

Adoption, implementation, alignment – maximising the performance benefits of digital investment

Summary of TPI Firms Research Programme 2023-2026

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Abstract

This report synthesises five research projects supported by The Productivity Institute (2023–2026) examining how digitalisation influences firms’ productivity, business model innovation, climate strategies, and investment decision-making. Drawing on UK-wide surveys, international firm-level datasets, and in-depth qualitative studies, the evidence shows that while digital adoption is widespread, it rarely delivers productivity gains on its own. Performance improvements depend critically on complementary investments in skills, organisational redesign, and, above all, strategic alignment. Across diverse contexts, the research highlights recurring “tipping point” dynamics, where excessive or misaligned digitalisation can reduce productivity. Digitalisation also supports more integrated climate mitigation and adaptation strategies, acting as an enabler rather than a determinant of outcomes. The report concludes that policy should move beyond promoting adoption towards supporting alignment, coherence, and effective use of digital technologies.

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Executive Summary

This report synthesises five major research projects supported by The Productivity Institute (TPI), examining how digital adoption, business model innovation, climate strategy, investment decision-making, and organisational alignment influence the productivity and sustainability performance of firms. Using diverse methods—including UK-wide surveys, large international datasets, and in-depth qualitative research—the evidence delivers a clear message: digitalisation offers substantial performance benefits, but only when complemented by additional investments, organisational coherence, and strategic alignment. Adoption alone is rarely sufficient. Across all studies, three themes recur:

1. Adoption is necessary but not sufficient - firms frequently adopt technologies without realising productivity gains because complementary assets - skills, organisational redesign, interoperable systems - are underdeveloped.

2. The biggest gains come from alignment - alignment is required at multiple levels, **within firms** (business models, processes, incentives, decision rights), **across organisational functions** (monitoring–analysis–planning–execution–knowledge sharing) and **across supply chains** (technology parity, data standards),

3. Policy should support both adoption and alignment – this is likely to involve support measures which can

- **Scale low-cost, high-reach adoption support for SMEs**, such as peer-learning models (e.g., Evolve Digital) and digital navigators.
- **Encourage more formal, strategic investment planning**, especially in SMEs, including support for ROI analysis and digital road mapping.
- **Expand Made Smarter across sectors**, providing coordinated digital diagnostics, skills training, and capital support.
- **Strengthen workforce development**, with a focus on digital and data literacy, cyber-safety, and STEM capability.
- **Promote interoperability and data standards**, especially in fragmented sectors such as construction.
- **Integrate digital and net-zero support programmes**, recognising the complementarities in the twin transition.
- **Support supply-chain digital diffusion**, reducing technological asymmetry and preventing productivity-eroding divergence.

Digital technologies offer significant new opportunities for productivity, innovation, and climate resilience. However, the UK’s challenge is not in adopting technologies but in aligning efforts. Achieving the “bits to benefits” pathway requires coordinated investment in skills, organisational redesign, strategic planning, and interoperable infrastructure. Policy should therefore focus not only on helping firms adopt technologies but also on enabling them to use these innovations effectively, coherently, and productively.

Digitalisation and Business Model Innovation (Section 2)

Research led by Chander Velu and colleagues (Ye et al., 2025) provides robust empirical evidence linking digital adoption with business model innovation (BMI) across value chains, value shops, and value networks.

The key empirical findings centre on coherence. In supply chains, increasing robotisation boosts partner productivity only up to a tipping point; beyond that, excessive technological asymmetry diminishes partner performance and erodes cooperation. The same tipping-point dynamic is seen in embedded finance within durable goods sectors: moderate levels improve customer

insights and sales, but excessive financialisation (beyond ~35–40% of assets) damages productivity. Productivity gains occur when technology choices, organisational processes, incentives, partner relationships, and the firm’s business model develop in harmony. Misalignment is a major cause of the UK’s “modern productivity paradox.”

Digitalisation and Firms’ Climate Strategies (Section 3)

Using European Investment Bank Investment Survey data covering 22,500 firms across the EU and US, Anastasia Ri and colleagues identify strong empirical links between digitalisation and integrated climate strategies (Kalantzis et al., 2025). Digitally advanced firms are significantly more likely to adopt dual climate strategies - combining mitigation (emissions reduction) and adaptation (climate risk resilience). Digitalisation also intensifies climate action, leading to broader adoption of mitigation and adaptation practices.

Digitalisation functions as an “affordance generator” - enabling improved sensemaking (data, monitoring, analysis) and practice - leading to coordination and operational change. It supports the UK’s twin transition by helping firms perceive and respond to climate risks and opportunities more effectively, provided organisational capabilities allow digital tools to be fully utilised.

Digital Adoption Across UK Firms (Section 4)

Silvia Massini and colleagues offer the most detailed overview so far of how advanced digital technology (ADT) is adopted in over 3,000 UK firms (Massini et al., 2025). Digital adoption is common but varies, with 80% of firms using at least one ADT. Adoption rates are highest for cloud computing (~80%), followed by AI (~50%) and Big Data (~37%).

Sector and size differences are more significant than regional ones. Large firms and those in manufacturing or utilities tend to adopt ADTs more heavily. SMEs fall behind due to costs, skills shortages, and uncertainty about benefits.

The clearest benefits relate to improved product and service quality. Impacts on costs and delivery times are inconsistent—some firms improve efficiency, while others face increased operational burdens. Adoption alone doesn’t guarantee productivity gains; complementary investments in skills and organisational change are vital.

How Firms Make Digital Investment Decisions (Section 5)

Eugenie Golubova and colleagues’ survey of UK firms (n=1,623) reveal how digital investment decisions are formed (Golubova and Roper, 2025a and 2025b).

Digital investment is integrated with broader investment portfolios. Most digital investors also invest in software, training, machinery, and IT infrastructure. However, investment planning is often informal - 42% of firms lack a formal investment plan. Informal investment processes may limit firms’ ability to align digital investment with broader strategic objectives, reducing potential productivity gains.

Digital Alignment for Net Zero (Section 6)

Jonatan Pinkse and colleagues’ interview study of 19 firms in the construction supply chain exposes significant challenges in aligning digital tools with net-zero goals (Pinske et al., 2026).

Digitalisation is strong in specific processes but weak across them. Organisational and institutional barriers outweigh technological ones, while legacy infrastructure limits automation. Sectoral fragmentation—characterised by short projects and numerous partners—also hampers alignment. Digital transformation for net zero requires coordinated organisational change, not just technology deployment.

Section 1: Aims and objectives

1.1 Introduction

Digitalisation, its challenges and potential benefits, has been the focus of several studies supported by the Productivity Institute (TPI). This report offers an overview and synthesis of these studies related to the benefits of digitalisation for business model innovation and net zero, digital adoption, and investment decisions.

The report builds on recent national assessments, including the UK Technology Adoption Review (2025)¹, recent survey evidence from the DSIT Innovation and Diffusion Survey² and recent DSIT/DCMS research into the barriers and enablers of digital adoption³. Each of these emphasises the behavioural, organisational, and technological barriers to effective digital adoption and implementation and the potential value of enhanced digitalisation for growth and productivity.

The TPI-funded research presented here extends this analysis in several directions. First, it confirms a positive relationship between digitalisation and both business model innovation and firms' climate strategies. Together, these findings indicate that the value of digitalisation goes beyond mere growth and productivity. Second, we examine the extent and nature of firms' digital investment decisions. How are these decisions made? What influences shape these choices? How do these factors interact across different types of firms to influence digital adoption across UK companies? Third, we offer new evidence that maximising the benefits of digital investments requires more than effective adoption and implementation.

Coherence or the alignment of digital decisions with other elements of investment strategy is essential for firms to progress beyond functional upgrading and maximise the potential for organisational transformation. The importance of alignment in strategic thinking is not new, being central to the McKinsey 7-S model (Peters and Waterman, 1982). However, placing digitalisation within this framework introduces new challenges with consequential implications for business support.

1.2 Report overview

The remainder of this report is organised as follows:

- Section 2 provides an overview of research conducted by Chander Velu, Myungun Kim, Yifeng (Philip) Chen, Chen Ye, and Nikolai Kazantsev at Cambridge, focusing on the links between business model innovation and digitisation across sectors and international contexts.
- Section 3 reports an analysis by Anastasia Ri, Effie Kesidou, Fotios Kalantzis and Stephen Roper of the relationship between digitisation and climate strategy. Conducted jointly with the European Investment Bank, the study focuses on data from the EU and the US.

¹ See

https://assets.publishing.service.gov.uk/media/6857e0995225e4ed0bf3ceb5/dsit_technology_adoption_review_web.pdf.

² See <https://www.gov.uk/government/publications/insights-from-the-uk-innovation-diffusion-and-adoption-survey>.

³ See <https://www.gov.uk/government/publications/barriers-and-enablers-to-advanced-technology-adoption-for-uk-businesses>.

- Section 4 is an analysis of an extensive national UK survey of digital adoption conducted by Silvia Massini, Mabel Sanchez-Barrioluengo, [Xiaoxiao Yu](#), Myungun Kim, Yifeng Chen, and Chander Velu. Section 5 is also survey-based and focuses on a large-scale survey of digital investment decision-making conducted by Eugenie Golubova and Stephen Roper.
- Section 6 returns to the themes of digitalisation and net zero and reports the key findings from an interview-based project conducted by Jonatan Pinkse, Anne-Lorène Vernay, Corine Genet, and Adélie Ranville. Interviewing firms along construction supply chains emphasises the value of digitalisation and the practical challenges of implementation and alignment.
- Section 7 summarises the key findings and outlines the implications for policy development.

Section 2: Digitalisation and Business Model Innovation

This Section draws on three studies by Dr Chander Velu, Myungun Kim and Philip Chen on the business model innovation benefits of digitalisation, undertaken at the IfM in Cambridge. The studies cover business model innovation in the UK, India and the US and emphasise the different dimensions of coherence between digitalisation and business model development.

Two key themes emerge from these studies. First, "more" adoption is not always "better." Both robot adoption in supply chains and the degree of embedded finance follow a "tipping point" dynamic: benefits initially rise, but beyond a certain threshold, they decline. Second, technology benefits depend strongly on firms' ability to establish and maintain coherence between technology adoption and business model components. In the digital era, where business models are increasingly driven by a "sense and act" logic, this becomes a core competency that managers must cultivate, and governments must support.

The findings demonstrate that deploying the latest technologies in isolation is unlikely to be sufficient for achieving transformative productivity growth. Instead, the coherence of the firm's business model - its "holistic systems level transformation" - is a prerequisite. Major productivity gains are realised only when there is multidimensional alignment between the technologies deployed, business model innovation, organisational design, and policy tools.

2.1 Why Business Model Innovation Matters in a Digital Economy

The increasing sophistication of digital technologies, such as the growth of big data, artificial intelligence (AI), and cloud computing, increasingly enables accurate analysis of customer behaviour in both business-to-customer (B2C) and business-to-business (B2B) settings. With this information, combined with the availability of flexible manufacturing equipment like robotics and 3D printing, there are more opportunities to precisely target individual customers and tailor products to their specific requirements. Consequently, conventional business models based on the mass production of standardised items are proving inadequate. The paradigm needs to shift from a rigid "make-and-sell" model to a responsive "sense-and-act" model that involves promptly sensing changes in customer preferences and adjusting production capabilities to meet fluctuating demand in a timely manner.

However, this transition to a "sense-and-act" model does not occur uniformly across all sectors. The organisation of production resources - whether internal or external - differs fundamentally depending on how a firm creates and captures value - its business model. Business models define the organisation's customer value proposition, its approach to value creation, the means of value capture, and the partners within the value network. Modes of value proposition, value capture, and value creation, as well as the structure of the value network, are based on an existing business - so business model innovation redefines what an existing product or service is, and how it is delivered to the customer, by seeking to identify unique configurations of business model attributes.

Broadly speaking, business model innovation (BMI) can be divided into three distinct archetypes: value chain, value shop, and value network. The value chain typifies firms with linear production processes that convert inputs into outputs; the value shop represents firms with processes tailored to specific customer requirements, such as healthcare or legal services; and the value network concerns the connections and exchanges between different customer groups and service providers. These three categories embody different logics of value creation and capture, and importantly, they leverage digital technologies in unique ways. Instead of applying a "one-

size-fits-all" approach to digitalisation, we must understand how emerging technologies specifically interact with each of these business model types to promote genuine productivity growth. The shift from a "make-and-sell" model to a "sense-and-act" approach will manifest differently across these business model archetypes, with implications for productivity.

Regardless of the specific archetype, a key challenge remains: the systemic nature of business models means that components are interconnected. When engaging in BMI, different aspects of the business model need to work in synchronisation (sync) with each other to achieve meaningful productivity gains. The introduction of new digital technologies often changes certain components of the business model without impacting others, thereby causing system-wide incoherence. The essential question for firms striving for higher productivity is how to restore and maintain coherence amid a rapidly evolving technological landscape.

2.2 The Core Framework: Solving the Productivity Paradox via Coherence

Despite significant investments in digital transformation in recent years, aggregate productivity growth remains sluggish – an observation often known as the "productivity paradox". A likely cause for this phenomenon is that the capabilities of emerging digital technologies remain underutilised. Our research suggests that the gap between what is technically feasible and what is actually achieved stems not from the technology's deficiency alone, but from "business model incoherence." In an era of constant disruption, digital adoption is often piecemeal, led by isolated business functions responding to immediate pressures. This results in misalignment between a firm's evolving business model - how it creates value - and its existing operating model - how it executes. When these two are out of sync, the business model becomes less effective, and the expected productivity gains may not materialise.

Based on our extensive qualitative study with senior leaders across multinational firms in manufacturing, logistics, and healthcare, we have identified the "blockers" that inhibit performance. We define these as the five primary sources of business model incoherence that must be aligned for digital transformation to succeed:

- First is the physical flow, ensuring raw materials and finished products are delivered at the right time and place.
- Second is the information flow, confirming that the right data reaches the right individuals or systems for efficient decision-making.
- Third are decision rights, clarifying whether the authority to make decisions is given to the right individuals or AI systems.
- Fourth is the incentives system, aligning stakeholders for timely and cohesive action.
- Finally, partner engagement ensures that the partner firms' processes and objectives are aligned with the focal firm.

To help executives and policymakers navigate this complexity, we propose the Business Model Coherence Scorecard (BMCS) as a diagnostic framework to map these misalignments and prioritise remedial actions.

Crucially, applying this framework requires recognising that value creation is not uniform across the economy. While coherence drives performance, the specific components that need to be aligned differ fundamentally depending on the business model archetype: value chain, value shop or value network. The value chain involves long-linked production technologies, where the main value creation lies in sequential processes that gradually refine inputs, such as raw materials and parts, into the final output that consumers want. Distinct from this is the value shop, which involves information acquisition and solving specific problems; here, the main value creation mechanism is responding to the specific requirements of the customer. This requires

mobilising resources and activities in a cyclical fashion rather than sequentially, as seen in medicine, professional services, and engineering firms. The value network, on the other hand, relies on mediating technology to connect clients and establish interdependence among those distributed by space and time. The value creation logic lies in facilitating direct or indirect exchanges between customers, with prime examples being banks and insurance companies.

The adoption of new digital technologies impacts the value generation logic of these three types in different ways, and consequently, requires different approaches to maintain coherence. Value chain innovation is primarily driven by changes in production capabilities, such as new processes; since these processes often span multiple firms, this heavily influences relationships with partner firms. Value shop innovation is affected through changes in how information is collected, analysed, and leveraged to target specific customer needs. Meanwhile, value network innovation is influenced by changes in how customers interact within the network. By categorising the BMI induced by emerging technologies in this way, we establish a robust framework to understand the various channels that contribute to productivity growth. In the following chapters, we examine specific examples of technology-driven BMI in each category - Robotisation in Value Chains, Financialisation in Value Shops, and Platformisation and Open Networks in Value Networks - to demonstrate how specific forms of incoherence arise and how restoring alignment unlocks productivity.

2.3 Value Chain Innovation - Robotisation & Digitalisation

In the area of value chain BMI, the promise of automation is often viewed through the lens of a single firm. However, production is rarely an isolated act; it relies on a complex web of buyer-supplier relationships. Therefore, to truly understand productivity growth, we must look beyond the "smart factory" to the "smart supply chain." The central challenge here is coherence between partner firms. If a lead firm races ahead with advanced robotics while its suppliers lag behind, this disparity creates a form of inter-firm incoherence, and the misalignment risks undermining the very productivity gains the technology was meant to deliver. The critical question for policymakers and managers is not just whether to adopt robots, but how technological asymmetry affects the delicate ecosystem of cooperation and competition in the supply chain.

When buyers and sellers interact in supply chains, one firm adopting robots can affect the relationship. On the one hand, improved capability by the adopting firm positively spills over to the partner firm, enhancing the latter's productivity. On the other hand, the adopting firm's bargaining position strengthens relative to the partner, allowing it to extract a greater proportion of the value from the cooperation. This creates a tension: does the technology help the partners grow together, or does it allow the stronger player to squeeze out the weaker one, which ultimately affects the supply chain negatively? Digital technologies further complicate this by enabling efficient coordination but potentially accelerating the power imbalance.

We obtain robotics and digitalisation patent data from the USPTO database, examining a sample of 2,104 firms forming a total of 4,653 pairs of buyer-supplier dyadic relationships (Qi et al., 2026). Our findings reveal a distinct "tipping point" dynamic regarding the relative adoption of robots (the gap between the focal and partner firm) and the partner firm's productivity. At low levels of disparity - where partners are relatively close in capability - the "value creation" effect dominates; the robotic adoption helps the whole chain. However, as the gap widens beyond a tipping point, the "value appropriation" effect takes over, and the partner's productivity suffers. This suggests that the basis of coordination and cooperation erodes if the technological divergence becomes excessive. Furthermore, digitalisation acts as an amplifier, making this

curve steeper: it increases the rewards of synchronisation between firms but also intensifies the penalties of appropriation by one firm over another.

The implications for managers are the need to be aware of the firm's own as well as the partner's level of automation, a need to "keep up" and avoid excessive divergence. Digitisation can be a tool that strengthens the adopting firm's range of options. or those of policymakers. This underscores that funding individual "national champions" is insufficient. Effective policy must align with the Industrial Strategy's goal of strengthening domestic supply chains by supporting the diffusion of technology to Small and Medium-sized Enterprises (SMEs) (The UK's Modern Industrial Strategy, 2025). Without support to bridge the capability gap, the power asymmetry may stifle the productivity of the smaller firms that form the backbone of the economy.

2.3.1 Value Shop Innovation - Financialisation

As manufacturers strive to escape the commoditisation of the "make-and-sell" model, they increasingly adopt "Value Shop" characteristics, offering embedded services and financial products to capture customers. However, this has the potential to generate "incoherence" in the business model system, as activities separate from the core business function now have to be managed to avoid conflicts. Where possible, the offering of financial products should be complementary to the firm's core activities, with the core and ancillary services supporting each other towards the same strategic goal. However, in practice, this creates an inevitable tension. The provision of financial products may grow to such an extent that it begins to "crowd out" core business activities or become a large proportion of the business yet the firm lacks the necessary competencies or advantages to manage financial products competitively.

This tension is particularly visible in durable goods sectors, such as automobile manufacturing, where firms increasingly offer embedded financial services coupled with product sales. On the one hand, this presents an opportunity to acquire customer information, better tailor products and encourage more sales of core products – which are typical value creation mechanisms of the value shop type BMI. On the other hand, it risks becoming a distraction that imposes additional managerial costs and strategic conflict. There is therefore a critical need to distinguish financial activities designed to support core activities, that constitute a service for customers, and those that are purely a financial investment – which can exacerbate the conflict without bringing much benefit. The former reinforces the business model; the latter dilutes it (Bock et al. 2026).

To quantify the impact of this diversification, we analysed embedded financial assets as a proportion of total assets across major automobile manufacturers globally. Our empirical analysis reveals that productivity and the degree of embedded finance exhibit a clear "tipping point" dynamic. The advantages of embedded finance initially dominate, driving sales and customer loyalty. However, these gains are eventually outweighed by escalating management costs and conflicting objectives, leading to a negative relationship with productivity as financialisation becomes excessive. The optimal zone - or tipping point - appears to be around 35-40% financialisation. Beyond this threshold, the complexity cost exceeds the value creation benefit.

The implications for managers and policymakers are distinct. Managers must seek to balance the degree of financialisation, avoiding the temptation to pursue unrelated services that promise quick returns but erode core competitiveness. For policymakers, this analysis provides a nuance to the Industrial Strategy (The UK's Modern Industrial Strategy, 2025). Policy should actively encourage embedded financial services that promote firms' core manufacturing competencies - such as financing schemes to accelerate the rollout of new electric vehicles (EVs) - whilst discouraging pure financial services that act as a drag on productivity. By promoting "industrial

finance" over "speculative finance," policy can align business model innovation with broader national goals like carbon emission reduction.

2.3.2 Value Shop Innovation – Servitisation

Closely related to the provision of embedded financial services is the broader trend of servitisation, where manufacturers shift from selling products to selling outcomes. While this transition offers a route to capture higher value, it presents a distinct risk of business model incoherence known as the "servitisation paradox." As firms move away from the standardised efficiency of the "value chain" to the customised problem-solving of the "value shop," they must increasingly tailor solutions to specific customer segments. This requires establishing new organisational forms, such as cross-functional teams, which can conflict with existing mass-production structures. If the services offered do not align tightly with the firm's overall strategy, they risk crowding out core activities and imposing managerial burdens that exceed the firm's cognitive capacity. The critical question, therefore, is not whether to offer services, but *which* services are consistent with the firm's overall strategy and contribute to productivity (Kim et al., 2026a).

For many new durable products, the heavy capital sunk costs and unproven functionalities of novel technologies present significant barriers to initial adoption. In such instances, firms can encourage a model of service where they assume the cost and responsibility of maintenance and upgrades for a regular fee, thereby reducing the risk for the client. However, it is unclear whether this arrangement universally contributes to higher productivity for the provider. On the one hand, servitisation can smooth out cashflow and accelerate technology adoption. On the other hand, it generates conflict with existing value-creation mechanisms if not managed correctly. Similar to the findings for financialisation, there is a crucial need to separate "industrial services" that support the core product from "non-industrial services" that are unrelated.

To test the impact of this distinction, we utilised the Office of National Statistics (ONS) Annual Business Survey (ABS), accessed through the Secure Research Service (SRS). By categorising manufacturing firms' data into industrial and non-industrial services, our results demonstrate that diversification into unrelated non-industrial services does *not* reinforce the synergistic effects of servitisation. Instead, productivity gains tend to arise from the *depth* of integration with aligned services, rather than the *breadth* of unrelated offerings. This supports the claim that simply adding a "service arm" without strategic coherence is a recipe for stagnation; the value comes from services that make the core product more effective.

The implications for managers are that they should prioritise industrial services, or services designed to support core production activities. Likewise, policymakers should seek to strengthen the complementarity between manufacturing and services. Their deep integration, rather than the range of services being offered by manufacturing firms, should be the chief concern of policymakers.

2.3.3 Value Network Innovation - Platformisation

In the value network archetype, digital platforms act as the central nervous system, connecting participants and facilitating exchange. With advancements in connectivity infrastructure, these platforms promise increasing returns to scale and scope, exhibiting strong network effects where the value of data grows with the user base. However, a critical strategic danger lies in the assumption that all platforms yield equal benefits for all firms. The use of platform technologies must be rigorously aligned with the firm's specific strategy and characteristics. Without this alignment, firms risk business model incoherence - investing in digital infrastructures that clash with their operational realities. We specifically examine "industrial platforms" that improve manufacturing efficiency, distinguishing them from consumer-based models, to understand how heterogeneity in firm size and strategy dictates the success of adoption (Kim et al., 2026b).

To navigate this landscape, we categorise platforms into two distinct strategic architectures based on their locus of integration: Operations-Centred Platforms (OCPs) and Distribution-Centred Platforms (DCPs). OCPs focus on internal integration: they connect disparate assets, such as machines and production systems, to optimise operational flows and develop internal capabilities. DCPs focus on integration with the marketplace: they function as multi-sided infrastructures that facilitate external exchange, connecting the firm to customers and suppliers. The choice of platform architecture must align with the firm's overall strategy - specifically, whether it seeks to be internally driven (enhancing operational capability via machine integration) or externally driven (expanding market access).

To empirically test the impact of these choices, we analysed data from a YouGov survey of over 3,500 businesses. Using robust statistical modelling, we examined the link between platform adoption and productivity uplifts, specifically looking at how they interact with advanced technologies such as AI, Big Data, and IoT. Our findings reveal a dichotomy based on firm size. OCPs amplify the productivity gains of large firms, especially when combined with AI and Big Data, creating a powerful compounding effect. In contrast, DCPs drive productivity primarily for small firms by opening new market channels and providing steady, incremental gains. Crucially, our data suggests that "more is not always better." Importantly, adopting both types of platforms simultaneously creates conflicting strategic logics. This leads to business model incoherence, where the complexity of managing opposing platform strategies ultimately undermines productivity.

The implications for managers are that strategic focus is paramount. Managers must be cognizant of their firm's size and resources when choosing a platform path; large firms should leverage OCPs for deep tech integration, while SMEs should leverage DCPs for market reach. Attempting to do both risks a "productivity penalty." For policymakers, the focus should shift from generic digitisation to supporting interoperability. Encouraging greater interoperability between platforms and supporting platform diagnostics allows firms to plug into the right networks without being locked into unsuitable architectures. This approach aligns with the Industrial Strategy's plan to leverage data usage and overcome barriers to data access, ensuring that the digital "value network" remains open and productive for firms of all sizes.

2.3.4 Value Network Innovation - ONDC (India)

The idea of the early internet was the democratisation of commerce making it easier for individuals and small businesses to participate in global markets without the gatekeeping of traditional institutions. However, the emergence of platform business models has been prevalent with increasing returns to information, resulting in concentration of power and focus on profitable markets. This results in uneven access to the benefits of digital commerce to society as experienced by India with a small fraction of approximately 7% of retail e-commerce going through electronic channels. Hence, there was an opportunity to rethink the business model of digital commerce enabled by India's digital public infrastructure, such as the digital identity cards, Aadhaar and the Unified Payment Interface (UPI). Open Network for Digital Commerce (ONDC) is a new business model sponsored by the Indian government based on open protocols to make digital commerce more inclusive and accessible to larger parts of society to stimulate productivity and economic growth.

ONDC is built on an interoperable open protocol to facilitate decentralised digital commerce by matching buyers and sellers directly. Such decentralised digital commerce enables unbundling and interoperability of components to facilitate transactions between market participants. Unlike a platform such as Amazon or Flipkart, there are no intermediaries between the buyers and sellers. The central problem this study addresses is the comparative effectiveness of open network architectures, versus conventional digital platform models in enhancing participation, innovation and economic value across the digital commerce ecosystem. We conducted 21

interviews with network participants across the food, transportation, electronics, and fashion sectors and with ONDC managers, and performed empirical analysis of the Open Network for Digital Commerce (ONDC).

The key strengths of the ONDC business model are that it enables firms and customers to plug into the network relatively easily which allows access to instant supplier and customer base without needing to negotiate independently. In particular, firms do not have to have the full capability to deliver the value proposition as they are able to mix and match the resources and capabilities provided by other stakeholders. Moreover, ONDC provides browsing and transaction information to the suppliers and customers which normally resides with the platforms.

We show that there are trade-offs between open networks and platform business models to achieve transaction and innovation efficiency to foster productivity and economic growth. In particular, the open protocol model of ONDC has trade-offs compared to the platform model across, scale and scope, assurance, information and innovation. Managers of open networks need to understand these trade-offs as they scale the business into new sectors. First, platforms are able to optimise by aggregating demand and supply and hence achieve scale and scope economies whilst ONDC optimise based on idle capacity. Second, complex and high value products need assurance of delivery and return which platforms can provide due to their market power with suppliers. ONDC need to have insurance or provide some form of assurance (e.g., by holding the payment in an escrow account until fulfilment of the transaction to the satisfaction of both buyer and seller respectively) and also need to build trust among the stakeholders to able to do so.

Third, platforms are able to aggregate information and hence design more personalised offerings. ONDC decentralises information ownership to supplies/customers but is able to provide anonymised aggregate information which needs leveraging further to help improve services. Fourth, platforms can orchestrate the partners to share information and innovate whilst ONDC need to enable open connectivity among its market participants to foster innovation. From a policy perspective, the objective is to make complex products less integrated and modular which might require reconfiguring the activity chain by adopting new technologies. Such policies will enable ONDC to build up capabilities, skills and knowledge of network participants to improve productivity and foster the economic development initiative. The lessons from the ONDC initiative would be applicable to future open network-based business models.

2.4 Conclusion

In conclusion, we argue that recent advancements in digital technologies present new opportunities that require the emergence of fundamentally new business models. These models can be classified according to value chain, value shop, and value network archetypes, each built on distinct logic and value creation mechanisms. When technologies evolve rapidly, their adoption often leads to conflict between different parts of the business model as they are implemented in a piecemeal fashion, leading to incoherence. Consequently, the extent to which the productive potential of new technologies is realised depends entirely on the ability of firms and policymakers to identify this incoherence and implement solutions to rectify it.

A common theme observed across our studies is that the link between technology use and productivity is rarely straightforward. For example, both robot adoption in supply chains and the degree of embedded finance follow a "tipping point" dynamic: benefits initially rise, but beyond a certain threshold, they decline. This confirms that "more" is not always "better." Meanwhile, for services and platforms, the impact varies significantly depending on firm size. This highlights that coordination within a firm, between firms in a supply chain, and across the wider ecosystem is often the constraining factor to the level of productivity attained. For complex products especially, effective coordination is critical. When the introduction of new technologies leads to

incoherence, restoring fit requires the bundle of technology, its application, and the organisational structure to be simultaneously aligned. From this perspective, the ability to establish and maintain coherence between business model components must be regarded as a critical adaptive strategic skill. In the digital era, where business models are increasingly driven by a "sense and act" logic, this becomes a core competency that managers must cultivate and governments must support.

Our findings demonstrate that deploying the latest technologies in isolation is unlikely to be sufficient for achieving transformative productivity growth. Instead, the coherence of the firm's business model - its "holistic systems level transformation" - is a prerequisite. Moreover, this coherence needs to occur on multiple levels: scaling from the level of individual firms, to partner firms and supply chains, across wider regional clusters, and ultimately to the national level. The alignment of technology and business models directly assists in the attainment of the Industrial Strategy goals for the eight critical industrial sectors identified (IS - 8). These goals are best attained through improved supply chain coordination, enhanced service capability, platform and data interoperability, and the diagnostics of financial services and business model coherence. To summarise, major productivity gains are only realised when there is multi-dimensional alignment between the technologies deployed, business model innovation, organisational design, and policy tools. Therefore, the implementation of the Industrial Strategy should focus on the attainment of coherence as a central pillar across the nation's industrial sectors.

Section 3: Digitalisation and firms' climate strategies

This chapter draws on a recent TPI empirical study (Kalantzis et al., 2025), which investigates how firm-level digitalisation relates to the adoption and extent of climate mitigation and adaptation. The project team included: Dr Anastasia Ri (Warwick), Professor Stephen Roper (Warwick), Professor Effie Kesidou (Bath) and Dr Fotios Kalantzis (EIB).

The study utilised data from the European Investment Bank Investment Survey (EIBIS). The EIBIS dataset includes around 22,500 firms across EU Member States and the United States, providing detailed measures of both digital technology use and climate-related actions.

The central finding is that digitalisation is strongly associated with more integrated and more intensive climate responses. Firms with higher levels of digitalisation are significantly more likely to pursue dual strategies that combine mitigation and adaptation, and they implement both types of actions more intensively.

Importantly, digitalisation alone does not guarantee improved climate performance. Instead, digital technologies provide enabling conditions – ‘affordances’- that help firms better identify climate-related risks and opportunities and act on them more effectively when digital investment is aligned with broader organisational priorities.

3.1 Introduction

Digitalisation and the green transition are increasingly recognised as interconnected structural transformations with potential implications for firm growth and productivity. A growing body of research highlights complementarities between digital technologies, business model innovation, and firms' environmental performance (George et al., 2021; Stern & Valero, 2021). Digital technologies can improve information flows, enable more efficient use of resources, support innovation, and enhance firms' ability to respond to both regulatory and physical climate risks. From a policy perspective, these complementarities suggest that digitalisation can support climate objectives while also strengthening firms' capacity to respond to environmental challenges.

This chapter distinguishes explicitly between climate mitigation and climate adaptation, two related but distinct dimensions of firms' climate responses:

- **Climate mitigation** refers to actions aimed at reducing greenhouse gas emissions or limiting environmental impacts, thereby helping prevent further climate change.
- **Climate adaptation**, by contrast, involves adjustments in business practices, assets, or processes to reduce vulnerability to the physical impacts of climate change or to take advantage of emerging opportunities (Klein et al., 2005; Fankhauser et al., 1999).

While mitigation typically generates broader social benefits, adaptation often yields more immediate and private returns to firms. Both are increasingly necessary for firms operating in a changing climate (Bleda & Pinkse, 2023).

Existing research points to potential synergies between mitigation and adaptation but also highlights organisational and strategic barriers that can limit their joint adoption (Tol, 2005; Daddi et al., 2020). Digitalisation has been identified as a potentially important enabler of such integration, by supporting organisational learning, coordination, and information processing (Autio et al., 2018; George & Schillebeeckx, 2022).

3.2 Digitalisation, climate strategy and organisational capabilities

Firms' responses to climate change involve strategic choices concerning two distinct but interrelated dimensions: climate mitigation and climate adaptation. While these responses have often been examined separately, there is growing recognition that firms increasingly need to consider both simultaneously in order to respond effectively to climate-related risks and uncertainties (Klein et al., 2005; Tol, 2005; Bleda et al., 2023).

The ability of firms to adopt integrated climate strategies depends in part on their organisational capabilities. Research in economics and management highlights substantial heterogeneity in firms' capacity to recognise external challenges, process information, and translate strategic intent into action (Dosi et al., 2001; Linnenluecke et al., 2013). These differences reflect accumulated routines and managerial practices rather than access to technologies alone. Digitalisation should therefore be understood not simply as the adoption of digital tools, but as a process that reshapes organisational activities, decision-making, and information flows (Nambisan et al., 2017; Ciulli & Kolk, 2023).

Digital technologies are particularly relevant in the context of climate change, which is characterised by uncertainty, long time horizons, and complex interactions between regulatory, physical, and market forces. Firms must interpret diverse and often imperfect information while coordinating responses across multiple organisational domains. Prior research suggests that digitalisation can support these processes by enhancing organisational learning, coordination, and experimentation (George et al., 2021; Pinkse, Demirel & Marino, 2024).

To capture these mechanisms, this chapter draws on the notion of digital affordances, defined as the action possibilities that digital technologies create when combined with firms' capabilities, objectives, and organisational contexts (Gibson, 1986; Markus & Silver, 2008; Autio et al., 2018). Digital affordances do not determine outcomes mechanically; rather, they shape what firms can perceive and do, depending on how digital technologies are embedded within organisational structures (Seidel et al., 2013; Faik et al., 2020).

Two types of digital affordances are particularly relevant for firms' climate responses. First, digital technologies can support sensemaking by improving the collection, monitoring, and analysis of information on emissions, energy use, supply chains, and exposure to physical climate risks. This can increase firms' awareness of both mitigation-related impacts and adaptation-related vulnerabilities, making it more likely that climate issues are incorporated into strategic deliberations rather than treated as isolated or compliance-driven concerns (Weick, 1995; Hahn et al., 2014; Bleda & Pinkse, 2023).

Second, digital technologies can support action and implementation by enabling more effective coordination across functions, locations, and activities. For mitigation, this may involve improved management of energy use, waste, and emissions; for adaptation, it may involve enhanced monitoring of physical risks and greater flexibility in operational planning (Fankhauser et al., 1999; Leal Filho et al., 2022). These affordances are likely to be strongest when digital technologies are implemented broadly and deeply within the firm, rather than in isolated applications.

Overall, this conceptual framing suggests that firms with more advanced and more deeply embedded digitalisation are better positioned to pursue integrated climate strategies that combine mitigation and adaptation. The empirical analysis that follows examines how differences in the extent and depth of digitalisation are associated with firms' climate strategy choices and the intensity of their mitigation and adaptation actions.

3.3. Data and methodology

The analysis draws on firm-level data from the European Investment Bank Investment Survey (EIBIS), using the 2022 and 2023 survey waves. EIBIS is an annual, harmonised survey covering investment activity, financing conditions, digitalisation, and climate-related actions among firms in the European Union and the United States. The survey is designed to be representative at the country level and covers firms across four broad sectors - manufacturing, services, construction, and infrastructure - and across firm size classes, from micro firms to large enterprises.

Firms are sampled from the Bureau van Dijk ORBIS database using a stratified sampling approach. Previous assessments of EIBIS data quality show that the survey provides good coverage of the business population and is well suited for analysing firm behaviour related to structural transformations such as digitalisation and the green transition. The final dataset consists of approximately 22,500 firms, pooling the 2022 and 2023 waves.

The survey includes detailed questions on firms' responses to climate change, allowing a clear distinction between climate adaptation and climate mitigation actions:

- **Climate mitigation** measures capture actions aimed at reducing greenhouse gas emissions and environmental impacts, including investments in energy efficiency, cleaner technologies, renewable energy generation, waste minimisation and recycling, and more sustainable transport solutions.
- **Climate adaptation** measures capture whether firms have taken steps to build resilience to physical climate risks, including the introduction of adaptation strategies, investments to reduce exposure to physical risks, and the use of insurance instruments to manage climate-related losses.

Based on these responses, two outcome variables are constructed. First, a climate strategy indicator classifies firms into four mutually exclusive groups: no climate response, adaptation only, mitigation only, and a dual strategy combining both mitigation and adaptation. Second, the intensity of climate action is measured as the share of available mitigation or adaptation measures implemented by each firm.

Digitalisation is measured using information on firms' adoption of advanced digital technologies, defined as state-of-the-art for each sector, such as artificial intelligence and big data analytics, the Internet of Things, robotics, platforms, drones, or virtual reality.

The measure captures not only whether firms have adopted these technologies, but also how deeply they are embedded within the organisation. For each technology, firms report whether it is not adopted, adopted in parts of the business, or implemented across the entire organisation. The resulting indicator reflects both the breadth and depth of digitalisation.

The empirical analysis proceeds in two steps. First, it examines the relationship between digitalisation and firms' choice of climate strategy. Second, it analyses how digitalisation relates to the intensity of mitigation and adaptation actions among firms that engage with climate action.

All models control for firm size, sector, country, and survey year, as well as firms' exposure to climate risks, perceptions of regulatory change, energy costs, innovation activity, and management practices. Robustness is assessed using alternative specifications, sub-sample analyses, and an instrumental variable approach exploiting regional variation in digital infrastructure growth.

As the data are cross-sectional, the results should be interpreted as robust associations rather than causal effects. Nevertheless, the consistency of findings across models and contexts provides confidence in the patterns documented.

3.4. Key findings: digitalisation and firms' climate strategies

This section summarises the main empirical findings on the relationship between digitalisation and firms' climate responses. The analysis distinguishes between firms' choice of climate strategy - mitigation, adaptation, both, or no response - and the intensity with which mitigation and adaptation actions are implemented.

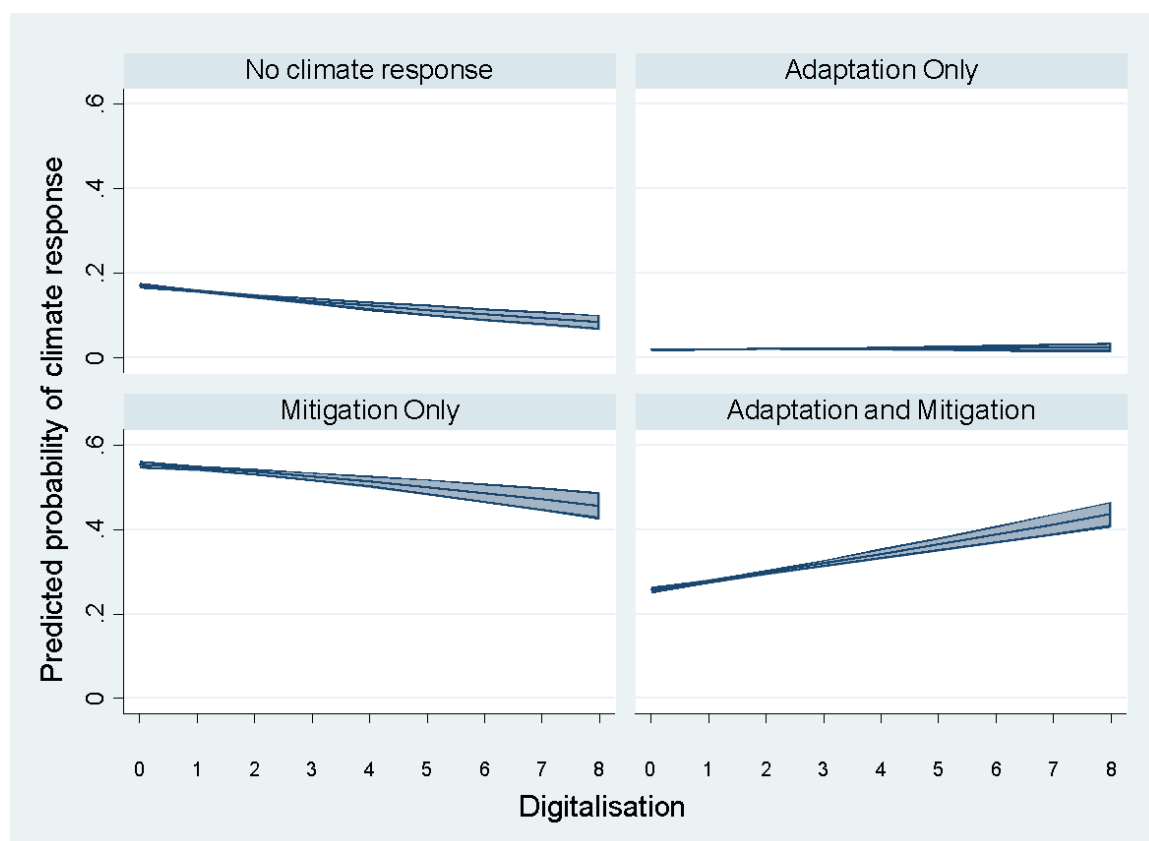
Digitalisation and the choice of climate strategy

Higher levels of digitalisation are strongly associated with firms adopting more comprehensive climate strategies. More digitally advanced firms are significantly more likely to pursue a dual strategy combining mitigation and adaptation, rather than focusing on a single dimension or taking no climate-related action.

As firms' digitalisation increases, the probability of having no climate response declines markedly (Figure 3.1). At the same time, the likelihood of adopting a mitigation-only or adaptation-only strategy does not increase proportionately. Instead, digitalisation is most strongly associated with the adoption of integrated strategies that address both emissions reduction and exposure to physical climate risks.

This pattern suggests that digitalisation is linked not simply to a greater propensity to act on climate issues, but to the way firms structure their response. More digitalised firms appear better able to recognise the relevance of both mitigation and adaptation and to combine them within a single strategic approach.

Figure 3.1: Predicted probabilities of climate change strategy alternatives



These relationships remain robust after accounting for firm size, sector, country, and a range of firm characteristics, including innovation activity, management practices, and exposure to climate risks. They also hold across different institutional and regulatory environments.

Digitalisation and the intensity of climate action

Digitalisation is positively associated with more intensive engagement in both mitigation and adaptation measures.

Firms with higher levels of digitalisation undertake a broader set of mitigation actions, such as energy-efficiency improvements, cleaner technologies, and waste-reduction practices. They are also more actively engaged in adaptation measures, including investments to reduce exposure to physical climate risks and improve operational resilience.

The relationship between digitalisation and action intensity is strongest among firms that pursue dual strategies. Among these firms, higher digitalisation is associated with more intensive simultaneous mitigation and adaptation. By contrast, among firms that focus on only one dimension, the relationship between digitalisation and action intensity is weaker and, in some cases, not statistically robust.

Robustness and heterogeneity

The association between digitalisation and firms' climate responses is observed across sectors, including manufacturing, services, construction, and infrastructure, and across firms of different sizes.

Levels of digitalisation nevertheless remain uneven. Smaller firms are, on average, less digitally advanced, which is reflected in a lower probability of adopting integrated climate strategies. This does not imply that the relationship between digitalisation and climate action is weaker for smaller firms, but rather that fewer smaller firms reach the levels of digitalisation associated with more comprehensive responses.

Regional differences are also evident, but the core pattern remains consistent: in all regions, more digitally advanced firms are more likely to combine mitigation and adaptation and to engage more intensively in climate action. Additional robustness checks confirm that these findings are not driven by omitted factors or reverse causality.

3.5 Summary and Implications

Three central empirical insights emerge. First, digitalisation is strongly associated with firms adopting integrated climate strategies that combine mitigation and adaptation. Second, digitalisation is linked not only to the presence of climate strategies but also to the intensity with which firms implement climate actions. Third, these relationships are most pronounced where digital technologies are embedded more deeply within firms and used to support coordinated strategic responses.

The findings of this chapter provide several policy-relevant insights into the relationship between digitalisation and firms' climate responses.

First, digitalisation is strongly associated with firms adopting more comprehensive climate strategies and implementing them more intensively. More digitally advanced firms are significantly more likely to pursue dual strategies that combine mitigation and adaptation and to engage more deeply with both types of action. This suggests that digital capabilities can play an important enabling role in helping firms address climate challenges in a more integrated and systematic way.

Second, these benefits are not automatic. Digitalisation appears to create enabling conditions - by improving information flows, coordination, and the capacity to act - but these conditions translate into stronger climate responses only when digital technologies are sufficiently

embedded within firms' operations. Partial or fragmented digital adoption is less strongly associated with integrated climate strategies or higher action intensity.

Third, the strong association between digitalisation and the adoption of dual mitigation–adaptation strategies suggests that digital capabilities may help firms overcome perceived trade-offs between different climate objectives. Firms with higher levels of digitalisation appear better able to recognise and manage both the private risks associated with climate impacts and the broader objectives linked to emissions reduction.

Fourth, although the relationship between digitalisation and climate action holds across firm sizes, sectors, and regions, digitalisation levels remain uneven. Smaller firms are less likely to be highly digitalised, which may constrain their ability to adopt integrated and intensive climate strategies.

Fifth, the analysis suggests that existing policy environments may be more strongly associated with firms' adaptation efforts than with mitigation intensity. While adaptation is essential for business continuity in the face of increasing physical climate risks, the weaker link between policy stringency and mitigation intensity underscores the challenge of encouraging firms to invest in actions that yield broader social benefits.

Finally, the findings underline the importance of complementary organisational capabilities alongside digital investment. Digital technologies create potential, but firms' ability to realise that potential depends on managerial practices, strategic autonomy, and the capacity to integrate information across functions. Policies that support digital investment may therefore be more effective when they also recognise the role of organisational capability and strategic decision-making in shaping outcomes.

Overall, this chapter shows that digitalisation can play a significant enabling role in firms' climate strategies, particularly when it supports integrated mitigation and adaptation. For policymakers, the evidence points to the value of considering not only whether firms adopt digital technologies, but also how these technologies are embedded within firms' strategic and organisational contexts.

Section 4: Adoption of Digital Technologies by UK firms

This Section draws on a 2024 national survey of UK firms' adoption of digital technologies. The project team included Professor Silvia Massini, Dr Mabel Sanchez Barrioluengo and Dr Xiaoxiao Yu (Manchester), Dr Myungun Kim, Dr Yifeng Chen, and Dr Chander Velu (Cambridge). The survey collected responses from over 3,000 senior decision-makers employed in the non-agricultural private sector.

The central finding from the study is that adoption alone does not guarantee productivity gains. Instead, to maximise the value of digital investments complementary investments in skills, and organisational change are essential to maximise returns. The survey also provides a detailed picture of the current state of digital adoption across UK firms:

- *Digitalisation is widespread but uneven* - Over 80% of firms have adopted at least one advanced digital technology (ADT). Joint adoption is common: one in four firms uses two out of six ADTs, and nearly one in five uses three.
- *Regional differences are modest* - London, the North West, and the West Midlands show the highest adoption rates. Sectoral variation is sharper and larger firms adopt more technologies and use them more intensively than SMEs.
- *Motivations and Barriers* - firms adopt ADTs primarily to upgrade outdated processes (66%), improve process reliability (66%), and enhance product/service quality (54%).
- *Barriers remain significant* - the most cited are immature technology (20%), high costs (19%), safety/security concerns (17%), and lack of skills (17%).

4.1 Introduction

This Section provides an analysis of the adoption and impact of advanced digital technologies (ADTs), including AI, Big Data, Cloud Computing, 3D Printing, Internet of Things (IoT), and Robotics. The data were collected through a bespoke survey on the Adoption of Digital Technologies and Skills in the UK (N-ADITS)⁴. The questionnaire was designed by the authors, and the data were collected by YouGov using a sample from a UK research panel. The survey sample was selected from the contact database using a random selection method based on the following eligibility criteria: business leaders (i.e., board-level management) in organisations with two or more employees across the private sector.

The N-ADITS survey collected responses from approximately 3,000 senior decision-makers employed in the non-agricultural private sectors in the UK, located across the 12 International Territorial Levels (ITL) at Level 1 (regions). It targeted a minimum of 300 responses per region, except for the North East (150), Wales (100), and Northern Ireland (100). A total of 3,175 valid responses were obtained by the end of the fieldwork, conducted between 19 March and 20 May 2024.

4.2 Adoption of Advanced Digital Technologies

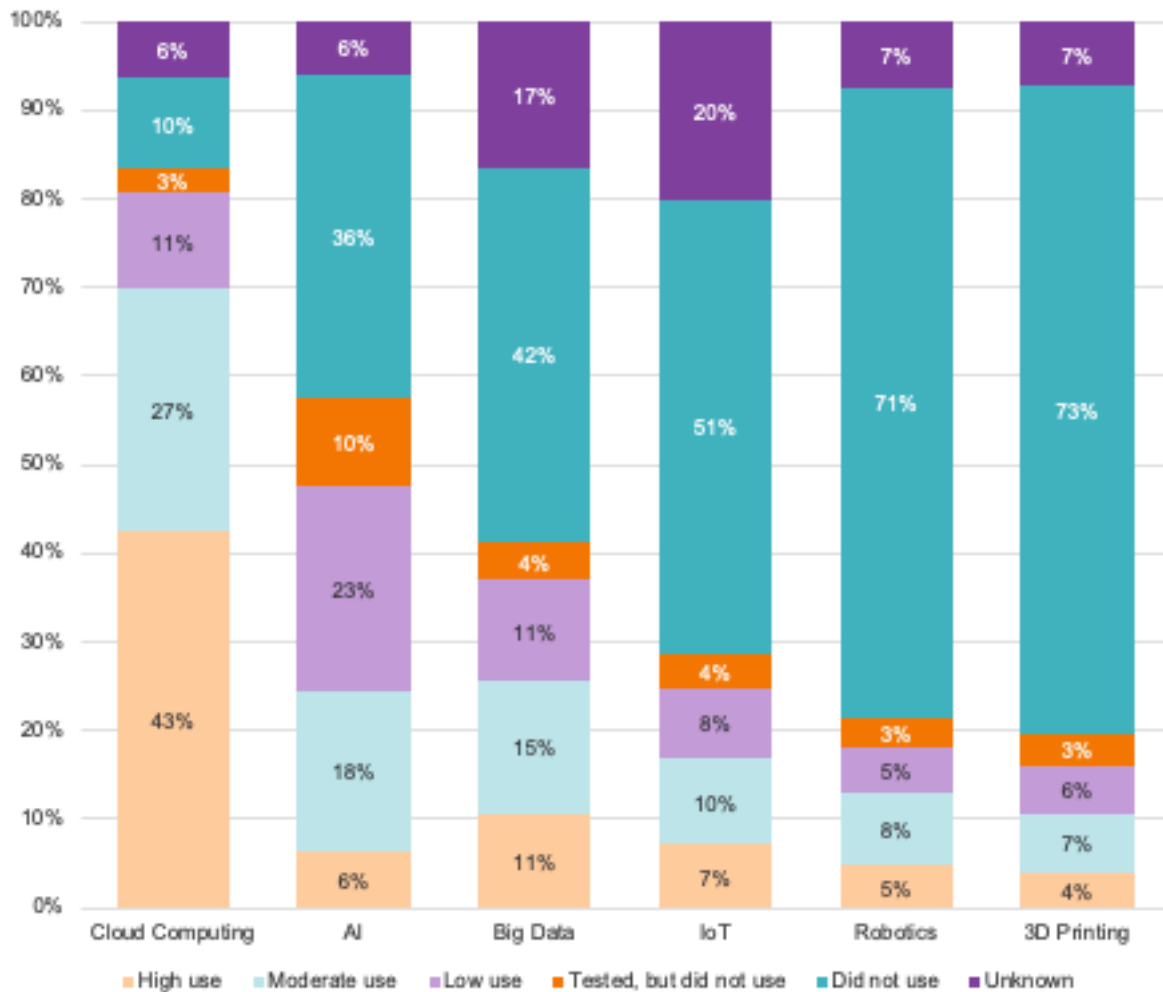
Among the six ADTs of interest, cloud computing is the most widely adopted, with four out of five companies using it at a high or moderate intensity (Figure 4.1). Following this, AI ranks second in usage, with nearly half of the companies adopting it. Notably, AI also has the highest rate of “tested, but did not use” (10%), which is more than twice that of any other ADT. Big Data ranks third, with a 37% adoption rate. Similar patterns of usage are observed for IoT and Robotics,

⁴ The survey was piloted in Greater Manchester (UK) in 2022 and the results are available [here](#).

though their overall adoption rates are lower. 3D Printing has a usage rate comparable to Robotics. Importantly, joint adoption of ADTs is common.

One in four adopters reported using two ADTs, while nearly one in five use three ADTs. The most frequent combinations are Cloud Computing and AI, and Cloud Computing and Big Data when two technologies are adopted. For three technologies, the most common combination is AI, Big Data, and Cloud Computing.

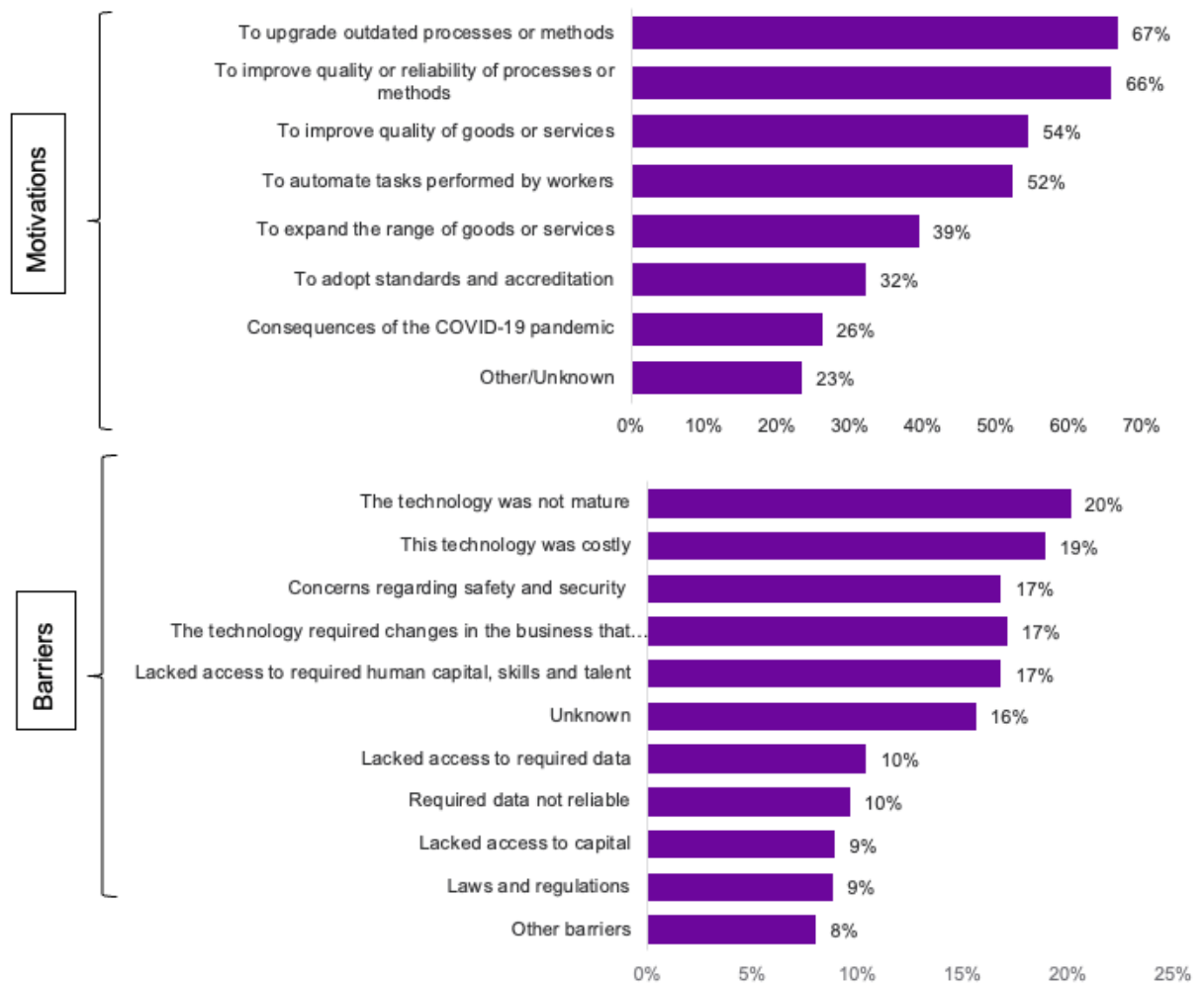
Figure 4.1: Adoption of ADTs per type of technology



Note: Weighted sample (n = 3,175).

The primary motivations for adopting ADTs include upgrading outdated processes, improving the quality of processes, methods, goods, or services, and automation (Figure 4.2). Conversely, the main barriers to adoption include concerns over the maturity and cost of the technology, issues with safety and security, the need for significant business changes, and a lack of human capital and skills.

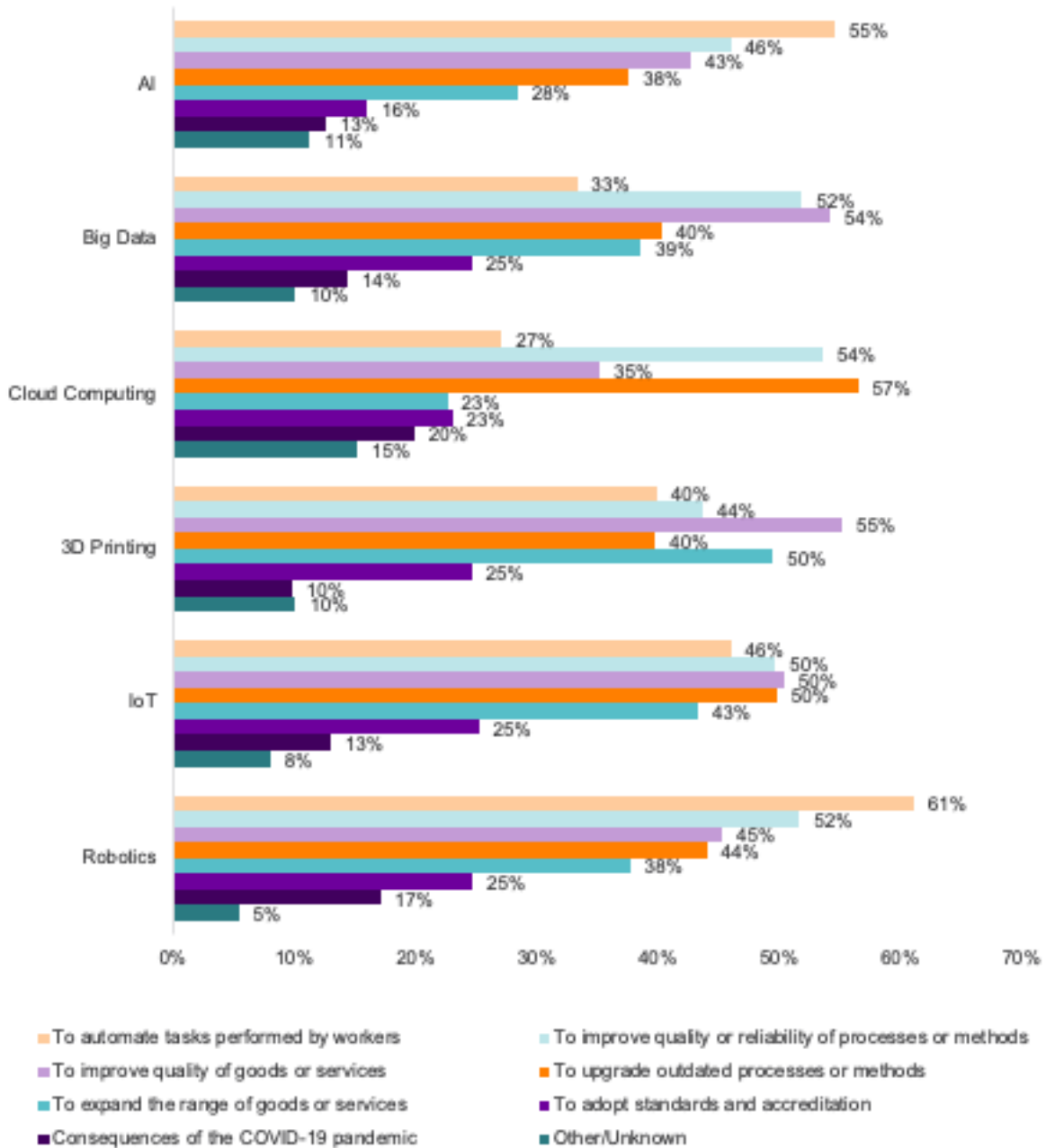
Figure 4.2: Motivations to and barriers for ADT adoption



Note: Weighted sample (motivations: n = 2,858; barriers: n = 2,773)

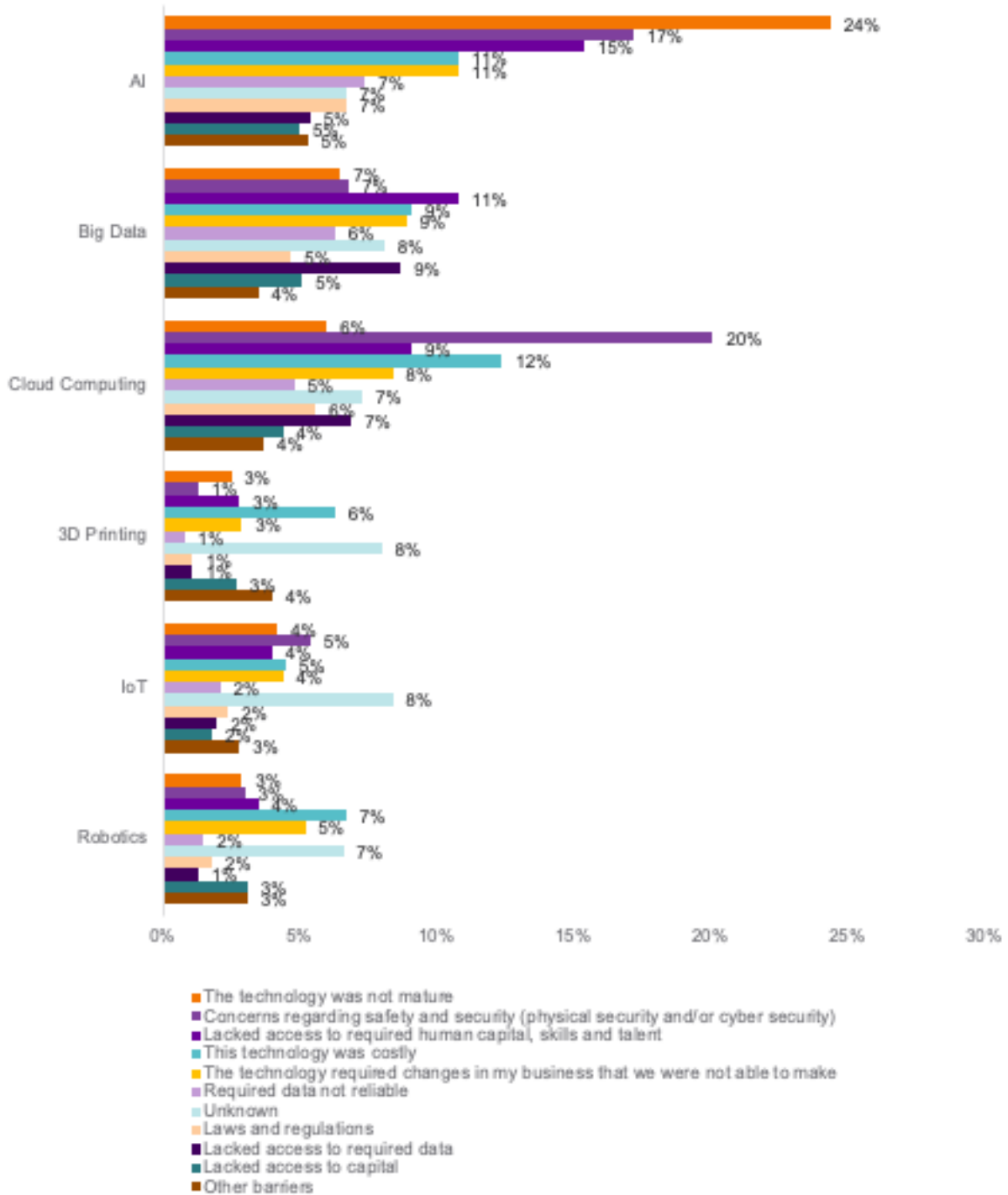
Figures 4.3 and 4.4 further break down motivations and barriers by ADT type. For AI and Robotics, automation is the primary motivation. For Big Data and 3D Printing, the main driver is improving the quality of goods and services. In the case of Cloud Computing, the motivation primarily relates to upgrading outdated processes or methods. Regarding barriers in Figure 4.4, despite widespread Cloud Computing adoption, some businesses refrain from adopting it due to safety and security concerns. For AI, adoption is hindered primarily by perceptions of insufficient maturity, followed by safety and security concerns, and a lack of human capital or skills. For Big Data, the main barrier is a lack of human capital. For other technologies, no single barrier stands out, and percentages remain relatively small.

Figure 4.3: Motivations for adopting each type of ADT



Note: Weighted sample (AI: n = 1,516; Big Data: n = 1,174; Cloud Computing: n = 2,559; 3D printing: n = 513; IoT: n = 788; Robotics: n = 570).

Figure 4.4: Barriers to adopting each type of ADT



Note: Weighted sample (AI: n = 1,468; Big Data: n = 1,476; Cloud Computing: n = 413; 3D printing: n = 2,429; IoT: n = 1,752; Robotics: n = 2,370).

4.3 The Impact of ADT adoption

ADT adoption has generally had a positive impact on employment, particularly by increasing employee skill levels and the proportion of STEM-skilled employees (Table 4.1). This trend is consistent across different ADTs, with the highest impact reported by companies adopting Big Data, 3D Printing, and Robotics. In terms of productivity-related and other outcomes, the primary impact of ADT adoption is on the quality of products and services. Interestingly, the effects on delivery time and production costs are polarised, with roughly 26–28% of adopters reporting positive impacts and 21–23% reporting negative impacts.

When examining differences by technology type, companies adopting AI report significant improvements in the quality of both services and products. However, AI adoption is associated with increased production or process costs and longer delivery times. Technologies related to data, such as Big Data, Cloud Computing, and IoT, similarly positively influence product and service quality but also lead to increased costs and delivery times. These technologies further support diversification of products, services, and customer bases. For technologies more related to manufacturing, such as 3D Printing and Robotics, the difference in the impact lies in reported increases in production volumes, although over 40% of robotics adopters report longer delivery times and higher production costs.

Table 4.1: Impact of ADTs on adopters

	Any ADT		AI		Big Data		Cloud Computing		3D Printing		IoT		Robotics	
	▲	▼	▲	▼	▲	▼	▲	▼	▲	▼	▲	▼	▲	▼
Employment														
Number of employees	17%	11%	26%	12%	37%	9%	23%	6%	48%	8%	40%	8%	36%	27%
Skill level of employees	38%	3%	54%	4%	62%	3%	49%	2%	65%	5%	59%	4%	61%	5%
STEM skilled employees	33%	3%	51%	3%	61%	4%	39%	2%	68%	5%	58%	2%	63%	4%
Productivity														
Production costs/cost of processes	21%	26%	32%	23%	37%	19%	28%	20%	52%	17%	42%	16%	41%	25%
Selling price of goods and/or service	22%	6%	35%	4%	44%	5%	27%	4%	57%	6%	51%	5%	46%	6%
Volume of production	31%	3%	48%	2%	50%	3%	38%	2%	62%	4%	53%	3%	66%	3%
Product diversification	27%	3%	44%	2%	51%	3%	32%	2%	67%	4%	54%	3%	52%	2%
Quality of product	36%	2%	53%	3%	63%	2%	43%	2%	69%	5%	58%	2%	59%	4%
Time to deliver product	21%	27%	35%	23%	36%	22%	25%	22%	53%	18%	39%	22%	43%	26%
Service diversification	27%	3%	45%	3%	52%	2%	34%	1%	64%	5%	57%	2%	54%	2%
Quality of service	46%	3%	58%	3%	67%	2%	57%	2%	69%	4%	64%	2%	65%	3%
Time to deliver services	23%	28%	41%	25%	37%	22%	28%	25%	53%	15%	44%	17%	46%	23%
Number of customers	28%	3%	42%	3%	52%	3%	34%	2%	60%	4%	51%	3%	49%	3%
Types of customers	21%	2%	34%	2%	47%	2%	27%	2%	59%	3%	51%	2%	48%	3%
n (weighted)	2,858		1,516		1,174		2,559		513		7,88		570	

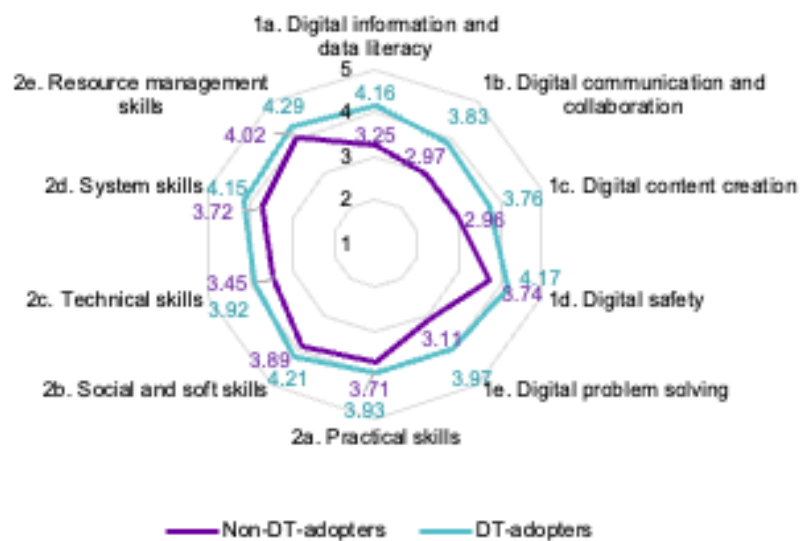
Note: This table presents the percentages of firms that declared increases or decreases in the factors in employment and productivity-related and other outcomes. Firms could select from five categories to describe the impact of adoption of ADTs: 5 – “increased considerably”, 4 – “increased”, 3 – “did not

change”, 2 – “decreased” and 1 – “decreased considerably”, for each particular statement. To present the effect of adopting a specific type of ADTs we classify 1 and 2 as “decrease” (▼), and 4 and 5 as “increase” (▲). The percentages for “any ADT” are based on the average impact of all the technologies adopted by a respondent: a factor of employment or productivity-related and other outcomes is considered “decreased” for the adopter if the average impact is between 1 and 3, and is considered “increased” if the average is between 4 and 5. Those that selected “did not change” are not reported in the table. Weighted sample (Any DT: n = 2,858; AI: n = 1,516; Big Data: n = 1,174; Cloud Computing: n = 2,559; 3D printing: n = 513; IoT: n = 788; Robotics: n = 570).

Figure 4.5 illustrates skill requirements for ADT adopters and non-adopters using mean values (on a scale of 1 to 5) to assess the importance of both digital and non-digital skills. Digital skills (values 1x in the figure) are notably more critical for adopters, who also report larger gaps in digital skills compared to non-digital skills (values 2x in the figure). T-test comparisons confirm significant differences in skill importance between adopters and non-adopters, with adopters consistently ranking skills as more critical.

Among digital skills, "digital information and data literacy" and "digital safety" are the most important for adopters, while "resource management skills" and "social and soft skills" are considered most essential among non-digital skills. For non-adopters, "digital safety" and "management skills" are the most relevant within each category. These patterns remain consistent when comparing adopters and non-adopters by ADT type with the exception of Big Data, 3D Printing, IoT, and Robotics, where "system skills" are prioritized over "social and soft skills" by technology adopters.

Figure 4.5: Comparison of skills importance between adopters and non-adopters of ADT



Note: Mean comparison using t-test suggests significant differences for all skills between adopters and non-adopters. Weighted sample (n = 3,175).

Turning to training for various ADTs, in general, nearly two-thirds of companies have organised training related to ADT adoption, although figures vary by technology (Table 4.2). More than half of companies report training on Cloud Computing, and at a smaller scale in AI and on Big Data. For all other technologies, training rates are lower, with fewer than 1 in 4 companies providing training. Training tends to be conducted on the job or through a combination of on- and off-the-job formats, with off-the-job training figures lower across all technology types.

Table 4.2: Training related to ADT adoption

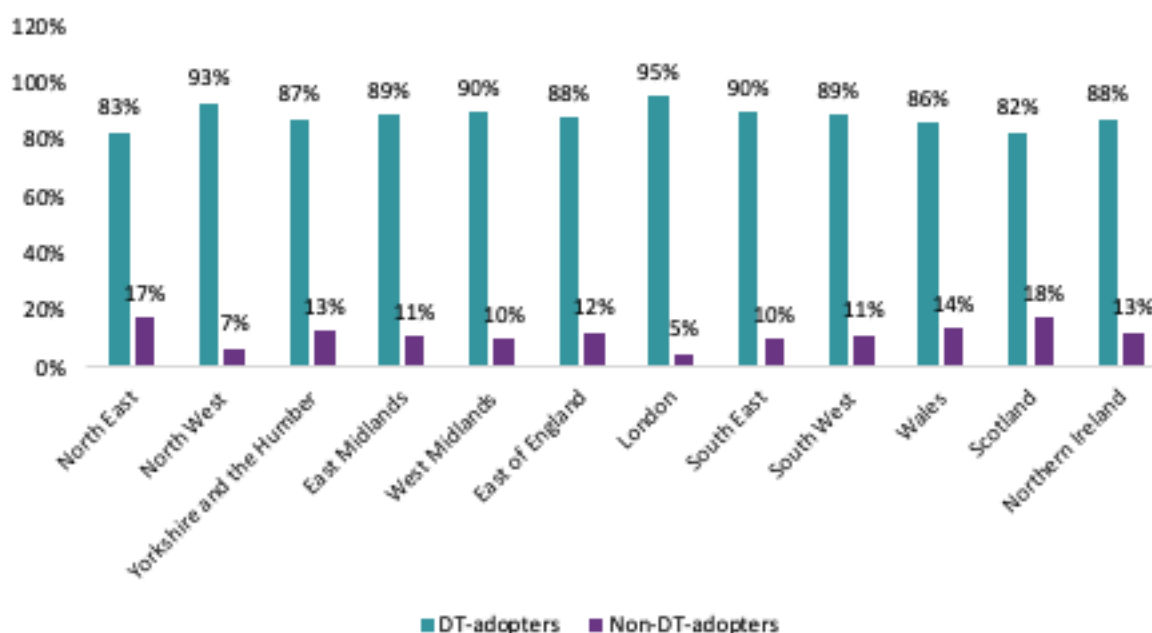
	Any ADT	AI	Big Data	Cloud Computing	3D Printing	IoT	Robotics
Organised	64%	39%	34%	55%	18%	24%	21%
On the job	-	15%	14%	28%	7%	10%	8%
Off the job	-	5%	3%	5%	3%	2%	3%
Both off and on the job		19%	17%	22%	8%	12%	10%
Not organised	27%	51%	51%	34%	67%	61%	65%
Unknown	9%	10%	14%	11%	15%	15%	14%
Total (n=3,175)	100%	100%	100%	100%	100%	100%	100%

Note: Weighted sample (n = 3,175)

4.4 Adoption of ADTs by region, sector and firm size

ADT adoption rates vary only slightly across regions in the UK (Figure 4.7), with more than four out of five businesses in each region adopting at least one of the listed ADTs. London, the North West, the West Midlands, and the South East have the highest adoption rates. However, differences emerge when considering specific types of technology, as shown in Figure 8.

Figure 4.7: Adoption of at least one ADT by region



Note: Weighted sample (n = 3,175).

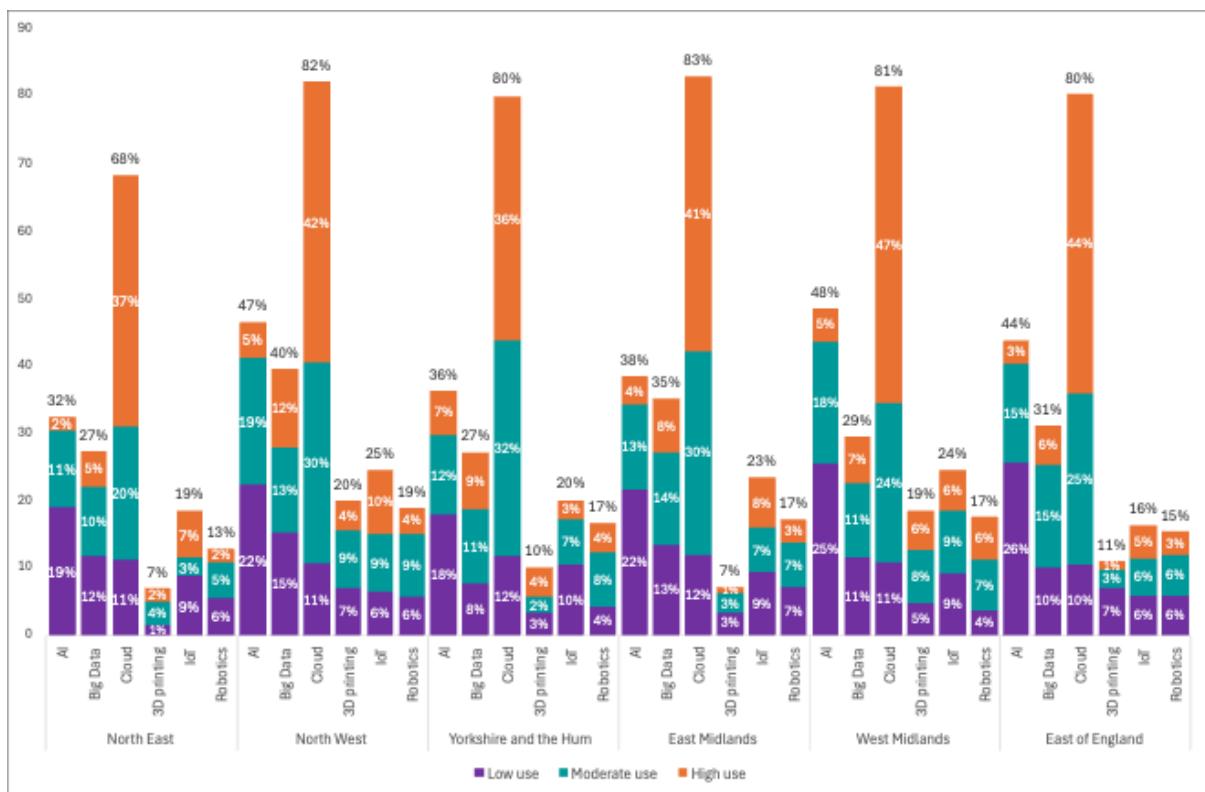
Across all regions, Cloud Computing, AI, and Big Data are most widely adopted, while IoT, Robotics, and 3D Printing are less commonly used. Cloud Computing is adopted by at least three-quarters of companies in every region. AI ranks as the second most adopted technology,

with London leading, followed by the South East, the West Midlands, and the North West. In other regions, AI adoption ranges from 32% (North East) to 44% (East of England).

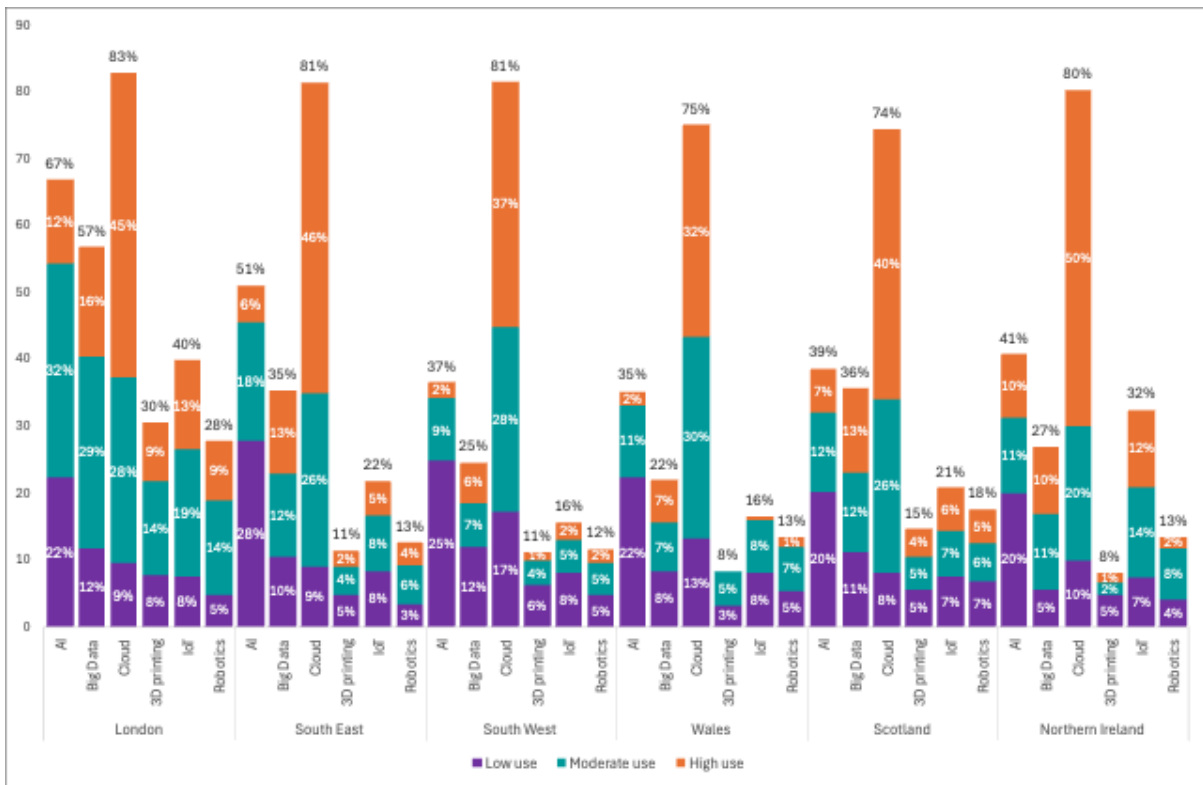
Big Data is primarily adopted in London and the North West, followed closely by Scotland, the East Midlands, and the South East. IoT adoption is highest in London, Northern Ireland, and the North West, with adoption in other regions remaining lower. Robotics and 3D Printing have lower adoption rates, with the highest levels in London, the North West, and the West Midlands.

Examining the intensity of use for the most adopted technologies, Cloud Computing stands out as the most widely used ADT, with about half of adopters in each region reporting high use. In contrast, AI is generally used at low levels in most regions, except in London. Big Data usage intensity is more balanced in terms of levels of use. For the other three technologies (IoT, 3D Printing, and Robotics), adoption rates are too low to distinguish clear usage intensity patterns, except in London, where companies report primarily moderate use of these technologies.

Figure 4.8: Adoption of each type of ADT by region



Note: Weighted sample (AI: n = 1,516; Big Data: n = 1,174; Cloud Computing: n = 2,559; 3D printing: n = 513; IoT: n = 788; Robotics: n = 570).



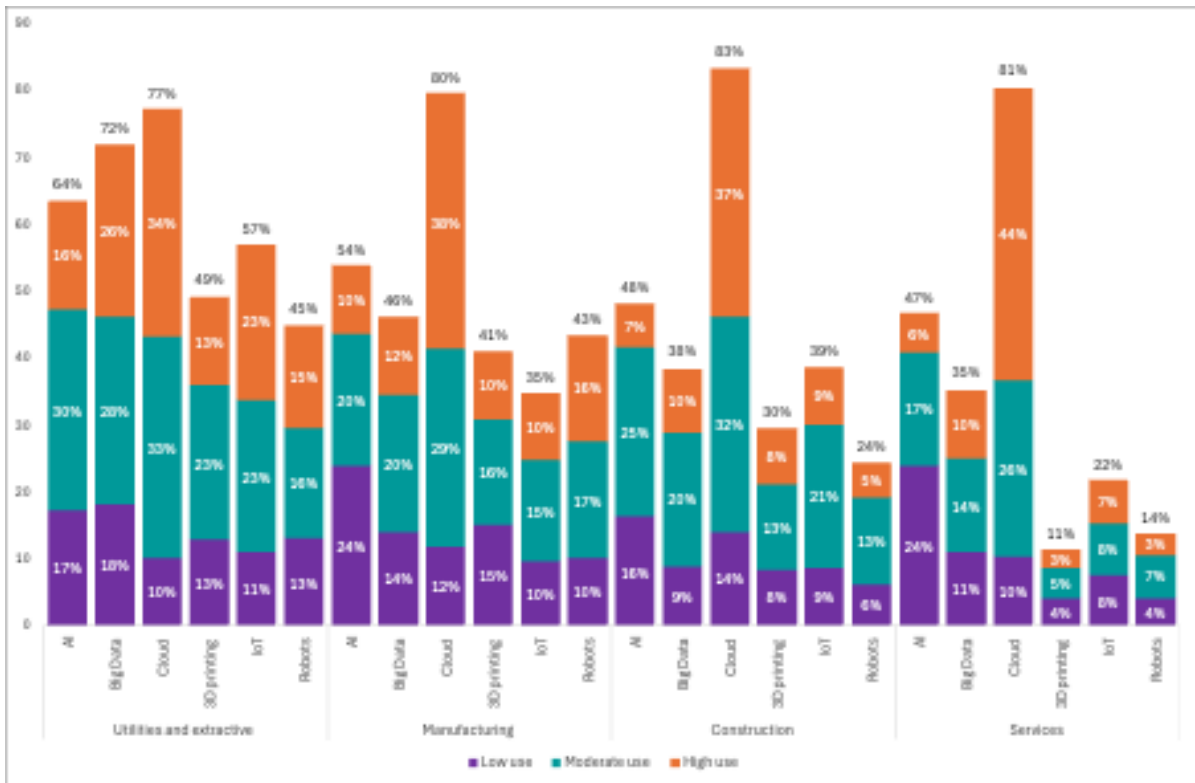
Note: Weighted sample (AI: n = 1,516; Big Data: n = 1,174; Cloud Computing: n = 2,559; 3D printing: n = 513; IoT: n = 788; Robotics: n = 570).

Figure 4.9 presents ADT adoption by industry sector, distinguishing between utilities and extractive, manufacturing, construction, and services. Cloud Computing is the most adopted technology across all sectors. The utilities and extractive sectors lead in adoption for all ADTs, with Cloud Computing followed by Big Data, AI, and IoT. Nearly half of companies in this sector also adopt 3D Printing and Robotics. In manufacturing, ADT adoption is more evenly distributed, with AI adopted by about 50% and IoT by one-third of companies in the sample. Robotics is adopted by almost half of manufacturing companies, representing the second-highest rate of Robotics adoption among sectors. IoT adoption in manufacturing is only higher than in services, with other ADTs showing intermediate adoption rates. In contrast, ADT adoption in services is more polarized, with high adoption of Cloud Computing, followed by AI and Big Data, while other ADTs like 3D Printing, Robotics, and IoT show the lowest adoption rates across all sectors.

When examining technology use intensity, there is a consistent pattern of moderate use across all technologies. However, in manufacturing and services, AI is primarily used at low levels.

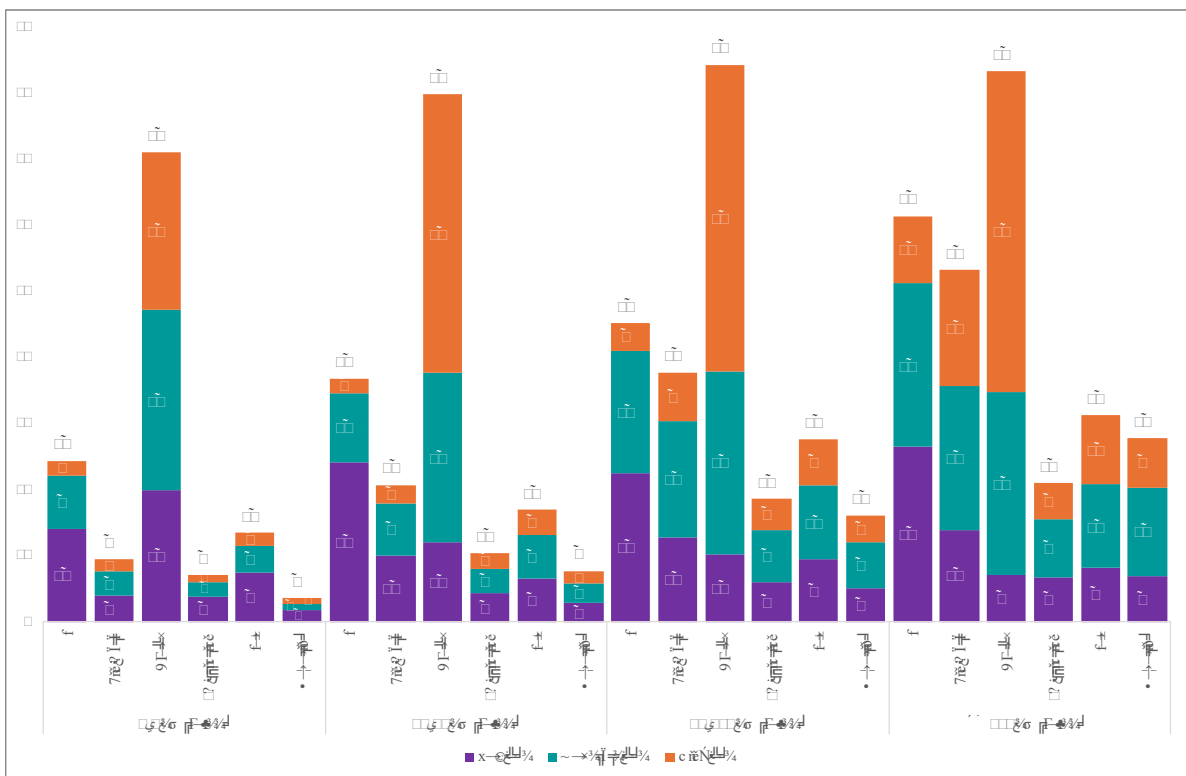
Figure 4.10 displays adoption rates by company size. Larger businesses generally show higher ADT adoption rates, except for Cloud Computing, where companies with 50–249 employees have a slightly higher adoption rate. Companies with fewer than 50 employees report Cloud Computing adoption rates similar to those of large firms; however, there are fewer adopters of AI in small firms (one in three) compared to almost two out of three in larger firms. Usage intensity also increases with company size, with larger firms using ADTs more intensively. Nonetheless, the highest percentage of AI adoption remains in the low-intensity category across all company sizes, while other technologies tend to see moderate use.

Figure 4.9: Adoption of each type of ADT by industrial sector



Note: Weighted sample (AI: n = 1,516; Big Data: n = 1,174; Cloud Computing: n = 2,559; 3D printing: n = 513; IoT: n = 788; Robotics: n = 570).

Figure 4.1: Adoption of each type of ADT by firm size



Note: Weighted sample (AI: n = 1,516; Big Data: n = 1,174; Cloud Computing: n = 2,559; 3D printing: n = 513; IoT: n = 788; Robotics: n = 570).

4.5 Summary and implications

The survey of Adoption of Digital Technologies and Skills in the UK (N-ADITS) suggests a number of key findings:

- **Digitalisation is widespread but uneven** - Over 80% of firms have adopted at least one ADT, with Cloud Computing leading (used by ~80% of firms), followed by AI (~50%) and Big Data (~37%). IoT, Robotics, and 3D Printing remain niche. Joint adoption is common: one in four firms uses two ADTs, and nearly one in five uses three. Most often Cloud Computing is combined with AI or Big Data.
- **Regional differences are modest** - London, the North West, and the West Midlands show the highest adoption rates. Sectoral variation is sharper - utilities and extractives lead in multi-technology adoption, while services lag in Robotics and IoT. Larger firms adopt more technologies and use them more intensively than SMEs.
- **Motivations and Barriers** - firms adopt ADTs primarily to upgrade outdated processes (66%), improve process reliability (66%), and enhance product/service quality (54%). Automation is a key driver for AI and Robotics, while quality improvements motivate Big Data and 3D Printing adoption.
- **Barriers remain significant** - the most cited are immature technology (20%), high costs (19%), safety/security concerns (17%), and lack of skills (17%). AI faces the greatest resistance due to perceived immaturity and skills shortages. Cloud Computing adoption is occasionally hindered by cybersecurity concerns.
- **Skills upgrading** - 38% of adopters report higher overall skill levels, and 33% report more STEM-skilled employees. For Big Data, 3D Printing, and Robotics, these figures exceed 60%. Employment effects are generally positive, though modest.
- **Productivity impacts are mixed** - the most consistent benefit is improved product/service quality (reported by 36–69% of adopters). However, effects on costs and delivery times are polarised: roughly 26–28% report reductions, while 21–23% report increases.

More generally, our results emphasise the importance of combining adoption of ADTs with intangible complementary assets, like digital skills, and firm characteristics, but also to pay attention to the place-based technological capabilities to boost long-term positive impact on firms' economic outputs, as technology adoption alone is insufficient for maximising returns.

Our findings suggest a set of recommendations based on the principle that the strategic adoption of Advanced Digital Technologies (ADTs) drives innovation, increases operational efficiency, and might result in delivering productivity gains:

- Implement a Place-Based Innovation Strategy that leverages existing regional technological strengths to foster contextualised specialisation within the growth-driving sectors.
- Adopt a Human-Centric Skills Approach to digital adoption that strengthens the development of ADT-specific skills, aligning workforce training with regional capacity for technology production and adoption.
- Provide Stage-Based Policy Support through a comprehensive perspective that addresses unique technical, financial, and organisational challenges with tailored initiatives across the different phases of the technology adoption process.
- Encourage Cross-Sectoral Diffusion by showcasing and demonstrating the diverse value and practical usages of ADTs to accelerate adoption beyond the eight Industrial Strategy growth sectors.

In conclusion, this research highlights the need to further understand the relation between ADTs and productivity, an issue associated to the "modern productivity paradox," which posits that the adoption of new technologies may not yield the anticipated productivity gains in the near future, nor over extended periods.

Section 5: How are digital investment decisions made?

This section draws on data from a 2025 survey of investment decision-making among 1,623 UK firms with 10 or more employees. The survey project was led by Eugenie Golubova (Warwick) and Prof Stephen Roper (Warwick). Of the firms which responded to the main survey, around 300 had made digital investments (i.e., computer software or databases) over the 2019-24 period. These were the most common types of intangible investments.

Focusing on digital investors reemphasises that digital investment is central to business growth and efficiency, but also that informal planning and financing constraints may hinder its full potential. Key findings relate to the frequent combination of digital and other investments, the similarity of motivations for digital and other investments and the informality of planning for many digital investments.

5.1 Introduction

The effects of the business environment – such as uncertainty and capital costs – on investment are well understood. However, what drives business investment and the decision-making process behind it is much less clear. In this section, we focus on the reasons and methods behind decisions to invest in digital technologies.

To understand why and how firms make investment decisions, we conducted a large-scale survey of 1,623 UK firms. The survey was limited to private companies with 10 or more employees and those that made ‘significant’ investments (£5,000 or more) in any year between 2019 and 2024. From this survey, we know that digital investments (i.e., computer software or databases) were the most common type of intangible investments, made by 74% of all respondents. In the following sections, we focus on those businesses that made digital investments – ‘digital investors’ (N = 299).

On average, digital investors employed 60 staff, had a turnover of £6.4 million, and were 33 years old. Over half of them (55%) were family businesses, and 9% were foreign-owned. Businesses that made significant digital investments mainly sold services (55%) or both goods and services (27%), with 18% selling only goods. 30% of businesses making digital investments exported.

5.2 Digital investment patterns

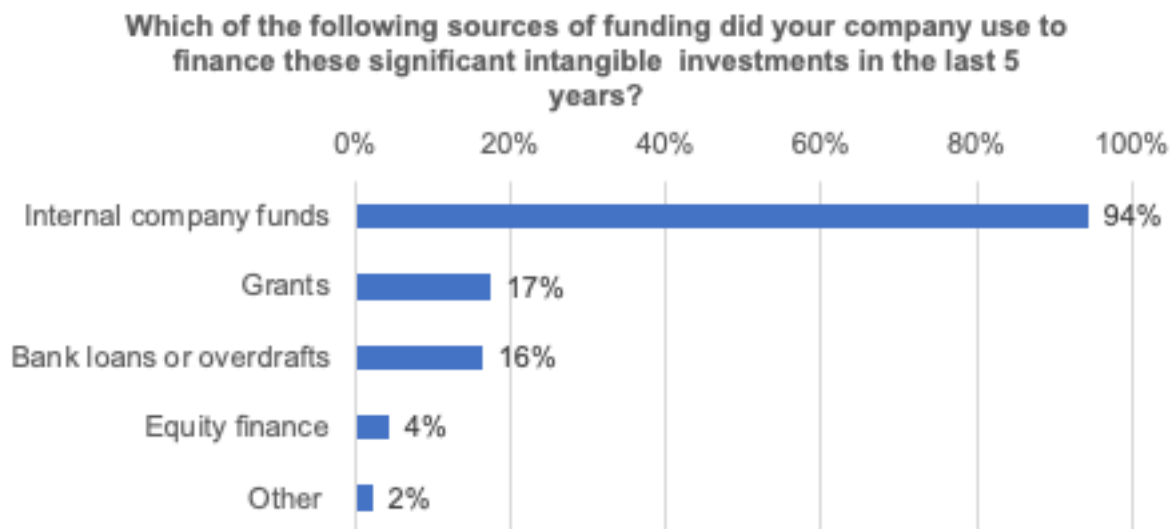
Most digital investors made digital investments alongside other types of investments, both tangible and intangible. On average, they made five significant investments between 2019 and 2024. These businesses mainly invested in both tangible and intangible assets: 75%, compared to 25% that invested solely in intangible assets. Concerning investment subtypes, businesses engaging in digital investments also frequently invested in physical IT equipment or systems (73%) and staff training or education (72%) (Table 5.1).

Table 5.1: Types of investment made by digital investors

Tangible investment sub-types	%	Intangible investment sub-types	%
IT equipment or systems excluding software	73%	Computer software or databases	100%
Machinery	62%	Staff training or education	72%
Other equipment (excl. IT)	58%	Branding or brand recognition	54%
Buildings or plants	54%	Business structure or organisation	40%
Inventory or stock	47%	R&D	40%
Vehicles	37%	Customer goodwill	31%
Land	10%	Intellectual property products	17%
Other	2%	Entertainment, literary and artistic originals	16%
		Other	3%

Digital investors allocated an average of 9% of their turnover to intangible assets from 2019 to 2024. Seventy per cent of these firms relied solely on internal company funds to finance their intangible investments, including digital ones. While 30% of firms used at least one external funding source - for example, grants - it was very uncommon for external funding to be the sole source of finance for intangible assets. Almost all firms (94%) utilised internal company funds to finance any intangible investments. (Figure 5.1)

Figure 5.1: Funding sources for investment by digital investors



5.3 Why make digital investments?

Businesses that made digital investments did so for various reasons, usually aligned with core business objectives such as increasing efficiency (cited by 89% of firms) or enhancing productivity (88%). Firms were much less likely to make intangible investments to improve environmental sustainability (41%) (Figure 5.2). The most important reason for investing was increasing company profit and growth (27% of firms) or boosting business efficiency (27%), while other reasons varied. Interestingly, although enhancing productivity was one of the main purposes for making any intangible investments (88% of firms), productivity was cited far less often as the primary reason for investment (11%) (Figure 5.3).

Figure 5.2: Rationale for intangible investments



Note: Don't know / refused responses (0.2%) are not displayed in the graph.

Figure 5.3: Main reason for making intangible investments



Note: Don't know / refused responses (1%) are not displayed in the graph

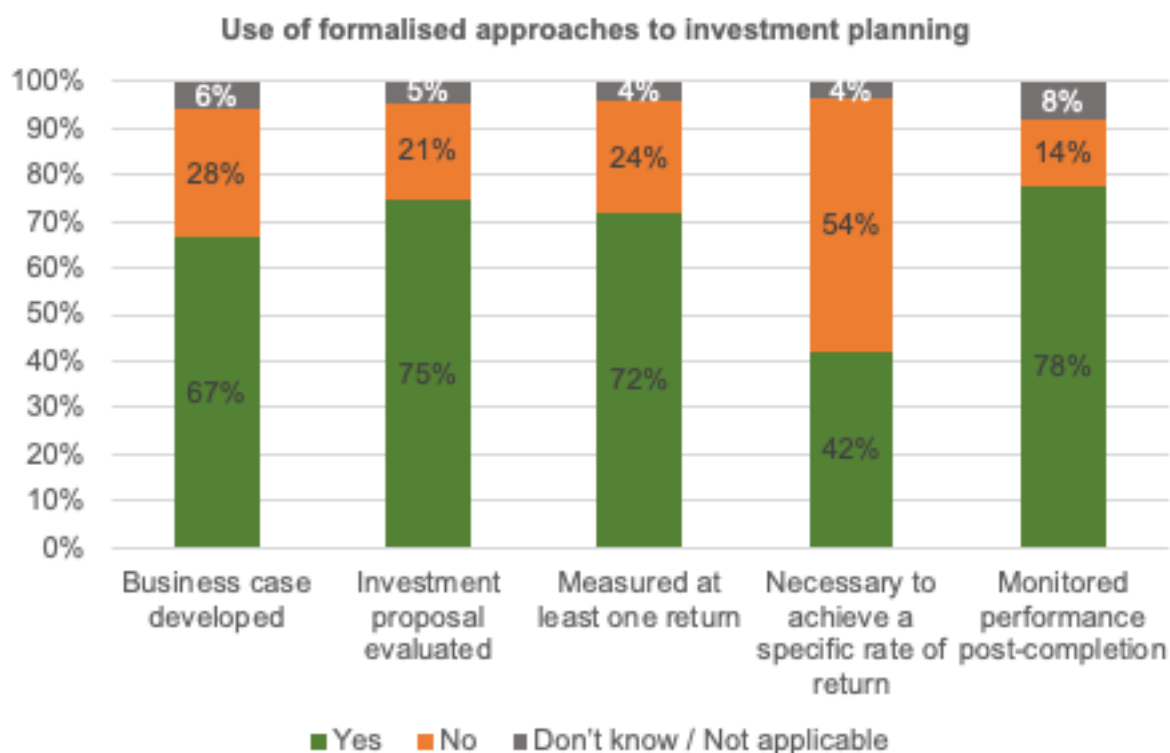
5.4 How digital investments are made

In 2024, a significant proportion of businesses making digital investments lacked a formal investment plan: 42% compared to 55% of those with a plan. Less than a third (29%) aimed to reach a specific return rate when investing in intangible assets.

Furthermore, we asked half of the digital investors to provide more details about the processes involved in making their most strategically significant investment. Computer software or database investments were the most common among their most strategically important intangible investments, cited by 62% of firms that identified intangible investments (either alone or combined with tangible assets) as their most strategically significant.

In those firms that identified digital investments as their most significant (N = 208), many did not adopt formalised approaches to investment planning. For instance, about a quarter of firms neither developed a business case nor evaluated the investment proposal or measured expected returns. Companies were somewhat more inclined to monitor their investment's performance after completion (78%), but less likely to pursue a specific rate of return (42%) (Figure 5.4).

Figure 5.4: Use of formalised approaches to investment planning

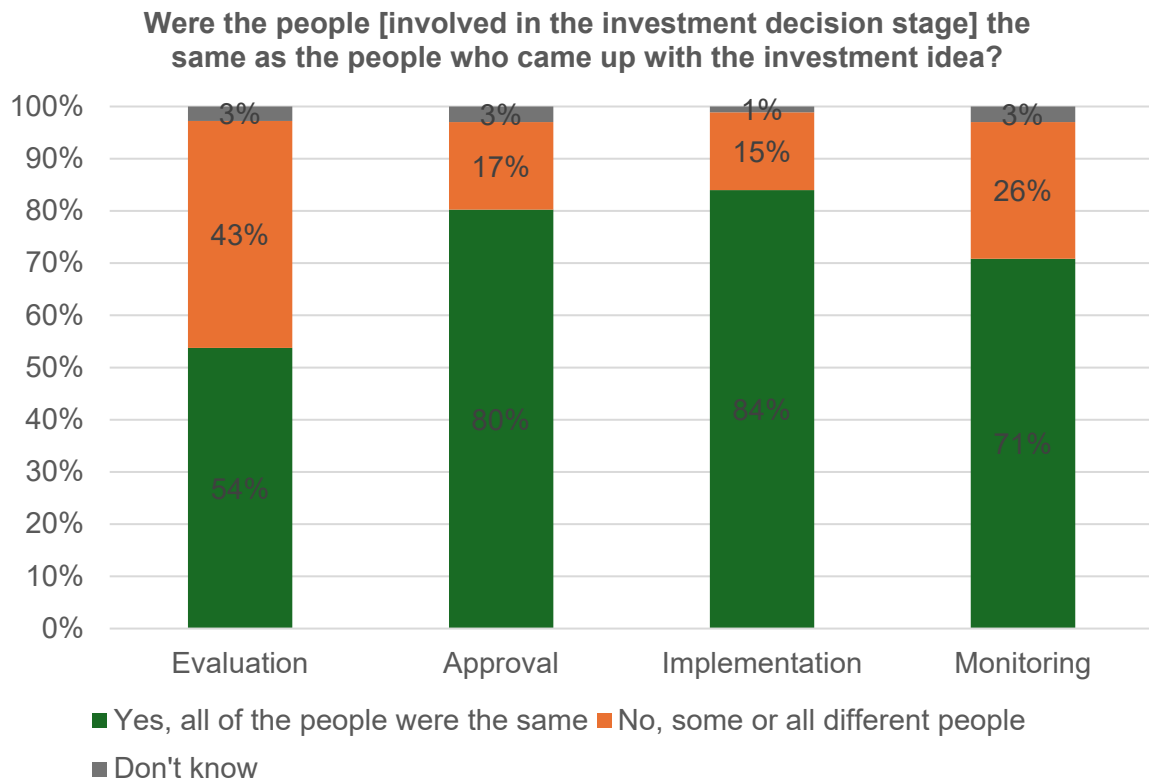


5.5 Investment decision-makers

Digital investors reported typically having five people involved in making business investment decisions. Across these firms, an average of 36% of investment decision-makers were women and 12% belonged to ethnic minority groups.

From examining the process of making the most strategic investment, we understand that the key decision-makers who proposed this investment were usually in senior roles such as company directors (50% of firms that prioritised digital investments), owners/founders (24%), department heads or senior managers (24%), and CEOs/managing directors (21%). Additionally, key decision-makers tended to remain consistent throughout the investment process (see Figure 5.5). This was less true during the evaluation stage, where a smaller proportion of firms, though still the majority (54%), retained the same decision-makers, compared to, for example, the approval stage, where 80% of firms maintained the same decision-makers. It is also worth noting that not all firms evaluated their most strategic investment proposals (75% did).

Figure 5.5: Continuity of the team making investment decisions



Note: evaluation and monitoring stages applied to the firms that evaluated and monitored their investments, i.e., 75% and 78% respectively.

Finally, among firms that regarded digital investments as their most strategic priority, 43% engaged external parties such as private consultants or other private companies in their digital initiatives.

5.6 Summary

A recent survey of 1,623 UK firms sheds light on patterns and drivers of digital investment among private companies with 10+ employees. The survey suggests a number of key findings:

Investment Patterns and Financing - Digital investments rarely occur in isolation. Most firms combined intangible investments (e.g., software, training) with tangible assets like IT equipment (73%) and machinery (62%). On average, firms made five significant investments over five years, allocating 9% of turnover to intangible assets. Internal financing dominated: 94% used company funds, while only 30% accessed external sources such as grants. External funding was seldom the sole source of finance, highlighting reliance on internal resources.

Motivations for Digital Investment - Efficiency and productivity gains were the primary drivers, cited by 89% and 88% of firms respectively. However, when asked for the main reason, responses shifted: 27% prioritized profit and growth, and another 27% focused on efficiency. Environmental sustainability was a secondary consideration (41%). This suggests that while productivity is widely valued, it is rarely the headline rationale for investment decisions.

Planning and Decision-Making - Investment planning was often informal. In 2024, 42% of digital investors lacked a formal investment plan, and only 29% targeted a specific return rate. Among firms identifying digital investments as their most strategic priority, a quarter did not develop a business case or evaluate proposals. Monitoring was more common (78%), but structured approaches - such as setting ROI targets - were limited (42%).

Investment decision-making typically involved five individuals, with 36% women and 12% from ethnic minority groups. Senior leaders dominated: directors (50%), owners/founders (24%), and CEOs/managing directors (21%). Continuity was strong during the approval and implementation stages but weaker during the evaluation. External consultants were engaged by 43% of firms for strategic digital initiatives.

Overall, the survey reemphasises that digital investment is central to business growth and efficiency, but informal planning and financing constraints may hinder its full potential. Targeted policy interventions can help firms maximise the benefits of digital transformation:

- **Encouraging Formal Planning:** Many firms lack structured investment processes, which may limit returns. Policies promoting business case development and ROI evaluation could improve outcomes.
- **Access to Finance:** Heavy reliance on internal funds suggests barriers to external financing. Expanding grant programs or tailored financial instruments could accelerate digital adoption.
- **Skills and Complementary Investments:** High rates of investment in staff training (72%) underscore the need for workforce development policies aligned with digital transformation.

Section 6: Digital alignment for net zero

In this section, authors Jonatan Pinkse, Anne-Lorène Vernay, Corine Genet, and Adélie Ranville consider the role of digital alignment with firms' net zero targets. In this qualitative, interview-based study, they examine how digital technologies influence sustainability management and efforts towards net-zero emissions in the construction sector. The study is based on 53 in-depth interviews conducted across 19 firms operating along the construction value chain in France and Germany.

Digital adoption is uneven across organisational processes; firms rarely achieve full alignment between digital tools and existing workflows, which limits their potential contribution to net-zero objectives. This lack of alignment is evident in various digital applications: monitoring, analysing, planning, executing, and knowledge sharing. Overall, while planning leads to successful digitalisation within isolated processes, it fails to create cross-process alignment, thereby restricting its transformative impact on sustainability performance.

6.1 Introduction

With the rapid rise of artificial intelligence and other digital technologies, there has been increased momentum around the potential of digital technology adoption to play a key role in firm decision-making (Hanelt et al., 2021). Digital technologies hold significant promise for managing complex data flows within and between firms and for boosting the productivity of many tasks. However, digital technologies are not adopted in a vacuum; they must be closely integrated with and aligned to existing organisational processes. Therefore, digital adoption is not merely a technological exercise but fundamentally an organisational and socio-technical change process (Hanelt et al., 2021; Mouthaan et al., 2023).

To understand how digital adoption influences other organisational processes, the research team conducted in-depth interviews with managers in the construction sector in France and Germany. These countries are often seen as leading the UK in terms of the adoption of digital technologies and provide close comparators to the UK. The research focused on how digital technologies affect sustainability management within the sector and on the ways they help firms achieve net-zero carbon emissions. To conceptualise the relationship between digital adoption and sustainability management, it examined how various organisational processes – from monitoring and analysis to planning, execution, and knowledge sharing – change with the introduction of digital technologies.

The findings indicate that aligning digital technologies with existing organisational processes remains challenging, facing numerous barriers and tensions along the way. While digital adoption shows promise for improving specific processes, such as monitoring and analysing carbon emissions to support better sustainability management, there is still limited alignment in how these technologies are harmonised across different processes. Consequently, digital adoption is not yet fully integrated, and much of its productivity potential, especially in enhancing sustainability performance, remains untapped. These findings suggest that substantial investment is still necessary to ensure all parts of a firm are equipped to utilise more advanced digital technologies, enabling their full potential to enhance productivity and sustainability.

6.2 Digital adoption, managing complexity, and net zero

Managing sustainability to reach net-zero carbon emissions is a complex process that requires companies to collect, monitor, and analyse large amounts of new data that previously went unnoticed (Mouthaan et al., 2023; Pinkse & Bohnsack, 2024). Recent evidence from Amazon's decarbonisation efforts indicates that digital technologies can play an important role in making this complexity more manageable (O'Rourke, 2025). For Amazon, digital technologies are essential in gathering data, modelling emissions, and pinpointing where in the organisation emissions can be most efficiently and effectively reduced. Additionally, the firm's digital platforms are crucial in creating and enforcing incentives for those responsible at different levels of the organisation to meet specific emission targets. For Octopus Energy, digital platforms also form the backbone of their green energy management, enabling them to significantly expand their operations while establishing themselves as leaders in sustainability (Pinkse & Bohnsack, 2024). What makes these two firms unique is that they are digital-first; digital technologies have been central to their business models since their inception (Falcke et al., 2024).

However, it is much more common for firms to adopt digital technologies only at a later stage of their development, simply attaching them to existing organisational processes (Falcke et al., 2024). As a result, digital adoption becomes more challenging because it requires integrating and aligning these new technologies with established practices. While digital technologies can motivate firms to rethink outdated methods, path dependencies often slow this process as firms tend to stick to what is familiar (Bohnsack et al., 2014). In other words, core competences can become core rigidities in the face of technological change (Leonard-Barton, 1992).

In our empirical research, we concentrated on the construction sector, an industry not typically recognised for leading the digital revolution. Many activities remain quite traditional and depend on long-established technologies and procedures. However, the sector has begun to experience the early effects of digitalisation. For instance, building information modelling (BIM) is increasingly utilised to assist firms in managing data and coordinating modelling efforts among partners within a project. This tension between the conditions necessary for adopting digital technologies and firms' willingness to abandon existing practices is central here. While digital tools present new opportunities for coordination and data management, their benefits can remain unrealised when they clash with deeply ingrained routines.

Managing net zero is a complex organisational process for examining the impact of digital technology adoption because it possesses qualities that make it both suitable for digitalisation (due to the extensive data integration required) and resistant to adoption (due to its interpretive and operational complexity). First, the objective function is not always clear. Although carbon targets generally aim for net zero, sustainability goals remain diverse and can be interpreted differently by various stakeholders (Dahlmann et al., 2019). Additionally, carbon emissions are challenging to measure and often require proxies or complex calculations such as life-cycle analysis.

Digital tools can help structure these measurements, but they also risk reproducing uncertainties when underlying data are incomplete or inconsistent. It is also difficult for firms to determine which interventions will most effectively reduce carbon emissions (Berger-Schmitz et al., 2023), because they operate within socio-technical systems undergoing systemic change, characterised by complex causalities, multiple interactions, layered structures and non-linear, evolutionary dynamics (Geels & Ayoub, 2023; Sovacool et al., 2025). Lastly, achieving net zero typically requires product, process and business model innovations that draw on complex knowledge bases (Pinkse et al., 2024), which necessitates significant learning, more challenging when activities are not repetitive.

Due to these complexities, managing net zero can be somewhat ambiguous, as there is often limited consensus on how it should be approached. This ambiguity hampers the potential of digital technologies to simplify and unify processes, because simpler and more standardised systems are generally easier to improve with digital tools (Malhotra & Schmidt, 2020; Mouthaan et al., 2023; Sovacool et al., 2025). Although digitalisation can theoretically enable more systematic and transparent routes to net zero, its success depends on organisational readiness, data quality, and stakeholder alignment.

6.3 Digital adoption for net zero in the construction sector

The empirical research conducted 53 interviews across 19 firms in France and Germany that operate at different stages of the construction value chain. These firms work in areas such as cement and concrete manufacturing, wood materials production, materials trading, building construction, architecture, building renovation, real estate development, and materials reuse. The interviews aimed to uncover what role digital technologies played in specific processes to manage sustainability and achieve net zero within the organisation. We distinguished between five processes – monitoring, analysing, planning, executing, and knowledge sharing – and identified how digital technologies were transforming these, as well as potential barriers and tensions preventing full-scale adoption.

Monitoring

Digital technologies enable companies to monitor emissions-producing activities using cameras, sensors, AI-based visual recognition, and Internet-of-Things devices. We identified several reasons why companies depend on digital-enabled monitoring in a net-zero context. Many interviewees highlighted that digital tools enhance the accuracy of activity monitoring, allowing production processes to be optimised for emissions more effectively than before. In cement factories, for instance, automatic sampling systems offer much quicker insights into oven operations. As one interviewee stated: “The rhythm used to be in the shift. Someone had to physically walk around and take it. This is now down to about once an hour in order to control the process even better” (Respondent Germany 4, (GE_4)).

Firms often need to gather large amounts of data from scattered sources. This is especially true for sustainability reporting, which depends on diverse datasets. As an interviewee explained: “Since the beginning of the year, we've been working on automating data collection for the CSRD, because we realise that we have many indicators to collect that aren't necessarily aggregated yet, and that makes things extremely complex” (FR_1). Digital monitoring is also used directly at construction sites. One interviewee demonstrated this with the following example: “The spinner arrives on site, he scans this QR code. It goes into a database which finds which formulation is in the spinner to calculate a carbon weight” (FR_3). Such tools also help to “produce auditable, verifiable, quality data” (FR_3).

Nevertheless, interviewees also reported several barriers that restrict how firms can utilise digital technologies for monitoring. Industrial assets are not always digitalised, meaning human operators still need to input data manually, which increases the risk of errors. As one interviewee explained: “The operator of the cement oven sees temperature data, quantities of fuel, all you want, and fills that in an Excel file. We have to hope he does not make mistakes” (FR_5). Sometimes, relevant data does not exist because what should be monitored has not yet been defined by regulators or standardisation bodies. For example, there are no standard product categories, prices, or insurance schemes for reused construction materials, which hampers effective monitoring in material reuse processes. Although 85,000 materials are listed in the national database, “only 30 are stamped and guaranteed as reusable” (FR_1).

Sometimes, data may exist but are hard to obtain in the required format. Discussing the energy consumption of a construction site, an interviewee noted: “I can have the bills from the energy supplier, with the euros, costs of the subscription, peak or off-peak hours. But if I want a kWh (needed to estimate a carbon footprint), it is very complicated to obtain” (FR_3). Interviewees also cited issues of accuracy and reliability. Raw data is sometimes “not sufficiently up to date” (FR_1). Finally, firms may be reluctant to share data. Explaining why material-reuse platforms struggle to attract participants, one interviewee noted: “Nobody wants to join in anymore because you're making yourself naked. You reveal your customers, you reveal your construction sites. That's the kind of thing you don't want” (GE_6).

Analysing

Interviews also indicate that firms utilise the analytical capabilities of digital technologies in the context of net zero. These technologies frequently include specialised software such as life-cycle assessment (LCA) tools, BIM systems, and CSRD reporting tools. The research team observed many examples of firms employing digital technologies to conduct assessments where they evaluate the carbon footprint of their products alongside financial and technical performance to comply with regulations or meet customer demands. Many interviewees highlighted that different supervisory bodies require various indicators (e.g., CSRD, BCorp, SBTi, Ecovadis, REP), making reporting complex. By aggregating and centralising data, digital tools “allow us to see all the benchmarks on which we can already have a KPI” (FR_3), simplifying the identification of missing information. Interviewees also emphasised that digital tools help reduce cognitive biases by “identifying wrong good ideas” (FR_2).

Firms also utilise digital technologies to explain and understand mechanisms and interrelationships. Speaking about the development of low-carbon cement, one interviewee noted: “When we have new products, new characterisations, we're going to use artificial intelligence to find influential factors, parameters that are correlated with each other” (FR_2). Interviewees further emphasised that digital tools assist in visualising large datasets and their interconnections: “A dynamic report makes it easier to assimilate and read information. The person can click, see graphs, etc., and so it's much more digestible than a big report where it's all written down” (FR_2).

However, interviewees also identified several barriers that limit the use of digital technologies for analysis. Many digital tools do not provide a comprehensive view that integrates all relevant indicators, such as price, performance, and carbon emissions. As one interviewee responsible for LCA analysis explained: “We often have projects where we model everything, and the economist needs to remodel again because the digital tool is not perfectly connected with our model and he does not obtain the costs automatically” (FR_2). Additionally, some digital tools, like energy audit and LCA software, require public certification to be recognised for compliance. Their usefulness varies across countries because legal standards differ. Interviewees also noted that the accuracy of analyses depends on the quality of the underlying data. LCA calculations may rely on generic hypotheses or ratios rather than actual values, leading to misleading conclusions.

Planning

Digital technologies such as digital twins, specialised design software, and scenario-generation tools can aid planning for net zero. Low-carbon transitions are not one-size-fits-all; they require customised solutions because the best technical design depends on biophysical conditions and local material availability. Final decisions, often made by the client, must also balance economic, technical, and environmental performance. Interviewees explained that digital technologies help create and compare alternative scenarios using predefined criteria. For example, the founder of an energy-audit and renovation firm described how their software displays alternative renovation scenarios: “Here, I'm going to have my two scenarios [...] I'm

either in D or B depending on the scenario, and I'm going to have the cost of the work modelled here" (FR_1). Interviewees also emphasised the importance of the design phase for determining a building's environmental performance; early design choices have significant long-term impacts. Digital technologies assist in optimising this phase.

Architects described using software with parametric-design features because they enable "a speed of conception that is quite insane" (FR_2) and facilitate rapid redesigns. The time saved allows for "more iteration cycles" (FR_4) before final decisions are taken. Digital tools are also employed to simulate future patterns and net-zero trajectories. Defining long-term goals and interim steps is inherently complex. One construction firm explained using AI to develop a trajectory that is both ambitious and realistic. Digital tools enabled them to analyse longitudinal datasets and incorporate diverse parameters amid varying levels of technical, economic, and social uncertainty.

However, interviewees also identified several limitations. In many cases, they reported that existing digital tools designed to support low-carbon design were not yet convincing because they lack the embedded knowledge necessary to produce trustworthy outputs. As one architect explained: "Software X knows all the impacts of a project [...] The problem is that they have a rather limited capacity to propose improvements because they do not have access to all the materials available or the location of the projects" (FR_3). The ability of digital tools to generate scenarios also depends on firms' access to sufficient data, which many lack. Similarly, interviewees expressed a desire to use a digital twin to simulate the performance of a future cement plant intended to sequester CO₂, with the aim of understanding how to operate the facility before construction. As one interviewee noted, this is crucial because "it's not going to be easy to make it work" (FR_4). However, since such systems have never been operated under real conditions, no empirical data exists, which slows the learning process.

Executing

Firms also reported using digital technologies such as 3D printing, automated factories, and digitally controlled machines to perform physical tasks automatically. Expert systems, for example, utilise AI and other models to operate complex industrial equipment. Referring to the work of a cement-plant operator, one interviewee explained: "He really has difficulty recognising where this is going. He looks at his process picture, sees six, seven, eight, nine or ten variables and would have to develop a trend as to where it is going. This expert system simply sees that. It works with trends. It sees the upward or downward trend and can initiate corrective measures in advance" (GE_4). Digital execution can also involve translating a digital model into actions performed by a robot. This is the case in concrete 3D printing, as an interviewee described: "We have developed software tools that convert these 3D files, first into a path for the robot, then into movements for the robot, and then the robot does the rest" (FR_3). Such digitally controlled machines can play a crucial role in industrialising more sustainable construction methods. Cutting machines, for instance, help produce less expensive customised wood structures by optimising the cutting process.

However, the ability to carry out tasks digitally depends on the digitalisation of physical assets, which is not always achieved. Interviewees, particularly in the cement and concrete industries where factories are often decades old, noted that some plants are not even connected to the internet, making automation impossible. They also explained that factories were designed for human operators and often feature characteristics that hinder robotisation, such as multiple staircases that robots cannot navigate. Additionally, interviewees highlighted that limited digital expertise within core professions restricts the adoption of digital technologies. Employees may lack the know-how needed to incorporate digital tools into industrial processes, further limiting automation efforts.

Knowledge-sharing

Finally, interviewees explained how digitalisation supports different stages of organisational decision-making by shaping how knowledge is created, organised, and shared. For monitoring, knowledge appears as accumulated data. Firms increasingly adopt digital technologies to store large amounts of information over long periods, whether in extensive spreadsheets or in data lakes designed to centralise sensor and process data. This long-term storage allows continuous activity tracking and makes data easier to organise. One interviewee, for example, mentioned having a decade of plant sensor data available, while another described retrieving information from the plant control system and consolidating it into a data lake before refining it for analysis.

Digital technologies also facilitate the sharing of knowledge within and across organisations. Internally, they can automate data transfers between systems and generate consistent reports after data has been cleaned and standardised. Interviewees described using tools such as PowerBI to create automated reports across factories or developing simple applications that connect CRM systems, databases, and measurement devices to produce reports without operator involvement. Collaborative platforms further support cross-divisional work; one sustainability manager emphasised the usefulness of MIRO for jointly developing the organisation's materiality assessment. Externally, digital communication channels enable the exchange of sustainability-related information, both in commercial relationships and in interactions with regulators. Commercial teams increasingly provide digital information on the carbon footprint of products, allowing customers to compare options and enhancing downstream traceability. On the regulatory side, digital energy performance assessments feed into government databases used both to map the housing stock and to detect fraud.

Although these advances are notable, gaps still exist between what providers of low-carbon solutions supply and what decision-makers actually need. As one architect pointed out, while manufacturers often provide technical documents or websites, practitioners require much simpler and more direct access to essential data. Challenges remain in coordinating digital data across organisational boundaries. Interviewees highlighted that managing bilateral information exchanges involves adapting to each partner's level of digitalisation: "everyone is more or less advanced in terms of digital systems, so we try to adapt" (FR_1). For example, a cement producer created its own app for smaller, less digitalised construction firms but still must use the digital tools mandated by larger, more advanced partners (FR-5).

Coordination challenges increase because firms must manage exchanges with a large number of actors, sometimes over 1,000 suppliers, and relationships are often short-lived: "actors do not know each other well and it is very volatile. Projects only last 18 months" (FR_5). Interviewees also highlighted the lack of digital continuity across the construction value chain. One noted that although design teams share digital models, "there is a rupture in the chain between design and manufacturing tools" (FR_1), because building design software is incompatible with the software used by digital cutting machines. Many interviewees pointed to ongoing difficulties in agreeing on shared norms and standards for exchanging data across firms (FR-5), underscoring the need to "standardise collaboration procedures and interfaces" (FR_5).

6.4 Conclusion

The analysis indicates that the integration of digital technologies into sustainability management for net zero remains inconsistent and only partly aligned with existing organisational processes. While firms increasingly see digital tools as vital for managing complex data flows and enhancing emissions-related decision-making, their transformative potential varies significantly across the main functions of monitoring, analysing, planning, executing, and knowledge sharing. This variation reflects not deficiencies in the technologies themselves but ongoing organisational, infrastructural, and institutional barriers.

When used for monitoring and analysis, digital tools such as sensors, IoT systems, automated sampling, and specialised software produce more accurate emissions data, supporting process optimisation and regulatory compliance. However, undigitalised assets, incompatible datasets, unreliable indicators, and reluctance to share information limit their effectiveness and hinder data sharing across organisational boundaries. In planning, digital tools facilitate scenario testing, parametric design, and long-term modelling to enable earlier low-carbon decision-making.

However, limited embedded expertise, uneven data availability, and the challenges of modelling emerging technologies diminish their practical value and contribute to ongoing misalignment across processes. Execution-focused digitalisation, such as 3D printing, robotic cutting, and AI-based process control, holds strong potential for emissions reductions but also faces significant obstacles. Legacy factories, outdated infrastructure, and low digital maturity in core trades often hinder the integration of advanced tools into production environments designed for manual labour. Knowledge-sharing tools, including data storage, automated reporting, and collaborative platforms, can standardise information flows, but the sector's fragmentation - characterised by short project cycles, numerous suppliers, and varied digital capabilities - creates gaps in digital continuity. Incompatible software ecosystems and the absence of shared standards further impede integration and cross-process alignment.

Our findings reaffirm that digital adoption is not merely a technological upgrade but a complex organisational and socio-technical transformation (Hanelt et al., 2021; Mouthaan et al., 2023). The main barriers to digitalisation's contribution to net zero are institutional fragmentation, legacy systems, and misaligned incentives for data exchange. Digital tools perform well within individual organisational units, but digitally enabled transitions require coordination across organisational and sectoral boundaries - coordination that technology alone cannot enforce. Achieving digitalisation's full potential for sustainability therefore requires investment not only in digital tools but also in digital literacy, organisational redesign, interoperability, and shared standards. Without these complementary capabilities, digitalisation risks reinforcing existing silos rather than enabling the integrated processes essential for effective sustainability management.

Section 7: Summary and policy implications

7.1 Bits to Benefits

The studies from The Productivity Institute (TPI) outlined here indicate the performance benefits that can result from digital investment. For example, Ye et al. (2025) have examined the relationship between digital investment and business model innovation across various national and sectoral contexts (see Section 2). Their research highlights two key themes. First, "more" digital adoption is not always "better." For instance, they demonstrate that both robot adoption in supply chains and the level of embedded finance follow a "tipping point" dynamic: benefits initially increase but then decline after a certain threshold. Second, technology benefits heavily depend on firms' ability to establish and maintain coherence or alignment between technology adoption and business model components.

Both findings indicate that simply deploying the latest technologies in isolation is unlikely to be enough to achieve transformative productivity growth. Significant gains are only realised when there is multidimensional alignment between the technologies used, business model innovation, organisational design, and policy tools.

Another recent TPI study, carried out in collaboration with the European Investment Bank, also indicated the advantages of digitalisation for the twin transition, that is, the simultaneous shift towards digital and green technologies (see Kalantzis et al., 2025, Section 3). The key finding is that digitalisation can help firms implement more sophisticated environmental strategies that integrate both climate mitigation and adaptation. Greater levels of digitalisation - meaning firms adopting a wider range of digital technologies - are also linked to more complex climate strategies.

Both studies indicate the potential advantages of digitalisation for organisational performance through business model innovation and the green transition. The conceptual approach used in the TPI study on the twin transition proves useful here by examining how these beneficial effects occur and what might limit their extent. Specifically, this suggests that digital adoption creates what are called 'affordances', meaning new potential opportunities for cost reduction, process improvement, and information gathering that would otherwise be unavailable to the firm. These affordances can be divided into 'sense-making' and 'practice-making' categories. Sense-making affordances occur when digital technologies support data collection, analysis, and insights. Practice-making affordances emerge where digital technologies enhance operational efficiency or process improvements and innovations. Both types may be vital in driving productivity transformation.

However, leveraging or actualising the benefits of these performance-enhancing affordances probably requires complementary investments and coherence between digital investments and other operational and strategic decisions. In other words, adoption and effective implementation might be necessary but not enough to fully realise the performance gains from digitalisation. To maximise these benefits, additional investment in skills, related capital equipment, and organisational change is likely needed.

7.2 Understanding digital investment in practice

Three additional TPI studies carried out during 2024 and 2025 offer new insights into how firms adopt digital technology, how these decisions are made, and how digital investment aligns with other strategic investments. The first of these studies, Massini et al. (2025) provides a thorough overview of the state of digital adoption among UK firms (see Section 4). Conducted in 2024, this study highlights the widespread use of advanced digital technologies, especially among firms in professional services, manufacturing, and larger size categories. The survey also stresses the complementarity between different digital technologies, notably in larger companies, which are investing in a variety of advanced digital tools. This echoes the findings of the earlier twin transition study, which suggests the cumulative benefits of combining digital technologies.

Interestingly, the survey shows few notable regional differences in adoption levels, with variations by sector and firm size being far more significant. This suggests that disparities in digital adoption are unlikely to explain spatial productivity differences within the UK.

A second TPI study examines in greater detail how decisions to invest in digital technologies are actually made (Golubova and Roper, 2025a and 2025b, Section 4). Here, the emphasis is primarily on the investment decision-making process rather than the nature of the investment itself. Based on a large-scale survey of investment decisions conducted in 2024, this study again highlights the strong links between motivations for digital investment and firms' broader business objectives. It also underscores the complex nature of many investments, which often combine digital technologies with either skills development or physical capital. Planning for digital investments is frequently informal, especially in smaller companies, with less than half of all firms having a specific ROI to justify digital investments. Once more, as with the survey of digital technology adoption, few regional differences are identified regarding the process of digital investment decision-making.

The third related TPI study, Pinske et al. (2026), investigates the digital investment motives and decisions of firms within the construction supply chain in France and Germany. In-depth interviews with these firms explored the decision-making process, the factors considered when making choices, and the relationship between digital investment strategies and other elements of the firms' investment approaches. The interviews indicate that integrating digital technologies into sustainability management for net zero remains inconsistent and only partially aligned with existing organisational processes. While firms increasingly regard digital tools as essential for managing complex data flows and improving emissions-related decisions, their transformative potential varies considerably across the main functions of monitoring, analysing, planning, executing, and sharing knowledge. This variation reflects not deficiencies in the technologies themselves but ongoing organisational, infrastructural, and institutional barriers.

The interviews clearly demonstrate both the sense-making and practice-making opportunities created by digital technologies. When used for monitoring and analysis – sense-making - digital tools such as sensors, IoT systems, automated sampling, and specialised software produce more accurate emissions data, supporting process optimisation and regulatory compliance. However, undigitalised assets, incompatible datasets, unreliable indicators, and reluctance to share information limit their effectiveness and hinder data sharing across organisational boundaries.

Execution-focused digitalisation – practice-making - such as 3D printing, robotic cutting, and AI-based process control, also holds strong potential for emissions reductions but also faces significant obstacles. Legacy factories, outdated infrastructure, and low digital maturity in core trades often hinder the integration of advanced tools into production environments designed for manual labour.

7.3 Adoption, implementation, alignment

These recent studies supported by TPI clearly indicate the potential organisational benefits of digitalisation, while also emphasising some of the key challenges in implementation and organisational change needed to achieve maximum benefit. Ye et al. (2025) demonstrate the advantages of digital technologies for business model innovation across various international contexts. Kalantzis et al. (2025) also highlight the benefits of digital technologies in supporting firms' moves towards net zero. Pinske et al. (2026) further reinforce this theme, suggesting the value of digital technologies across multiple functional areas that can contribute to firms' net zero objectives.

As Pinske et al. (2026) make clear, the potential benefits of digital technologies span various functions. Implementing digital techniques can assist firms with sense-making in complex environments, supporting measurement, data analysis, and interpretation. Similarly, digital technologies can aid in practice-making, with the potential to drive process improvement, transformation, and innovation.

As the survey-based study by Massini et al. (2025) suggests, the extent of digital adoption across the UK business landscape varies considerably. Firms in professional services, manufacturing, and larger organisations are leading in technology adoption, while smaller firms and those in the everyday economy tend to lag behind. Where digitalisation investments are being made, Golubeva and Roper (2025a and 2025b) suggest that these digital investments are often accompanied by complementary investments in skills and capital equipment.

Such complementary investments are probably necessary for effective implementation. However, as the study by Pinske et al. (2026) shows, effective implementation within a specific functional area is unlikely to deliver the full advantages of digitalisation. Adoption and effective implementation might be enough to produce functional benefits from digitalisation. To maximise organisational advantages, wider alignment with other elements or a firm's investment strategy is likely required.

7.4 Policy implications

While digital adoption is increasingly common among UK businesses, both the adoption and the broader use of digital technologies remain limited to specific sectors and larger companies. For many organisations, decisions about digital adoption and expanding digitalisation are likely to be deferred to the future. Policy measures aimed at supporting digitalisation, especially in smaller firms and those in the everyday economy, will therefore likely continue to be important. Cost-effective interventions that can be implemented at scale are probably the most beneficial. The Evolve Digital trial, supported by DBT as part of the Business Basics initiative, offers a possible approach using peer-learning groups to foster digital confidence and uptake (Jibril et al., 2022). Such approaches may be a useful complement to more automated approaches, such as the digital navigator app mentioned in the Technology Adoption Review 2025.

How firms decide on digital adoption or investment might also be a target for policy intervention. For many firms, especially smaller ones, decision-making about investments remains informal and often unstructured. Furthermore, many firms, particularly those in lower size categories, tend to make investments on an ad hoc basis rather than as part of a strategic plan. This likely limits the opportunity to align digital investment decisions with other areas of their activities. Policy support that encourages firms to take a more strategic approach to digital and other investments could help synchronise digital efforts with broader business activities. Such support probably involves both building capabilities and improving data analysis. Measures that enhance firms' access to and ability to interpret market and financial data may reduce uncertainties linked to investments, while better financial planning might enable firms to more effectively evaluate

investment opportunities. A recent report from Imperial College presents a series of interventions relevant to investing in low carbon technologies, which could also be adapted to support decision-making related to digitalisation (Oluleye et al. 2025).

While the potential organisational benefits of digitalisation are clear from the studies by Chander Velu and Anastasia Ri, the challenges of moving beyond functional integration are exemplified by the study by Jonatan Pinske and colleagues. Establishing a broader alignment between digital investment strategy and organisational transformation presents a more complex and strategic challenge. Policy support for this type of digital transformation is likely to be intricate and require a bespoke approach tailored to the needs of individual organisations. This support is provided through the digital adoption element of the Made Smarter programme, which offers customised specialist advice, a digital roadmap, and potentially financial backing for skills training and capital investment. Currently, such support is limited in scale and coverage, focusing on manufacturing. As suggested by the Technology Adoption Review 2025, extending the scope of Made Smarter to other sectors would be potentially valuable. Other support models may also be beneficial here, such as the Knowledge Transfer Partnership programme, which has supported some projects leading to digital transformation within firms.

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