productivity Institute' (The Productivity Institute, 2024a), has explored these influences within MSMEs. Notably, spatial effects reveal that firms located in London and the Southeast exhibit higher labour productivity. Business type also impacts productivity, with microbusinesses, sole traders, and particularly women-led businesses exhibiting lower productivity (Maioli et al., 2020). While observable characteristics such as size, age, number of subsidiaries, or fixed investments do not directly correlate with firm growth and productivity (Jibril et al., 2020), other characteristics such as strategic leadership (Bloom et al., 2014, 2021; Office for National Statistics, 2024a), effective people management processes (Henley, 2022), data-driven operations, strategic investments, innovation (Gkypali et al., 2021; Jibril & Roper, 2022), business advice (Henley, 2024), and exports (Driffield et al., 2019) do play an influential role.

The economic value of investments in Information Technology (IT) and its critical role in enhancing business performance and productivity is extensively documented (Brynjolfsson & Hitt, 2000; Hitt & Brynjolfsson, 1996; Pilat & Criscuolo, 2018; Pilat et al., 2003; Van Ark, 2016; Van Ark et al., 2013). However, MSMEs face several impediments in adopting digital technologies (Baker et al., 2015; Department for BEIS, 2024a, 2024b; Ri & Luong, 2021). These challenges include the inherent risks and complexities associated with integrating new tools into existing workflows, and a lack of awareness and understanding of available technologies (Pilat & Criscuolo, 2018). Managerial attitudes and constraints further complicate the adoption process (Be the Business, 2024c; Enterprise Research Centre, 2022b; Jibril et al., 2022). Practical constraints, such as time limitations, insufficient external support, and resource allocation (Velu, 2024), along with technical issues such as connectivity (Ofcom, 2023, 2024) and cybersecurity risks, further impede progress (Department for BEIS, 2024a, 2024b). Despite the availability of Generative AI solutions, the media attention, and optimism about the indicative productivity benefits of Artificial Intelligence (AI) (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2023; Brynjolfsson et al., 2018; Filippucci et al., 2024), the UK lags in the adoption of AI (Be the Business, 2024a; Cunha et al., 2024; Goldman Sachs, 2024a; Microsoft & Public First, 2024; Office for National Statistics, 2024a).

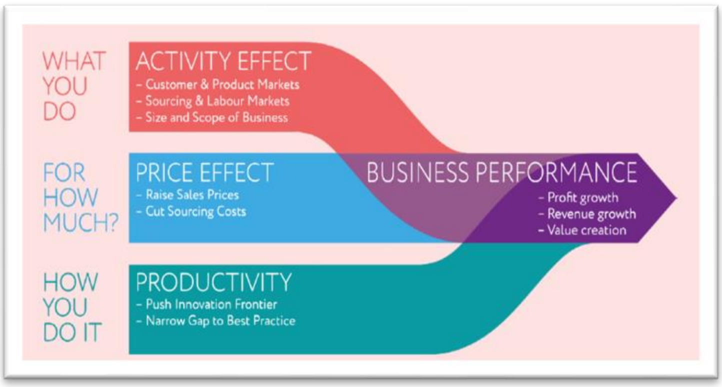
During the period 2021-22, just **8%** of the MSMEs had achieved concurrent growth in revenue, workforce expansion, and productivity enhancements (Hart & Bonner 2024). The seminal Bolton report (Bolton, 1982; Bolton, 1971) highlighted managerial competencies as a significant barrier to MSME performance, leading to various government initiatives. However, Wapshott and Mallett (2024) observe that fifty years later managerial competencies continue to remain a persistent challenge for UK MSMEs.

Strategic management capabilities (Prahalad, 1993) are crucial for boosting productivity (Bloom et al., 2014, 2021; Office for National Statistics, 2024a) and achieving a competitive advantage (Porter, 1985). These capabilities empower firms to effectively create and mobilise resources, as posited by the Resource-Based View (Barney, 1991), and to adeptly adapt to environmental changes, a central tenet of the Dynamic capabilities framework (Eisenhardt & Martin, 2000; Teece et al., 1997). Furthermore, they enable the leveraging of organisational knowledge (Eisenhardt et al., 2000; Grant, 1997; Maijanen, 2020), and the balancing of stakeholder interests (Freeman, 2010; Freeman et al., 2018), thereby fostering a holistic approach to strategic management.

The Productivity Institute (2024a) synthesised the above productivity drivers into a visual frame (**Exhibit 1**). Additionally, it outlined the activity effects on business performance and productivity (Grifell-Tatje & Lovell, 1999) into another visual artefact (**Exhibit 2**) (The Productivity Institute, 2024b)

Exhibit 1: Five key drivers of productivity in firms (Penny & Pendrill, 2022; The Productivity Institute, 2024b)

Exhibit 2: Productivity as a determinant of business performance (Grifell-Tatje & Lovell, 1999; The Productivity Institute, 2024b)



Uber (Uber, 2024) may be drawn as an example to illustrate the interplay of **Exhibit 1** and **Exhibit 2**. The founders of Uber (Uber, 2024) capitalized on Google Earth Engine data (Google, 2024) to construct their business model (Garud et al., 2022; Min et al., 2019). By virtue of being based in California, Uber benefited from a rich pool of financial and human resources (Occhiuto, 2021; Schneider, 2017; Stone, 2017). Through innovative marketing, it pioneered the market for shared mobility (Cramer & Krueger, 2016). By harnessing big data, Uber could experiment with surge pricing (Cohen et al., 2016) and expand into new ventures such as Uber Eats (Griesbach et al., 2019). However, despite these strategic efforts, Uber only recently achieved profitability (Howcroft & Leaver, 2024; Tsanacas, 2022), underscoring the importance of strategic cost management.

The Project --*The AI Catalyst* -- designed as a participatory action research initiative, uses the above visual aids during the Knowledge Exchange sessions to guide firms to develop the organisational capabilities. The operational details of the project are presented in section 3.
The **key findings** from the research initiative are as follows:

- Participants in *The AI Catalyst* were motivated by the prospects of using AI to improve productivity and efficiency. They identified strategic leadership, effective resource utilisation, processes for continuous improvement, maintaining high standards of quality, cost management, process optimisation, innovation, and the use of key performance indicators (KPIs) as key drivers of productivity.
- Each firm employed a minimum of **three** digital applications **(Annex 3,5,6, and 7)**, however, the overall diffusion of digital technologies remained limited **(Table 2).** Additionally, the data on investment in intangible assets was sparse (**Exhibit 12**). MSMEs faced several challenges to accelerate digitalisation and digital transformation which included the burden of researching digital technologies (Pilat & Criscuolo, 2018) and the lack of in-house digital capabilities, which had led to delays in technology adoption.
- The integration of AI into a firm is inherently a **sociotechnical** process (Brynjolfsson & McAfee, 2011, 2014; Butler et al., 2023), which necessitates comprehending technology, firm, people, occupations, and tasks as components of a unified system (Kraus et al., 2022; Sawyer & Tyworth, 2006; Vial, 2019, 2021). Both Generative AI and Non-Generative AI demonstrate applications across a broad spectrum of industries as outlined in **Table 3** and **Table 4.** However, the identification of specific opportunities for adoption is contingent upon a thorough understanding of the underlying business processes and the corresponding tasks associated with it.

The report is structured as follows: **Section 2** provides a comprehensive literature review, examining the productivity dynamics within UK MSMEs. It also delves into the correlation between the adoption of digital technologies and productivity, and the roadblocks MSMEs face for digital transformation; in-addition to exploring the concepts and economic potential of Artificial Intelligence (AI). **Section 3** details the operationalisation of the participatory action research-- *The AI Catalyst*. **Section 4** presents the research findings, research outcomes, and research impact. Lastly, **section 5** culminates with a synthesis of the research findings and conclusions.

2 Literature Review

The literature review provides a brief overview of the private sector business landscape in the United Kingdom (UK), with a focus on the productivity dynamics within Micro-, Small-, and Medium- enterprises (MSMEs). It then explores the diffusion of digital technologies across MSMEs in the UK, highlighting the challenges they face. The chapter concludes with an introduction of the concepts to Artificial Intelligence (AI), its economic potential, and the landscape and barriers to AI adoption.

2.1 An overview of the UK Private Sector: The lay of the land

The economic landscape of the UK private sector is significantly shaped by its MSME business population. At the beginning of **2024**, The UK was home to approximately **5.5 million** private sector businesses (Department of Business and Trade, 2024). The UK private sector can be broadly categorised into four groups: large enterprises and Micro-, Small-, and Medium MSMEs. The Department for Business and Trade (DBT) classifies businesses employing fewer than **250** employees as Micro-, Small-, and Medium enterprises (MSMEs). At the start of **2024**, MSMEs contributed to **£2.8 trillion,** or **52%** of the turnover, and accounted for nearly **60%,** or **16.6 million jobs** (Department of Business and Trade, 2024).

A significant proportion -- Approximately **three-quarters** -- of private sector businesses in the UK operate without employees. Additionally, many of these firms are not registered for 'Value Added Tax (VAT)' or 'Pay as You Earn (PAYE)'. According to the Office for National Statistics, at the start of **2024**, only **48%** (**2.6 million businesses**) of the estimated total population of private sector businesses were registered for VAT or PAYE. In contrast, **52%** (approximately **2.9 million businesses**)—categorised as unregistered entities-- operated without VAT or PAYE registration (Department of Business and Trade, 2024). This data highlights the complexity and diverse characteristics of the United Kingdom's private sector landscape.

Table1 provides a summary of the number of firms in each category along with their respective employment and turnover.

Table 1: The UK private sector landscape (Department of Business and Trade, 2024)

Firm types	*Number of firms*	*Employment (thousands)*	*Turnover (millions)*
Micro firms (1 to 9 employees)	1,161,270	4,205	679,147
Small firms (10 to 49 employees)	219,895	4,316	780,563
Medium firms (50 to 249 employees)	37,750	3,677	926,431
Large firms (250 or more employees)	8,250	11,116	2,520,453

Note: The above table excluding firms that do not employ any employees.
Source: The table is created using the Business Population Estimates (BPE) published by the Department of Business and Trade (DBT), in October 2024 (Department of Business and Trade, 2024).

2.2 Deciphering the productivity conundrum

Explainer: Productivity

Productivity is a multi-faceted phenomenon. The average 'Gross Domestic Product (GDP)' per working hour is extensively used as a measure of labour productivity by economists, policymakers, and the media (The Productivity Institute, 2024b). Labour productivity is calculated as the ratio of output to labour input, with labour input typically quantified in terms of hours worked, or the number of workers. In contrast, Total Factor Productivity (TFP) or Multi-Factor Productivity (MFP) considers multiple inputs in the production process, including both labour and capital (Office for National Statistics, 2022).

At the firm level, productivity may be defined as the measure of an organisations efficiency in transforming its resources into products and services. These resources include human capital--encompassing both the hours worked by employees and investments in their skill development; physical capital, such as machinery and infrastructure; the adoption and integration of digital technologies; and the collective organisational knowledge (The Productivity Institute, 2024b).

Since the onset of the Global Financial Crisis (GFC), productivity in the United Kingdom (UK) has experienced a downward trend. A rather sluggish growth rate of **0.7%** was recorded for the period spanning 2008 to 2020 (Chadha & Samiri, 2022).

Goodridge and Haskel (2023) argue that the observed stagnation in productivity growth is a consequence of the slowdown in innovation, intangible capital, and Total Factor Productivity (TFP) growth. This perspective is further nuanced by the works of Criscuolo et al. (2019) and Coyle et al. (2022), who underscore an escalating disparity in productivity performance among firms in the UK. While this trend is not confined to the UK alone, and mirrored across other OECD nations, there are specific reasons why the UK productivity record has been specifically bleak: underinvestment, weak knowledge diffusion, and fragmented governance of public institutions (Coyle et al., 2023)

At the firm's level, it has become clear that the most productive firms progressively outpace the rest. Interestingly, this heterogeneity is not uniform; it varies across firms and is influenced by multiple factors. Coyle et al. (2024) identify these factors as -- the size of the firm, the extent of digital technology utilisation, the performance in research and development (R&D), and the intensity of exports. Thus, the landscape of productivity performance is a complex interplay of these elements, leading to the observed disparities.

Roper et al. (2019) found that business leaders across various sectors had differing interpretations of 'productivity', often equating it with operational efficiency rather than 'value added per employee'. This nuanced understanding was further highlighted by a survey from The Productivity Institute and Chartered Management Institute (CMI), which revealed diverse productivity Key Performance Indicators (KPIs) across sectors, including cost efficiency and output per worker (Penny & Pendrill, 2022).

This underscores the varied interpretations and measures of ‘productivity’ across different sectors and organisations.

2.3 Unpacking Productivity Dynamics in UK MSMEs

The UK private sector economy is characterised by a long tail of less productive businesses (Haldane, 2018) and significant spatial variations in productivity (Maioli et al., 2020). A comprehensive analysis by Hart and Bonner (2024) indicates that during the period **2021-22**, only **8%** of MSME firms, referred to as 'Productivity Heroes', managed to increase revenues, expand their workforce, and improve productivity at the same time. In 2022, the ‘Productivity Heroes’- **36,298** businesses contributed **£268 billion** to the UK economy.

Maioli et al. (2020) conducted a regression analysis using data from the UK Longitudinal Small Business Survey (LSBS) for the period **2015-2017**. Their findings revealed that firms located in London and the Southeast exhibited higher labour productivity. Rural firms also demonstrated productivity levels comparable to their urban counterparts. The study also indicated that microbusinesses and sole traders typically exhibit lower productivity, with women-led businesses exhibiting significantly lower productivity. Additionally, sector-specific variations were noted.

Jibril et al. (2020) investigated the determinants of productivity growth in UK MSMEs from **2016-2018** across manufacturing and service sectors using a mixed-methods approach. The quantitative analysis found no strong correlation between a firm’s growth and observable characteristics such as size, age, number of subsidiaries, or fixed investments. However, qualitative interviews revealed that high-performing MSMEs often exhibited unobservable characteristics such as strategic leadership, effective people management, data-driven operational processes, strategic investments, and innovation. These unobservable factors may be crucial in understanding the drivers for productivity.

Maioli et al. (2020) found that productivity is positively influenced by a firm’s ability to formulate and execute business plans, secure external funding, participate in networks, and seek external advice. In a secondary analysis of the UK LSBS, Henley (2024) found that firms experienced a **10%** increase in productivity (revenue per employee) within **a year** of accessing business advice. The impact of advice varied, with regulatory, legal, and taxation advice showing significant benefits, while advice on operational efficiency, workforce skills, and management did not strongly correlate with improvements in productivity. This highlights the complexity of corelating productivity improvements and the role of business advice.

Studies by Gkypali et al. (2021) and Barrett et al. (2018) underscore the significance of sales growth objectives, product innovation, leadership capability, export intent, access to external finance, IT skills training, and digital marketing in driving productivity and export proficiency among UK MSMEs.

Research undertaken by the Enterprise Research Centre (2024) highlights that firms engaged in international activities and innovation, experience enhanced performance metrics, including growth in productivity. Driffield et al. (2019) note that inward foreign direct investment (FDI) increases productivity through collaboration or competition, raising demand for skilled labour and exerting wage pressure on local firms. Jibril and Roper (2022) argue that exporting directly enhances productivity, while innovation indirectly boosts it by positively influencing exporting, advocating for support programs targeting non-exporters.

The interplay of management skills and productivity in MSMEs: Research from the World Management Survey (Bloom et al., 2021) and the recent Office for National Statics—Management practices in the UK:2016 to 2023 survey (Office for National Statistics, 2024a) underscore a significant co-relation between management practices and productivity (Bloom et al., 2014; Office for National Statistics, 2024a).Peng et al. (2019) empirically investigated this relationship in MSMEs, finding that Human Resources (HR) practices can boost productivity by approximately **2%** over **three** years. They suggest that a symbiotic relationship between management skills and practices is a key driver of productivity growth. The authors propose a combined approach of training and mentoring to improve management skills and incorporating them into management practices, which is important for promoting productivity growth in MSMEs.

Strategic management capabilities (Prahalad, 1993) are instrumental in enhancing productivity (Bloom et al., 2014, 2021; Office for National Statistics, 2024a) and securing a competitive advantage (Porter, 1985). These capabilities include effective resource management, as outlined by the Resource-Based View (Barney, 1991), and the ability to adapt to change, central to the Dynamic capabilities framework (Eisenhardt & Martin, 2000; Teece et al., 1997). Furthermore, they encompass the leverage of knowledge, emphasised by the Knowledge-Based View (Eisenhardt et al., 2000; Grant, 1997; Maijanen, 2020) and the balancing of stakeholder interests, as illustrated in the Stakeholder theory (Freeman, 2010; Freeman et al., 2018).

The seminal Bolton report (Bolton, 1982; Bolton, 1971) identified a lack of managerial competencies within MSMEs as a significant barrier to their performance, which led to numerous government initiatives and support programs such as 'Help to Grow Management' (Department of Business and Trade, 2021), 'LEAD' (Chartered Institute of Personnel and Development, 2024), and the 'Goldman Sachs 10,000 Businesses' (Goldman Sachs, 2024b; Henley, 2022) . More recently, the report -- 'Productivity in MSMEs', presented to the UK House of Commons Business, Energy, and Industrial strategy Committee (House of Commons, 2018) in **2018**, outlined several critical areas impeding productivity: strategic leadership, inadequate human resource management capabilities, strategic planning, project management, business planning, and a lack of confidence in adopting digital technologies.

In the 'Business Productivity Review' published in November **2019**, several financial allocations were outlined to enhance productivity within the MSME sector. These include **£11 million** for the 'Small Business Leadership Programme', **£20 million** to improve access to local peer-to-peer networks, and **£25** million for 'Knowledge Transfer Partnerships' to support **200** businesses (Department for Business and Trade, 2019). Furthermore, the 'Business Basics' initiative, in collaboration with Innovate UK and Nesta's Innovation Growth Lab, funded **32** projects from **2018** to **2022**, investing **£6.4 million** to engage **3,500** MSMEs in testing novel ideas and interventions (Department for BEIS, 2024a, 2024b).

Despite several interventions, Wapshott and Mallett (2024) conclude that **fifty** years after the Bolton Review (Bolton, 1971), management issues continue to overshadow the MSME landscape in the UK. This persistent challenge underscores the need for ongoing research and innovative solutions.

In summary, the UK private sector economy continues to face persistent productivity challenges, characterized by a significant proportion of less productive firms and notable spatial variations. Despite a small subset (**8%**) of MSMEs, known as 'Productivity Heroes,' making substantial economic contributions, the majority of firms continue to encounter difficulties. Key factors such as strategic leadership, effective people management, and innovation are critical for productivity growth. Although various support programs have been implemented, ongoing research and innovative solutions remain essential to address these enduring issues and enhance productivity across the MSME landscape.

2.4 The Digital Leap: Essential steps to improve productivity

Explainer: Digitisation, digitalisation, and digital transformation

Digitisation refers to the process of converting analogue information into a digital format, typically represented by binary codes ('0' s and '1's). This conversion enables computers to store, process, and transmit information with enhanced efficiency. For example, scanning a paper document and saving it as a digital file exemplifies digitisation. Essentially, digitisation involves transforming a non-digital artefact into a digital entity (Kohe, 2020; Maxwell & McCain, 1997; Parviainen et al., 2017; Yoo et al., 2010) thereby facilitating new forms of value creation (Hagberg et al., 2016).

Digitalisation involves the use of digital technologies to automate tasks, thereby enhancing efficiency and productivity. Examples include the use of software to generate reports and RFID (Radio Frequency Identification) scanners to capture and store data in databases. This transformation of business operations into digital formats improves operational efficiency (Kohe, 2020). Essentially, digitalisation transforms existing socio-technical structures, previously mediated by non-digital artefacts or relationships, into those mediated by digitised artefacts embedded with digital capabilities (Eling & Lehmann, 2018; Thorseng & Grisot, 2017; Yoo et al., 2010).

Digital transformation is a comprehensive process that leverages digital technologies--such as information systems, social media, mobile devices, analytics, and embedded devices--to drive significant changes in an organisation's business processes, operational routines, and capabilities. This transformation aims to enhance customer experiences, streamline operations, and create new business models (Velu, 2024). It often leads to fundamental economic and technological shifts at both organisational and industry-sector levels (Chanias et al., 2019; Hanelt et al., 2021; Li et al., 2018; Nadkarni & Prügl, 2021; Nambisan et al., 2019; Schallmo et al., 2017; Vial, 2019, 2021; Warner & Wäger, 2019).

The exploration of the value of information technology (IT) investments has evolved over the years. Hitt and Brynjolfsson (1996) were among the first to delve into the multifaceted benefits of IT, highlighting its contributions to productivity (Brynjolfsson & Yang, 1996; Pilat et al., 2003; Van Ark, 2015, 2016; Van Ark et al., 2003a, 2003b, 2003c; Van Ark et al., 2013), business profitability, and consumer surplus. They emphasised that the economic value of IT investments (Pilat et al., 2003; Van Ark et al., 2003b; Van Ark et al., 2013) is deeply intertwined with organisational changes, suggesting that technology alone is not sufficient to drive substantial gains (Brynjolfsson & Hitt, 2000; McAfee & Brynjolfsson, 2012). Building on this foundation, Brynjolfsson and Hitt (2000) further explored the intangible and often elusive benefits of IT. They underscored the importance of considering both technological and organisational factors when assessing the impact of IT on productivity (Brynjolfsson & Hitt, 2000; Brynjolfsson & McAfee, 2011, 2014). Their work suggested that the true value of IT emerges from a synergy between technology and organisational transformation (Brynjolfsson & Hitt, 2000; McAfee & Brynjolfsson, 2012).

In a recent study, Gal et al. (2019) provided empirical evidence from various European countries, combining firm-level productivity data with industry-level data on digital technology adoption. Their findings revealed significant productivity enhancements driven by technology adoption, particularly in the manufacturing sector and firms engaged in routine-intensive activities. The study also noted that these productivity gains were more pronounced in highly productive firms and influenced by the presence of appropriate skills. This finding is echoed by Gaglio et al. (2022) and Cheng et al. (2023) through studies conducted in South Africa and China respectively. Further supporting these insights, Cheng et al. (2023) identified a non-linear U-shaped relationship between digital transformation and Total Factor Productivity (TFP) across firms of different sizes and types.

The onset of the Covid-19 pandemic has accelerated the pace of digital transformation in MSMEs. Case-study research by Pfister and Lehmann (2023) identifies five key benefits of digital transformation: increased revenue, improved customer satisfaction, improved employee satisfaction, enhanced efficiency, and productivity. Additionally, these case studies reported a weighted Return on Investment (ROI) average of **13.44**, with **25** positive ROIs in various cases where data analytics solutions were implemented to boost revenue or reduce costs.

The transformative potential of digital technology adoption is particularly evident in MSMEs. For instance, micro-firms adopting cloud-based computing solutions experienced a **13.5%** increase in sales per employee after three years. Similarly, implementing customer relationship management (CRM) systems had yielded productivity gains of **18.4%**, while e-commerce technology adoption was associated with a **7.5%** rise in productivity. (Jibril et al., 2022).

These findings collectively highlight the role digital technologies play in optimising business performance and driving productivity enhancements.

2.4.1 Digital transformation roadblocks: MSMEs at the crossroads

While the productivity gains from adopting digital technologies are well-documented, Pilat and Criscuolo (2018) highlight the specific challenges faced by MSMEs in undertaking digital transformation. They emphasize that digital transformation entails a process of exploration and experimentation with new technologies and business models (Velu, 2024), resulting in varied outcomes where some firms thrive and others do not (Pilat & Criscuolo, 2018). The authors also provide several recommendations to address these challenges.

In 2015, an evidence review undertaken for the Department for Business Innovation and Skills revealed a diverse landscape in digital technology adoption among UK MSMEs (Baker et al., 2015). This heterogeneity was echoed in a subsequent study by Ri and Luong (2021). The Enterprise Research Centre (ERC) in the UK identified **two** key barriers in small firms to accelerate digital technology adoption: confidence in implementing new technologies and awareness of their benefits (Enterprise Research Centre, 2022b). ERC notes that smaller, particularly risk-averse family-owned firms, may be hesitant to invest in new technologies or innovation (Enterprise Research Centre, 2024).

During the Covid-19 crisis, the ERC examined digital application and technology adoption among **1,000** MSMEs using the 'Business Futures' survey. The survey focused on ten digital solutions: digital marketing, accounting or human resources (HR) software, e-commerce, customer relationship management (CRM) systems, video conferencing tools, cloud computing, computer-aided design (CAD) software, Internet of Things (IoT), augmented reality/virtual reality (AR/VR), and artificial intelligence/machine learning (AI/ML). This study revealed the interplay between digital readiness, perceived barriers, and technology adoption, highlighting the need for tailored technological guidance to address specific business requirements (Ri & Luong, 2021).

In a randomised control trial (RCT) involving **420** family businesses in the UK, the Evolve Digital programme showed positive outcomes but faced several implementation challenges. These included high dropout rates, poor responses to the facilitation style, and feedback indicating that the programme content did not adequately address specific business issues, Additionally participants noted that the emphasis on leadership models diverted attention from practical business and technology solutions. This feedback highlighted the need for personalised advice tailored to MSMEs specific technology adoption needs (Jibril et al., 2022).

In a recent podcast with 'The Productivity Institute' (The Productivity Institute, 2023), the CEO of 'Be The Business' highlighted a confidence and capability gap between the UK and its G7 peers. 'Be The Business' manages the Productive Business Index for UK firms, comparing productivity across G7 countries. Notably, only **64%** of **1,500** UK MSMEs agreed that employees had access to technologies for productivity improvements, while only **28%** confirmed technology investments. This data underscores the need for greater investment and adoption of digital technologies in UK MSMEs (Be the Business, 2024c; The Productivity Institute, 2023). **Exhibit 3** presents the survey question used to assess technology investment and **Exhibit 4** presents the survey question used to assess digital skills.

Exhibit 3: Be The Business survey question used to assess technology investment (Be the Business, 2024c)

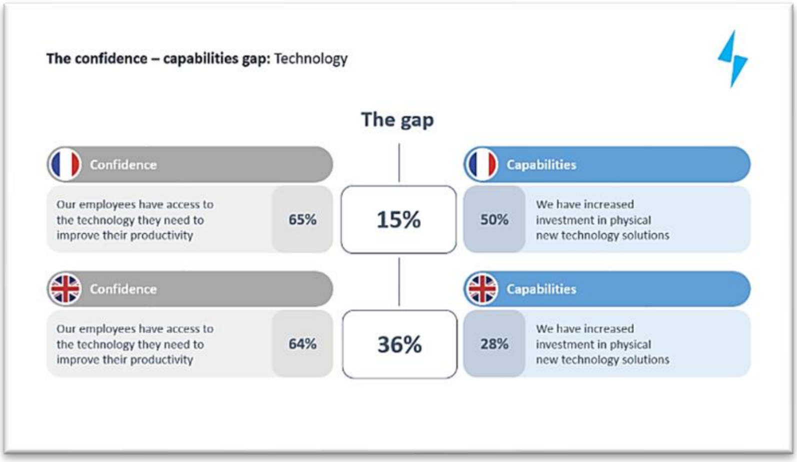
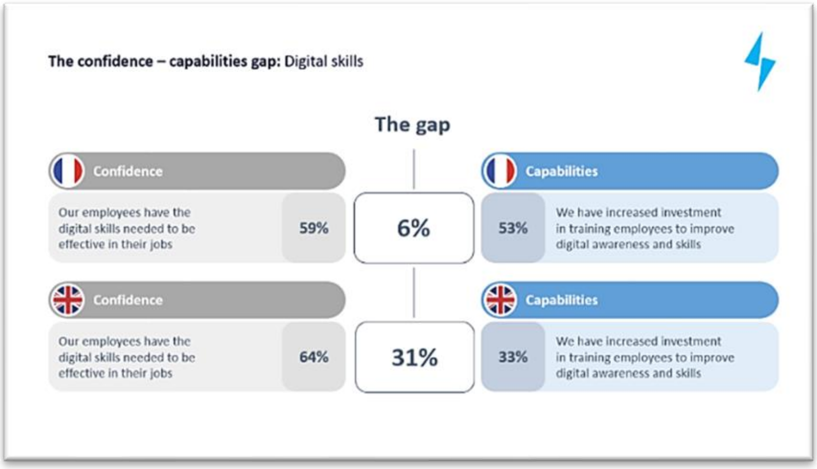


Exhibit 4: Be The Business survey question used to assess digital skills (Be the Business, 2024c)



The 'Help to Grow: Digital' program in the UK was established to offer free advisory services and vouchers of up to **£5,000** to MSMEs to purchase pre-approved software. However, due to lower-than-anticipated participation rates, the UK government discontinued the program on February 2, 2023 (Department for Business and Trade, 2022). This development raises critical questions regarding the resources, and capabilities within MSMEs to adopt digital technologies.

Recent research undertaken for 'The Productivity Institute' highlighted the presence of **73** contracted training providers within the West Midlands Combined Authority. However, only **48** of these courses integrated both management and digital technology elements. Moreover, these courses were predominantly offered as full-time, degree-level programs delivered by Higher Education Institutions (HEI), with only a limited number of short courses available for businesses (Dickinson et al., 2024). This finding underscores the critical need for enhanced support mechanisms to facilitate digital technology adoption in MSMEs. In contrast, Germany has established several programs and support centres to promote the diffusion and adoption of digital technologies within the MSME sector (OECD, 2024b).

The 'Business Basics' project report (Department for BEIS, 2024a, 2024b) categorised the barriers MSMEs face in adopting digital technology into **four** categories: inherent barriers, awareness and attitudes, practical barriers, and technical barriers.

- **Inherent barriers** are those that arise from the risks and complexities associated with integrating new tools into existing workflows.
- **Awareness and attitudes** encompass a lack of understanding about available technologies and their alignment with business practices, as well as managerial mindset and ambition in decision-making.
- **Practical barriers** involve challenges related to time constraints, availability of external support, and resource allocation for technology adoption.
- **Technical barriers** include issues such as connectivity and cybersecurity risks.

These insights collectively underscore the importance of tailored interventions to bridge the gap and empower MSMEs in their digital transformation journey.

According to McKinsey (2023b), digital transformation fundamentally rewires organisational operations, to build competitive advantage by deploying technology at scale, thereby enhancing customer experience and optimising costs. Unlike traditional business transformations, which conclude upon achieving new behaviours, digital transformations are ongoing efforts driven by the continuous integration and evolution of technology. The potential of Artificial Intelligence (AI) in generating business insights and decision-making compels that digital transformations also facilitate AI integration. McKinsey emphasises that successful digital transformation depends more on becoming a digital business than merely using digital technologies.

Vial (2021) underscore that digital transformation reshapes business models, processes, and capabilities; arguing that leadership, culture, and strategic alignment are crucial in overcoming challenges such as resistance to change; and continuous learning and adaptation are equally essential for sustaining digital transformation initiatives. Kraus et al. (2022) highlight the dual dimensions of digital transformation: the adoption of disruptive digital technologies and the actor-guided organisational transformation of capabilities, structures, processes, and business-model components.

Drawing on the experience of leading multiple digital transformation initiatives with MSMEs, Stich et al. (2020) recommend that MSMEs should initially analyse their corporate strategy, objectives, and environment. The authors argue that MSMEs should then identify which core objectives to pursue and evaluate how digital transformation can contribute to the efficient and effective achievement of these objectives. A survey by Ramadan et al. (2023) of **270** MSME employees indicates that digital transformation leadership fosters organisational agility, enabling effective digital transformation and business model innovation through robust knowledge transfer systems. Velu (2024) explores MSME and start-up business models, highlighting challenges such as limited resources, restricted market access, and the need for agility. The utilisation of digital technologies and strategic partnerships focussed on niche markets are recommended for MSMEs to achieve sustainable growth. Velu (2024) also underscores the importance of experimentation, customer feedback, and iterative development in commercialising new technologies and bringing innovative solutions to market.

2.5 From Enigma to Enabler: Can AI solve the productivity puzzle?

Definition: An AI system

According to the Organisation for Economic Co-operation and Development (OECD), an AI system is defined as a machine-based system that, for explicit or implicit objectives, infers from the input it receives how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. AI systems differ in their levels of autonomy and adaptiveness post-deployment (OECD, 2024a).

2.5.1 The economic potential of AI: A production function perspective

Artificial Intelligence (AI) significantly influences the economic landscape, functioning as a multifaceted force(Acemoglu, 2024; Brynjolfsson et al., 2019). The OECD conceptualises AI through a 'production function' framework, integrating intangible inputs -- such as software, skills, and data --with substantial computing capacity and complementary technologies such as robotics and biotechnology. Consequently, AI systems demonstrate a remarkable ability to produce diverse outputs, including complex analytical tasks (e.g., prediction, recommendations, optimisation) and content creation, as well as executing complex physical tasks, such as autonomous vehicle operation (Brynjolfsson & McAfee, 2014; Filippucci et al., 2024).

AI's distinctiveness lies not only in its capacity to perform complex tasks but also in its enhanced potential for autonomy and self-improvement, thereby accelerating innovation(Acemoglu & Restrepo, 2018; Brynjolfsson & McAfee, 2014; Brynjolfsson et al., 2018). These attributes distinguish AI from previous major technologies, such as computers and the internet, often classified as 'General Purpose Technologies' in growth and innovation literature (Lipsey et al., 2005). Preliminary evidence suggests that AI enhances productivity and performance at both the micro and macroeconomic levels (Acemoglu, 2024; Brynjolfsson et al., 2019). This, coupled with several promising innovations across various industries, supports the expectation that AI's development and widespread adoption could revive sluggish productivity growth (Filippucci et al., 2024).

Explainer: Generative AI systems

Generative AI systems represent a significant advancement in AI, designed to produce diverse content forms, including text, code, images, videos, and sounds, in response to natural language prompts. Large Language Models (LLMs), such as GPT-3 and GPT-4 (Open AI, 2024a), exemplify these systems.

The breakthrough enabling Generative AI is the 'transformer' architecture, introduced in 2017. Unlike recurrent neural networks, transformers process natural language input in parallel rather than sequentially, which significantly reduces training and computing time while enhancing efficiency (OECD, 2023). This architecture supports the handling of large-scale data and has driven exponential growth in model scale and complexity. State-of-the-art models now feature billions of parameters, enabling them to capture intricate data patterns and nuances (Lorenz et al., 2023).

Generative-AI models can be categorised into 'foundation models' and tailor-made models. Foundation models, such as DALL-E (Open AI, 2024b) and ChatGPT (Open AI, 2024a), are versatile and applicable across various fields, while tailor-made models focus on specific tasks. For example, Sora (Open AI, 2024c) excels in video synthesis.

In summary, Generative AI systems, empowered by the transformer architecture, have revolutionised content creation. Their ability to generate diverse forms of content has significant implications for fields ranging from art to software development, making them a crucial area of study for researchers and policymakers (Filippucci et al., 2024). According to McKinsey, Generative AI technologies have the potential to automate **sixty** to **seventy percent** of employees work activities today. This underscores the role of Generative AI in automating tasks (Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2018) related to natural language understanding, which accounts for **twenty-five percent** of employees work hours (McKinsey, 2023a).

Explainer: Non-Generative AI system

Non-Generative AI (NGAI) systems primarily rely on algorithms that extract information directly from vast data sets to detect patterns, forecast outcomes, and support decision-making. The predominant technique with NGAI is machine learning (ML), which encompasses more advanced subsets such as Deep Learning (DL). NGAI models excel at recognising patterns in various data types, including text, images, and audio. They are adept at identifying unusual or unexpected events (anomaly detection) within datasets. Additionally, NGAI can analyse user behaviour to personalise recommendations or experiences. For tasks such as traffic routing, NGAI optimises outcomes based on predefined goals (OECD, 2022). Furthermore, NGAI is capable of effectively handling extremely large and potentially unlabelled and unstructured datasets (Filippucci et al., 2024).

In summary, while Non-Generative AI (NGAI) focuses on analysing existing data and making predictions, Generative AI extends its capabilities by creating new content. Both types of AI have unique applications and strengths. Understanding these distinctions is crucial for identifying scenarios where AI can be effectively utilised in businesses, particularly in small and medium enterprises.

Previous General Purpose Technologies (GPTs) such as steam and electricity, primarily impacted physical tasks through energy output. In contrast, computers, the internet, and AI affect cognitive tasks. While AI shares similarities with computers and the internet, its versatility and advanced capabilities arise from sophisticated predictions, analytics, and content generation (Brynjolfsson & McAfee, 2014; Filippucci et al., 2024). The idea generation and testing capacity of AI extends beyond mere automation. It not only enhances productivity by improving existing processes but also serves as an invention technology, fostering research and innovation to boost overall productivity growth (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson & McAfee, 2014; Cockburn et al., 2018).

Explainer: Productivity gains with AI

Empirical studies investigating AI adoption at the firm level have historically found productivity effects ranging from **0% to 11%** (Brynjolfsson & Hitt, 2003; Filippucci et al., 2024; Gal et al., 2019). With the advent of Generative AI technologies, particularly large language models such as ChatGPT, recent research has explored the impact of specific AI tools on worker performance. Experimental methods have provided more causal evidence, revealing substantial effects of Generative AI on labour productivity in specific tasks, ranging from **10% to 56%** (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024). Notably, Generative AI offers even greater gains for inexperienced workers, resulting in up to one-third higher output per hour compared to the **14%** improvement observed for workers with average experience levels (Brynjolfsson et al., 2023) Additionally, employees using AI tools report enhanced performance, increased enjoyment, and improved mental and physical health (Filippucci et al., 2024).

Brynjolfsson et al. (2021) explore the concept of the Productivity J-Curve, which illustrates how investments in intangible assets complement general-purpose technologies (GPTs) like AI and lead to productivity gains over time. The authors argue that the initial adoption of GPTs often shows a paradoxical slowdown in productivity growth due to the substantial, yet poorly measured, investments in intangible assets such as business process redesign, co-invention of new products, and human capital development. These investments are crucial for realising the full potential of GPTs but are not immediately reflected in productivity statistics.

The study highlights historical examples, such as steam engine and electrification, to demonstrate how similar patterns have occurred with past GPTs. The authors suggest that the current slowdown in productivity growth can be partly explained by the early stages of AI adoption, where significant intangible investments are being made. For instance, to account for the **0.55%** of "lost" output in **2017** U.S. GDP, the ratio of correlated intangible investments to tangible investments must be between **2.7** to **4.1** times the observable investment values (Brynjolfsson et al., 2019, 2021). They emphasise the importance of recognising and measuring these intangible investments to better understand and anticipate the long-term productivity benefits of new technologies.

2.5.2 A review of AI adoption in MSMEs: Synthesising landscape and barriers

Despite the notable productivity gains, MSMEs continue to encounter considerable challenges in adopting AI. Ulrich and Frank (2021) conducted an empirical survey of **283** MSME firms and found that these firms predominantly utilise AI for process automation. However, the authors identified a critical barrier to AI adoption within MSMEs: the qualifications of their employees. Similarly, Baabdullah et al. (2021) employed structural equation modelling on survey data collected from **392** MSMEs. Their analysis revealed that technology road-mapping and attitude substantially influence AI acceptance among MSMEs. Additionally, infrastructure availability and awareness play crucial roles in shaping AI practices. The authors also assert that AI acceptance impacts relational governance and performance with MSMEs.

Watney and Auer (2021) studied the obstacles to AI implementation in MSMEs across the European Union. The authors highlight several key challenges. These include a lack of public or external funding (**37%**), concerns about liability for AI-induced damage (**33%**), strict standards for data exchanges (**33%**), the need for clear laws or regulations (**30%**), and a lack of trust among citizens (**28%**). Additionally, MSMEs face limited access to high-quality private data (**26%**) and a scarcity of publicly available data (**21%**). Reputational risks associated with AI use (**17%**) also contribute to these challenges. Furthermore, Schueffel et al. (2019) found that the perceived importance of AI and its estimated impact increase with firm size in a study encompassing MSME firms in Switzerland.

Recently, the 'AI for SMEs' project in the UK conducted a randomised control trial (RCT) to investigate whether market-convening workshops, voucher, or tailored one-to-one support could enhance awareness of AI technologies among MSMEs in the retail and hospitality sectors in Greater London. The key policy takeaways from the published report (Department for BEIS, 2024a, 2024b) include the following:

- **Challenges in adoption**: Promoting emerging technologies emerged challenging when MSMEs were distant from adoption.
- **Prioritisation and readiness:** The project team identified that AI technologies should align with the priorities of MSMEs and be readily usable off-the shelf.
- **Complementary assets:** It was noted that realising the benefits of AI may require complementary assets.

Multiple reports highlight AI adoption rates among UK MSMEs and the associated barriers. According to Goldman Sachs (2024a), **60%** of the surveyed participants identified a lack of understanding of AI as a barrier to adoption. Research by Microsoft and Public First (2024) revealed that **31%** of MSMEs had not adopted cloud services, and **47%** were not using any dedicated AI tools or features. A survey by Be the Business (2024a) found that **52%** of MSMEs were not utilising AI, with cost identified as the primary barrier. Additionally, a survey by the London School of Economics Centre for Economic Performance and the Confederation of British Industry (Cunha et al., 2024) reported that AI was used in less than **30%** of firms, citing a lack of information on technology as the top barrier.

Besides, it is argued that the introduction of AI into any organisation is an inherently **sociotechnical** process (Brynjolfsson & McAfee, 2011, 2014; Butler et al., 2023; Sawyer & Tyworth, 2006). Therefore, prioritising education and support to address these barriers, while promoting the wider adoption of both Generative AI and Non-Generative AI in MSMEs, is crucial to enhancing productivity among firms.

2.5.3 Frameworks to assess the proliferation of digital technologies

Over the years, researchers have developed several frameworks to understand why people adopt new technologies. The Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1977) and the Technology Acceptance Model (TAM) (Davis, 1989; Davis et al., 1992) are foundational. They focus on attitudes, subjective norms, and perceived usefulness. The Motivation Model (MM) (Davis et al., 1992) and the Theory of Planned Behaviour (TPB) (Ajzen, 1991) add dimensions of intrinsic motivation and perceived behavioural control. Integrating these the Combined TAM and TPB (C-TAM-TPB) (S. Taylor & P. Todd, 1995; S. Taylor & P. A. Todd, 1995) offers a more comprehensive view. The Model of PC Utilisation (MCPU) (Thompson et al., 1994), Innovation Diffusion Theory (IDT) (Rogers, 1971; Rogers, 1995), and Social Cognitive Theory (SCT) (Bandura, 1986) further explore factors such as job fit, innovation attributes, and self-efficacy. Additionally, the Technology-Organisation-Environment (TOE) (Baker, 2012) framework explains how technological, organisational, and environmental contexts influence technology adoption (Tomatzky & Fleischer, 1990).

To unify these insights Venkatesh et al. (2003) proposed the **Unified Theory of Acceptance and Use of Technology (UTAUT)**. This framework synthesises elements from the eight previous frameworks to provide a robust framework for predicting Information Technology (IT) acceptance. UTAUT identifies **four** key constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions, which together explain user intentions and behaviours regarding technology use. Additionally, UTAUT includes **four** moderators – gender, age, experience, and voluntariness of use- that influence the impact of the **four** key constructs on user intention and behaviour. This framework has been validated across various organisational contexts, demonstrating its robustness in predicting technology acceptance and guiding effective implementation strategies.

The Net-Enabled Business Innovation Cycle (NEBIC) model, developed by Wheeler (2002) provides a framework for understanding how firms leverage digital networks to drive business innovation. **NEBIC** outlines a cycle where firms employ dynamic capabilities to exploit net-enablement, which refers to the innovative use of networked information technologies. The **NEBIC** consists of **four** stages: choosing enabling technologies, matching technologies to opportunities, executing business innovation, and assessing value creation.

The principles of the **UTAUT** and the **NEBIC** model will be used in this research to assess the diffusion of technologies in the firm. The digital technologies are chosen from the McKinsey digital transformation survey (McKinsey, 2018), and a weighted scoring model (**Exhibit 5**) is developed. The working of the weighted scoring model is presented in **Annex 1**

Exhibit 5: Weighted scoring model to assess the diffusion of digital technologies in firms

	Web Technologies	Mobile Internet Technologies	Cloud based services	Big data architecture	Internet of Things	Design Thinking	Robotics	Augmented Reality	Additive Manufacturing (e.g 3-D printing)	AI Tools and Applications	Neural networks, Machine Learning
WEIGHTAGE SCORING MODEL	**0.25** - Company Website **0.25** - Business to Business portal **0.25** - Ecommerce portal **0.25** - AI-NLP (Artificial Intelligence - Natural Language Processing Chatbot Integration **0** - None of the above	**0.25** - Use of mobile devices for work. **0.25** -Use of mobile apps for business processes. **0.25** - Use of mobile to access company data and resources. **0.25** - Use of mobile to collect data for business processes **0** - None of the above	**0.25** - SaaS (Software as a Service) **0.25** - Compute as a service **0.25** - IaaS (Infrastructure as a Service) **0.25** - PaaS (Platform as a Service) **0** - None of the above	**0.6**- If the firm has organised its structured and unstructured data into data lakes to leverage AI. **0.4** - If the firm is in the process of organising its data. **0** - If the firm has not started the process of organising the data.	**0.25** - If the firm uses sensors or RFID scanners in its operations **0.25** - If the firm collects data from sensors and manages the device. **0.25** - If the firm uses AI on the data collected from the sensors to improve the operational efficiency of the firm. **0.25** - If the firm has built a service model using the data collected from the sensors **0** - None of the above	**1 -** Evidence of use of computer aided designing (CAD) and computer aided manufacturing (CAM) software. **0** - No evidence of use of computer aided designing (CAD) and computer aided manufacturing (CAM) software.	**0.8** - Use of Hardware robotics. **0.2** - Use of software robotics in processes. **0** - No use of robotics either hardware or software	**1 -** Evidence of use of Augmented reality devices and software. **0** - No evidence of use of Augmented reality devices and software	**1 -** Evidence of use of 3D printer. **0** - No evidence of use of 3D printer.	**0.25** - AI through SaaS **0.25** - AI through Compute as a service **0.25** - AI through IaaS **0.25** - AI through PaaS **0** - None of the above	**1 -** Evidence of use of Machine Learning or Neural Graphs **0** - No evidence of use of Machine Learning or Neural Graphs

Note: The methodology for the weighted scoring model, detailed in **Annex 1**, aims to provide a granular analysis of the diffusion of a spectrum of digital technologies within firms from web technologies to Artificial Intelligence (Gopal et al., 2019; McKinsey, 2018; World Economic Forum, 2023). This model draws on the principles of the Unified Theory of Acceptance and Use of Technology (**UTAUT**) (Venkatesh et al., 2003) and the Networked Business Innovation Capability (**NEBIC**) (Wheeler, 2002) frameworks. Its primary focus is to assess the diffusion of digital technology within the firm and in turn the digital transformation readiness (Kraus et al., 2022; Vial, 2019, 2021) of the firm.

3 The Research Project – *The AI Catalyst*

The Productivity Institute (The Productivity Institute, 2024a) and the Enterprise Research Centre (Enterprise Research Centre, 2024) have conducted extensive research on the productivity challenges faced by MSMEs in the UK. Despite their comprehensive analyses, there remains a notable gap in understanding the underlying factors contributing to these productivity issues. In particular, the impact of digitalisation and Artificial Intelligence (AI) adoption within MSME firms requires further in-depth investigation.

The AI Catalyst, developed by 'The Productivity Institute' (The Productivity Institute, 2024a) in collaboration with the 'Be the Business' (Be the Business, 2024b), was designed as a 'Participatory Action Research' (PAR) initiative, (Bradbury, 2015; Bradbury et al., 2019; Swantz, 2008; Vaughn & Jacquez, 2020) with the aim to explore the causal factors impacting productivity in MSME firms, assess their digital readiness, and determine if tailored, research-led 'Knowledge Exchange' sessions and support can facilitate the adoption of AI.

PAR involves systematic inquiry conducted in collaboration with those directly affected by the issue under study, with the primary aim of facilitating action or change. This method incorporates the participation of individuals who, while may not be formally trained in research, represent the interests of the affected population or firms (Vaughn & Jacquez, 2020). PAR empowers these stakeholders to identify and articulate their challenges, and collaborate actively with researchers to implement transformative changes (Swantz, 2008).

3.1 Research Questions

Guided by the comprehensive literature review, this research enquiry is structured around the following research questions:

- What is the understanding of productivity in MSMEs across UK?
- What do MSMEs in the UK measure for productivity?
- How do MSMEs in the UK measure productivity?
- Do MSMEs in the UK have the resources and capabilities to enhance their productivity?
- What is the digitisation readiness of MSMEs in the UK? And
- Are MSMEs in the UK ready to take advantage of the ongoing AI revolution?

3.2 Research Design

This research was guided by the principles of the Dynamic Capabilities (Eisenhardt & Martin, 2000; Teece et al., 1997), Knowledge- Based View (Eisenhardt et al., 2000; Grant, 1997; Maijanen, 2020), Resource-Based View (Barney, 1991), Stakeholder Theory (Freeman, 2010; Freeman et al., 2018), and sustained competitive advantage (Porter, 1985).

Dynamic Capabilities: This concept underscores a firm's capacity to integrate, build, and reconfigure internal and external competencies to navigate the rapidly changing environment. It posits that firms must cultivate essential capabilities to effectively sense opportunities and threats, seize opportunities, and sustain competitiveness through ongoing resource configuration (Eisenhardt & Martin, 2000; Teece et al., 1997).

The Knowledge-Based View (KBV) posits that knowledge constitutes the most strategic resource for firms, forming the foundation for competitive advantage. Eisenhardt et al. (2000) emphasise the role of knowledge in shaping strategic management practices, particularly in knowledge creation, integration, and application. Grant (1997) highlights the practical implications, advocating for the development and leverage of intellectual capital to boost performance and innovation. Maijanen (2020) integrates KBV with other strategic management approaches, and underscores its importance in dynamic and complex business environments, where knowledge assets are crucial for maintaining competitiveness.

Resource-Based View (RBV) posits that a firm can achieve sustained competitive advantage by possessing resources that are valuable, rare, inimitable, and non-substitutable (VRIN). The unique tangible and intangible resources enables firms to strategically exploit external opportunities. By developing and leveraging such resources, firms can effectively differentiate themselves from competitors and maintain a better market position (Barney, 1991).

Stakeholder Theory posits that businesses should create value for all stakeholders, including employees, customers, suppliers, communities, and investors. It emphasises the importance of ethical management practices that consider the interests and well-being of all parties involved. The theory advocates for aligning stakeholder interests to achieve long-term success and sustainability, highlighting the interconnected relationships between a business and its various stakeholders (Freeman, 2010; Freeman et al., 2018).

Sustained Competitive Advantage Porter (1985) posits that firms can achieve long-term success by creating unique value for customers in ways that are difficult for competitors to replicate; which can be accomplished through three primary strategies: cost leadership, differentiation, and focus. Additionally, Porter (1985) highlights the critical role of technological innovation in sustaining competitive advantage since it enables firms to continuously adapt and enhance their offerings.

The above principles align closely with NEBIC (Wheeler, 2002), and the observations drawn by Vial (2021) and Kraus et al. (2022) for digital transformation.

3.3 The scan tool

In alignment with the aforementioned principles, a scan tool was designed to map the landscape of resources and capabilities, alongside the systems (both digital and non-digital) employed by the firm to generate value for its stakeholders.

The scan tool, a Microsoft Excel workbook, comprised of five worksheets:

1. **Resources Worksheet**: This worksheet systematically catalogued resources into tangible and intangible assets. Participating firms self-assessed the effectiveness of each resource, identified factors affecting productivity, and assigned priority levels (immediate, medium, and long-term) to enhance the effectiveness of the resource and mitigate any potential impact on productivity.
2. **Capabilities Worksheet**: This worksheet documented the landscape of capabilities and organised them into innovation, relational, and technological categories. Participating firms self-assessed the effectiveness of each capability and its impact on productivity. They assigned priority levels to enhance the effectiveness of the capabilities and consequently productivity.
3. **Stakeholder Process Worksheets**: The remaining three worksheets were dedicated to documenting the processes employed by the firm to create value for its stakeholders: customers, employees, and suppliers and partners.
    - **3a. Customer Worksheet:** Recorded both digital and non-digital processes, including an assessment of their effectiveness, impact on productivity, and the priority level for addressing its effectiveness.
    - **3b. Employee Worksheet:** Similar to the Customer Worksheet, it recorded and assessed the employee processes used by the firm.
    - **3c. Supplier and Partner Worksheet:** Similar to the Customer Worksheet, it recorded and assessed the processes employed by the firm to collaborate with its suppliers and partners.

3.4 Frameworks leveraged for organisational change

To guide firms towards enhancing productivity, the principles of the '**Theory of Change**'(Centre for Theory of Change, 2023) were adopted. The ultimate long-term goal, referred to as 'The Change', was to improve the productivity of the firm. The transformation process was informed by the **root-cause analysis** undertaken during the project.

The **SOSTAC** framework-- an acronym for Situation, Objectives, Strategy, Tactics, Action, and Control--guided the delivery of the 'Knowledge Exchange' sessions, which is detailed in the subsequent section. The framework advocates for an initial situational analysis (captured through the scan tool) to understand the firms current standing, which in-turn informs the specific objectives, strategy, tactics, and Key Performance Indicators (KPIs) to achieve the desired change.

3.5 Operationalising the research

Firm selection and recruitment: *The AI Catalyst* was designed with a target to deliver personalised 'Knowledge Exchange' sessions to **twenty** firms. The eligibility criteria, for the firms, included prior participation in management programmes offered by Be The Business (Be the Business, 2024b). A shortlist of **100** firms was developed using publicly accessible data from sources such as the firm websites, UK Companies House (Companies House, 2024), and the Office for National Statistics (Office for National Statistics, 2024b).

The recruitment efforts were spearheaded by 'Be The Business' (Be the Business, 2024b), while 'The Productivity Institute' (The Productivity Institute, 2024a) executed all other aspects of the project. Shortlisted firms were contacted with an invitation detailing the research project. While the recruitment target for the project was **twenty firms**, this number was not met. The challenges of recruitment of MSME firms for action research is detailed in the Business Basics Programme report (Department for BEIS, 2024a, 2024b). Firms who expressed willingness to participate in the research received a copy of the participant information sheet and a consent form. **Fifteen firms** were successfully recruited. A summary view of the firms and their descriptive characteristics is provided in **Exhibit 6** and **Annex 2**, respectively.

The cohort consisted of an equal distribution of firms across manufacturing and non-manufacturing sectors. **Eight** firms were from the manufacturing sector and the remaining **seven** were from the non-manufacturing sector representing the foundational economy. The latter group encompasses industries such as marketing services, hospitality, professional services, and charities.

Structure and Schedule of the Knowledge Exchange sessions:

The 'Knowledge Exchange' sessions, which totalled to **100** hours, were held over **115** days from **19 March to 12 July 2024**. The sessions were scheduled fortnightly and conducted online using Microsoft Teams. Each firm received a minimum of **six** tailored sessions. They followed the **SOSTAC** structure and addressed specific research questions.

All **fifteen** firms attended all the fortnightly 'Knowledge Exchange' sessions and completed the programme feedback. One firm attended only the first session and subsequently withdrew due to business reasons. That slot was allocated to another firm later. Ninety-minute sessions were trialled with one firm and weekly sessions with another. However, it was concluded that fortnightly sessions of **one-hour** each were most effective, based on participant feedback.

Session 1 introduced the programme, the scan tool, and provided a brief overview of Artificial Intelligence (AI). The session detailed the contents of the scan tool and guided firms on self-assessing their resources and capabilities. This session addressed the following Research Questions (RQ) through interview questions.

RQ1*: What is the understanding of productivity in MSMEs across the UK?*

RQ2*: What do MSMEs in the UK measure for productivity?*

RQ3*: How do MSMEs in the UK measure productivity?*

Session 2 focused on discussing the details populated in the scan tool and the objectives for undertaking digital transformation, including the adoption of AI to enhance productivity. This session addressed the following research questions:

RQ4: Do MSMEs in the UK have the resources and capabilities to enhance their productivity?

RQ5: What is the digitisation readiness of MSMEs in the UK?

Session 3 to 6 addressed the following research question**:**
RQ6: Are MSMEs in the UK ready to take advantage of the ongoing AI revolution?

Session 3 introduced the strategy to introduce AI in the firm. It supported the firms with corresponding employee communications and the formation of an AI ethics policy using resources from the Information Commissioners Office (Information Commissioners Office, 2024a), Alan Turing Institute (The Alan Turing Institute, 2024), and OECD AI Policy Observatory (OECD.AI Policy Observatory, 2024).

Session 4 introduced readily available **Generative AI** solutions for integration into the firm to improve worker productivity.

Session 5 identified specific **Non-Generative AI** solutions for each firm such as integrating sensors and using Machine Learning for predictive maintenance.

Session 6 outlined the steps to implement a change programme, onboard employees, manage projects, and set KPIs to measure progress.

Each participating firm received a copy of the productivity primer (The Productivity Institute, 2024b). Discussions centred around the five drivers of productivity (**Exhibit 1**) and the determinants of business performance (**Exhibit 2**). The drivers of productivity also informed the set of KPIs. Several case studies, solutions, and tools such as the website grader (Hubspot, 2024) and SEMrush analytics (Semrush, 2024) were used to illustrate the concepts. At the conclusion of each session, every participating firm received their tailored content in the form of slides, research papers, and web resources.

In addition to the aforementioned research questions, two sets of interviews were conducted during the first and last session. The findings derived from the analysis of the scan tool, the 'Knowledge Exchange' sessions, and the interview questions are comprehensively documented in the section titled 'Research Findings,' and are further substantiated by annexes. The discussions that took place during the 'Knowledge Exchange' sessions provided substantial context to the data collected.

Exhibit 6: *The AI Catalyst* – Firm, sector, and participant demographics

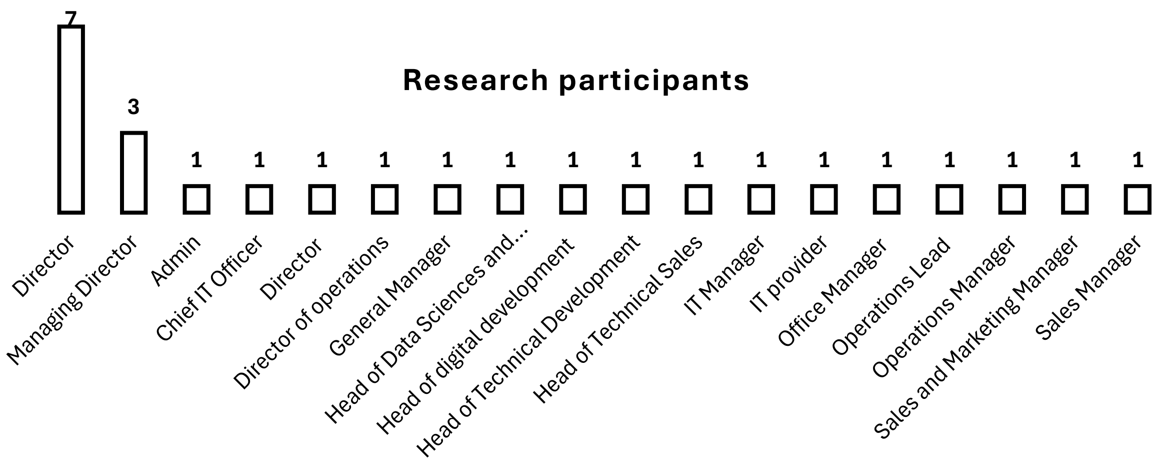
- Number of employees: Mean – **65,** Median **– 25**
- Annual turnover of the firm – Mean - **£9,674,410**, Median - **£3,300,000**
- Total number of research participants – **26**

Note: The above data is computed using data provided during the interviews.

Industry Sector	***Number of firms***	***SIC Code***
Food and Beverage service	1	56100
Legal Services	1	69102
Manufacturing	8	10831,11010,14120,25600,26511, 29201, 30400,32300
Real Estate	1	68320
Sales	1	46140
Services	2	43220,88990
Event Services	1	82301
Total	**15**	

Region	***Number of firms***
Northwest	7
Scotland	2
Southeast	1
Southwest	4
Yorkshire and The Humber	1
Total	**15**

Type of Business	***Number of firms***
Medium (50 -249 employees)	*6*
Small (10 - 49 employees)	*7*
Micro (1 - 9 employees)	*2*
Total	***15***



Note: For descriptive characteristics of the firm and their SIC codes please see **Annex 2**

4 The Research Findings

This section delves into the core motivations that led firms to participate in the participatory action research project--*The AI Catalyst*. It explores their conceptualisation of 'productivity', the metrics, and measurement approaches they employed, and the challenges they faced in their pursuit of optimal productivity. Furthermore, it examines the integration of digital technologies within the firms and outlines the progress achieved throughout the action research.

4.1 Firm motivations for participating in *The AI Catalyst*

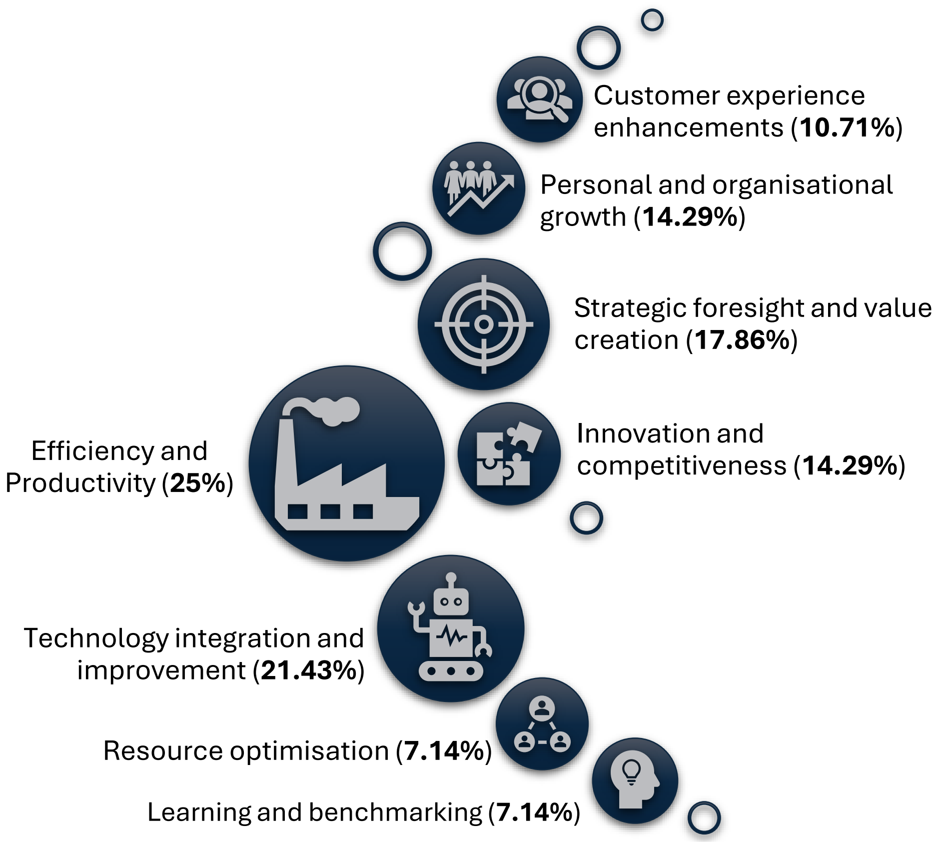
During the initial session, each firm was asked the interview question (IQ): *'What are your motivations for joining the programme?'.* The responses were meticulously analysed and categorised into overarching themes, which are presented below in order of relative importance in terms of the frequency of mentions during the sessions.

- **Efficiency and Productivity (25%)**: The potential of AI to enhance productivity and operational efficiency emerged as a prominent motivation among respondents. They highlighted how AI can streamline routine tasks, thereby enabling employees to focus on more value-added activities. This included optimising the use of existing digital tools, pre-emptively addressing potential issues, and improving overall business processes and resource allocation.
- **Technology integration and improvement (21.43%)**: The need to enhance productivity and reduce costs through better technology integration emerged as a recurring theme among respondents. They expressed frustration with current systems that fail to deliver on their promises and view AI as a solution to automate manual processes and generate more useful reports from their data. This reflects a desire to leverage AI for more effective use of existing technology.
- **Strategic foresight and value creation (17.86%)**: Several respondents articulated a strategic vision for AI adoption that extended beyond immediate operational benefits. They highlighted the long-term value creation opportunities that AI presented, both for their customers and their own business trajectories. This included enhancing scalability and generating additional value.
- **Innovation and competitiveness (14.29%)**: Most respondents underscored the imperative of remaining at the cutting edge of technological innovation. The integration of AI was viewed as essential for future-proofing products and sustaining a competitive advantage in the marketplace. The potential risk of obsolescence, should AI not be adopted, highlighted the strategic importance of this technology for both self-preservation and ongoing competitiveness.
- **Personal and organisational growth (14.29%)**: Finally, the responses revealed a personal dimension to the motivations for joining the programme. Some respondents expressed a personal desire to understand AI and its implications, aligning this with the organisational goal of staying competitive. This dual motivation reflects a holistic approach to AI adoption, where personal growth and organisational development were seen as intertwined.

- **Customer-Experience enhancements (10.71%)**: Several interviewees identified the enhancement of customer experience as a key driver for AI adoption. They mentioned specific applications such as automated email responses, chatbots for 24/7 assistance, and online client portals as opportunities to leverage AI for improved client interactions. This focus on customer-centric solutions underscored the importance of meeting and exceeding client expectations in a competitive landscape.
- **Resource optimisation (7.14%)**: Maximising efficiency and optimising resources were key motivations for many respondents. They aimed to enhance the efficiency of their administrative processes to enable revenue growth without a proportional increase in human resources. This strategic approach to resource management underscores the potential of AI to drive operational improvements and support sustainable business growth.
- **Learning and benchmarking (7.14%)**: The opportunity to learn from experts, researchers, and other businesses was another motivation for few respondents. They expressed a preference for observing the success stories of others before fully committing to AI adoption. This reflective approach was coupled with considerations of licensing and cost implications, particularly in relation to the use of existing software.

Exhibit 7 presents a visual representation of the above themes.

Exhibit 7: Visual summary of the firm's motivation for participating in *The AI Catalyst*



Note: The weighted scores were computed using Microsoft CoPilot.

4.2 Productivity narratives, measurement approaches, and metrics

Extensive research has established that digital technologies and Artificial Intelligence (AI), often regarded as the next 'general purpose technology', holds significant potential to enhance productivity (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024; Pilat et al., 2003; Van Ark, 2015, 2016; Van Ark et al., 2003a, 2003b, 2003c; Van Ark et al., 2013). To elucidate how firms conceptualise and measure 'productivity', the following interview questions (IQ) were posed prior to introducing participants to the productivity primer (The Productivity Institute, 2024b), an explainer for Productivity.

IQ1: Describe your understanding of productivity.
IQ2: Do you measure productivity? If yes, what do you measure for productivity?
IQ3: Describe the methods you employ to measure productivity.

The following section provides a synthesis of the responses to the above interview questions, detailing the productivity narratives, methodologies employed by firms to measure productivity, and the productivity metrics they track.

Productivity narratives:

Manufacturing Industries emphasised that productivity is primarily about maximising output within set timeframes. They highlighted the importance of optimising the use of machinery and human resources to achieve higher productivity. Effective utilisation of resources, including capital, technology, and skilled labour, was deemed crucial for enhancing productivity. Maintaining high product quality while minimising rework was also a key focus, with continuous improvement in production processes considered essential. Respondents noted that individual contributions are vital, with each worker's efficiency directly impacting overall productivity. Strategic leadership and effective management practices were seen as enhancing productivity through process optimisation and cost management. Additionally, innovation in production techniques and fostering a productive culture were seen as further enhancing productivity. Many interviewees mentioned that they often rely on key performance indicators (KPIs) to monitor production efficiency, quality, and error rates. Furthermore, processes for continuous improvement were established.

Non-manufacturing and service industries emphasised that productivity is about delivering high-quality services efficiently within set timeframes. They highlighted the importance of maximising the use of staff time and resources to provide excellent service. Effective utilisation of human resources and technology was deemed essential for enhancing service delivery. Continuous improvement in service processes and maintaining high customer satisfaction were identified as key priorities. Respondents noted that individual and team contributions play a significant role, with collaboration and efficiency deemed crucial for achieving productivity goals. Strategic leadership and effective management practices were seen as driving productivity by optimising service processes and managing costs. Additionally, innovation in service delivery techniques and fostering a productive culture were deemed essential to achieve productivity. Many interviewees mentioned that service firms often use KPIs to monitor service efficiency, quality, and customer satisfaction to drive continuous improvement.

Common themes: Across both manufacturing and non-manufacturing industries, several common themes emerged regarding productivity. Both sectors emphasised the importance of effective resource utilisation, whether it be machinery and skilled labour in manufacturing or staff time and technology in services. Continuous improvement and maintaining high standards of quality were identified as crucial for enhancing productivity. Strategic leadership and effective management practices were consistently highlighted as key drivers of productivity, with a focus on process optimisation and cost management. Innovation and fostering a productive culture were also seen as essential across both sectors. Additionally, the use of KPIs to monitor various aspects of productivity, such as efficiency, quality, and satisfaction, was a common practice to ensure continuous improvement.

Exhibit 8: Key themes from the productive narratives

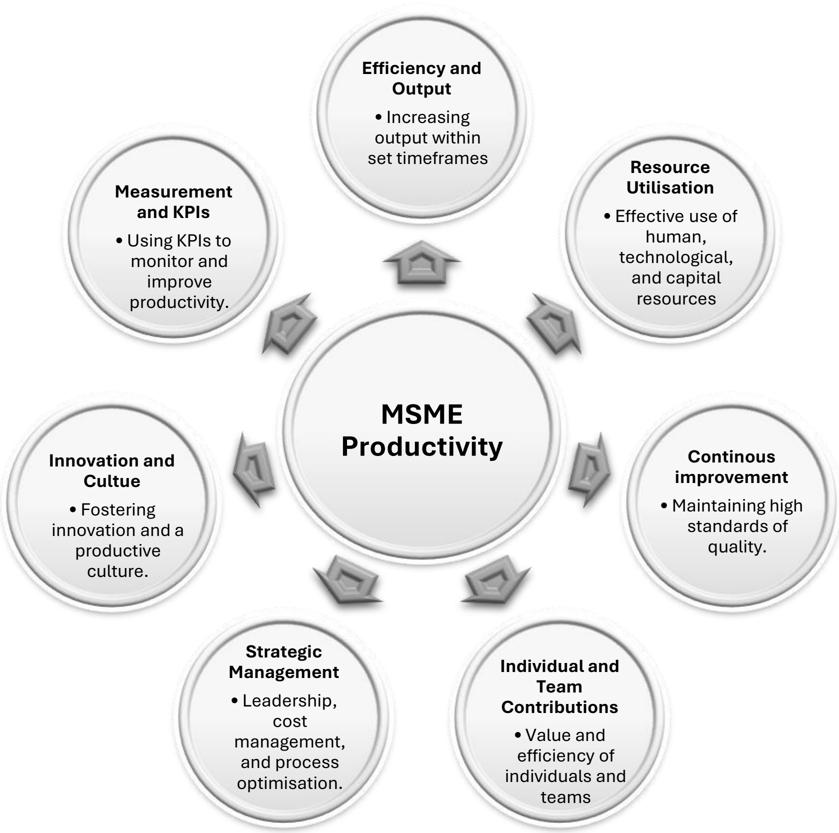


Exhibit 8 illustrates a notable shift in productivity narratives in comparison to those documented in the research undertaken by Roper et al. (2019). This shift could possibly be attributed to the cohort's engagement in initiatives such as those offered by 'Be The Business' (Be the Business, 2024b) among other programs, including the broader awareness and national debate around productivity led by The Productivity Institute (2024a).

Approaches used by firms to measure productivity:

Manufacturing firms highlighted the manual nature of their productivity measurement processes. They rely on tools such as Microsoft Excel and paper-based data collection to track manufacturing targets and achievements. Team leaders capture production data on paper, which is then periodically updated onto Microsoft Excel to compute monthly productivity reports. The manual approach underscores the need for more automated and efficient systems to streamline productivity measurement.

Non-manufacturing firms rely on a mix of manual and digital methods for productivity measurement. Some use Microsoft Excel spreadsheets and paper-based data collection, while others employ digital recorders and accounting packages to log hours and bill clients accordingly. The reliance on manual methods highlighted a need for more automated systems to streamline processes and reduce repetitive tasks.

Productivity metrics:

Manufacturing firms track various parameters for productivity including output-based measurement, time savings, continuous improvement, and turnover. While there is a clear intention to measure productivity, it is not necessarily automated or digitised. Volume-based manufacturing firms tend to adopt output-based measurements, as measuring productivity in their facilities is straightforward and revolves around output. Some manufacturing firms also prioritise capturing and analysing the time involved in production processes. This focus on time savings and continuous improvement projects aims to enhance efficiency and reduce waste. By meticulously tracking and analysing process time over several years, these firms strive to make incremental improvements that collectively boost productivity. Firms that produce scientific, engineering, highly specialised, made-to-order, low volume but high-quality products tend to adopt the later approach.

Across both volume and value-based manufacturing, interviewees expressed that measuring productivity in office tasks and management functions was rather difficult due to less clear metrics and a lack of well-established processes. However, both categories of firms tracked turnover and budget, sometimes measuring these daily and monthly. Tracking against these KPIs offered them the flexibility to move people between departments to get work done more efficiently.

Non-manufacturing firms often employ a wide range of KPIs and metrics to measure productivity. These include energy efficiency, labour hours to complete a job, yields, and gross profit margins. Firms involved in sales measured revenue outcomes as a metric of converting enquiries into sales. Similar to manufacturing firms, they use metrics to assess the quality aspects of their work. However, there is a broader emphasis on overall business performance, which takes precedence over measuring individual productivity.

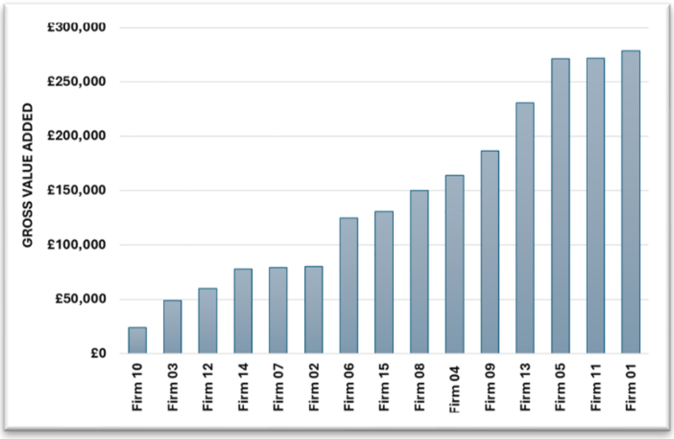
Some of these metrics such as output-based measurements, time savings, and continuous improvements align with those captured in the research undertaken by Penny and Pendrill (2022).

To assess the productivity of the firm, specifically its Gross Value Added (GVA) per employee, responses to the following interview questions (IQ) were utilised:

IQ4: 'What is the annual turnover of your company?'
IQ5: 'How many employees are employed by the firm?'

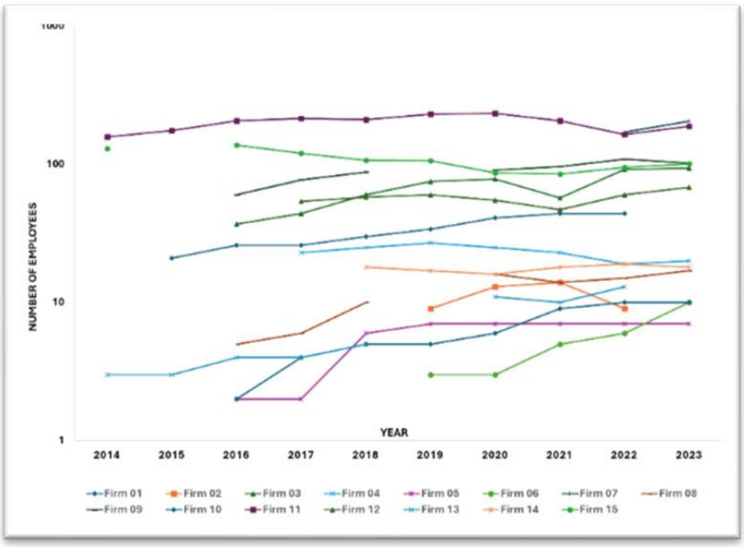
GVA per employee is computed by dividing the firm's annual turnover by the number of employees. The computed GVA per employee for the firms is presented in **Exhibit 9**.

Exhibit 9: Gross Value Added by the firms for the FY2023-24



Following the analysis presented in **Exhibit 9**, It was observed that **ten** out of the **fifteen** firms reported an annual turnover of **less than £5 million**, and **eight** out of the **fifteen** firms had fewer than **fifty** employees. Furthermore, the growth in the number of employees over the past decade, summarised using data from Companies House (Companies House, 2024) and the FAME (*Fame*) database, has remained relatively flat, as depicted in **Exhibit 10**.

Exhibit 10: Employee growth trends over the past decade



Note: The chart uses a logarithmic scale.

In the context of *The AI Catalyst* initiative, all participating firms expressed a strong aspiration to improve their productivity. However, they encountered various constraints that hindered their progress. These challenges became focal points of discussion during the 'Knowledge Exchange' sessions and prompted a comprehensive analysis of the data collected through the scan tool. The obstacles impeding firms from achieving optimal productivity are categorised into external and internal barriers.

External barriers:

- **Access to finance:** The past decade has witnessed several developments such as the rise in cloud computing, regulatory changes including the implementation of GDPR (Information Commissioners Office, 2024b), and the global COVID-19 pandemic. Although the UK government provided support to businesses through the furlough scheme (HM Revenue & Customs, 2021) during the pandemic, the subsequent economic challenges-- such as inflation, rising energy prices, Brexit-related hurdles, and disruptions in supply chains and transportation – have had a profound impact on MSMEs (Albonico et al., 2020; Bartik et al., 2020; Mizen et al., 2022). These challenges were comparable to those faced by larger enterprises, as discussed by two MSME business leaders in a podcast with 'The Productivity Institute' (The Productivity Institute, 2023). However, MSMEs may not often have access to substantial financial resources, which exacerbated the economic repercussions of the pandemic. Consequently, several long-established MSMEs, which have been integral to the UK economy for centuries, were compelled to undergo mergers to secure the necessary capital to sustain their operations within UK.

- **Access to talent:** Nearly every business reported difficulties in sourcing candidates with STEM (Science, Technology, Engineering, and Mathematics) skills, including digital technologies. This shortage has led to several adverse outcomes such as untapped sales enquiry pipeline, missed opportunities for automation, and improvements in operational efficiency. More critically, it has resulted in lost opportunities for advancing innovation in key engineering and scientific areas. The challenge was notably more pronounced in the northern regions. Furthermore, operational issues often take precedence over strategic -- organisation-wide capability development.

Internal barriers

- **Leadership in practice: The impact of operational burden**
  Three distinct categories of leadership was identified in MSME firms: family members as directors, partnership directors, and corporate management structures. Regardless of the category, all interviewees exhibited a profound passion for their business and were actively engaged in day-to-day operations. Additionally, many assumed multiple roles as necessary to ensure smooth functioning of the business.

  A lack of diversity in leadership was noted in a few family-owned firms. In contrast, firms with partnership directors (non-family members) had outlined responsibilities for each director, who managed specific aspects of the day-to-day operations. Meanwhile, firms with a corporate management structure exhibited diverse leadership with well-defined roles, such as a finance director, operations director, and managing director. These firms displayed the most dynamic characteristics within the cohort. The distribution of responsibilities through well-defined roles likely assisted in adopting a strategic orientation, leading to above the average growth in innovation and productivity.

- **Efficiency of resources and capabilities:** The data obtained through the scan tool revealed that most businesses reported up to **50%** of their resources and capabilities as less effective. To illustrate the impact of the sub-optimal effectiveness of the resources on productivity, consider the example of a manufacturing firm. The firm, which operates approximately ten machines, identified that some were functioning at only **80%** of their performance capacity. Additionally, due to the ageing infrastructure, these machines tended to break down every few weeks. The lack of sufficient engineering resources meant the business had to fly in an engineer from a neighbouring European region, incurring several thousands in expenses for each visit. Furthermore, additional costs were incurred for machine parts and their replacement service charges. Cumulatively, these issues led to a decline in the expected output from the manufacturing process. The increased costs and reduced efficiency at the firm level resulted in a noticeable decline in productivity, which subsequently impacted the firm's turnover performance due to limitations on the production batches they could process.

In addition to the above, the following section presents a detailed summary of the findings related to digitalisation and the diffusion of digital technologies within MSME firms.

4.3 Digitalisation in UK MSMEs: Diffusion, adoption, and barriers

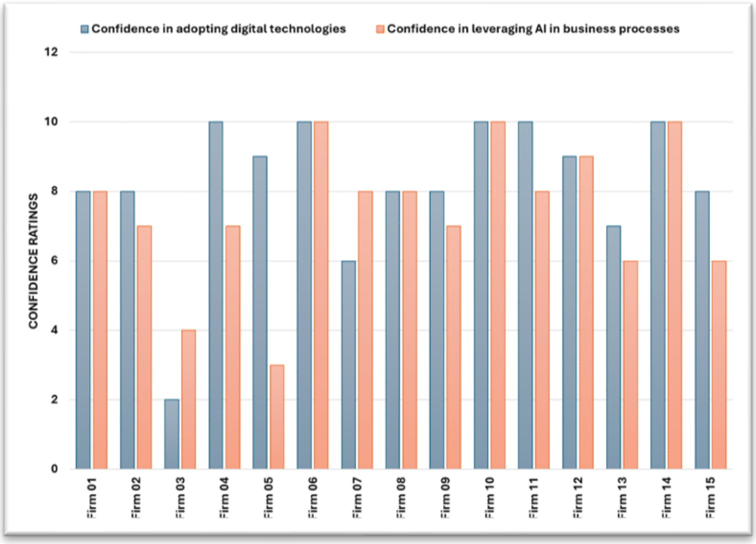
A precursor to adoption of AI is the firm's willingness to invest and adopt digital technologies prior to exploring avenues for integrating AI in business processes.

To assess this readiness, firms were posed with the following interview questions (IQ):

IQ6: 'On a scale of 1-10 (with 10 being the highest), how confident is your firm to adopt digital technologies within your business'?
IQ7: 'On a scale of 1-10 (with 10 being the highest), how confident are you on leveraging Artificial Intelligence in your business process'?

Exhibit 11 presents the findings from these questions

Exhibit 11: Firm confidence levels in adopting digital technologies and AI

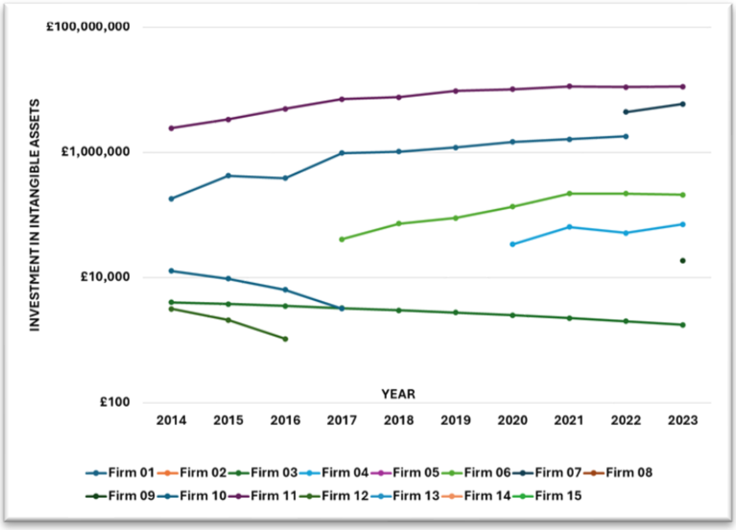


Note: Confidence rating scale 1=low confidence and 10=very confident

While some firms exhibit high confidence, a few indicate hesitancy, particularly in AI integration and this could be led by several barriers, in particular awareness of how AI can be integrated in the business processes, as identified in the Business Basics report (Department for BEIS, 2024a, 2024b), and surveys undertaken by Cunha et al. (2024), Be the Business (2024a), Goldman Sachs (2024a), Microsoft and Public First (2024).

Furthermore, the analysis of the firm's investments in intangible assets over the past decade was conducted using data sourced from Companies House (Companies House, 2024) and FAME (*Fame*). **Exhibit 12** presents this investment data.

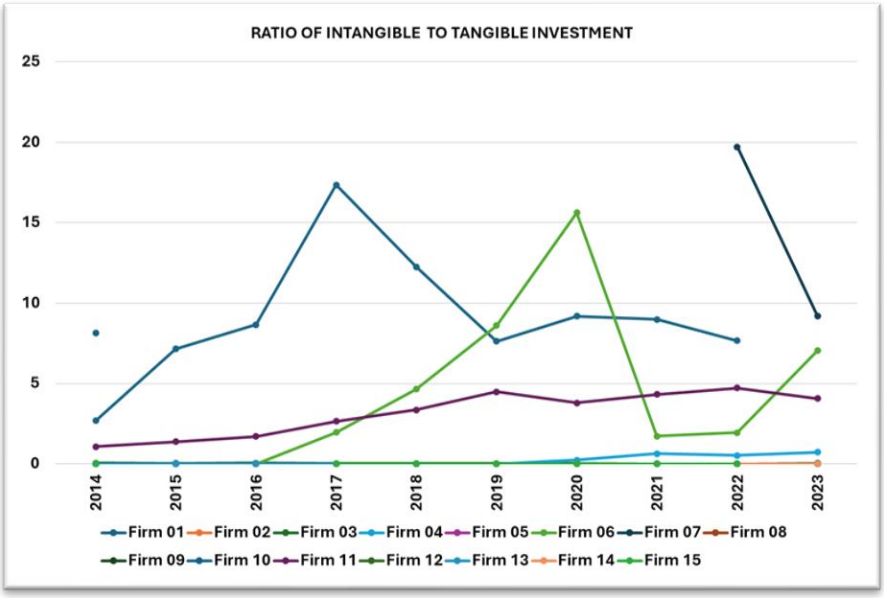
Exhibit 12: Trends in intangible asset investment-2014-2023



Note: The chart uses a logarithmic scale. The Intangible asset investment is drawn from FAME database and can be broadly categorised into assets such as goodwill, development costs, and patents by accounting standards adopted by the accounting firm and does include the comprehensive intangibles categorisation as defined by Bontadini et al. (2024).

Among the **fifteen** firms who participated in the research initiative, only a few reported investments in intangible assets, which may be an inadvertent discrepancy. Brynjolfsson et al. (2021) emphasised the importance of recognising and measuring intangible investments at the firm level to understand the long-term productivity benefits of new technologies. For instance, to account for the **0.55%** of 'lost' output in the 2017 U.S GDP, the ratio of intangible investments to tangible investments (at the microeconomic – firm level) is expected to be between **2.7** to **4.1.** To assess the possible impact of AI on productivity in the firms who participated in *The AI Catalyst* initiative, the ratio of intangible investments to tangible investments (**Exhibit 13**) was charted.

Exhibit 13: Ratio of intangible assets to tangible asset investments



Note: The vertical axis represents the ratio of Intangible/tangible investment. The note on Intangible investment shared for Exhibit 12 applies for Exhibit 13.

While marquee firms exhibited a ratio of **9:1**, the overall average across the cohort was **2:1**. The inadvertent underreporting of intangible investments by some firms limits the ability to accurately assess any impact of AI technologies on productivity at a firm level.

In addition to the confidence of the firm in adopting digital technologies, and its corresponding investment in intangibles, it was crucial to understand the existing landscape of digital applications, the levels of digitalisation, and the diffusion of digital technologies within the firms. This understanding was essential to identify avenues to integrate AI to enhance productivity and efficiency. **Annex 3** lists the digital applications used by firms in customer processes, **Annex 4** details those used in employee processes, and **Annex 5** outlines the applications used in supply chain processes. **Annex 6** provides a comprehensive list of all the applications across the above processes as shared by firms through the scan tool. **Annex 6** highlights the diverse landscape of applications in use at MSME firms. For instance, several applications were identified for employee (human resources (HR)) processes, such as Breathe HR, Bright HR, People First, and Safe HR. It was also observed that MSME firms utilise a minimum of **three** applications, with some firms employing more than **twelve**. Notably, a majority of the firms, **twelve** of the **fifteen**, preferred Microsoft 365 for productivity tools. Despite the widespread presence of digital applications in MSME firms, the segment continues to encounter productivity challenges, which prompted an assessment of the diffusion of digital technologies.

Table 2 presents the weighted scores for the diffusion of digital technologies in firms.

Table 2: Weighted scores of digital technology diffusion in firms

Firm/Digital Technologies	*Web Technologies*	*Mobile Internet Technologies*	*Cloud based services*	*Big data architecture*	*Internet of Things*	*Design Thinking (CAD/CAM)*	*Robotics*	*Augmented Reality*	*Additive Manufacturing (e.g. 3-D printing)*	*AI Tools and Applications*	*Neural networks, Machine Learning*	*Total*
Firm 01	0.25	0.5	0.75	0.4	0.5	1	0	0	1	0.75	1	**6.15**
Firm 02	0.25	0.5	0.25	0	0	0	0	0	0	0	0	**1**
Firm 03	0.25	0.5	0.25	0	0	0	0	0	0	0	0	**1**
Firm 04	1	0.5	0.25	0	0.25	0	0	0	0	0	0	**2**
Firm 05	0.5	0.75	0.25	0	0	0	0	0	0	0	0	**1.5**
Firm 06	0.75	0.5	0.25	0	0	0	0	0	0	0	0	**1.5**
Firm 07	0.25	0.25	0.25	0	0	0	0	0	0	0	0	**0.75**
Firm 08	0.25	0.25	0.25	0	0	1	0	0	0	0	0	**1.75**
Firm 09	0.25	0.25	0.25	0.4	0.25	0	0	0	0	0	0	**1.4**
Firm 10	0.5	0.5	0.25	0	0	0	0	0	0	0	0	**1.25**
Firm 11	0.25	0.25	1	0.4	0.75	1	0	0	0	0.5	1	**5.15**
Firm 12	0.25	1	0.25	0	0	0	0	0	0	0.25	0	**1.75**
Firm 13	0.25	0.25	0.25	0	0	0	0	0	0	0	0	**0.75**
Firm 14	0.25	0.25	0.25	0	0	0	0	0	0	0	0	**0.75**
Firm 15	0.25	0.25	0.25	0.4	0	1	0	1	1	0	0	**4.15**

Note: The scores for digital technology diffusion is computed using the weighted scores presented in model developed (**Exhibit 5). Annex 1** presents the literature that underpins the scores and the model. The green cadre refers to the firms which exemplify the **NEBIC** model (Wheeler, 2002), and the red cadre represents the low diffusion of AI technologies.

As highlighted horizontally in green cadre in **Table 2**, it is evident that two firms with a weighted score exceeding **five** displayed higher scores in cloud-based services, big data architecture, Internet of Things, and the use of CAD (computer-aided designing) and CAM (computer-aided manufacturing) in manufacturing in comparison to the rest of the cohort. These firms also exhibited higher scores on AI tools and applications, indicating investment in machine learning. Cross-referencing this with the GVA (Gross-Value Added) per employee data presented in **Exhibit 9**, these firms also demonstrated a higher GVA per employee value, exceeding **£250,000**.

During the 'Knowledge Exchange' sessions, it was noted that these firms possessed advanced STEM and digital capabilities. Literature supports that firms investing in digital technologies and capabilities tend to achieve higher productivity (Brynjolfsson & Hitt, 2000; Cheng et al., 2023; Gal et al., 2019; Hitt & Brynjolfsson, 1996) and the **NEBIC** model (Wheeler, 2002) further illustrates how firms leverage net-enabled interconnected technologies for business innovation (Ramadan et al., 2023; Velu, 2024; Wheeler, 2002). These two firms exemplify this correlation within the cohort.

Although all firms in the cohort had either utilised ChatGPT (Open AI, 2024a) or were aware of other AI applications, AI was not deeply integrated into their business processes. This is evident from the vertical red cadre highlight in **Table 2**.

The lower scores for technology diffusion across other firms raise the pertinent question of the barriers faced by other firms in exploiting digital technologies. The barriers identified during the 'Knowledge Exchange' sessions are grouped below into internal barriers and external barriers.

***Internal barriers faced by MSME firms in exploiting digital technologies*:**

- **The burden on MSMEs to research technology for adoption**: Pilat and Criscuolo (2018) underscored the challenges faced by MSMEs in the realm of digital transformation. They note that 'digital transformation of firms involves a process of search and experimentation with new technologies and business models, where some firms succeed and grow, while others fail and exit' (Pilat & Criscuolo, 2018, p. 3). This sentiment was echoed during our discussions by research participants, one research participant articulated the practical difficulties encountered as follows:

"Apart from running the business, I do get excited about new technology. I research and implement technology, but it is exhausting, particularly when you haven't got the team to hand it over to. And I have been mindful that the success of any new technology introduced lies with its adoption. Despite us undertaking quite a bit of technology adoption in a short span of time, it can become all-consuming."

- **Insufficient in-house technology capabilities:** A significant challenge faced by MSMEs in their digital transformation journey is the lack of in-house technology capabilities. Only **five** of the **fifteen** firms, who participated in *The AI Catalyst*, possessed in-house digital technologies expertise to explore and develop systems using digital technologies. This limited internal capacity compels many MSMEs to rely heavily on external IT service providers for basic IT services. While these providers offer essential support, they often lack the capacity to understand the business processes, drive innovation, or facilitate the deep integration of advanced digital technologies within the firm, as communicated by the research participants.

This dependency on external providers creates several barriers. Firstly, it limits the firm's ability to conduct independent research and experimentation with new technologies. Without the internal expertise to understand and implement these technologies, firms are less likely to engage in the trial-and-error process that is crucial for innovation. Secondly, reliance on external providers can lead to increased costs and delays, as firms must wait for external support to implement changes or resolve issues.

Moreover, the lack of sufficient digital capabilities within the firm can stifle the development of further advancements. Firms may find it challenging to keep pace with rapid technological changes and could miss out on opportunities to leverage new tools and systems that could enhance their operations and competitiveness. This situation underscores the importance of building in-house digital capabilities to support sustainable growth and innovation in the long term.

- **Delays in technology adoption:** Despite operating for several years or even decades, many MSME firms have only recently accelerated their technology adoption, primarily due to the circumstances brought about by the Covid-19 pandemic. This reactive approach highlights the challenges of integrating new technologies without prior strategic planning.

  The success of digital transformation hinges on the widespread adoption of new technologies by all members of the firm. However, many firms have struggled to achieve this, a situation further exacerbated by inadequate training. These issues create bottlenecks preventing the full realisation of digital transformation benefits.

  Moreover, the rapid pace of technological advancement necessitates continuous adaptation, which can be resource-intensive for MSMEs. Addressing these challenges requires fostering a culture of continuous learning and ensuring all employees are proficient with new technologies.

- **Insufficient levels of digitalisation:** With the exception of a very small number of firms, many reported that at least **50%** of their processes remained non-digitalised. This notable level of digitalisation has substantial implications for MSMEs, as it limits their ability to generate the data and insights necessary for continuous improvement and strategic decision-making.

  Manual processes can be time-consuming and prone to errors, leading to inefficiencies and increased operational costs. Without digital tools, firms struggle to collect and analyse data that could inform better business practices and drive innovation. This gap in digitalisation also affects the firm's agility in responding to market changes and customer demands, putting them at a disadvantage compared to digitally mature firms.

  Furthermore, the lack of digitalisation can impede collaboration and communication within the firm, causing bottlenecks and delays. Addressing these challenges requires a strategic approach to digital transformation, including investing in infrastructure, training employees, and fostering a culture that embraces digital innovation. By prioritising the digitalisation of processes, MSMEs can unlock new opportunities for growth and enhance their competitive edge.

- **Insufficient data analytics:** Particularly for business systems such as CRM (Customer Relationship Management) or ERP (Enterprise Resource Planning), small businesses often lacked access to enterprise-grade systems, which were either cost-prohibitive or MSMEs could not meet the qualification criteria (often in terms of number of users) set by larger firms. Consequently, MSMEs relied on non-enterprise grade or locally developed solutions that did not provide the business insights typically offered by enterprise-grade platforms.

  This reliance on less sophisticated systems has several implications. Firstly, these systems often lacked the advanced data analytics capabilities necessary for generating meaningful business insights. Without these insights, MSMEs struggle to make data-driven decisions that could enhance their operational efficiency and strategic planning. Additionally, the absence of robust data analytics tools means that MSMEs miss out on opportunities to identify trends, optimise processes, and improve customer experiences.

  Addressing these challenges requires MSMEs to invest in more advanced data analytics solutions, either through scalable enterprise-grade platforms or by enhancing their existing systems with additional analytics capabilities. By fostering a data-centric culture, MSMEs can better utilise the data they collect to drive more informed decision-making for sustainable growth.

- **Non-Complementary technology deployments:** Technology deployments are often undertaken to enhance workforce productivity and overall organisational efficiency (Brynjolfsson & Hitt, 2000; Hitt & Brynjolfsson, 1996). Therefore, technology is carefully selected to complement and integrate seamlessly with other systems. However, our research noted that in many firms due to the lack of in-house technology capabilities, recommendations by consultants, or led by constraints such as budgets or access to enterprise-grade systems, several isolated applications were deployed by MSMEs. These applications did not necessarily complement or integrate well, thereby failing to improve workforce productivity or the firm's overall efficiency.

  This lack of integration has several implications. Firstly, isolated applications can create silos within the organisation hindering effective communication and collaboration. Without seamless integration, data flow between systems is disrupted, leading to inefficiencies and potential errors. Secondly, the deployment of non-complementary technologies often results in a fragmented IT landscape, making it challenging to manage and maintain systems effectively.

***External barriers faced by MSME firms in exploiting digital technologies*:**

- **Inconsistent digital broadband:** Numerous MSMEs, irrespective of the region, reported on the lack of consistent and adequate publicly available gigabit broadband. This inconsistency in digital infrastructure has notably hindered their ability to scale digital adoption effectively. Reliable broadband is crucial for integrating and utilising advanced digital technologies, particularly AI, which requires substantial data processing capabilities and seamless connectivity. Without robust broadband infrastructure, MSMEs face barriers in accessing and leveraging AI-driven solutions, essential for enhancing productivity, innovation, and competitive advantage. According to Ofcom's 2024 report, while **80%** of the premises in UK can access gigabit broadband, significant gaps remain, particularly in rural areas (Ofcom, 2023, 2024).

4.4 AI Adoption and Productivity: Are UK MSMEs ready?

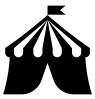
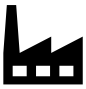
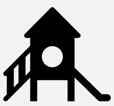
A key aspect of *The AI Catalyst* --participatory action research-- initiative was to evaluate whether research-informed and tailored 'Knowledge Exchange' sessions could effectively facilitate AI adoption among MSME firms. The process commenced by assisting firms in developing strategies to introduce AI and formulating an AI ethics policy by utilising resources from the Information Commissioners Office (ICO) (Information Commissioners Office, 2024a), the Alan Turing Institute (The Alan Turing Institute, 2024), and the OECD AI policy observatory (OECD.AI Policy Observatory, 2024).

In light of the fact that **twelve** out of the **fifteen** firms (**80%**) utilised Microsoft 365 services for their routine knowledge work, it was a logical progression to investigate the Generative AI solutions from Microsoft. This investigation was informed by the digital platforms identified through the scan tool and the discussions during the 'Knowledge Exchange' sessions. **Table 3** succinctly encapsulates the Generative AI solutions examined during the 'Knowledge Exchange' sessions and **Table 4** provides a list of Non-Generative AI solutions.

Table 3: List of Generative AI solutions explored

Generative AI solutions
Microsoft CoPilot is a Generative AI offering seamlessly integrated into Microsoft 365 applications such as Word, Excel, PowerPoint, Outlook, and Teams. It enables users to draft documents, create compelling presentations, analyse complex data, and manage communications efficiently, providing real-time assistance to enhance creativity and productivity (Microsoft, 2024d, 2024e).
Microsoft Dynamics 365 CoPilot is an AI tool embedded within Dynamics 365, designed to automate routine tasks, generate insights from data, and enhance customer interactions. It supports business functions such as sales, customer service, and supply chain management with predictive analytics and personalised recommendations (Microsoft, 2024a, 2024f).
Microsoft Power BI CoPilot, integrated into Power BI, enhances the intuitive creation of data visualisations and reports. This AI solution generates insights, suggests visualisations, and automates data analysis, thereby facilitating businesses in comprehending and leveraging their data effectively (Microsoft, 2024g, 2024h).
Microsoft Power Apps CoPilot, an AI assistant integrated within Power Apps, empowers users to build custom applications with minimal coding. It offers suggestions, automates workflows, and aids in designing app interfaces, thereby making app development more accessible and efficient (Microsoft, 2024b, 2024c).
Microsoft Pages CoPilot, integrated into Microsoft Power Pages, assists in the creation and management of web content. This AI tool aids users in generating text, designing layouts, and optimising content for search engines, thereby streamlining the process of building and maintaining websites (Microsoft, 2024i, 2024j).
SAP CoPilot, a digital assistant within SAP applications, enhances productivity by enabling voice or text interactions. It facilitates quick task completion such as creating products, sales orders, and notes in the SAP system (SAP, 2024).

Table 4: List of Non-Generative AI solutions explored

Sector	*Symbolic representation of the firm*	*Non-Generative solutions explored*
Manufacturing		Road Tagger – Uses AI to enrich digital maps (Matheson, 2020), Artificial Neural Networks for navigation systems (Jwo et al., 2023), Automated Driving (Bosch, 2024a), Model-based systems engineering for autonomous vehicle development (Siemens, 2024c), Digital Twin accuracy for sustainable mobility solutions (Siemens, 2024d), Multimodal sensor systems of unmanned surface vehicles (Hong et al., 2022).
Manufacturing		The use of AI to create whisky (Microsoft, 2019), the use of AI to make better beer (MIT Technology Review, 2024), the use of AI to buy a better bottle of wine (Smale, 2023), the use of AI and IoT to improve the quality of beer (Bandoim, 2019), Factory Automation (Siemens, 2024e).
Food and Beverage services		Sage cloud-based accounting with robotic process automation and natural language processing (Sage, 2024). Zoning of the restaurant using smart thermostats to save on energy bills.
Manufacturing		Smart textiles with sensors integrated (Embro, 2024), condition-based monitoring of manufacturing equipment, and SMART buildings with sensors (Siemens, 2024b).
Manufacturing		Use of AI to generate tea flavours (Caratti et al., 2024).
Services		Event based vision sensor (Sony, 2024), Smart textiles with sensors integrated (Embro, 2024), Infrared thermal imager (Rika Sensor, 2020),and Robots at events (ITSY Robot, 2024)
Manufacturing		Real-time anomaly detection in cold chain transportation using IoT (Gillespie et al., 2023), Smart containers (Bosch, 2024b).
Manufacturing		Object detection using multimodal sensor systems of unmanned surface vehicles (Hong et al., 2022), collision detection and avoidance for underwater vehicles using omnidirectional vision (Ochoa et al., 2022), predictive maintenance using digital twins (van Dinter et al., 2022).
Services		Drain overflow detection using AI (Siemens, 2024a), and fleet management (Samsara, 2024).
Manufacturing		Condition-based monitoring of manufacturing equipment and smart manufacturing.
Manufacturing		Playground safety innovations (Playground Guardian, 2023), the use of sensors and devices for safety surveillance and preventive maintenance (Bennett, 2024).

In addition to the above discussed solutions, each firm was introduced to the concept of graphs through illustrate examples, including those from Google, Wikipedia, Uber, and Amazon. It was observed that all **fifteen** firms had their websites developed on the WordPress platform and were found to be underutilising the potential of the web technologies. This conclusion was derived from the analytics provided by tools such as the Website Grader (Hubspot, 2024) and SEMrush analytics (Semrush, 2024).

Table 4 elucidates two pivotal insights. Firstly, of the **fifteen** firms that participated in *The AI Catalyst* initiative, only **eleven** (**73%**) were able to leverage **Non-Generative AI (NGAI)**. Conversely, **Generative AI** demonstrated the potential to enhance productivity in routine knowledge work and tasks across most industries. However, the extent of usage of Generative AI and its potential for productivity varied by sector. For instance, Generative AI could substantially enhance productivity in the legal services sector, which involves extensive research and document creation. Similarly, marketing firms could utilise Generative AI to improve productivity in content creation, including documents, presentations, imagery, and videos. Likewise, accounting firms might find Generative AI more beneficial for expediting data analysis processes. In contrast, in the food and beverage industry, Generative AI could assist directors or managers in analysing operational data and managing email communications, though it may not be broadly useful for all employees compared to other sectors. Therefore understanding the tasks in each business process is crucial to understand where AI can be integrated (Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2023; Brynjolfsson et al., 2018)

Similarly, Non-Generative AI (NGAI) exhibited varying degrees of usage across sectors. For example, in the food and beverage industry, the use of sensors to manage heating could not only reduce emissions but also save on operational costs. In the manufacturing sector, NGAI presented various opportunities for innovation. For instance, in the drinks manufacturing industry, NGAI could be used to craft new recipes, streamline production processes, and facilitate predictive maintenance of the equipment. Likewise, in the vehicle manufacturing industry, NGAI can be used to analyse data from sensors integrated to monitor the performance of various components. Firms also chose to invest in creating digital twins for remote monitoring and maintenance of vehicles. Furthermore, NGAI offered firms the opportunity to innovate and develop new business models (Velu, 2024) such as condition-based maintenance or usage-based models. However, to fully leverage NGAI and maximise innovation, an ecosystem encompassing research institutions, public, and private entities is essential. NGAI also requires significant resources in terms of data, compute, human capital and time; therefore, drawing upon an ecosystem eases the process of commercialising the innovation.

Regardless of whether MSMEs are exploring Generative AI or Non-Generative AI, a granular, microscopic level of understanding of business processes at the Standard Industry Classification (SIC) code level is necessary to design productivity-focused research initiatives to maximise the potential of AI. Research has established that Generative AI has the potential to diffuse faster and impact labour productivity across a wide range of estimates: **10-56%** (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson & Hitt, 2003; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024). In contrast, NGAI involves time to develop the machine learning models and could take potentially longer to diffuse and for firms to realise the benefits, but it does have the potential to impact total factor productivity in the range of **0-11%** (Brynjolfsson & Hitt, 2003; Brynjolfsson et al., 2021; Filippucci et al., 2024).

4.5 *The AI Catalyst* outcomes

Among the firms that participated in *The AI Catalyst*, **two** firms were already engaged in the development of AI-driven products. However, other firms initiated the implementation of Generative AI solutions from Microsoft, inspired by the advantages highlighted during the 'Knowledge Exchange' sessions. To encapsulate the Generative AI and Non-Generative AI solutions these firms intended to trial, adopt, and explore in the future, the following interview questions (IQ) were posed during the concluding session:

IQ8: What initiatives or tools of AI do you plan to introduce in the firm in the next 3 months?
IQ9: What initiatives or tools of AI do you plan to introduce in the firm by the end of 2024?
IQ10: From the AI ideas presented in sessions (which outlined a roadmap of possible AI solutions for your firm), do you envisage exploring the implementation of those ideas in 2025 and beyond, and which might those be?

Table 5 summarises the responses to the above questions captured before 31st August 2024.

Table 5: Generative and Non-Generative AI solutions in trial, adoption, and exploration

Generative AI solutions	Non-Generative AI solutions under exploration, trial, adoption, or development
Microsoft CoPilot (Microsoft, 2024d) Microsoft Dynamics Business central (Microsoft, 2024f), and ChatGPT- OpenAI (Open AI, 2024a)	Multimodal sensor systems of unmanned surface vehicles (Hong et al., 2022). Sage Cloud based Accounting with Robotic Process Automation and Natural Language processing (Sage, 2024). Zoning of the restaurant using smart thermostats to save on energy bills. Event based vision sensor (Sony, 2024). Collision detection and avoidance for underwater vehicles using omnidirectional vision (Ochoa et al., 2022). Predictive maintenance using digital twins (van Dinter et al., 2022). Drain overflow detection using AI (Siemens, 2024a). Condition-based monitoring of manufacturing equipment and smart manufacturing. Playground safety innovations (Playground Guardian, 2023). The use of sensors and devices for safety surveillance and preventive maintenance (Bennett, 2024).

Research Impact

Twelve of the **fifteen** firms (**80%**) that participated in *The AI Catalyst* initiative chose to adopt Microsoft CoPilot (Microsoft, 2024d), the Generative AI solution from Microsoft, which complemented their existing investment in Microsoft 365 productivity platform (Microsoft, 2024e). Additionally, **three** firms initiated trials on the Microsoft Dynamics platform (Microsoft, 2024f) for their ERP and CRM requirements, and **one** firm upgraded their accounting package to leverage cloud, robotic process automation, and natural language processing capabilities from Sage (Sage, 2024). Few firms also invested in upgrading their broadband infrastructure to Gigabit broadband.

Collectively, these initiatives resulted in an estimated investment of more than **£100,000** to support more than **360** users, representing over **one-third** of the workforce employed by the **twelve** firms. The investment was computed based on user and cost data provided by the firms. It includes the annual subscription cost incurred by the firm for Generative AI solutions (Microsoft CoPilot), the Sage accounting package upgrade by one firm, the cost incurred in business process software (Microsoft Dynamics Business Central) subscription and the broadband upgrades.

Most importantly, these efforts increased the weighted score of technology diffusion across these firms by **0.25**, thereby increasing the overall weighted average of the cohort from **2.0** to **2.25**. **Table 6** presents the technology diffusion scores before and after *The AI Catalyst* initiative, while **Table 7** highlights the changes across the firms.

Although the duration of **five months** was insufficient to directly measure the impact on productivity- defined in economic terms as the ratio of output to input -- *The AI Catalyst* –initiative, however, influenced the input side of the productivity equation through capital investment. If Generative AI solutions are deeply integrated and widely adopted, they have the potential to increase labour productivity by at least **10%**, according to established research (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson & Hitt, 2003; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024).

Table 6: Technology diffusion scores before and after *The AI Catalyst* initiative

Firm	*Technology diffusion score before AI Catalyst*	*Technology diffusion score after AI Catalyst*
Firm 01	6.15	6.4
Firm 02	1	1
Firm 03	1	1.45
Firm 04	2	2.25
Firm 05	1.5	1.5
Firm 06	1.5	1.75
Firm 07	0.75	1
Firm 08	1.75	1.75
Firm 09	1.4	1.65
Firm 10	1.25	1.5
Firm 11	5.15	5.4
Firm 12	1.75	1.75
Firm 13	0.75	1
Firm 14	0.75	1
Firm 15	4.15	4.4

Table 7: Technology diffusion scores after *The AI Catalyst* initiative

Firm/Digital Technologies	*Web Technologies*	*Mobile Internet Technologies*	*Cloud based services*	*Big data architecture*	*Internet of Things*	*Design Thinking (CAD/CAM)*	*Robotics*	*Augmented Reality*	*Additive Manufacturing (e.g. 3-D printing)*	*AI Tools and Applications*	*Neural networks, Machine Learning*	*Total*
Firm 01	0.25	0.5	0.75	0.4	0.5	1	0	0	1	1	1	**6.4**
Firm 02	0.25	0.5	0.25	0	0	0	0	0	0	0	0	**1**
Firm 03	0.25	0.5	0.25	0	0	0	0.2	0	0	0.25	0	**1.45**
Firm 04	1	0.5	0.25	0	0.25	0	0	0	0	0.25	0	**2.25**
Firm 05	0.5	0.75	0.25	0	0	0	0	0	0	0	0	**1.5**
Firm 06	0.75	0.5	0.25	0	0	0	0	0	0	0.25	0	**1.75**
Firm 07	0.25	0.25	0.25	0	0	0	0	0	0	0.25	0	**1**
Firm 08	0.25	0.25	0.25	0	0	1	0	0	0	0	0	**1.75**
Firm 09	0.25	0.25	0.25	0.4	0.25	0	0	0	0	0.25	0	**1.65**
Firm 10	0.5	0.5	0.25	0	0	0	0	0	0	0.25	0	**1.5**
Firm 11	0.25	0.25	1	0.4	0.75	1	0	0	0	0.75	1	**5.4**
Firm 12	0.25	1	0.25	0	0	0	0	0	0	0.25	0	**1.75**
Firm 13	0.25	0.25	0.25	0	0	0	0	0	0	0.25	0	**1**
Firm 14	0.25	0.25	0.25	0	0	0	0	0	0	0.25	0	**1**
Firm 15	0.25	0.25	0.25	0.4	0	1	0	1	1	0.25	0	**4.4**

Note: The scores in the highlighted cell under robotics represents the software robotic process automation implemented through the cloud accounting package adopted by the firm. The scores in the highlighted vertical columns in AI Tools and applications represent the Generative AI solutions adopted by the firms. The score in the highlighted last column indicates the changes in score due to the increased adoption of technology, co-relating with the summary presented in **Table 6**. **Table 2** represents the baseline.

4.5.1 *The AI Catalyst* – Programme effectiveness assessment

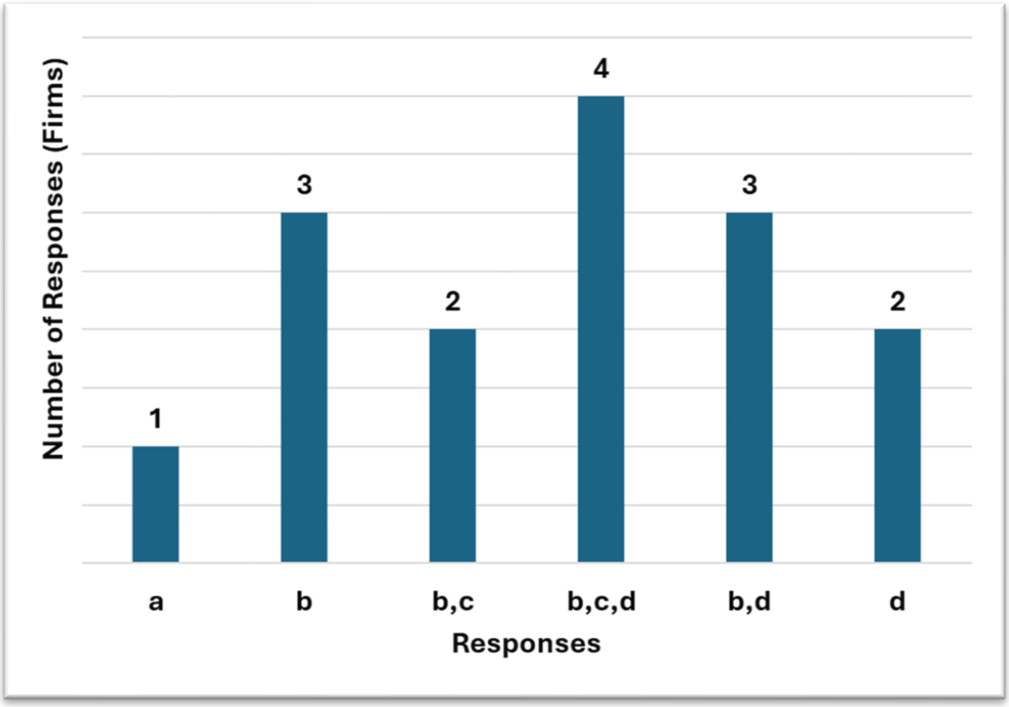
To evaluate the effectiveness of *The AI Catalyst* programme, participants were asked the following interview question (IQ):

IQ11: In your opinion, what would have happened to the benefits (understanding/ideas/confidence) regarding AI had you not participated in the programme?

a. Would not have occurred at all.
b. Would have occurred, but at a slower rate.
c. Would have occurred, but at a lower scale.
d. Would have occurred, but not of the same quality.
e. All the benefits would have occurred.

Exhibit 14 provides a visual representation of the responses from the firms.

Exhibit 14: Firms responses to the benefits of participating in *The AI Catalyst*



Note: The horizontal axis refers to the **a, b, c, d, e** choices presented in the interview question (IQ 11) above.

The responses indicate that most firms perceived the benefits of AI would have occurred at a slower rate, lower scale, or with reduced quality without the programme. This underscores the role the programme played in enhancing the speed, scale, and quality of AI awareness and its application within businesses.

"The initiative dedicated considerable effort to comprehending our business operations and identifying opportunities for AI integration to enhance productivity. This has facilitated our initial steps towards digital transformation"

Additional questions revealed unanimous agreement among participants on the programme's effectiveness in developing an understanding of AI concepts and their adoption to improve productivity, with all respondents **(100%)** affirming this. Furthermore, all participants **(100%)** rated the programme's schedule as effective and expressed willingness to participate in subsequent phases of *The AI Catalyst*.

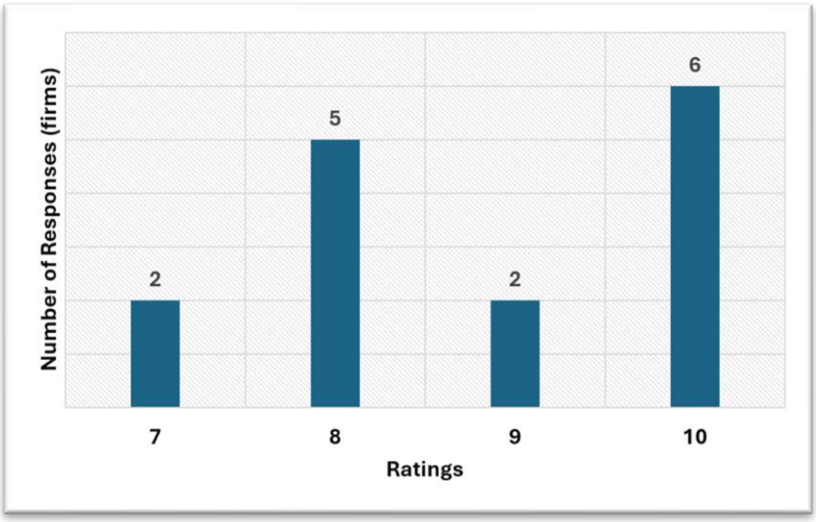
> *"Our business objective for 2024-2025 is to increase the adoption of AI tools into business processes in each department and scale it companywide. The program provided a structured approach to considering change, evaluating the company's various assets and capabilities, and identifying projects for AI integration."*

Participants were posed with further interview questions (IQ) to evaluate the programme's effectiveness and likelihood of recommendation.

IQ12: On a scale of 1-10, where 1 represents low expectations and 10 represents exceeded expectations, please rate the effectiveness of the programme.
IQ13: On a scale of 1-10, with 10 being the highest, please rate how likely are you to recommend the programme.

Exhibit 15 provides a summary of the responses to **IQ12**.

Exhibit 15: Participant ratings on *The AI Catalyst* programme effectiveness



Note: Rating **1** indicates low expectations and rating **10** indicates exceeded expectations.

The average rating for IQ12 was '**8.8',** reflecting a high level of satisfaction. Specifically, **six** firms rated '**10**' and five firms rated the programme a '**8**'. This distribution underscores the programme's effectiveness and the likelihood of its recommendation among participants. Notably, **fourteen** out of the **fifteen** firms that participated in *The AI Catalyst* rated the likelihood of recommending the programme (IQ13) as '**10**', while one firm rated '**7**'. This high level of recommendation highlights the programme's perceived value and effectiveness among participants. The responses to IQ12 and IQ13 indicate a strong positive reception of the programme.

4.5.2 The AI Catalyst - participant asks from the government

Lastly, participants were asked the following question: *What initiatives would you like to see from the Government to support the adoption of digital technologies including AI?*

The interview responses from various MSMEs highlighted several key initiatives that the government should consider for the adoption of digital technologies, including AI. These initiatives are categorised into five main areas: access to expertise and training, targeted and personalised support, industry collaboration and governance, regulatory framework and ethical considerations, and financial support and subsidies.

- **Access to expertise and training:** Participants highlighted the critical need for access to specialised expertise and comprehensive training programs. They called for government-funded initiatives to provide AI expertise and mentors who could guide businesses through the adoption process. Additionally, there was a strong demand for training initiatives to raise awareness and build AI literacy among business leaders and employees to facilitate a smoother transition to digital transformation. The importance of bringing case-studies to life and organising productivity roundtables was also emphasised to demonstrate the practical benefits of AI.
- **Targeted and personalised support:** The necessity for targeted and personalised support was a recurring theme. Participants argued that a one-size-fits-all approach would be ineffective in addressing the unique challenges faced by different businesses. They advocated for tailored assistance, including sector-specific case studies and personalised consulting services to help businesses navigate the complexities of AI adoption. They argued that the focused support would ensure that the advice and resources provided are relevant and impactful.
- **Industry collaboration and governance:** Participants underscored the importance of grants and industry collaboration for the common good. They highlighted the necessity of establishing a role akin to a 'chief data officer,' dedicated to diagnosing, baselining, and assisting businesses in adopting AI. This role was deemed essential to ensure a coordinated and strategic approach to digital transformation. Furthermore, participants emphasised the need to address societal concerns particularly the fear of AI-induced job displacement. They advocated for comprehensive support for small businesses, including access to expertise and deployment assistance to facilitate a smooth transition to AI technologies.
- **Regulatory frameworks and ethical considerations:** Participants highlighted the need for guidance to facilitate the adoption of Generative AI tools, while also reflecting on the challenges encountered in adhering to GDPR guidelines (Information Commissioners Office, 2024a), when introduced. They underscored the imperative for a robust framework to navigate the societal transformations induced by AI. Drawing parallels to the industrial revolution, participants proposed the establishment of a dedicated government ministry to oversee AI developments, tasked with addressing ethical dimensions, privacy, and security concerns. Furthermore, they advocated for the exploration of policies such as universal basic income to mitigate the disruptive impacts of AI. The formation of a steering committee to formulate laws and regulations governing AI was also

recommended. Crucially, participants emphasised the necessity of a legal framework and guidance for companies developing AI; supported by government teams with sufficient AI literacy to effectively regulate and hold companies accountable.

- **Financial support and subsidies:** Participants identified cost as a barrier to scaling AI services across the entire workforce, noting that subscribing to AI services integrated with productivity tools could cost up to **£500 per user per year**. This financial outflow was seen as a potential impediment to widespread AI adoption. Additionally, participants highlighted the importance of funding to access expertise, given the high costs associated with consulting services. They emphasised that making AI expertise and software affordable for small businesses was crucial to help MSMEs realise the value AI could deliver.

5 Observation and conclusions

A synthesis of the research findings

Extensive research has established that digital technologies and Artificial Intelligence (AI), often regarded the next ‘general purpose technology’, holds significant potential to enhance productivity (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024; Pilat et al., 2003; Van Ark, 2015, 2016; Van Ark et al., 2003a, 2003b, 2003c; Van Ark et al., 2013). At a firm level, productivity is a measure of the efficiency with which an organisation transforms its resources and capabilities into products or services (The Productivity Institute, 2024b).

Despite a decade characterised by rapid technological advancements, including the rise of Artificial Intelligence (AI), a global pandemic, and subsequent economic challenges (Albonico et al., 2020; Bartik et al., 2020; Mizen et al., 2022), micro-, small-, and medium- enterprises (MSMEs) involved in *The AI Catalyst* exhibited notable resilience and adaptability, and continued to contribute to the UK economy (**Exhibit 8**).

Participants in *The AI Catalyst* were motivated by the prospects of using AI to improve the productivity, while also pursuing innovation to attain a competitive advantage (Porter, 1985). Effective resource utilisation, continuous improvement processes, maintaining high standards of quality, strategic leadership, cost management, process optimisation, innovation, and the use of KPIs emerged as key drivers of productivity.

Manufacturing firms monitored productivity using output-based metrics, time savings, and turnover. In contrast, non-manufacturing firms utilised a range of key KPIs that concentrated on overall business performance rather than individual productivity.

Manufacturing firms employed manual processes to measure productivity, often utilising paper-based data collection and tools such as Microsoft Excel, which underscored the need for automation. Similarly, non-manufacturing firms used a combination of manual and digital methods, further highlighting the need for automation.

Although firms strived to continuously enhance productivity, they faced several obstacles. These included limited access to financing, difficulties in obtaining STEM talent, and operational challenges that impeded a strategic orientation. Furthermore, firms encountered issues in optimising resource and capabilities and there was a noticeable slow progress in digitalisation of business processes.

Each firm employed a minimum of **three** digital applications (**Annex 3, 5, 6,** and **7**), however, the overall diffusion of digital technologies remained limited (**Table 2**). Additionally, the data on investment in intangible assets was sparse (**Exhibit 12**). MSMEs faced several challenges to accelerate digitalisation and digital transformation which included the burden of researching digital technologies (Pilat & Criscuolo, 2018) and the lack of in-house digital capabilities, which led to lower levels of digitalisation and delays in technology adoption, with most firms adopting digital platforms during or after the pandemic. Furthermore, there was a noticeable lack of aggregated data analytics. Limited access to publicly available broadband (Ofcom, 2023, 2024) and a shortage of talent with digital skills further limited the acceleration of digital transformation.

Most organizations, with the notable exception of **two** firms, had not yet commenced the integration of AI into their business processes (**Table 2**). Nonetheless, these organizations had exposure to AI through applications such as ChatGPT (Open AI, 2024a).

According to the Unified Theory of Acceptance and Use of Technology (**UTAUT**) (Venkatesh et al., 2003), firms and individuals are more inclined to adopt technology if they perceive it enhances efficiency and productivity, find it user-friendly to use, and receive positive social reinforcement and supportive conditions. The **NEBIC** model (Wheeler, 2002) further demonstrates how firms leverage net-enabled interconnected technologies for business innovation (Ramadan et al., 2023; Velu, 2024; Wheeler, 2002). Two firms in the cohort exemplify the correlation between net-enabled interconnected technologies for innovation and their corresponding impact on productivity (**Table2**). Both the firms portrayed a 'Gross-Value Added per employee' in excess of **£250,000** and a sustained growth in the ratio of intangible assets to tangible assets over the decade.

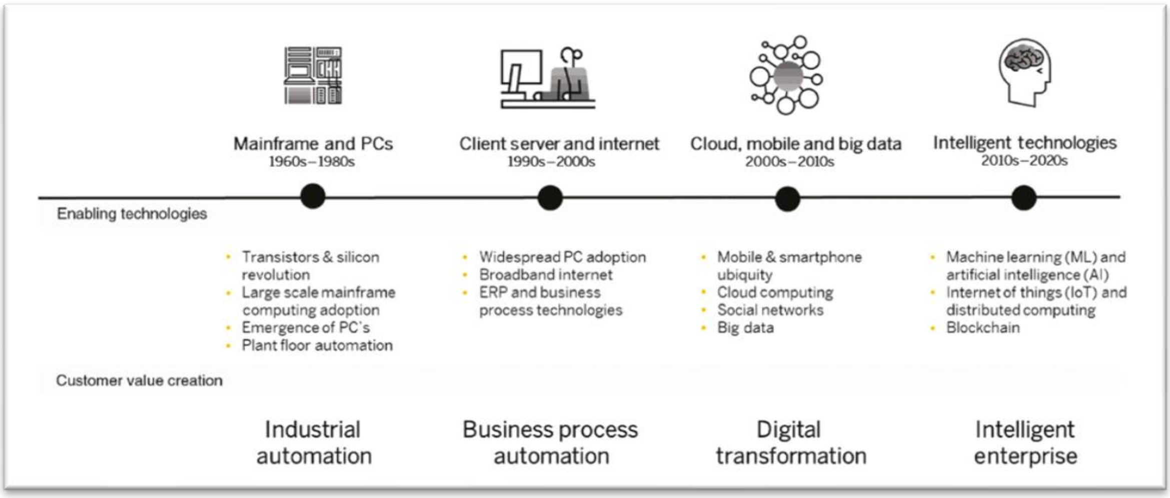
The introduction of AI into a firm is often a sociotechnical process (Butler et al., 2023), which involves understanding the technology, firm, people, occupations, and tasks as components of a unified system (Kraus et al., 2022; Sawyer & Tyworth, 2006; Vial, 2019, 2021). The confidence of the cohort in adopting AI (**Exhibit 11**), the supportive conditions provided during 'Knowledge Exchange' sessions, and the firms simultaneously drawing support from their Alma mater during the initiative through industrial PhD's, 'Knowledge Transfer Partnerships', summer interns, business executive education programs, alumni network, and business network, all contributed to easing adoption barriers. This underscores the necessity of an ecosystem to facilitate the transition to AI. Consequently, **twelve** out of **fifteen** firms took the first steps to adopting Generative AI for knowledge work.

Conclusions

Digital technologies, particularly Artificial Intelligence (AI), considered a 'General Purpose Technology' , not only aids in improving labour and total-factor productivity (Acemoglu, 2024; Acemoglu & Restrepo, 2018; Brynjolfsson & Hitt, 2003; Brynjolfsson et al., 2023; Cambon et al., 2023; Filippucci et al., 2024; Jaffe et al., 2024; Pilat et al., 2003; Van Ark, 2015, 2016; Van Ark et al., 2003a, 2003b, 2003c; Van Ark et al., 2013), but also serve as an invention technology (Brynjolfsson & McAfee, 2011, 2014; Cockburn et al., 2018). Both Generative AI and Non-Generative AI (NGAI) demonstrate applications across a broad spectrum of industries, as delineated in **Table 3** and **Table 4**. However, the identification of specific opportunities for adoption is contingent upon a thorough understanding of the underlying business processes, the tasks inherent to various occupations, and the operational dynamics within these environments. The extent of adoption for both Generative AI and NGAI is therefore intricately tied to the recognition and leveraging of these opportunities.

Most critically, AI can be harnessed to augment human capabilities through novel task management strategies. By deconstructing complex tasks into smaller manageable subtasks, these processes can be further streamlined and optimised through automation (Brynjolfsson et al., 2023; Brynjolfsson et al., 2018; McKinsey, 2023a; Teevan, 2016). This necessitates the codification--digitalisation-- of tasks within a business process. Within an enterprise, this often occurs through the process of business process automation which lays the foundation for digital transformation and ultimately for an evolution towards an intelligent enterprise (Gopal et al., 2019), as depicted in **Exhibit 16.**

Exhibit 16: The evolution of digital technologies (Gopal et al., 2019)**.**



In a comprehensive study involving 18,156 tasks, Brynjolfsson et al. (2018) identified that machine learning (ML) impacted different occupations compared to previous waves of technology automation. The findings indicated that most occupations included at least some tasks suitable for ML integration, although few occupations were completely automatable using ML. To fully leverage the potential of ML, a redesign of the task was necessary in some occupations. Consequently, individuals performing these tasks had to develop new skills and capabilities to effectively interact with and benefit from AI. A firm involved in *The AI Catalyst* had undertaken the process of redesigning the business process to augment and automate certain tasks. This case-vignette is presented in **Annex 7**.

The digitalisation and automation of tasks often culminate in the accumulation of big data, which serves as a cornerstone for innovation (Brynjolfsson & McAfee, 2011, 2014). To fully leverage the potential of big data and transition into an intelligence era, it is imperative, as Brynjolfsson and Hitt (2000) and McAfee and Brynjolfsson (2012) suggest, that organisations foster leadership that espouses a data-driven culture and informed decision-making (Prahalad, 1993). As data becomes increasingly accessible, the requisite tools and skills to interpret and utilise this data become paramount. This underscores the necessity for organisations to either develop internal capabilities or recruit talent proficient in extracting actionable insights from big data. Furthermore, substantial investment in technology to manage the volume, velocity, and variety of big data is essential (McAfee & Brynjolfsson, 2012). Ultimately, the transition to an intelligence era represents a significant shift towards prioritising intangible assets and laying the foundation for creating new business models (Kraus et al., 2022; Velu, 2024; Vial, 2019, 2021).

Analysis presented in **Table2 and Exhibit 13** reveals that two firms in the process of transitioning into the Intelligence Era exhibited a higher ratio of intangible to tangible assets –**9:1**. Additionally, these firms demonstrate enhanced productivity, as evidenced by a 'Gross Value Added per employee' exceeding **£250,000**; an outcome of their strategic orientation and a workforce possessing advanced STEM skills. Consequently, it can be inferred that organisations enjoying unique resources, skills and capabilities, and those that effectively harness the potential of technology, data, and insights, are more likely to achieve a competitive advantage (Porter, 1985; Prahalad, 1993) and generate greater value for stakeholders. These conclusions resonate with the tenets of the Resource-Based view (Barney, 1991), Dynamic Capabilities (Eisenhardt & Martin, 2000; Teece, 1986; Teece et al., 1997), Stakeholder Theory (Freeman, 2010; Freeman et al., 2018) and the Knowledge-based View (Eisenhardt et al., 2000; Grant, 1997; Maijanen, 2020).

The Team

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Adam Hardy is the Head of Research and Insight at Be The Business. As a seasoned economist, he has spent several years in government evaluating policies aimed at boosting MSME entrepreneurship and growth. At Be The Business, he oversees evaluation and research, focussing on understanding the factors that drive impact for MSMEs.

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Supplementary appendices

Annex 1: Development of the *Weighted Scoring Model* to assess the diffusion of technologies

Technology	*Weighted Score*	*Explanation*
Web Technologies	**0.25** - Company Website **0.25** – Business to Business (B2B) Portal **0.25** - Ecommerce **0.25** - AI-NLP (Artificial Intelligence - Natural language processing) Chatbot Integration **0** - None of the above	The weighted scoring model evaluates the integration of key web technologies within a firm. It assigns equal weights of **0.25** to company website, B2B portal, E-commerce, and AI-NLP chatbot integration. This balanced approach ensures a comprehensive assessment of the firm's web capabilities. Pathak et al. (2023) emphasise the importance of a robust company website for online presence and customer engagement. Sila and Dobni (2012) highlight the role of B2B portals in enhancing business transactions. Bawack et al. (2022) review the significant impact of AI in e-commerce on operational efficiency and customer satisfaction and Sidlauskiene et al. (2023) explore the pivotal role of AI-NLP chatbots in improving customer interactions. These references were selected to underpin the choices made in the model.
Mobile Internet Technologies	**0.25** - Use of mobile devices for work. **0.25** -Use of mobile apps for business processes. **0.25** - Use of mobile to access company data and resources. **0.25** - Use of mobile to collect data for business processes **0** - None of the above	The weighted scoring model evaluates the integration of key mobile technologies within a firm. It assigns equal weights of **0.25** to the use of mobile devices for work, mobile apps for business processes, mobile access to company data and resources, and mobile data collection for business processes. This balanced approach ensures a comprehensive assessment of the firm's mobile capabilities. Heitmayer (2020) emphasizes the productivity benefits of mobile devices in the workplace. Ngai and Gunasekaran (2007) highlight the efficiency gains from mobile access to company data. Chang et al. (2014) explore the optimisation of business processes through mobile data collection. Stephens (2020) addresses the complexities of mobile use at work, while Tarasewich (2003) provides insights into designing mobile commerce applications. These references underpin the choices made.

Technology	*Weighted Score*	*Explanation*
Cloud based services	**0.25** - SaaS (Software as a Service) **0.25** - Compute as a service **0.25** - IaaS (Infrastructure as a Service) **0.25** - PaaS (Platform as a Service) **0** - None of the above	The weighted scoring model evaluates the integration of cloud-based services within a firm. It assigns equal weights to SaaS, IaaS, PaaS, and Compute as a Service. This balanced approach ensures a comprehensive assessment of the firm's cloud capabilities. Ibrahim et al. (2023) emphasises the importance of SaaS for providing on-demand access to cloud-hosted application software, which enhances operational efficiency. Jha and Chaturvedi (2024) highlight the role of Compute as a Service in offering scalable computing resources, enabling businesses to handle varying workloads effectively. Wulf et al. (2021) review the significant impact of IaaS in providing virtualised computing resources, offering flexibility and control over IT infrastructure. Additionally, Venters and Whitley (2012) explore the pivotal role of PaaS in simplifying the development, running, and management of applications by removing the complexity of infrastructure management. These references were selected to underpin the choices made in the model.
Big data architecture	**0.6**- If the firm has organised its structured and unstructured data into data lakes to leverage AI. **0.4** - If the firm is in the process of organising its data. **0** - If the firm has not started the process of organising the data.	The weighted scoring model evaluates the integration of big data within a firm. It assigns weights based on the organisation of structured and unstructured data into data lakes to leverage AI. A weight of **0.6** is assigned if the firm has organised its data into data lakes, **0.4** if the firm is in the process of organising its data, and 0 if the firm has not started the process. This approach ensures an assessment of the firm's data management capabilities. Li et al. (2019) emphasise the importance of data lakes in supporting AI applications by providing a centralised repository for both structured and unstructured data. Barlette and Baillette (2022) highlight the challenges and methodologies involved in the process of organising big data, which is crucial for future AI capabilities. Thayyib et al. (2023) review the economic implications of delayed big data adoption, underscoring the missed opportunities for firms that have not started organising their data. These references were selected to underpin the choices made in the model.

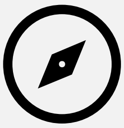
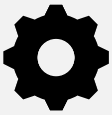
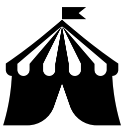
Technology	*Weighted Score*	*Explanation*
Internet of Things (IoT)	**0.25** - If the firm uses sensors or Radio Frequency Identification (RFID) scanners in its operations **0.25** - If the firm collects data from sensors and manages the device. **0.25** - If the firm uses AI on the data collected from the sensors to improve the operational efficiency of the firm. **0.25** - If the firm has built a service model using the data collected from the sensors 0 - None of the above	The weighted scoring model evaluates a firm's IoT integration. It assigns **0.25** for using sensors or RFID scanners, **0.25** for data collection and management, **0.25** for AI application on sensor data, and **0.25** for developing a service model from the data. This approach ensures a comprehensive assessment of IoT capabilities. Landaluce et al. (2020) highlight the importance of RFID and wireless sensor networks in data collection. Costa et al. (2021) emphasise RFID sensors critical role in IoT. Diène et al. (2020) discuss essential data management techniques for IoT. Javaid et al. (2022) demonstrate how AI applied on IoT data enhances operational efficiency. Rymaszewska et al. (2017) illustrate the economic benefits of IoT based service models and Aagaard et al. (2019) provide insights into leveraging IoT for business model innovation and digital transformation. These references support the model's criteria.
Design Thinking (CAD/CAM)	**1** - Evidence of use of computer aided designing (CAD) and computer aided manufacturing (CAM) software. **0** - No evidence of use of computer aided designing (CAD) and computer aided manufacturing (CAM) software.	The weighted scoring model evaluates the use of CAD/CAM software within a firm. It assigns a score of **1** for evidence and **0** for no evidence. This approach ensures an assessment of the company's adoption of advanced design and manufacturing technologies. Shivegowda et al. (2022) provide an overview of CAD/CAM processes, highlighting their integration in design and manufacturing. Ikubanni et al. (2022) discuss the present and future impacts of CAD/CAM across various sectors, emphasising its role in enhancing efficiency and innovation. Musta'amal et al. (2009) gather empirical evidence linking CAD to creativity, demonstrating how CAD tools can foster creative behaviours in design. These references support the model's criteria.

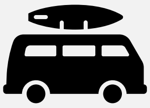
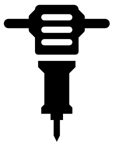
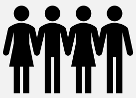
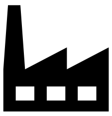
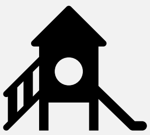
Technology	Weighted Score	Explanation
Robotics	**0.8** - Use of Hardware robotics. **0.2** - Use of software robotics – Robotic Process Automation (RPA) in processes. **0** - No use of robotics either hardware or software	The weighted scoring model evaluates the use of robotics within a firm. It assigns a score of **0.8** for the use of hardware robotics, **0.2** for the use of software robotics in processes, and **0** for no use of robotics. This approach helps assess the investment in hardware robotics by the firm. Raj and Seamans (2019) provide an introduction to the economic and organisational consequences of robotics, highlighting their impact on firm strategy and organisational design. Arduengo and Sentis (2021) discuss the concept of the 'robot economy', outlining the economic challenges and opportunities presented by increased automation and autonomy in robotics. Weidemann et al. (2023) present a comprehensive analysis of collaborative robotics in the industrial working world, focusing on their impact on human work, safety, and health in the context of Industry 4.0. Additionally, Willcocks et al. (2017) explore the economic and business implications of RPA emphasising its role in transforming business processes and enhancing efficiency. These references support the model's criteria.
Augmented Reality (AR)	**1** - Evidence of use of Augmented reality devices and software. **0** - No evidence of use of Augmented reality devices and software	The weighted scoring model evaluates the use of Augmented Reality (AR) within a firm. It assigns a score of **1** for evidence of use of AR devices and software, and **0** for no evidence. Azuma et al. (2001) provide a foundational overview of AR, discussing its applications and potential impacts on various industries. Porter and Heppelmann (2017) explore how AR is transforming business operations, highlighting its role in enhancing productivity and innovation. Peddie (2023) examines the economic implications of AR, emphasising its potential to drive significant value across different sectors. These references support the model's criteria.

Technology	*Weighted Score*	*Explanation*
Additive Manufacturing (e.g. 3-D printing)	**1** - Evidence of use of 3D printer. **0** - No evidence of use of 3D printer.	The weighted scoring model evaluates the use of additive manufacturing (3D printing) within a company, assigning a score of **1** for evidence of use of 3D printers and **0** for no evidence. This approach ensures a clear assessment of the company's adoption of advanced manufacturing technologies. Gibson et al. (2015) provides a comprehensive overview of additive manufacturing technologies, discussing their applications, and benefits across various industries. Berman (2012) explores the economic implications of 3D printing, highlighting its potential to revolutionise manufacturing processes and reduce costs. Rayna and Striukova (2016) examine the impact of 3D printing on business models, emphasising its role in fostering innovation and customisation. These references support the model's criteria.
AI Tools and Applications	**0.25** - AI through Software as a Service (SaaS) **0.25** - AI through Compute as a service **0.25** - AI through Infrastructure as a Service (IaaS) **0.25** - AI through Platform as a Service (PaaS) **0** - None of the above	The weighted scoring model evaluates the deployment of AI within a firm. It assigns **0.25** for AI through SaaS, **0.25** for AI through Compute as a Service, **0.25** for AI through IaaS, and **0.25** for AI through PaaS. A score of **0** is assigned if none of these are used. This approach ensures a comprehensive assessment of the company's AI capabilities. Lins et al. (2021) provide an in-depth analysis of AI as a Service, discussing how cloud providers offer AI capabilities through SaaS, IaaS, and PaaS models, enabling organisations to leverage AI without significant upfront investments. Davenport and Ronanki (2018) explore practical applications of AI in business, highlighting how companies are utilising cloud-based AI services to enhance their operations and drive innovation. These references support the model's criteria.

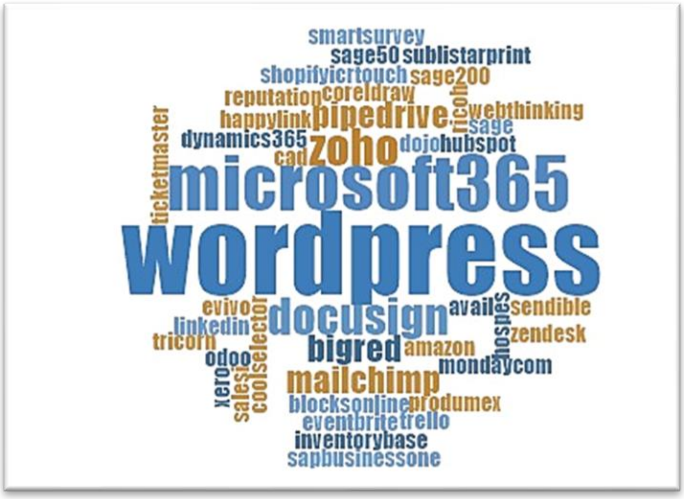
Technology	*Weighted Score*	*Explanation*
Neural networks, Machine Learning	**1** - Evidence of use of Machine Learning or Neural Graphs **0** - No evidence of use of Machine Learning or Neural Graphs	The weighted scoring model evaluates the use of machine learning (ML) and neural networks within a firm. It assigns a score of **1** for evidence of use and **0** for no evidence. This approach ensures an assessment of the company's adoption of advanced AI technologies. LeCun et al. (2015) provide a comprehensive overview of Deep Learning, discussing the principles and applications of Neural Networks in various industries. Jordan and Mitchell (2015) explore the broader field of Machine Learning, highlighting its impact on business processes and decision-making. Goodfellow (2016) delve into the technical aspects of Deep Learning, emphasising its potential to drive innovation and efficiency in organisational operations. These references support the model's criteria.

Annex 2: Descriptive characteristics of the fifteen firms

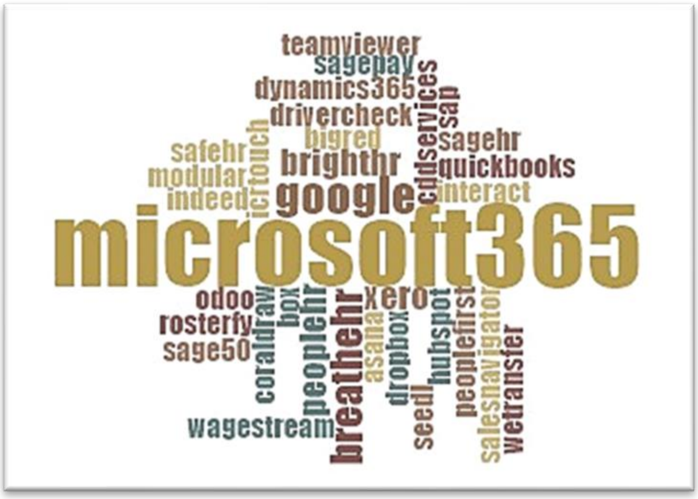
SIC Code	***Symbolic representation***	***Descriptive characteristics of the firm***
26511		The firm specialises in providing advanced positioning, navigation, and timing (PNT) solutions. The company offers a comprehensive array of services and products, encompassing Global Navigation Satellite System (GNSS) technology, inertial navigation systems, and integrated solutions tailored for diverse sectors, including maritime, defence, and surveying.
11010		The firm specialises in small batch bottling for craft sodas, mixers, ready-to-drink beverages, beers, and ciders. It offers a range of services, including beverage development, trial production, and branding. Their ‘Concept to Shelf’ package assists clients in transforming their drink ideas from initial concept to market-ready products.
56100		The firm is a popular chain of three pubs and restaurants known for its welcoming atmosphere and quality food. It offers a diverse menu that includes traditional pub dishes, vegetarian and vegan options, and a daily carvery.
14120		The firm is a leading supplier of high-visibility workwear and personal protection equipment (PPE). It offers a wide range of workwear, including embroidered and branded clothing, and is known for its reliable service and competitive pricing.
46140		The firm offers a wide range of hydraulic products and solutions, including hydraulic pumps, motors, valves, and power packs for customers in both the UK and international markets.
10831		The firm specialises in herbal teas, which are available in international markets and across 3,000 independent stores and major supermarkets in the UK.
69102		The firm offers a comprehensive range of legal services for both private clients and businesses, with expertise in corporate law, dispute resolution, employment law, family law, personal injury, and property law.
82301		The firm specialises in the design, development, and delivery of mass participation events. It focusses on creating experiences that engage, inspire, and motivate large audiences. Their services include bespoke research, campaign strategy, product innovation, project management, and event delivery

SIC Code	***Symbolic representation***	***Descriptive characteristics of the firm***
29201		The firm is a manufacturer of temperature-controlled vehicles, specialising in refrigerated van conversions. Recognised for innovative solutions and industry-leading payload capabilities, it serves various sectors including foodservice, pharmaceuticals, and home delivery. The firm offers a range of products, including van conversions and portable refrigerators.
68320		The firm specialises in residential block and estate management. It offers comprehensive management solutions for residential, commercial, and independent living developments.
30400		The firm specialises in designing and developing equipment for harsh environments. It provides a wide range of products and services across various sectors, including defence, oil and gas, renewable energy, and nuclear power.
43220		The firm is a franchisee of British Gas, providing plumbing and drainage services to both domestic and business customers.
88990		The firm is one of the UK's leading LGBTQ+ charities dedicated to promoting equality and celebrating LGBTQ+ culture. The organisation is part of a global Pride movement that challenges discrimination and supports LGBTQ+ communities through various initiatives.
25600		The firm provides high-quality, bespoke finishing solutions, including paint, print, engraving, and treatment for critical parts, boxes, panels, and labels.
32300		The firm specialises in the design, manufacture, and installation of outdoor playground equipment. It provides a wide range of products for schools, nurseries, local authorities, community groups, and leisure operators. Their equipment includes traditional climbing frames, modern sensory playground areas, and bespoke designs tailored to specific needs.

Annex 3: Digital applications used by firms in customer processes



Annex 4: Digital applications used by firms in employee processes



Annex 5: Digital applications used by firms in supply chain processes

Annex 6: Comprehensive list of digital applications used by firms

Sl No	*Digital Platform*	*Description*	*Website*
1	Altium	PCB design software	https://www.altium.com/altium-designer
2	Asana	A work management platform	https://asana.com/
3	AutoCAD	Computer-Aided Design (CAD) drawing software	https://www.autodesk.com/uk/solutions/cad-software
4	Avail	Legal due diligence software	https://www.avail.ai/#home
5	BACS	Automated payment platform	https://www.bacs.co.uk/
6	BIG RED	Business-to-Business portal	https://www.big-red-digital.com/services/big-red-platform/ecommerce
7	Blocks Online	A blocks management software	https://www.blocksonline.co.uk/
8	Box	A cloud content management platform	Box — Secure Cloud Content Management, Workflow, and Collaboration
9	Breathe HR	A HR Management Platform	https://www.breathehr.com/en-gb/
10	Bright HR	HR software to manage staff data	Award-Winning Digital HR Solutions for SMEs | BrightHR
11	CDD services	A due diligence check software	CDD Services Spotlite: digital due diligence checks
12	Cool selector	A software to manage energy consumption in HVACR systems	https://www.danfoss.com/en-gb/service-and-support/downloads/dcs/coolselector-2/#tab-overview
13	Corel Draw	A professional imaging software	https://www.coreldraw.com/en/
14	Digi star	A Label creation software	https://lombardi-na.com/digistar/
15	DocuSign	Contract management software	https://www.docusign.com/en-gb
16	Dojo	A payment software	https://dojo.tech/
17	Driver Check	Driving license and vehicle document check software	https://www.drivercheck.co.uk/
18	DropBox	A file share platform	https://www.dropbox.com/en_GB/features/share

Sl No	Digital Platform	Description	Website
19	Event Safety Plan	A software to collate, write, and manage safety paperwork	https://eventsafetyplan.com/
20	Eventbrite	A platform which hosts tickets for multiple events	Eventbrite - Discover the Best Local Events & Things to Do
21	Evivo	Room booking software	https://eviivo.com/
22	Google Workspace	Productivity software	https://workspace.google.com/intl/en_uk/features/
23	Happy Link	Software that connects embroidery machines	https://happyemb.com/happy-link-lan/
24	Hospes	Room booking software	https://www.bgsoft.mk/en/hospes-en/
25	HubSpot	CRM software	Streamline Your Entire Business with a Free CRM | HubSpot
26	ICR Touch	Pub Grub sales - EPOS (Electronic Point of Sales)	https://icrtouch.com/
27	Indeed	Provides a job posting platform for employers	Advertise a job | Indeed for Employers
28	Interact Intranet	An intranet software	Interact - Intranet Software To Connect Your Employees (interactsoftware.com)
29	Inventory Base	Property inventory management software	Property Inventory Software | Inspection App | InventoryBase
30	iZettle	A Point of Sale (POS), payment and integration software	https://www.zettle.com/gb
31	JotForm	A platform to create forms and surveys	Free Online Form Builder & Form Creator | Jotform
32	Ledger	A software used to securely manage digital assets	https://www.ledger.com/
33	Legl	A software to automate client payments	https://legl.com/
34	LinkedIn	Professional networking platform	https://uk.linkedin.com/
35	LinkedIn Sales Navigator	LinkedIn sales navigator platform	https://business.linkedin.com/sales-solutions/compare-plans
36	Mailchimp	Marketing automation and email marketing software	https://mailchimp.com/?currency=GBP
37	Microsoft 365	Productivity software	https://www.office.com/

Sl No	*Digital Platform*	*Description*	*Website*
38	Microsoft Dynamics 365	A CRM and ERP application from Microsoft	Business Applications | Microsoft Dynamics 365
39	Microsoft SharePoint	An Intranet platform from Microsoft	https://www.microsoft.com/en-gb/microsoft-365/sharepoint/collaboration
40	Modular	An ERP solution	ERP Software - Distribution ERP Solutions | Modular Software Ltd. (mod-soft.com)
41	Monday.com	A project management software	monday.com | Your go-to work platform
42	MRP Easy	A manufacturing platform	https://www.mrpeasy.com/
43	Odoo	An Open-source ERP system	https://www.odoo.com/
44	People HR	A HRM software	https://www.peoplehr.com/en-gb/
45	People First	A HRM platform for HR payroll, finance, and learning	https://mhrglobal.com/uk/en/products/peoplefirst
46	Pipedrive	CRM Software	https://www.pipedrive.com/
47	Pleo	A business expenses solution	https://www.pleo.io/en
48	Produmex	A warehouse management system	https://www.boyum-solutions.com/produmex-wms-warehouse-management-solution
49	QuickBooks	An accounting software	Smart, Simple Accounting & Bookkeeping Software | QuickBooks UK (intuit.com)
50	Reputation	A social media management platform	https://reputation.com/
51	Ricoh Printing	Printing software	https://www.ricoh.co.uk/products/software-apps/office-software/mobile-printing-and-sharing/smart-device-connector/
52	Rosterfy	Volunteer management software	https://www.rosterfy.com/
53	SafeHR	A HR management software	Alcumus SafeHR- Formerly CitrusHR (safe-hr.com)
54	Sage HR	HRM software	https://www.sage.com/en-gb/sage-business-cloud/hr/
55	Sage Pay	An integrated payment solution from Sage	Integrated Payment Solutions | Sage UK
56	Sage200	An accounting business management solution	https://www.sage.com/en-gb/products/sage-200/

Sl No	Digital Platform	Description	Website
57	Sage50	An accounting software	https://www.sage.com/en-gb/products/sage-50-accounts/
58	Sales-i	A sales dashboard software	https://www.sales-i.com/
59	SAP Business One	Enterprise Resource Planning (ERP) software for small businesses	https://www.sap.com/uk/products/erp/business-one.html
60	Seedl	An employee training platform	https://www.seedl.com/
61	Sendible	Social media management platform	Sendible: Social Media Management Tool for Agencies & Brands
62	Shopify	An online storefront software	https://www.shopify.com/uk
63	Smart Survey	Digital survey solutions	Online Survey Software and Questionnaire Tool - SmartSurvey
64	SolidWorks	3D CAD programme	https://www.solidworks.com
65	Sublistar Printing	A printing software used in garment manufacturing	https://www.subli-star.com/
66	TeamViewer	Software used for remote access and remote control	TeamViewer – The Remote Connectivity Software
67	Tensor	Attendance monitoring, access control, and HR management platform	https://www.tensor.co.uk/
68	Ticket Master	A ticket sales and distribution platform	Tickets for concerts, theatre, football, family days out. Official Ticketmaster Site
69	Trello	A project management software	Manage Your Team's Projects From Anywhere | Trello
70	Tricorn	A production control, scheduling, and quality management application	https://www.tricorn.tech
71	UPS supply chain solutions	Solution used to dispatch manufactured goods using UPS services	https://www.ups.com/us/en/supplychain/Home.page
72	Wage stream	A financial wellbeing platform	Financial wellbeing for frontline workers - Wagestream
73	Web Thinking	An E-Commerce platform	https://www.webthinking.co.uk/
74	WeTransfer	A file sharing platform	WeTransfer | Send Large Files Fast - Up To 2GB Free

Sl No	*Digital Platform*	*Description*	*Website*
75	WordPress	A web content management system	https://wordpress.com/
76	Works Drawing	Works drawing software	https://www.solidworks.com/product/solidworks-3d-cad
77	Xero	An accounting software	https://www.xero.com/uk/
78	Z2Data	A Supply Chain and CRM solution	https://www.z2data.com/
79	Zendesk	A Helpdesk management solution	Zendesk: The complete customer service solution
80	Zoho	A CRM software	https://www.zoho.com/one/

Annex 7: Case-Vignette (Source – Liverpool Chamber of Commerce Magazine)

MEMBER NEWS

DYNO MACHMADE LEADS THE WAY IN AI INNOVATIONS WITH THE PRODUCTIVITY INSTITUTE

At DYNO Machmade, we're committed to leveraging cutting-edge technology to enhance efficiency, both internally and externally. Our collaboration with The Productivity Institute at Alliance Manchester Business School has enabled us to integrate AI innovations that are revolutionising the way we operate and serve our clients.

One of our key breakthroughs is the development of a CCTV AI solution. In partnership with businesses in the Liverpool City Region, we've tested an AI-driven system that significantly speeds up the reporting and mapping of drainage issues. This advanced solution automates the analysis of CCTV footage, quickly identifying problems and reducing manual processing time. As a result, businesses can resolve issues faster, minimising downtime and improving operational efficiency.

We've also improved our internal processes by automating Planned Preventive Maintenance (PPM) for drainage and plumbing surveys. From the engineer in the field to the account manager and ultimately to the client, our system ensures smooth communication and fast delivery of detailed reports. This automation enhances service accuracy and streamlines project management, reducing errors and improving client satisfaction.

DYNO Machmade has fully integrated these innovations with the Microsoft suite, utilising AI tools like Microsoft CoPilot to analyse management information (MI) data. With CoPilot, we can extract valuable insights into efficiency, profitability, and resource allocation in real-time, ensuring our operations are always optimised for success.

Even our latest recruitment advertising campaign is AI-generated, showcasing our commitment to utilising advanced technologies at every level of the business, including talent acquisition.

As part of our ongoing commitment to Liverpool Chamber customers, we're excited to offer a free PPM survey. This is an excellent opportunity for businesses to stay prepared rather than reactive, improving efficiency while enhancing their Environmental, Social, and Governance (ESG) credentials.

DYNO Machmade's partnership with The Productivity Institute and our integration of AI technologies are reshaping the plumbing and drainage industry.

Reach out today to schedule your free PPM survey and experience the benefits of AI-powered maintenance solutions first-hand – info@machmade.co.uk

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