AI ACTIVITY IN UK BUSINESSES

An assessment of the scale of AI activity in UK businesses and scenarios for growth over the next twenty years

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A report by Capital Economics for the
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EXECUTIVE SUMMARY

Capital Economics has been commissioned by the Department for Digital, Culture, Media & Sport (DCMS) to model and report on the current and future use of artificial intelligence (AI) by UK businesses. The study is based on a combination of existing literature and survey evidence, official statistics, discussions with experts at DCMS and an original survey of businesses.

In this report we present indicative numbers about the current and potential future scale of AI adoption and expenditure in the UK under different scenarios, with splits by business size and sector. The purpose of the study is to add to the existing evidence base and to highlight results from the modelling and identification of barriers that may be of interest to policy makers and regulators, as well as broader stakeholders such as investors and AI companies themselves.

The definition of AI used in this report is based on five technology categories: machine learning, natural language processing and generation, computer vision and image processing/generation, data management and analysis, and hardware. A business is classed as having adopted AI if it uses at least one of these technologies. Expenditure is broken down by spending on these AI technologies and the cost of labour that is related to the development, operation or maintenance of them. **All results should be considered as estimates; they are based on modelling conducted using survey results and publicly available statistics.**

The five key findings of this report are:

1. Current usage of AI technologies is limited to a minority of businesses, however it is more prevalent in certain sectors and larger businesses

- Around 15% of all businesses have adopted at least one AI technology, which translates to 432,000 companies.

- Around 2% of businesses are currently piloting AI and 10% plan to adopt at least one AI technology in the future, equating to 62,000 and 292,000 businesses respectively.

- As businesses grow, they are more likely to adopt AI; 68% of large companies, 34% of medium sized companies and 15% of small companies have adopted at least one AI technology; the latter make up the majority of the UK business landscape and hence drive the UK average result of a 15% adoption rate.

- AI solutions for data management and analysis are most prevalent, with 9% of UK firms having adopted them, followed by natural language processing and generation (8%), machine learning (7%), AI hardware (5%), computer vision and image processing and generation (5%).

- The IT and telecommunications (29.5%) and legal (29.2%) sectors currently have the highest rate of adoption, while the sectors with the lowest adoption rates are hospitality (11.9%), health (11.5%), and retail (11.5%).

- Large companies are more likely to adopt multiple AI technologies, however there are innovative companies using multiple AI technologies across all size brackets; around 480 large firms (20%), 1,500 medium firms (8%) and 49,300 (3%) small firms are currently using four or five AI technologies to assist in their business activities.

2. Different routes are used by businesses to source AI technologies

- Approximately 40% of businesses (172,000 firms) that have adopted AI primarily develop it in-house and 40% (171,000 firms) purchase 'off-the-shelf' solutions; the remaining 20% (88,500 firms) out-sourced the development of AI applications to external providers.

- Medium sized firms were the most likely to develop AI solutions in-house. Around 49% of these firms did this compared to 40% of large firms and 34% of small firms.

3. The scope for increased adoption is large if conditions are right

- In our central scenario, the adoption rate increases from 15.1% in 2020 to 22.7% in 2025, with an additional 267,000 businesses using AI in their operations.

- The adoption rate for small firms increases by 7.6 percentage points between 2020 and 2025 compared to 9.7 percentage points in medium sized companies and 11.2 percentage points in large companies.

- By 2040, the overall adoption rate will reach 34.8%, with 1.3 million businesses using AI in the central scenario.

4. Future spending on AI technologies is set to increase, but has a wide range of possible trajectories

- In 2020, the 432,000 companies in the UK who have already adopted AI, spent a total of £16.7 billion on AI technologies. The average spend was £9,500 per small business, £380,000 per medium business and £1.6 million per large business.

- Expenditure on AI technologies could increase to between £27.2 billion and £35.6 billion by 2025, at annual growth rates of roughly 10% and 16% respectively. In the central scenario, expenditure rises from £16.7 billion to £30.3 billion at a compound annual growth rate of 12.6%. Overall, between 2020 and 2040 expenditure on AI technologies increases from £16.7 billion to £83.5 billion in 2040 at a compound annual growth rate of 8.4% in our central scenario.

- In the downside scenario, AI technology expenditure increases to £50.4 billion by 2040 at an annual growth rate of 5.7% and in the upside scenario it increases to £127.0 billion at an annual growth rate of 10.7%.

5. Spending on labour related to AI will to increase to support AI technologies' rising prevalence

- In 2020, the 432,000 companies in the UK who have already adopted AI, spent a total of £46.0 billion on labour associated with the development, operation or maintenance of those technologies.

- The average labour spend was £24,400 per small business, £1.7 million per medium business and £3.1 million per large business.

- Expenditure on AI related labour could increase to between £80.2 billion and £103.2 billion by 2025, at annual growth rates of roughly 11.7% and 17.5% respectively. In the central scenario, expenditure rises from £46.0 billion to £88.7 billion at a compound annual growth rate of 14%. In our central scenario, expenditure on labour related to the development, operation or maintenance of AI technologies increases from £46.0 billion in 2020 to £304.2 billion in 2040 in nominal terms at a compound annual growth rate of 9.9%.

- In the downside scenario, AI labour expenditure increases to £185.2 billion by 2040 at an annual growth rate of 7.2% and in the upside scenario it increases to £456.0 billion at an annual growth rate of 12.1 %.

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1 DEFINITION OF AI AND LITERATURE REVIEW OF ADOPTION AND EXPENDITURE

In this chapter, we review the definitions of AI used in the existing literature and define AI for the purposes of this report and modelling exercise. The section also includes a review of evidence on the current scale and nature of the use of AI in businesses globally and in the United Kingdom specifically.

1.1 Definition of AI

In broad terms AI refers to the simulation of human intelligence processes by machines; it is a technology process that can learn from experience. However, there is no clear-cut unifying definition of AI and which technologies it encompasses. There are four key aspects that make it hard to develop a single, comprehensive definition of AI.

First, AI is evolving, making definitions more complicated. Rapidly increasing computing power has made it possible to compile and share ever larger volumes of valuable data, enabling the application and development of AI beyond fundamental research.[1] Today, it can be found in smartphones or in self-driving cars. It is used across industries to optimise processes and has helped governments to combat the COVID-19 virus last year.[2]

Second, there isn't agreement on what falls into the bracket of 'intelligent'. Generally, dictionary definitions of intelligence rely on relating it to human intelligence and they are as yet unable to characterise in general what kinds of computational procedures should be called intelligence. Some, such as Dr Kate Crawford, senior principal researcher at Microsoft Research, even argue that AI is not intelligent at all.[3] Over time, as the way companies use AI changes and people become accustomed to previous advances, perhaps the idea of what intelligence means will evolve.

Third, AI can seldom be regarded as a stand-alone technology, and it does not have clear-cut boundaries. It ranges from software, such as voice assistants or facial recognition, to hardware-embedded systems, including robots or autonomous vehicles. Taking the example of self-driving cars, it becomes clear how AI software is embedded into non-AI technology, which makes it hard to disentangle.

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[1] McKinsey (2017), *Artificial Intelligence – the next digital frontier?*.

[2] IBM (2020), *Artificial Intelligence (AI)*, Available at: https://www.ibm.com/cloud/learn/what-is-artificial-intelligence [Accessed August 2021].

[3] Crawford, K. (2021), *Atlas of AI - Power, Politics, and the Planetary Costs of Artificial Intelligence*, New Haven, US: Yale University Press.

Fourth, definition attempts are hampered by the fact that it is difficult to establish clear-cut boundaries amongst AI sub-fields. Computer vision for example draws heavily on machine learning algorithms but builds on and extends these.

Bearing in mind the difficulties in defining AI, there have been several different approaches used in the literature. These can be broadly summarised into three categories: qualitative, technology-based and usage-based. (See Box 1.) What they have in common is that all studies consider 'narrow' or feasible AI, rather than artificial general intelligence (AGI). They attempt to measure firms' adoption of AI technologies that cannot perform outside the task it has been designed for. It thus stands in contrast to AGI, a phenomenon still of the future, in which technology would be able to do any intellectual task a human can do.

Box 1: Definitions of AI by category

Qualitative definition

In its May 2019 Council Recommendation on Artificial Intelligence, the OECD defines AI as follows:

'An AI system is a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments. AI systems are designed to operate with varying levels of autonomy.' [4]

Similarly, in 2021, the UK National AI Strategy also defined AI as:

'Machines that perform tasks normally requiring human intelligence, especially when the machines learn from data how to do those tasks.' [5]

Usage-based definition

In its 2020 global survey on the state of AI, McKinsey defined AI based on 33 use cases across eight business functions. These include amongst others:

'Product-feature optimisation, predictive maintenance, service-operations optimization, customer segmentation, risk modelling and analytics, capital allocation, logistics-network optimisation, and performance management'. [6]

Technology-based definition

For the purposes of its Community Survey on ICT Usage and E-commerce in Enterprise, Eurostat defined AI as artificial intelligence systems that use technologies such as:

'text mining, computer vision, speech recognition, natural language generation, machine learning, deep learning.' [7]

And these are employed to

'gather and/or use data to predict, recommend or decide, with varying levels of autonomy, the best action to achieve specific goals.'

Sources: OECD, Office for AI, Eurostat, McKinsey.

First, organisations such as the OECD or the Office for AI have used a broad qualitative description.[8] This type of description allows discussion of AI with a wider audience of non-experts. However, it is not precise enough to allow quantification of AI adoption or spending, as it does not outline specific metrics for measurement. The usage-based definition employed in McKinsey's global 2020 State of AI study provides a categorisation based on business functions. It facilitates quantification of AI adoption and could potentially provide more insights than a technology-based definition on its own. However, the downside of this definition is that it does not provide explicit information on what constitutes an AI technology and in the context of a survey may capture AI activity inconsistently across different organisations or activity that is not using AI.[9][10]

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[4] OECD (2019), *Artificial Intelligence in Society*, OECD Publishing, Paris, https://doi.org/10.1787/eedfee77-en.
[5] Office for AI (2021), *National AI Strategy*, Available from: https://www.gov.uk/government/publications/national-ai-strategy.
[6] McKinsey (2020), *Global survey: The state of AI in 2020*.
[7] Community Survey on ICT Usage and E-commerce in Enterprises 2021.
[8] OECD (2019), *Artificial Intelligence in Society*, OECD Publishing, Paris, https://doi.org/10.1787/eedfee77-en.
[9] McKinsey (2020), *Global survey: The state of AI in 2020*.
[10] Office for AI (2021), *National AI Strategy*, Available from: https://www.gov.uk/government/publications/national-ai-strategy.

Conversely, using a technology-based approach such as employed by Eurostat does not provide detail on precisely what AI is used for, but does give a more robust method to determine what is included in AI and what is not. It is also able to highlight how AI systems may be software-based or embedded in devices. By clearly sorting technologies into 'AI' and 'non-AI' buckets, it makes for easier quantification but risks being too narrow and missing out certain technologies, given the interconnectedness of AI sub-fields. [11]

For the purposes of this study, we have devised a technology-based definition of AI based on a thorough review of existing studies, academic definitions, and discussion with experts at DCMS. This approach allowed us to provide specific criteria for what is included in our definition of AI to ensure the modelling was conducted on a consistent basis. This also makes it easier for survey respondents to understand and respond to the questions asked of them. In addition, although we have used broader categories than some, given constraints on sample sizes, our definition overlaps with other studies that have used a technology-based definition of AI. These include the European Commission's *European enterprise survey on the use of technologies* and a benchmark study of 1,200 European firms by ESI ThoughtLab. [12][13]

Our definition of AI includes five broad categories covering what we believe are the most commonly used technologies in the field of AI. These are (i) machine learning, (ii) natural language processing and generation, (iii) computer vision and image processing/generation, (iv) data management and analysis, and (v) hardware. (See Figure 1.1.).

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[11] Community Survey on ICT Usage and E-commerce in Enterprises 2021.

[12] European Commission (2019), European enterprise survey on the use of technologies based on artificial intelligence, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[13] ESI ThoughtLab (2021), *Driving ROI Through AI. AI best practices, investment plans, and performance metrics of 1,200 firms.*

Figure 1.1: Adopted definition of Artificial Intelligence
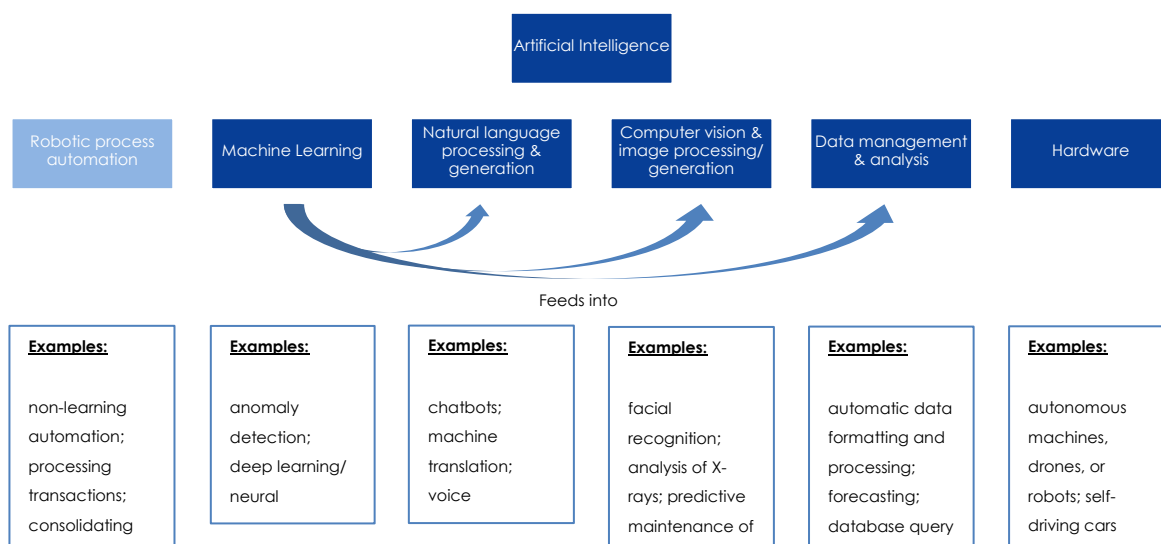
These technologies are not used in isolation; machine learning technologies often underpin or feed into other AI technologies and processes. We have presented them as separate categories and allowed survey participants to pick multiple technologies that they use. The following list provides details about the five technology categories:

- **Machine learning** (ML) refers to the ability of machines to learn and improve from experience automatically, without being specifically programmed for each possible use case. Applied cases include for example autonomous machinery, anomaly detection, or the use of deep learning and neural networks. Further, supervised, unsupervised, and reinforcement learning paradigms fall into applications of ML. It is the most general of the five applications named here.

- **Natural language processing** and **natural language generation** (NLP and NLG) are text and audio based. These technologies allow machines to interpret written or spoken text and perform tasks ranging from translation exercises and sentiment analysis to more involved chatbot services. NLG also includes voice assistants and voice recognition use cases. The automation of both these processes is enabled by ML techniques.

- **Computer vision and image processing** spans tasks such as 'seeing' or sensing a visual stimulus, understanding what is being seen, and extracting information into a form that can be used in other processes. It includes facial recognition and image classification, as well as image restoration. It is amongst others applied in manufacturing for predictive maintenance of machinery, for augmented reality purposes, or for the analysis of X-rays.

- The AI sub-field of **data management and analysis** refers to AI processes that are embedded in data management systems. It includes use cases such as database query optimization to reduce

system overload and improve outputs. Another example is the automatic gathering, formatting, and processing of data to ensure accessibility and reliability, or the use in forecasting exercises.

- ▪ **Hardware** includes autonomous machines or robots in warehouses, autonomous drones, and self-driving cars. These AI hardware units orchestrate and coordinate computations for the AI process.

In our survey, conducted for the quantification of AI adoption rates and expenditure across the UK, we also asked respondents about their adoption of robotic process automation (RPA). RPA refers to software that does repetitive manual tasks, but that does not learn from experience, and as such is not included in our core definition of AI. Usage examples include the processing of transactions or insurance claims, as well as consolidating client information to support call centre agents through screening questions at the beginning of the call. In the survey, respondents were asked about RPA to ascertain that we capture valid responses. The inclusion of RPA helps respondents to not mistakenly attribute the non-AI technology to the machine learning bucket.

1.2 Summary of literature on AI adoption

There have been a number of studies conducted globally that have attempted to measure the adoption of AI. Most have employed survey tools to aid their understanding of AI implementation and usage. (See Table 1.1.)

The studies vary in their definition of AI as well as differences in methodology, sector coverage, sample size and geography. What's more, several different metrics are used to determine adoption rates, including whether businesses use AI or not, the number of different technologies used and the extent to which these have been adopted across business functions. As such, any direct comparisons between estimates of adoption should be done with caution. For this reason, we saw the necessity of developing our own consistent definition of AI, as demonstrated in section 1.1. However, there are some common themes that emerge from the literature.

First, AI technologies have not spread equally across countries, and some are more AI mature than others. Maturity here refers to the number and scale of AI technologies implemented and is often used synonymously with 'leadership'. In a study from ESI ThoughtLab, Japan was found to be the leading AI adopting nation, with nearly a quarter of companies having implemented AI solutions at a wide scale, while the US came in second place with 18%. Substantial government investment supplementing high corporate expenditure on AI, and a more favourable view of AI technologies as augmenting rather than replacing jobs were offered as possible reasons for Japanese leadership in the study. In a European study, highest adoption of at least one AI technology was recorded in the Czech Republic (61%), lowest in Cyprus (27%), with the UK at the bottom end of the spectrum with an adoption rate of 34%. The country with the highest share of firms having adopted at least two technologies, was also the Czech Republic (40%), while the figure for the UK was 16%.[14]

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[14] ESI ThoughtLab (2021), *Driving ROI Through AI. AI best practices, investment plans, and performance metrics of 1,200 firms*.

Second, current usage of AI solutions within businesses is most prevalent in customer service functions. However, particularly amongst firms that have not been using AI technologies for a long time(non-leading), the interest in applying AI technologies in IT and data security is growing.[15]

Third, the adoption of AI varies considerably by sector. Globally, automotive and ICT sectors come out on top across several studies. Evidence from the UK suggests that finance and technology, as well as media and telecom industries are leading in AI adoption, with healthcare lagging behind.[16]

Fourth, larger companies are more likely to adopt AI in their operations than smaller ones. All studies that were reviewed found a positive relationship between business size and adoption rates. In their 2014 paper, Brynjolfsson and McAfee argued that this relationship derives from the fact that larger firms are more likely to have the computing power and amounts of digital information ('big data') necessary to make AI adoption feasible and worthwhile [17] This led Zolas et al. to hypothesize that the adoption of advanced technologies such as AI can further entrench differences between business sizes rather than act as a leveller of the playing field.[18]

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[15] [15] ESI ThoughtLab (2021), *Driving ROI Through AI. AI best practices, investment plans, and performance metrics of 1,200 firms*.

[16] EY (2021), *Data foundations and AI adoption in the UK private and third sectors.*

[17] Brynjolfsson, E. and McAfee, A. (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, W. W. Norton & Company.

[18] Zolas, N., Z. Kroff, E. Brynjolfsson, K. McElheran, D. Beede, C. Buffington, N. Goldschlag, L. Foster, and E. Dinlersoz (2020), Advanced technology adoption and use by U.S. firms: Evidence from the Annual Business Survey, Mimeo, Center for Economic Studies, U.S. Census Bureau.

Table 1.1: Summary of literature on AI adoption by maturity, use case, sector and size

Study	Maturity	Use	Sector	Business size
McKinsey Digital (2020), 'Global Survey: The state of AI in 2020' *Survey of 2,400 businesses across regions, industries, company sizes, and functional specialties*	-	• 50% of respondents had adopted AI in at least one business function in 2020 • Highest AI adoption within product- or service-development and service-operations functions (25%) • Lowest AI adoption in performance management of personnel and M&A support (less than 10%)	• Highest likelihood of AI adoption in high-tech and telecom sectors, followed by the automotive and assembly sector	-
IBM and Morning Consult (2021), 'Global AI adoption Index 2021' *Survey of IT professionals across 5,500 businesses globally*	-	-	-	• Larger companies were almost 70% more likely than smaller companies to have actively deployed AI as part of their business operations
European Commission (2020), 'European enterprise survey on the use of technologies based on the use of AI' *Survey of 9,600 firms across European economies*	-	• 42% of companies in Europe had adopted at least one AI technology • 25% of companies in Europe had adopted at least two AI technologies • 34% of UK firms had adopted at least one AI technology	• Highest adoption of at least one AI technology in Europe in ICT (63%), education (49%), and healthcare sectors (47%) • Lowest AI adoption rate in construction (36%) • Sector variation in planned AI adoption insubstantial • Highest growth prospects over two years in finance and insurance	• 39% of large enterprises (over 250 employees) employed at least two AI technologies • 21% of micro-sized enterprises (5-9 employees) employed at least two AI technologies • Difference between medium-sized and large enterprises found not to be particularly high
ESI Thoughtlab (2020), 'Driving ROI through AI' *Survey of 1,200 firms across 12 industries and 15 countries*	• APAC region the most AI mature (ahead of the Americas) • 25% of Japanese firms are AI leaders • 18% of UK and US firms are AI leaders • 15% of firms globally have reached the highest stage of AI maturity • 50% of global respondents were still at early AI adoption stages (considering or piloting simple AI functions)	• AI leaders ahead of non-leaders in the number of AI use cases implemented across their operations • 9/10 AI leaders largely or fully implemented AI in 19 functional areas • Non-AI leaders use AI technology the most in customer service functions • AI leaders aim to use AI in more outward facing functions in the future • Non-AI leaders looking to leverage AI to improve internal functionalities such as IT operations (26%) and data security (23%) in the future	• Most AI leaders globally in automotive, healthcare, and banking sectors (50% of firms at advanced or mature AI adoption stages) • Fewest advanced or mature AI firms in investment management and Insurance (<20%) • Possible increase to 80% of automotive firms and over 75% of healthcare and banking firms within 3 years • Highest growth rates over next 3 years in investment	• 50% of AI leaders had revenues exceeding $20billion • 50% of AI beginners reported revenues less than $1 billion

	• Percentage of businesses at mature or advanced adoption stages expected to more than double from 30% to 63% three years from 2019		management and insurance (over 300%)	
EY (2021), 'Data foundations and AI adoption in the UK private and third sectors' *Survey with 400 quality responses from UK businesses*	• 41% of firms younger than 10 years had employed AI in at least one business process • 1/3 of companies older than 20 years had adopted AI in at least one business process • 1/3 of respondents had not adopted AI and are not planning to do so	• 27% of firms employed AI in IT, technology, or digital business functions • AI least used in administration, finance, or procurement	• Highest AI adoption in finance and technology, as well as media and telecoms (52% and 38% respectively)	• 13% of large firms were advanced AI adopters compared to 7% of SMEs • Over 2/5 of SMEs have not adopted AI nor were planning to do so, compared to just 10% of large companies
CDEI (2021), 'UK Business Innovation Survey' *Survey of 965 UK companies in 8 sectors*	-	• 1/2 used AI and data driven technologies for marketing and sales purposes, and for adding new features to existing products • 2/5 used AI and data driven technologies in customer service and for service operations (including operations optimisation and predictive intervention)	• Highest incidence of AI adoption amongst digital and comms sectors (21%) • Lowest incidence of AI adoption in healthcare sector (12%)	-

1.3 Summary of literature on AI expenditure and sourcing

Evidence on the sourcing of, and spending on, AI technologies is more limited than that for adoption. The key findings from the literature are summarised below. (See Table 1.2.)

Businesses can source their AI technologies in various ways, which broadly fit into three categories:

- The technology is developed in-house by staff, either fully, or through modifying existing commercial or open-source systems
- Firms outsource the development of AI capabilities to external providers
- Companies purchase software or ready-to-use systems from a third party

The evidence suggests that most firms in Europe use a combination of all three, with a higher propensity of mature AI adopters, i.e. those adopting multiple AI solutions across business functions, and larger firms developing AI solutions in house according to the literature.

Spending on AI is difficult to measure, in part because it is hard to disentangle AI spend from general technology spend when AI software is embedded in non-AI investments. This is reflected in the lack of evidence on business spending on AI technologies generally. A study assessing global expenditure on AI by the International Data Foundation estimated total spending of $50 billion in 2020, which they projected could more than double to $110 billion by 2024.[19]

One finding from more recent literature is that the COVID-19 pandemic has accelerated the trend of increasing AI investments, and the recognition of its value by governments and firms. In the past year, AI has supported society in dealing with the pandemic and its large-scale disruption of business through for example optimising hospital capacity and monitoring compliance of social distancing rules in the US.[20]

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[19] IDC (2020), *Worldwide Spending on Artificial Intelligence Is Expected to Double in Four Years*, 25 August 2020, Available at: https://www.idc.com/getdoc.jsp?containerId=prUS46794720 [Accessed July 2021].

[20] Mayo Clinic COVID-19 Predictive Analytics Task Force (2021), *Deployment of an Interdisciplinary Predictive Analytics Task Force to Inform Hospital Operational Decision-Making During the COVID-19 Pandemic,* Mayo Clinical Proceedings, Volume 96 (03), pp. 690- 698.

Table 1.2: Summary of literature on the sourcing of and expenditure on AI technologies

Study	Sourcing of AI	Expenditure on AI
McKinsey Digital (2020), 'Global Survey: The state of AI in 2020' *Survey of 2,400 businesses across regions, industries, company sizes, and functional specialties*	-	• Largest shares of firms raising AI expenditure in response to the COVID-19 pandemic wee healthcare and pharma, as well as automotive (over 40% of firms in these sectors specified increased investments)
IBM and Morning Consult (2021), 'Global AI adoption Index 2021' *Survey of IT professionals across 5,500 businesses globally*	-	• 43% of firms had accelerated their rollout of AI as a result of the COVID-19 pandemic • Larger companies were 12 percentage points more likely than smaller ones to have done so
European Commission (2020), 'European enterprise survey on the use of technologies based on the use of AI' *Survey of 9,600 firms across European economies*	• Most firms employ multiple sourcing strategies to acquire AI technology • 6/10 firms in Europe sourced their AI technologies externally through purchase of software and/or ready-to-use systems • 38% hired external providers to develop AI technology • 1/5 firms developed AI solutions in-house • The larger the number of AI technologies used or the larger the size of the firm, the more likely it selected the internal development of these technologies over the purchase of non-customized ready-to-use systems	-
ESI Thoughtlab (2020), 'Driving ROI through AI' *Survey of 1,200 firms across 12 industries and 15 countries*	• Firms in early stages of AI adoption relied on outsourcing instead of internal development. Over time, these firms developed their in-house competencies, and the share of outsourced AI procurement would drop	• 2019 total expenditure on AI technology equalled $46 billion • 2019 average AI technology expenditure of $38 million per firm (0.75% of their revenue) • Leaders outspent AI beginner firms by 18% (measured as share of revenue) or by factor 7.6 (in dollar terms) more • 2019 average budget for AI was largest in absolute dollars in automotive and healthcare firms ($59.4 million and $54.1 million), • 2019 average budget for AI largest in technology firms as a share of revenue (1.21%) • Annual spending on AI to increase by 8.3% per annum • Non-leading AI adopters to drive this result: annual AI spending rising from 4.4% in 2019 to 9% in three years (AI leaders to trim spending growth from 6% in 2019 to 4.5%) • AI leaders to continue out-spending non-leading counterparts by factor 2.6 in absolute dollars

EY (2021), 'Data foundations and AI adoption in the UK private and third sectors' *Survey with 400 quality responses from UK businesses*	-	• Majority of future investments in UK likely undertaken by firms already leading in AI technology
Deloitte (2020),' Thriving in the era of pervasive AI', State of AI in the Enterprise, 3rd Edition *Survey of 1,700 firms across 9 countries*	• 50% of firms bought more AI capabilities than they built • 30% of firms used an even blend of buying and building • Firms go through a period of internal experimentation before turning towards the market to acquire AI • 50% of 'seasoned' AI users bought more than they built • 44% of firms starting out on their AI adoption journey bought more AI systems than they built	• 50% of firms had invested $500,000 - $5 million the year period • 33% recorded investments exceeding $ 5 million • 89% of firms intend to raise their AI investments in 2018 (of which 50% expect to invest 10-20% more)
IDC (2020), 'Worldwide Spending on Artificial Intelligence Is Expected to Double in Four Years *Analysis across 32 countries*	-	• 2020 spending on AI: $50 billion • 2024 spending on AI: $110 billion • Retail and banking industries to spend most on AI solutions • Fastest growth in AI spending over 2020-2024 to occur in media, the public, and professional services sectors

2 BARRIERS TO GROWTH IN THE ADOPTION OF AI

In this chapter, we synthesise third-party literature and draw upon expertise in DCMS to identify the barriers that firms face in developing and adopting AI technologies. We consider both internal barriers (those that are within a firm's control) and external barriers, as well as identifying supply and demand side issues. (See Table 2.1.) This review will feed into the modelling in section 3 and will highlight any areas that have policy implications.

Table 2.1: Key internal and external barriers

Internal barriers *These are barriers that are within a firm's control.*	External barriers *These barriers are outside a firm's direct control.*
Cost of AI adoption *High procurement and operation costs of AI as well as an uncertain return on AI investments impact on a firm's* **demand** *for AI solutions.*	**Labour supply** *Lack of sufficient skilled personnel within the firm and in the overall labour market constrain the* **supply** *of AI solutions.*
Data *Legacy infrastructure and insufficient data sophistication to leverage data's potential reduce a firm's* **demand** *for AI solutions.*	**Regulation** *Regulatory costs, restrictive privacy laws, and uncertainties around the liability for damages caused by AI limit* **demand** *for AI solutions and* **supply** *of AI technologies.*
The human factor *An incomplete understanding of the benefits of AI technologies and a lack of desire to move off the well-trodden path limit a firm's* **demand** *for AI solutions.*	**Ethics** *Opacity and lack of explicability and accountability inhibit the creation of trust in AI technologies, slowing* **demand** *for AI solutions.*

Notes: Based on quantitative evidence from the European enterprise survey on the use of technologies and additional qualitative evidence. Classification of internal and external barrier may differ from European Commission study.

2.1 Internal barriers

Barriers to the adoption of AI technologies are often broken down into those that are internal and those that are external.[21] Internal barriers are specifically within a firm's control, while firms are subject to external barriers such as labour supply challenges or the regulatory environment that they cannot directly influence.

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[21] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

We have identified three main internal barriers: financial factors, data challenges, and human traits and enterprise culture. These all act as limiting factors to demand for AI.

Amongst the nearly 10,000 replies from EU companies participating in the EU Commission's European enterprise survey, financial factors posed the biggest internal barrier to the adoption of AI technologies.[22]. Half of respondents stated that the procurement cost of the relevant technologies as well as the subsequent operational costs posed a challenge for them. Results for the UK are similar to the EU average. Two in five respondents to a survey by CDEI spanning nearly 1,000 firms already using AI and data-driven technologies (DDT) named lack of funds to purchase or develop further technologies as a barrier.[23] SMEs in the UK struggled particularly with the procurement costs of AI technologies, with a quarter of micro firms and 13% of small and medium-sized firms highlighting the cost barrier in a 2019 survey of 1,500 firms by Be the Business.[24]

A second financial factor inhibiting the adoption of AI across firms is the uncertain return on investment (ROI) and the measurement of AI induced benefits. While revenue increases or time saved could be easily quantified, an improved customer experience arising from the adoption of AI is difficult to measure accurately. Having surveyed 3,000 global CIOs in 2019, Gartner found that 42% did not fully understand the benefits and uses of AI in the workplace.[25] A study by ESI Thought Lab found that for many of the 1,200 firms surveyed across 15 countries, calculating the ROI on AI was still an art, not a science; 79% of surveyed firms that had reported negative or no ROI had no system in place to measure returns.[26] This lack of understanding and performance metrics could explain the widespread scepticism the MAPI Foundation found amongst 200 US manufacturing firms on achieving sufficient ROI from AI solutions. In their 2019 study, 40% of respondents cited this as a key barrier.[27] Consequently, an uncertain ROI depresses demand for AI.

The second main barrier to adoption of AI technologies cited by firms can be classified as 'data challenges'. Growth in the adoption of AI technologies across economies has been found to be inhibited by legacy infrastructure; existing information systems are often not structured to facilitate advanced analytics. Legacy infrastructure mainly poses a challenge for firms at the beginning of the AI adoption journey. The European enterprise survey found that 42% of companies not currently using AI technologies cited insufficient or incompatible existing IT infrastructure as a major barrier to AI adoption.[28] The findings are supported in the UK by evidence from the roughly 400 respondents to a survey by EY that existing infrastructure is the current biggest internal barrier to the improvement of data foundations and subsequent implementation of AI solutions, especially for large companies.[29]

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[22] Definition of external and internal barriers differ slightly between European Commission study and this current work, some separate categories were grouped together, for example, categories 'lack of public or external funding', 'cost of adoption', and 'cost of adapting operational processes' have been combined into one barrier named financial factors.

[23] CDEI (2021), *UK Business Innovation Survey.*

[24] Be the Business (2019), *The UK's Technology Moment – why 2020 can be the year that changed our trajectory.*

[25] Gartner (2019), *3 Barriers to AI Adoption,* Available from: https://www.gartner.com/smarterwithgartner/3-barriers-to-ai-adoption/ [Accessed July 2021].

[26] ESI ThoughtLab (2021), *Driving ROI Through AI. AI best practices, investment plans, and performance metrics of 1,200 firms.*

[27] MAPI Foundation (2019), *The Manufacturing Evolution: How AI Will Transform Manufacturing & the Workforce of the Future,* Available at: https://static1.squarespace.com/static/58862301f7e0ab813935c244/t/5d48788e7b132300013f15b0/1565030557296/MAPI-ITIF-AI-workforce-report-F.pdf [Accessed July 2021].

[28] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[29] EY (2021), *Data foundations and AI adoption in the UK private and third sectors.*

Even if a firm is not struggling with legacy infrastructure, successful AI adoption relies on it having a well-functioning data ecosystem. Companies need to have reached sufficient data sophistication to be able to break down data silos, and to have the capability to aggregate, pre-analyse, and identify high-value data. This is because factors such as data completeness, relevancy, and bias will affect the output value and overall quality of an AI system. Firms in the European Union seem to have recognised the need to improve data processes before moving into the use of advanced technologies to leverage the data's potential. Only one fifth of respondents cited lack of internal quality data as a major obstacle in their implementation of AI technologies – with a greater share of non- AI technology adopters than AI adopters considering this a challenge.[30]

The barriers to AI adoption relating to data ecosystems vary by company size. According to findings from IBM's Global AI Adoption Index 2021, surveying 5,500 IT professionals, difficulty collecting data represents the largest hurdle for small firms. Conversely, the biggest barrier for large firms was related to increasing data complexity and data silos, which inhibit the transparent and efficient flow of information across the firm. [31] In the UK, access to quality data and data management remain a key concern amongst companies, according to the Business Innovation Survey. Half of respondents were concerned about the former and nearly three quarters stated fragmentation of data across different sources as a challenge in their internal processes. Given that a solid data ecosystem is a prerequisite for the adoption of (further) AI technologies, this represents a drag on AI adoption growth in the country.

Lastly, company culture and typical human traits can stand in the way of the adoption of new technologies. Few surveys attempt to capture these factors. As creatures of habit, humans can be reluctant to change their method of doing things once they have found a way they deem effective and efficient. Considering technology specifically, there is often a fear of human redundancy. The difficulty in understanding and predicting decisions made by computer algorithms can lead to a feeling of loss of control amongst the workforce and can generate a negative perception of new technologies.[32] For example, today AI is already capable of evaluating X-rays as well as radiologists can in research settings. If this technology is adopted by healthcare providers more broadly, the role of radiologists will have to transform.[33] These general human tendencies often translate into either failing to see the need for AI, or an incomplete understanding of technologies' advantages.

For these reasons, support for AI adoption amongst leadership staff is required to ensure a broad company stakeholder buy-in and to avoid unnecessary frictions.[34] Top management support ensures that sufficient organisational resources are employed in the adoption of new technologies and helps reduce organisational resistance.[35] In the UK, lack of management sponsorship of AI was cited as one of the least pressing barriers

[30] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[31] IBM Watson and Morning Consult (2021), *Global AI Adoption Index 2021*.

[32] Marr, B. (2019), *The 4 biggest barriers to AI adoption every business needs to tackle*, Forbes, Available at: https://www.forbes.com/sites/bernardmarr/2019/02/25/the-4-biggest-barriers-to-ai-adoption-every-business-needs-to-tackle/?sh=670f7b452731 [Accessed August 2021].

[33] Gartner (2019), *3 Barriers to AI Adoption,* Available from: https://www.gartner.com/smarterwithgartner/3-barriers-to-ai-adoption/ [Accessed July 2021].

[34] Forbes (2019), *The 4 Biggest Barriers To AI Adoption Every Business Needs To Tackle*, Available at: https://www.forbes.com/sites/bernardmarr/2019/02/25/the-4-biggest-barriers-to-ai-adoption-every-business-needs-to-tackle/?sh=3e5b4bb92731 [Accessed July 2021].

[35] Yoon, T. E., & George, J. F. (2013), *Why aren't organizations adopting virtual worlds?*, Computers in Human Behaviour, 29(3), 772–790. https://doi.org/10.1016/j.chb.2012.12.003.

by firms. Respondents had broadly accepted the need for the adoption of data driven technologies, which could reflect positively on AI adoption rates over time.[36]

2.2 External barriers

External barriers are hinderances to the adoption of AI that are outside a firm's immediate control. Amongst those most frequently cited in the literature surveyed for this study are labour supply constraints, the regulatory framework, and ethical considerations.

First, the most cited external barrier to the successful adoption of AI technologies was the lack of AI and data science skills amongst existing employees and a shortage of talent in the wider workforce in both EU and UK surveys.[37] These shortages constrain the supply of AI technologies. AI technologies require workers who are educated and trained not just to develop, but also to maintain and troubleshoot AI systems. In addition, it requires people without the technical ability, but who understand how and where the use of AI technologies could improve the business process. A skilled workforce generates trust in AI and will reduce the impact of some of the anxieties and organisational cultural influences mentioned above around the adoption of AI.[38] This will ultimately have an impact on demand for AI technologies, if AI systems are more widely trusted and accepted.

The three key relevant skills lacking amongst the EU workforce were programming, big data management, and machine learning or modelling skills. Needs for the first were more pronounced in the financial and insurance sector, where 59% of firms highlighted an undersupply. Manufacturing firms on the other hand were more likely to report machine learning or modelling skills as being in short supply.[39] [40]

Among existing staff, 55% of AI companies not adopting AI technologies in the EU reported lacking skills relevant to AI – for companies using AI this percentage was considerably less, 28%.[41]

With respect to the external workforce, there is no significant difference in AI adopting and non-adopting firms struggling to fill vacancies with people possessing the right skills. Both face the same job market, with nearly six out of ten firms in the EU highlighting this challenge in the European enterprise survey. However, small firms face an uphill battle competing for talent: they are often unable to offer the rewards needed to attract and retain skilled data scientists, being outbid by larger companies that often already heavily invest

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[36] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[37] EY (2021), *Data foundations and AI adoption in the UK private and third sectors*.

[38] European Parliamentary Research Service (2020) *The ethics of artificial intelligence: Issues and initiatives*, Brussels: Scientific Foresight Unit, Available from: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/634452/EPRS_STU(2020)634452_EN.pdf [Accessed September 2021].

[39] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[40] Ipsos Mori (2020) *Understanding the UK AI labour market: 2020*, Available at: https://www.gov.uk/government/publications/understanding-the-uk-ai-labour-market-2020 [Accessed October 2021].

[41] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

in AI (such as Google, Facebook, Amazon, etc.).[42] This is problematic because small firms require skilled staff to leverage the potential of AI solutions. Currently, 42% of micro firms (<10 employees) reported finding complex algorithms to be difficult to understand and trust. Consequently, the relative advantage of firms who have already heavily adopted AI technologies is extended, and technology adoption differences become more entrenched.[43]

Second, regulatory uncertainty and costs have been quoted by firms across surveys as one of the key reasons why they progressed cautiously in the adoption of AI technologies. In spite of awareness of AI's benefits, for example in claims administration and underwriting in the case of the insurance industry, regulatory uncertainty ultimately acts as a drag on demand for AI technologies.[44]

Uncertainty with respect to the scope and implementation of privacy laws can constrain the adoption of AI for example in the healthcare and finance sectors, where there are strict rules regarding physical, network, and process security measures to ensure sufficient protection of personal data.[45] In the European enterprise survey, both for the EU on average and the UK, strict standards for data exchange relating to privacy laws were cited as a barrier to AI adoption by around one-third of firms. Significant differences in responses from AI adopters and firms planning to adopt AI technologies did not exist, albeit firms with more than 250 employees were more likely to cite privacy laws as a barrier. Compliance with data security and protection guidelines becomes more complicated with scale – the larger the firm, the more likely it reported data security compliance as a major hurdle in the adoption of AI technologies.[46]

Another obstacle in the adoption of AI for firms are uncertainties around the liability for damages that could be caused by the technologies. This is not universally relevant but depends on the business context each company operates in. For automakers and manufacturers as well as healthcare providers, however, it does pose a particular concern.[47] Amongst EU firms, an average of 27% of AI adopters cited this as a considerable barrier to their adoption of further AI technologies, while 38% of non-AI adopting firms were concerned about these liability aspects. In the UK, an average of 30% across firms at all stages of AI adoption mentioned liability as a key challenge.

Moreover, in its third edition of the State of AI in the Enterprise, Deloitte found that nearly 60% of its 2,700 surveyed firms across 9 countries that had adopted at least one AI technology worried about future regulatory directives. Their responses came in light of Canada's 'Directive on automated decision-making' and the EU's 'European strategy for data'. Firms did not oppose further regulation, but 62% feared that ineffective or regressive regulation would be implemented, that would hamper research and stifle innovation. Further, prospective AI companies might be deterred from starting given regulatory uncertainties, limiting the supply of AI technologies on the market. This is something for policymakers to be

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[42] Metz, C. (2017), *Tech giants are paying huge salaries for scarce A.I. talent,* New York Times, Available at: https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html [Accessed September 2021].

[43] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[44] ESI ThoughtLab (2021), *Driving ROI Through AI. AI best practices, investment plans, and performance metrics of 1,200 firms*.

[45] European Parliamentary Research Service (2020), *The impact of the General Data Protection Regulation (GDPR) on artificial intelligence*, Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/641530/EPRS_STU(2020)641530_EN.pdf [Accessed October 2021].

[46] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[47] *Ibid.*

aware of when devising strategies to increase AI adoption amongst firms and encourage the supply of AI technologies. [48]

Lastly, 44% of respondents to ESI Thought Lab's survey ranked managing ethical issues of AI adoption as amongst their top three adoption obstacles. Scale and AI maturity increased the likelihood of firms identifying ethics as a major barrier. Concerns revolve around trained biases and algorithmic transparency: the real world is biased in many ways (naming just a few with gender, sexuality, ethnicity, religion), meaning that real-world data will also have these features. With this training data feeding into them, algorithms internalise biases and they become embedded into the technologies – exacerbating the problem of bias. [49][50] In addition, AI's ability to detect patterns in data may pose privacy risks; even when no direct access to personal data is provided, AI has the potential of allowing the re-identification of anonymised personal data in ways that were not foreseen before machine learning capabilities became widespread. Further, there are concerns around the transparency and accountability of algorithms themselves. There is no clear guidance as to which ethical guidelines are being encoded into them, how algorithms have reached their conclusions, and who effectively is responsible for algorithms' outputs. [51] The interdependencies between these issues and the questions regarding liability mentioned in the paragraph above add complexity and complicate the development of universal ethical guidelines.

Together, opacity and lack of explicability and accountability inhibit the creation of trust in AI technologies and thereby slow down demand for and adoption of these technologies amongst businesses. IBM's Global AI Adoption Index[52] for 2021 showed that 58% of respondents considered these factors their third biggest impediment to AI adoption, after lack of skilled staff and data challenges. In the UK, the Business Innovation Survey from 2021[53] found that half of respondents said they had processes in place to address bias and discrimination in datasets, However, around a fifth of respondents still considered they were lacking the in-house skills to ensure appropriate ethical governance, a skills deficit that was a hinderance to their adoption of (further) AI technologies.

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[48] Deloitte (2020), *Thriving in the era of pervasive AI. Deloitte's State of AI in the Enterprise*. 3rd edition.

[49] Hao, K. (2019), *This is How AI Bias Really Happens -— and Why It's so Hard to Fix*. MIT Technology Review, 4 Feb 2019

[50] Angwin, J., Larson, J, Mattu, S., and Kirchner, L. (2016), *Machine Bias: There's software used across the country to predict future criminals. And it's biased against blacks*, ProPublica, 23 May 2016.

[51] McKinsey (2017), *Artificial Intelligence – the next digital frontier?*.

[52] IBM Watson and Morning Consult (2021), *Global AI Adoption Index 2021*.

[53] CDEI (2021), *UK Business Innovation Survey.*

3 MODELLING CURRENT ADOPTION OF AI AND SCENARIOS FOR GROWTH

This chapter sets out our findings on the adoption of AI technologies by UK businesses.[54] Using results from a survey of firms, we estimate the number of businesses currently adopting AI technologies and present the breakdown by business size, sector and type of technology. Subsequently, we produce three scenarios to demonstrate the potential path of AI adoption over the next twenty years.

About the survey

In order to collect primary data on the adoption of AI by UK businesses we conducted a survey of businesses in conjunction with YouGov. The survey asked four questions covering current practices and future plans for both AI adoption and spending. The total sample size was 2,008 firms, covering all sectors of the economy and all business sizes. Surveyed businesses were exclusively in the private sector.

The responses to the survey have been used as the key input into the modelling of current and future adoption. Businesses were asked whether they use or were piloting any of the technologies as set out in the definition of AI and for how long. Subsequently, they were asked whether they intend to adopt any of the technologies in the future.[55] Please see appendix for further details on the survey and methodology.

3.1 Current adoption of AI

There are a range of estimates in the literature regarding the adoption of AI, however due to the difficulties in defining and measuring AI highlighted in section 1.1, these estimates vary and are often not directly comparable. Using our survey of UK businesses, we have estimated adoption based on the definition of AI set out in section 1.1.

Overall adoption in the UK

Our survey results suggest that 15% of the 2.8 million UK private businesses have adopted at least one AI technology[56], which translates to 432,000 organisations when scaled to the total private business population. A further 62,400 firms are currently piloting at least one AI technology, corresponding to 2% of the business

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[54] The term 'businesses' for the purposes of our study refers to private sector firms.

[55] Sector categorisation based on self-identification from survey from the following options: manufacturing, construction, retail, finance & accounting, hospitality & leisure, legal, IT & telecoms, media/marketing/advertising/PR & sales, medical & health services, education, transport & distribution, real estate, other.

[56] See Appendix A2 for details on the methodology.

population. An additional 292,000 have not yet employed any AI technology but are planning to adopt at least one in the future – this equates to 10% of all UK businesses. (See Table 3.1.)

Table 3.1:Share and number of businesses adopting AI, UK, 2020

	Share of businesses	Number of businesses
Adopting	15%	431,672
Piloting	2%	62,376
Planning to adopt in the future	10%	292,469

Notes: Based on analysis of survey results. Sample size for adopting, piloting, and planning to adopt is 2,008. Results have been scaled to UK private business demographics.
Source: Capital Economics analysis of YouGov survey.

This estimate is on the conservative side relative to other published estimates. The European Commission's pan-European study found an adoption rate of 34% for the UK and a rate of 20% for UK firms planning to adopt AI. [57] A paper by McKinsey suggests that half of businesses responding to their survey had adopted AI. However, these figures are not directly comparable, with the former not claiming to have a representative sample of the UK economy and the latter focussed predominantly on larger companies. Meanwhile, a study based on a survey of US businesses with a large and representative sample suggested a lower adoption rate of 8.9% but this was only focused on machine learning solutions. [58]

Of the businesses that have adopted AI, our survey suggests that two fifths were only using one type of technology, with 10% using all five.

As well as a likely increase in the number of companies using AI, given the 10% of firms that are planning to adopt AI, responses from the survey also indicated that the intensity of use within companies will also increase. Three out of ten companies who have already adopted at least one AI technology intend to introduce further technologies in the future. Those that have already adopted two technologies were most likely to respond they would adopt at least one more (44%), followed by adopters of one technology (39%).

Adoption by business size

Results from our survey suggest that there is a positive correlation between business size and AI adoption rates. This overall relationship is in line with estimates in previous studies, including the European

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[57] European Commission (2019), European enterprise survey on the use of technologies based on artificial intelligence, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[58] Zolas, N., Z. Kroff, E. Brynjolfsson, K. McElheran, D. Beede, C. Buffington, N. Goldschlag, L. Foster, and E. Dinlersoz (2020), *Advanced technology adoption and use by U.S. firms: Evidence from the Annual Business Survey*, Mimeo, Center for Economic Studies, U.S. Census Bureau.

Commission's European enterprise survey, EY's report on data foundations in the UK, IBM's *2021 Global AI Adoption Index* and statistical analysis for the United States by Zolas et al. [59][60][61][62]

Our survey found that large companies are twice as likely as medium-sized companies to have adopted AI; 68% of large companies have adopted compared to 34% of medium-sized businesses and 15% of small businesses. Our results here differ from the European Commission's study which concluded that the adoption rate for medium and large firms was similar.[63] The difference in the two studies' results could stem from the European Commission's work having a considerably bigger number of large businesses in their sample. (See Table 3.2.)

As with current adoption, the proportion of businesses piloting or planning to use AI in the future vary by business size. Around 9% of large firms were piloting at least one AI technology in 2020. This compares to 5% of medium sized firms and 2% of small ones. In the future, AI adoption will likely increase across all business sizes, with the biggest anticipated increase in large companies. Among those large businesses that have not adopted AI yet, 40% anticipate doing so in the future, according to our survey responses. This stands in contrast to 16% of small firms and 18% of medium firms. (See Table 3.2.)

Table 3.2: Share and number of businesses adopting AI by business size, 2020

	Per cent			Number of businesses		
	Small	**Medium**	**Large**	**Small**	**Medium**	**Large**
Adopting	15%	34%	68%	414,387	12,080	5,204
Piloting	2%	5%	9%	59,895	1,781	700
Planning to adopt in the future	16%	18%	40%	287,875	3,879	715

Notes: Based on analysis of survey results. Sample size of 1,116 for small adopting or piloting businesses, 291 for medium-sized firms, and 601 for large firms. Sample size for planning to adopt is 947 for small,185 for medium, and 216 for large businesses. Source: Capital Economics analysis of YouGov survey.

In terms of the intensity of AI use, large companies are more likely to adopt more AI technologies; 21% of AI adopting large companies are using all five technologies compared to 11% in AI adopting medium sized companies and 10% in small companies. This is likely due to larger budgets, a wider scope of activities and greater benefits from implementation through economies of scale, or the higher ability of large companies to employ people with the appropriate skill set. However, there are innovative companies using multiple AI technologies across all size brackets. Over 3,000 medium firms and 90,000 small firms are currently using

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[59] IBM Watson and Morning Consult (2021), *Global AI Adoption Index 2021*.

[60] EY (2021), *Data foundations and AI adoption in the UK private and third sectors*.

[61] Zolas, N., Z. Kroff, E. Brynjolfsson, K. McElheran, D. Beede, C. Buffington, N. Goldschlag, L. Foster, and E. Dinlersoz (2020), *Advanced technology adoption and use by U.S. firms: Evidence from the Annual Business Survey*, Mimeo, Center for Economic Studies, U.S. Census Bureau.

[62] European Commission (2019), European enterprise survey on the use of technologies based on artificial intelligence, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

[63] *Ibid.*

four or more AI technologies to assist in their business activities. This translates to 3% and 8% respectively of all firms of that business size in the UK. (See Figure 3.1.)

Figure 3.1: Number of technologies adopted by business size, 2020 (per cent of adopting businesses)
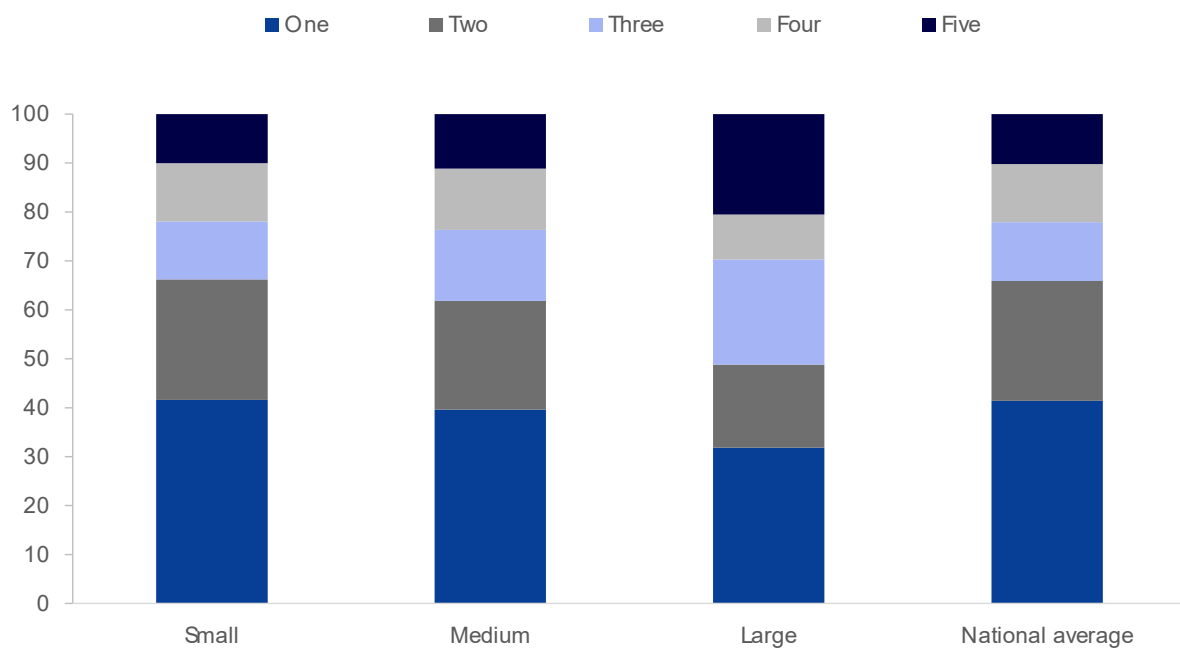
Notes: Sample size of AI adopting firms is 660.
Source: Capital Economics analysis of YouGov survey.

Data management and analysis is the most commonly adopted AI solution, with 60% of all AI adopting companies in the UK, or 256,000 businesses, using it in the past year. The second most prevalent AI solution adopted in our sample was natural language processing and generation, which 213,000 businesses have adopted. Typical use cases here could be in customer service functions, where chatbots and voice assistants streamline customer queries and direct them to the most relevant department or person. (See Figure 3.2)

This trend looks set to continue. Surveyed companies that do not currently use AI, but are planning to, responded most frequently that they were intending to adopt AI solutions for data management and analysis. This equates to 259,000 companies or 89% of current non-AI using businesses that communicated plans to use AI in the future. The adoption of natural language processing technology is the second most frequent response amongst non-AI using companies in the UK; 248,000, or 85% of non-AI using firms intending to adopt any AI in the future, plan on adopting the technology in the future.[64]

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[64] Survey respondents could select multiple technologies they intended to adopt in the future.

Table 3.3: Share and number of businesses planning to adopt AI by technology, 2020

	Per cent	Number of businesses
Data management and analysis	89%	259,000
Natural language processing and generation	85%	248,000
Machine learning	67%	196,000
Hardware	50%	146,000
Computer vision and image processing and generation	39%	114,000

Notes: Share calculated as a percentage of UK businesses that have not yet adopted any AI technology but plan to do so in the future, 292,469 businesses.
Source: Capital Economics analysis of YouGov survey.

The technology mix is similar across business sizes.AI solutions for data management and analysis were the most frequent use case in each business size; 204,000 small, 6,000 medium-sized, and 3,000 large businesses have adopted this AI technology. AI solutions revolving around natural language processing and generation were the second most frequently adopted AI technologies, but in each business size the technology remains 10 to 16 percentage points below the adoption rate of data management AI solutions amongst AI-using businesses. Interestingly, the share of medium-sized AI-adopting UK businesses that use machine learning is roughly the same as the share adopting natural language processing. Conversely, a large gap between the adoption of these two technologies exists amongst small and large AI-adopting businesses. This result might be driven by the finding that medium-sized companies in our sample are more likely to develop AI solutions in-house and machine learning technology is potentially the easiest of the five to do this for. (See Figure 3.2.)

Figure 3.2: Adoption by technology and business size, 2020 (per cent of UK businesses that have adopted AI)
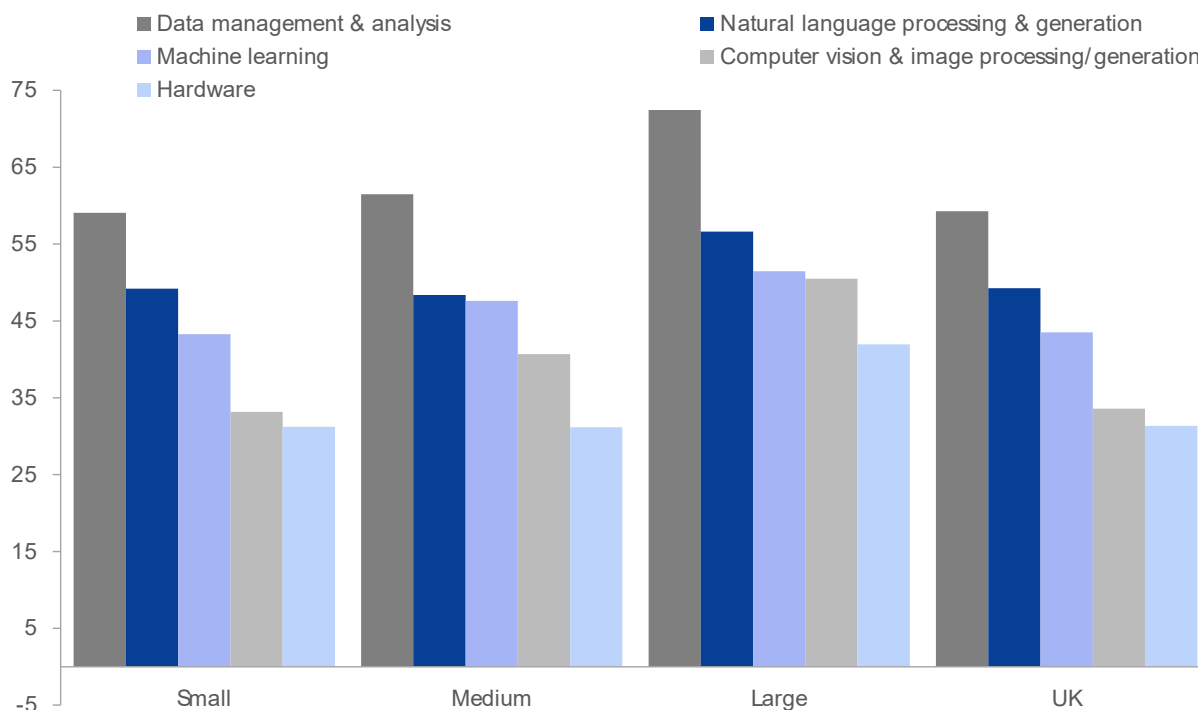
Notes: Sample size of AI adopting firms is 660. Respondents could select multiple technologies.
Source: Capital Economics analysis of YouGov survey.

Adoption by sector

We can disaggregate results on adoption by business sector. However, the results should be treated with caution as small sample sizes in some sectors mean that estimates were made based on business size across the entire sample.

The sectors with the highest shares of businesses currently adopting at least one AI technology are legal and IT & telecoms; both record adoption rates of around 30%. In the legal sector, the uses of AI range from reviewing contracts and legal research to generating forecasts of litigation outcomes.[65] The next highest sectors in terms of adoption rate are finance and accounting as well as the media, marketing, and sales industry.[66] Among other things, AI is used in the latter industry to process data and customer profiles to tailor messages to each client. According to our survey, AI technologies are currently being used least in retail and health services, where around 12% of businesses have adopted at least one AI technology. (See Figure 3.3.)

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[65] Emerj (2021), *AI in Law and Legal Practice – A comprehensive view of 35 current applications*, Available at: https://emerj.com/ai-sector-overviews/ai-in-law-legal-practice-current-applications/ [Accessed September 2021].
[66] YouGov sector: Media/marketing/advertising/PR & sales.

These findings are supported by previous work done on AI adoption. In its global survey of 2,400 companies on the State of AI, McKinsey reported the highest likelihood of AI adoption in high-tech and telecom sectors. UK evidence from the 2021 *Business Innovation Survey* equally highlighted that the incidence of AI users was highest in the digital and communications sectors, and lowest in healthcare.[67]

The four sectors with the highest adoption rates (legal, IT & telecoms, finance and accounting, and the media, advertising and sales industry) also have the highest incidence of non-AI users that plan to adopt at least one AI solution in the future. Additional sectors that might see sizeable increases in AI adoption rates in the near to medium term based on their survey responses are transport and distribution, and education. Nearly one fifth of transport and distribution companies are currently employing AI in some capacity, while 16.5% of current non-AI adopters are planning to do so in the future, equating to 14,500 businesses. For the education sector, the adoption rate in 2020 is 17% (or 5,500 firms), with a further 4,500 (or 17% of current non-adopting companies) planning to do so. (See Figure 3.3.)

Figure 3.3: Share of businesses adopting by sector, 2020 (per cent)
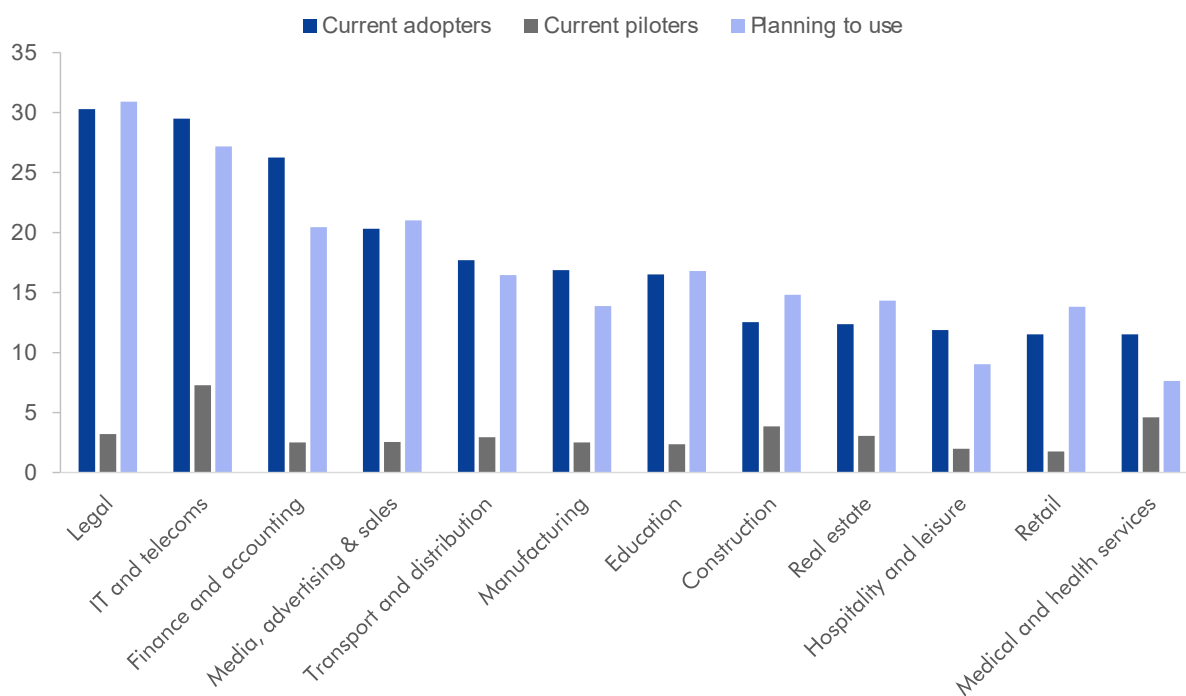
Accounting for the size of sectors, the majority of AI adopters in absolute terms are working in IT & telecoms and hospitality & leisure, with 66,500 and 52,500 firms currently using AI respectively. In comparison, the legal sector, which has the highest adoption rate, has nearly 18,000 firms currently using AI. (See Figure 3.4.)

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[67] CDEI (2021), *UK Business Innovation Survey*.

Conversely, the highest absolute number of firms not deploying any AI currently is in hospitality and leisure, with 380,000 non-users. This is followed by the construction and retail sectors in which 288,000 and 210,000 businesses respectively are currently not using any AI. Measured in absolute numbers, there is a lot of potential to increase the number of firms adopting AI in these sectors.

Two per cent of businesses across the United Kingdom are currently piloting at least one AI technology. As with adoption, there is variation between sectors. IT & telecoms is the leading sector in terms of piloting AI, with over 16,000 firms doing so, or 7.3% of all businesses in the sector. Although the health services sector has the lowest incidence of AI adopters, it has the second highest share of companies currently piloting at least one AI technology; one in twenty of businesses in the sector currently do so. This result could be driven by the COVID-19 pandemic, which has accelerated the spread of AI adoption in the sector as AI solutions were developed to combat the challenges posed by the pandemic, such as optimising hospital capacity.

Figure 3.4: Number of businesses adopting by sector, 2020 (thousands)
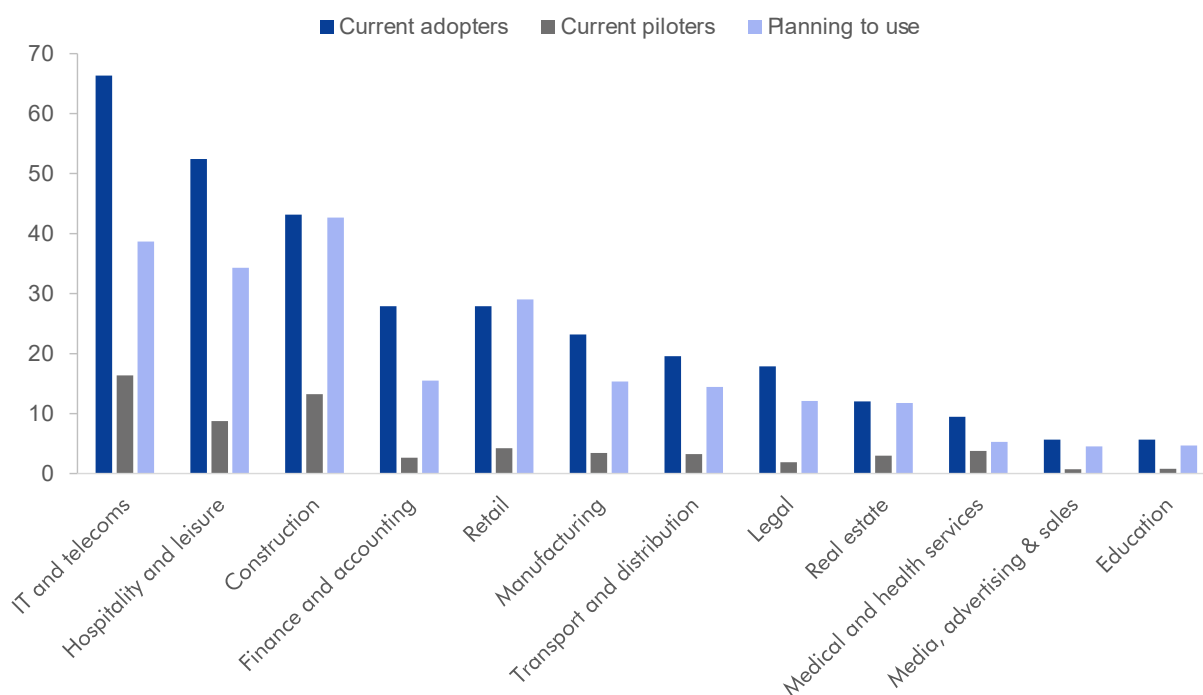
Notes: Sample size for adopting and piloting is 2,008; Sample size for planning to adopt is1,349; Excludes 'Other' category.
Source: Capital Economics analysis of YouGov survey.

3.2 Adoption rate scenarios

To estimate the potential path of AI adoption over the next twenty years we have developed three scenarios for the adoption rate by business size and sector.

Overall adoption in the UK

The scenarios are driven by results from the survey of businesses. Respondents were asked specifically about whether they plan to adopt in the next year and these results are used as the projections in 2021 for all scenarios. The overall adoption rate increases from 15.1% in 2020 to 15.5% in 2021.

Over time, the rate of adoption will be affected by whether firms can overcome barriers to adoption or whether the government can remove or reduce some of these obstacles. The scenarios reflect this. Between 2021 and 2025, the AI adoption rate across the UK economy increases by between five (downside) and ten (upside) percentage points from its current level.

Data from the European Commission's survey of businesses conducted in 2019 is used to determine the extent to which current barriers to adoption prevent businesses that have said they plan to adopt AI in the future from doing so by 2025. In the downside scenario, we assume that the most frequently cited barrier is not overcome by that percentage of businesses. This barrier is the difficulty in hiring new staff in most sectors and translates to an average of 55% of firms that are planning to adopt being unable to do so by 2025. In the upside scenario, we use the barrier which the smallest share of firms considers an obstacle to AI adoption and assume that all but these firms will overcome any constraints and adopt AI by 2025. In most sectors, this barrier is a lack of external funding or concerns about liability for damages caused by AI in most sectors. An average of 22% of firms consider it to be an obstacle to their adoption. In the central scenario the mid-point between the upside and downside is used (38.5%).

In the central scenario, AI adoption grows at an annual rate of 10% until 2025, translating to 267,000 more businesses adopting an AI technology and thereby increasing the share of businesses adopting from 15.1 to 22.7%. In the downside scenario, adoption increases by 8% annually, so that 64,000 fewer businesses have adopted AI by 2025 than in the central case, and the overall share of businesses adopting is 20.6% by that point. Meanwhile, in the upside scenario in which more barriers to adoption are overcome, 762,000 businesses have adopted AI by 2025, compared to 699,000 in the central scenario. The share of businesses adopting is 24.8% in 2025 in this scenario, with annual adoption growth of 12%.

Further ahead, the number of businesses adopting by 2030 is determined directly by the share of businesses that responded to the survey that they were either piloting AI or planned to adopt it. In the central scenario, it is assumed that all these businesses do adopt AI by 2030. This equates to a total of 912,000 businesses, or 27.5% of all UK businesses.[68]

In the upside and downside scenarios, it is assumed that the equivalent of 120% and 80% of these businesses adopt AI by 2030 respectively. Although it is difficult to accurately assess these values, it is plausible that a certain number of businesses fail in their adoption of AI after piloting. This could for example be because they do not see a sufficient return on their investment, or because they encountered disruptions when switching from an existing to an AI system.[69] On the other side of the spectrum, some businesses previously hesitant in adopting AI, may change their mind and implement AI solutions as they see others reaping benefits.

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[68] It has been assumed that the total UK business population grows at an annual rate of 1.5% for small and medium-sized firms, and 0.4% for large firms between 2020 and 2040. For further detail, see Methodology section A.3, page 58.

[69] Be the Business (2019), *The UK's Technology Moment – why 2020 can be the year that changed our trajectory.*

In the longer term, we assume that varying shares of businesses adopt AI in the period between 2030 and 2040 who in 2020 indicated no plans to do so - businesses are unlikely to have foresight more than a decade in advance, and AI technologies will become better understood, easier to implement and cheaper over time. This assumption is informed by academic models on the diffusion of innovation, which suggest there are a considerable share of entities that adopt a 'wait and see' approach before adopting an innovative new technology.[70] This results in the adoption rates in the three scenarios fanning out further. Our modelling suggests that between 1.1 million and 1.6 million, or 18.8% to 40.6%, of UK businesses could have adopted AI technologies by 2040.

Figure 3.5: Share of businesses adopting by scenario, 2020-2040 (per cent)
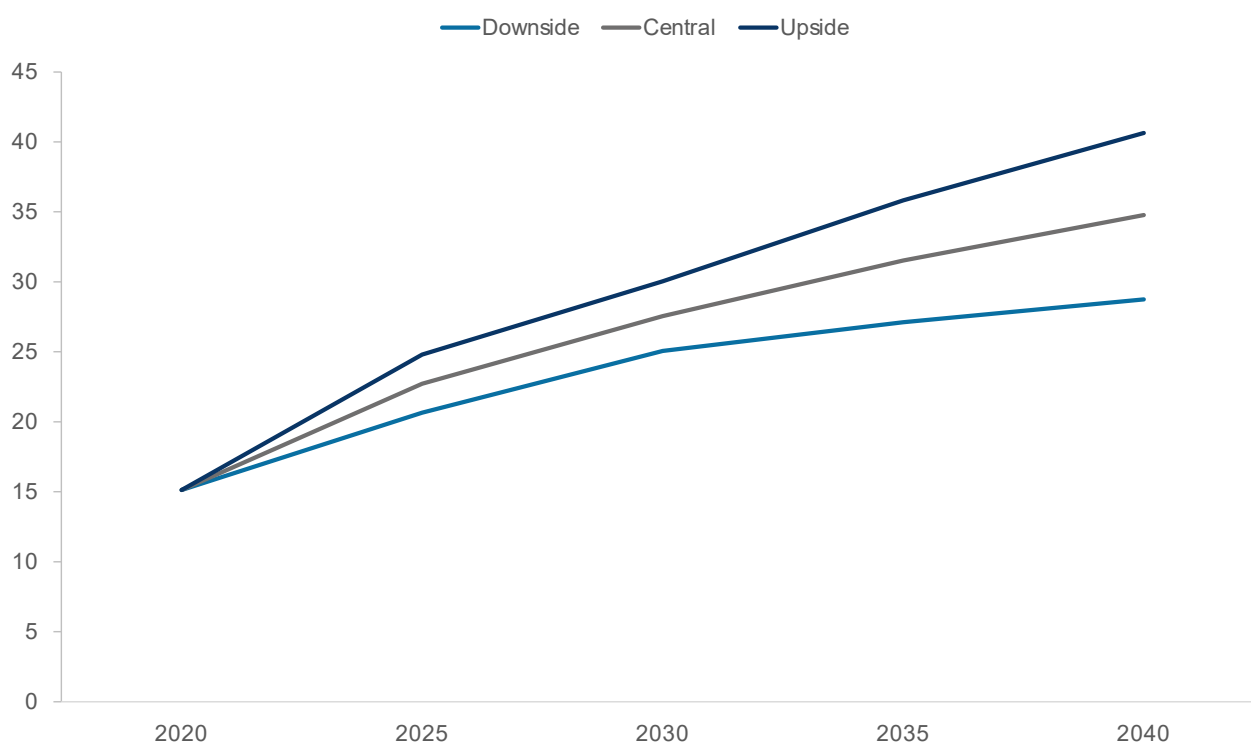
Source: Capital Economics analysis of YouGov survey.

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[70] Dearing, J.W. and Cox, J. G. (2018), *Diffusion of Innovations Theory, Principles, And Practice*, Health Affairs, Vol. 37 (No. 02), pp. 183-190.

Figure 3.6: Number of businesses adopting by scenario, 2020-2040 (thousands)
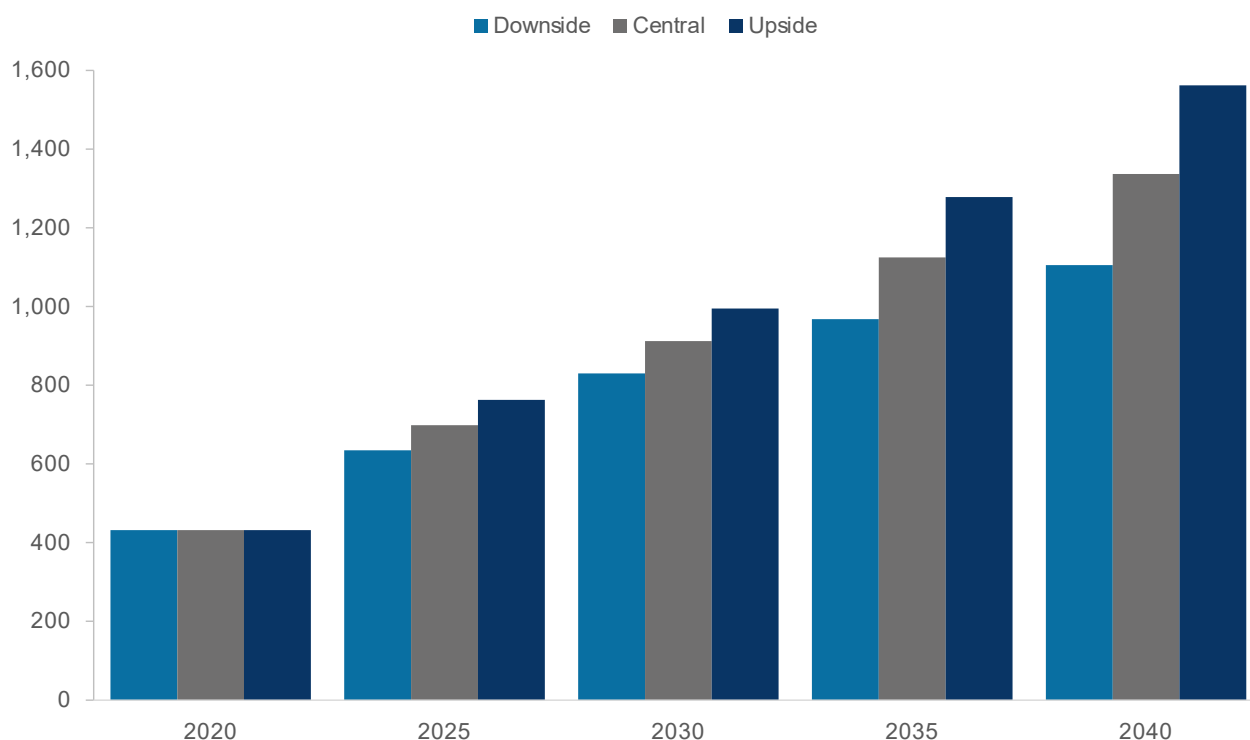
Source: Capital Economics analysis of YouGov survey.

Adoption by size

Large firms remain the most likely to adopt AI in all scenarios. With an adoption rate of 68% in 2020, nearly twice that of medium companies, AI adoption amongst large companies reaches 86% by the end of this decade in the central scenario before flattening out. By 2040, between 6,900 (downside) and 7,600 (upside) large companies will have adopted at least one AI technology.

Small firms could reach the 2020 adoption rate of medium firms (34%) by 2040, with a total of 1.3 million small businesses adopting at least one AI technology in the central scenario. Meanwhile, the adoption rate for medium sized companies increases from 34% in 2020 to 55% in 2040 in the central scenario.

Across all scenarios, adoption rates by 2040 for small businesses range between 28 and 40%, for medium firms between 50 to 61 %, and for large firms between 83 to 92 %.

Figure 3.7: Share of businesses adopting by size, central scenario 2020-2040 (per cent)
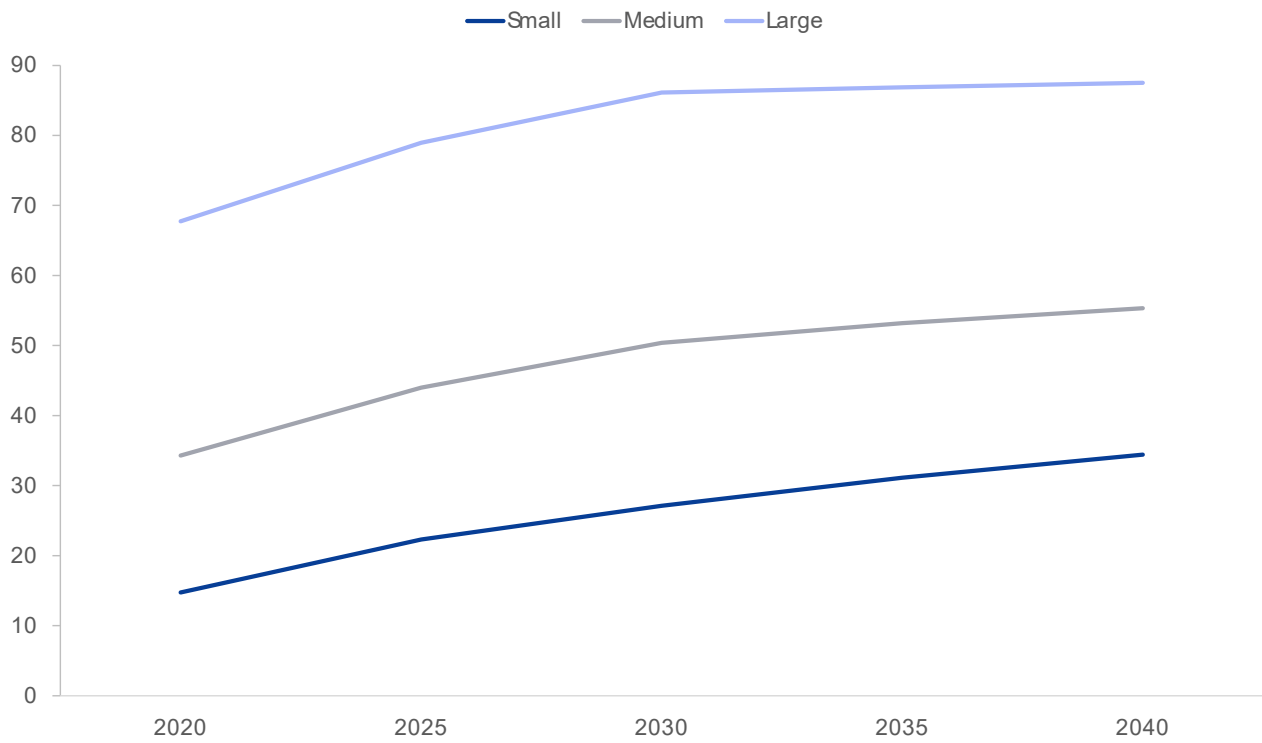
Source: Capital Economics analysis of YouGov survey.

4 MODELLING EXPENDITURE ON AI AND SCENARIOS FOR GROWTH

This chapter sets out our findings on UK businesses' expenditure on AI technologies and labour associated with AI in 2020, and its potential growth over the next twenty years under three scenarios.[71]

4.1 Current sourcing and expenditure on AI

About the survey

The responses to the survey have been used as the key input into the modelling of current and future expenditure. Businesses who answered that they had adopted at least one AI technology were asked how much they had spent on AI related labour in the past twelve months and AI technologies over the past three years. Subsequently, they were asked how much they intended to increase their current total expenditure on AI, combining labour and technology, in the next year and the coming five years. Please see appendix for further details on the survey and methodology.

AI sourcing

Businesses deploy different methods to acquire the AI technologies that they use. Some have dedicated in-house resource to develop software appropriate for their business, either from scratch or by adapting existing code. Some businesses out-source this process to an external provider, while others purchase 'off the shelf' solutions.

The incidence of in-house development, either fully or by adapting existing software, was the same as the purchase of external software or ready-to-use AI systems. For all businesses, these accounted for around 40% of sourcing each, with 20% of businesses purchasing ready to use technologies. The survey only allowed respondents to pick their primary source, and it is likely that many companies deploy a combination of approaches.

Sourcing strategies varied by business size. Small firms were most likely to have purchased external software or ready-to-use systems; half of small firms that use AI did this compared to an average of 40% across all businesses. This is likely to reflect that there are more limited resources available to small businesses and that many small firms will be looking for simpler, less tailored, AI solutions for tasks such as channelling customer queries to the relevant person or department, and basic analysis of mentions of the company in the social media space.

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[71] The term 'businesses' for the purposes of our study refers to private sector firms.

Medium sized firms were the most likely to develop AI solutions in-house. Around 49% of these firms did this compared to 40% of large firms. This is also reflected in the expenditure figures discussed further below in this section, which show medium sized companies have a higher spend on labour related to AI relative to their turnover. Although we don't have information on the reasons for this from the survey, it may be as a result of high growth tech-based companies which are more focused on achieving growth through deploying AI backed processes. (See Table 4.1.)

Figure 4.1: Adoption rates by sourcing type, 2020 (per cent of adopting UK businesses)
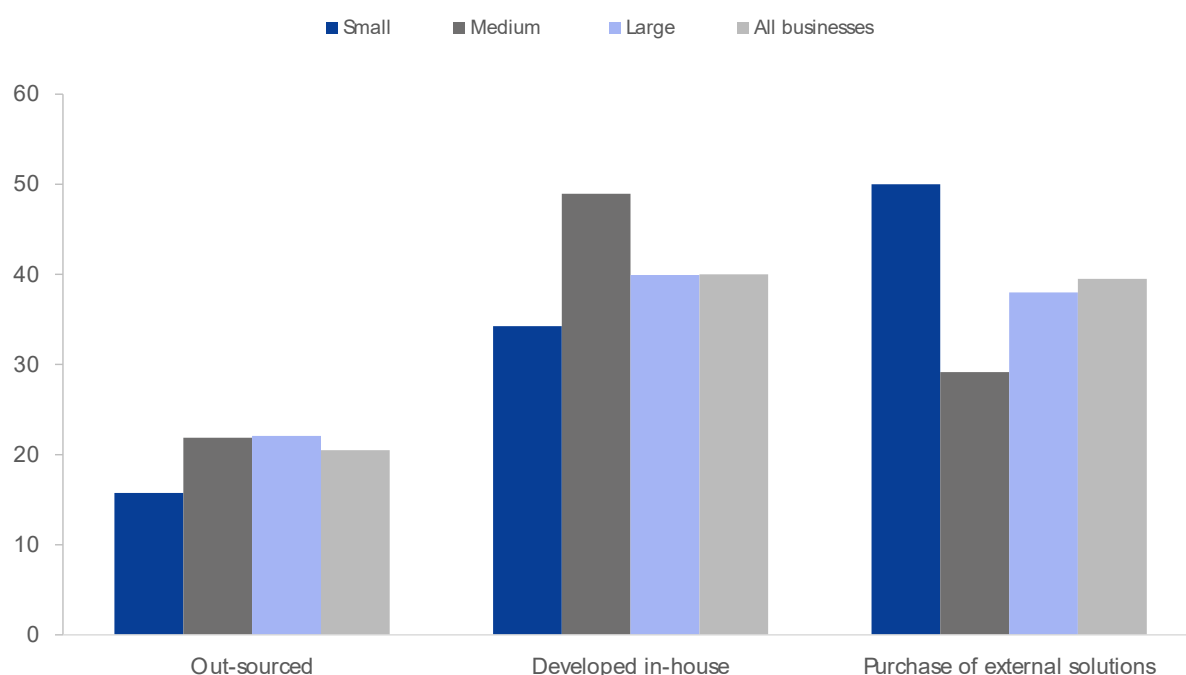
Notes: Sample size of AI adopting firms is 660.
Source: Capital Economics analysis of YouGov survey.

Evidence from other countries suggests a higher share of businesses purchasing 'off the shelf' solutions. For example, in a pan-European survey of businesses, nearly six in ten (59%) rather than 40% of firms responded that they had sourced their AI technologies externally through purchase of software and/or ready-to-use systems. [72] Furthermore, the share of firms who developed AI solutions in-house compared to sourcing externally did not vary significantly by business size. Much of the difference with the results from our survey is likely to be explained by the fact that these are not exclusive options and the European Commission survey allowed firms to pick more than one option. Businesses who said that they mainly develop AI in-house may also have purchased some software externally, but this would not be captured in our numbers.

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[72] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

Overall expenditure on AI

Our survey suggests that, in 2020, the estimated 432,000 companies in the UK who have already adopted AI, spent a total of £16.7 billion on AI technologies and £46.0 billion on labour associated with development, operation or maintenance of those technologies. The expenditure across the UK last year equates to an average labour spend of £106,700 per company. The estimate of spending on technologies includes both new investment and investment in updating and maintaining existing capital. Meanwhile, the labour cost estimate is likely to include a range of workers that have some involvement with AI but are not necessarily focused on it for the entirety of their role. Within spending estimates there will be some large contributing companies that are high tech and entirely AI focused. However, there are also many companies that incorporate some form of AI to improve operations across a broad range of industries and activities.

Trying to benchmark these spending figures is difficult because of the lack of available AI expenditure data and different studies' divergent scope of what is considered AI. According to the International Data Corporation, global expenditure on AI technologies only totalled $50.1 billion in 2020.[73] This would suggest that our estimate of £16.7 billion for the UK only is at the high end, but we do not have information on their sample and it is possible that they have employed a different definition of AI, have a smaller sample size per country or do not have a representative sample by business size and sector.

Meanwhile, comparing to other technologies our estimate looks reasonable. In real terms, our estimate of spending on AI technologies is equivalent to total spending on software by UK companies in 1999, or 19% of expenditure on hardware, software, and R&D in 2019.[74] Furthermore, AI technologies spending is a fraction of the total supply chain spending of UK businesses (around 1%), which totalled £1,738 billion in 2020. In addition, combined total expenditure on AI technologies and labour represents 9% of turnover of adopting businesses.[75]

Expenditure by size

As with adoption rates, expenditure on AI technologies and labour related to AI shows considerable variation by business size.

On average, small firms spent £9,400, medium firms spent £380,000 and large firms spent £1.6 million on AI technologies in the last year, equating to 1.6, 4.0, and 2.4% of their turnover respectively. Consequently, medium sized firms are spending more of their turnover on AI than large or small companies. This is consistent with the fact that a higher share of medium sized firms who adopt AI develop it in-house. Large companies accounted for nearly half of total expenditure on AI technologies in the UK in 2020 (£8.2 billion), having spent nearly twice the amount medium-sized companies did (£4.6 billion). Small companies comprised 23% of total AI technologies spending in 2020 (£3.9 billion).

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[73] IDC (2020), *Worldwide Spending on Artificial Intelligence Is Expected to Double in Four Years*, 25 August 2020, Available at: https://www.idc.com/getdoc.jsp?containerId=prUS46794720 [Accessed July 2021].

[74] ONS (2020), *Annual gross fixed capital formation by industry and asset*, Software, Available at: https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/annualgrossfixedcapitalformationbyindustryandasset [Accessed September 2021].

[75] ONS (2020), *Supply and Use Tables,* Available at: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables [Accessed September 2020].

In terms of spending on labour, total spend was £46.0 billion. If we assume an average total coast per employee of £50,000, this expenditure figure would translate to 920,000 people, or roughly 3% of the UK workforce, currently having exposure to AI technologies in their jobs. Medium-sized companies made up £20.0 billion of the total labour spend of £46.0 billion, having spent nearly £4 billion more than large companies (£16 billion). This is consistent with the fact that a higher share of medium sized firms who adopt AI develop it in-house.

Taken together, overall spending related to AI amounted to £62.8 billion last year, equivalent to 9.0% of adopting firms' turnover. Large firms spent a little over £24 billion, while small firms spent around £14 billion. Medium-sized firms spent the most in absolute terms and relative to turnover, having bought £24.5 billion of AI technologies and related labour in 2020, representing around one fifth of the total expenditure that year. (See Table 4.1.)

Table 4.1: Labour and technology expenditure on AI, 2020 (£ billion, per cent of turnover)

	£ billion				% of AI adopting firms' turnover			
	Total	Small	Medium	Large	Small	Medium	Large	Total
Total	62.8	14.0	24.5	24.2	5.8	21.3	7.0	9.0
… of which labour	46.0	10.1	20.0	16.0	4.2	17.3	3.4	6.6
… of which technology	16.8	3.9	4.6	8.2	1.6	4.0	2.4	2.4

Notes: Sample size of AI adopting firms is 660.
Source: Capital Economics analysis of YouGov survey.

Expenditure by sector

Given the importance of business size in determining spend, and because of differences in the composition of the sample between sectors, it is difficult to draw conclusions about sectoral differences other than those that are driven by the mix of business sizes within the sector. As such, the breakdown by sector is driven by the number of different sized businesses adopting AI technologies within the sector, rather than any underlying behavioural variation in AI expenditure.

Expenditure results for each sector are consequently driven by the number of businesses having adopted AI technologies in each. We find that manufacturing businesses spent the most in 2020, a total of £9.6 billion. The sector is followed by leading AI adopting sectors (in terms of number of businesses) IT and telecoms and hospitality and leisure, which have spent £6.3 billion and £6.2 billion on AI technologies and labour last year respectively.

Table 4.2: Labour and technology expenditure on AI by sector, 2020 (£ billion)

Expenditure on AI in 2020	Technologies	Labour	Total
Manufacturing	2.5	7.1	9.6
Construction	1.0	2.7	3.7
Retail	1.5	3.8	5.3

Finance and Accounting	1.1	2.9	4.0
Hospitality and leisure	1.6	4.5	6.2
Legal	0.3	0.9	1.2
IT and telecoms	1.7	4.7	6.3
Media/marketing/advertising/ PR & sales	0.2	0.4	0.6
Medical & human health services	0.8	2.4	3.2
Education	0.2	0.8	1.1
Transport and distribution	0.8	2.3	3.1
Real estate	0.4	1.0	1.3
Other	4.7	12.5	17.2

4.2 Spending scenarios

To estimate the potential trajectory of AI expenditure over the next twenty years we employed the same three scenarios as in chapter 3 for the expenditure on AI technologies by business size and sector, including a central, upside and downside scenario.

Overall expenditure in the UK

In 2020, the 430,000 AI adopting firms spent a combined £16.7 billion on AI technologies and £46.0 billion on labour associated with AI. Technology expenditure includes investment in new AI solutions as well as the replacement and maintenance cost of existing AI technologies.

For technologies spending, we separate out new investment from spending on the update and maintenance of existing assets. Of the £16.7 billion spent in 2020, we estimate that £3.8 billion was new investment with the remainder comprising update and maintenance spend. An estimate of depreciation is used to calculate this expenditure, which is based on a four year life-cycle for software assets.[76] (See Appendix A.3 for more detail.)

We use survey responses to a question about businesses' anticipated increase in expenditure to project new investment forward over the next five years and total investment from previous years to calculate update and maintenance investment. The modelling also accounts for the additional businesses that adopt AI during this period as estimated in section 3.2. In the central scenario, spending on AI technologies increases by £13.5 billion to £30.3 billion between 2020 and 2025, at a compound annual growth rate of 12.6%.

These figures seem reasonable given other estimates of the rate of spending growth. Deloitte's *State of AI in the Enterprise* report suggested that firms intended to spend 10% to 20% more on AI in 2019.[77] Meanwhile,

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[76] NIESR (2017), *Academic review of asset lives in the UK,* IESR Discussion Paper No. 474 , Available at:
https://www.niesr.ac.uk/sites/default/files/publications/DP474.pdf [Accessed September 2021].
[77] Deloitte (2020), *Thriving in the era of pervasive AI. Deloitte's State of AI in the Enterprise*. 3rd edition.

IDC's forecast of global AI technologies spending suggests that spending on AI will double over the next four years, equivalent to an annual rate of 22%.[78]

Considering the downside and upside scenarios, AI technologies spend could increase to between £27.2 billion and £35.6 billion by 2025, at annual growth rates of roughly 10 and 16% respectively.

For the longer-term projections, for which we do not have survey data, there are three key factors to consider: the increase in number of firms using AI, the increase in intensity of use by a given firm and the change in the price of technologies. In order to capture these in our scenarios, we use long term projections for automation and employment to create a volume index, take the annual change in this index to represent the flow rather than stock, and then convert this into nominal terms using a price deflator. (See Appendix A.3.)

A study by McKinsey provides estimates of maximum potential automation by 2050 in each sector, as well as a range of scenarios for the pace of adoption.[79] In their study, they also consider the development of new technologies – we exclude this and focus only on the expenditure on current AI technologies. In addition, we adjust the pace of adoption by sector based on the adoption rates from our modelling. (See Appendix A.3.)

In our central scenario, the percentage of work hours automated reaches around half of its potential maximum by 2040, with some variation between sectors. Total spending on AI technologies increases to £83.5 billion by 2040 at a compound annual growth rate of 8.4%. The average spend of AI adopting firms increases from £38,800 to £62,400 over the period. As a percentage of turnover, spending on AI technologies remains approximately constant between 2020 and 2040, at around 2.4% (See Figure 4.3.)

The rate of growth slows later in the forecast period as the price of technologies falls over time. To estimate the fall in the price of current AI technologies we considered the scale of price falls seen in other similar technologies. The price of software and computers and other electronic products dropped by between 20% and 35% over ten-year periods (from 1997). Subsequently, prices tended upwards, likely due to new and better technologies coming onto the market, such as smart phones and tablets. Our modelling does not account for new AI technologies, and therefore we have assumed a 30% drop in prices over the twenty year period. Recent supply chain disruptions have been taken into account and result in increases in the price index until 2023. (See Figure 4.2.)

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[78] IDC (2020), Worldwide Spending on Artificial Intelligence Is Expected to Double in Four Years, 25 August 2020, Available at: https://www.idc.com/getdoc.jsp?containerId=prUS46794720 [Accessed July 2021].

[79] McKinsey Global Institute (2017), *A future that works: Automation, Employment, and Productivity*, Available at: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary [Accessed September 2021].

Figure 4.2: Price index of varying technologies (Index, Year 0 = 100)
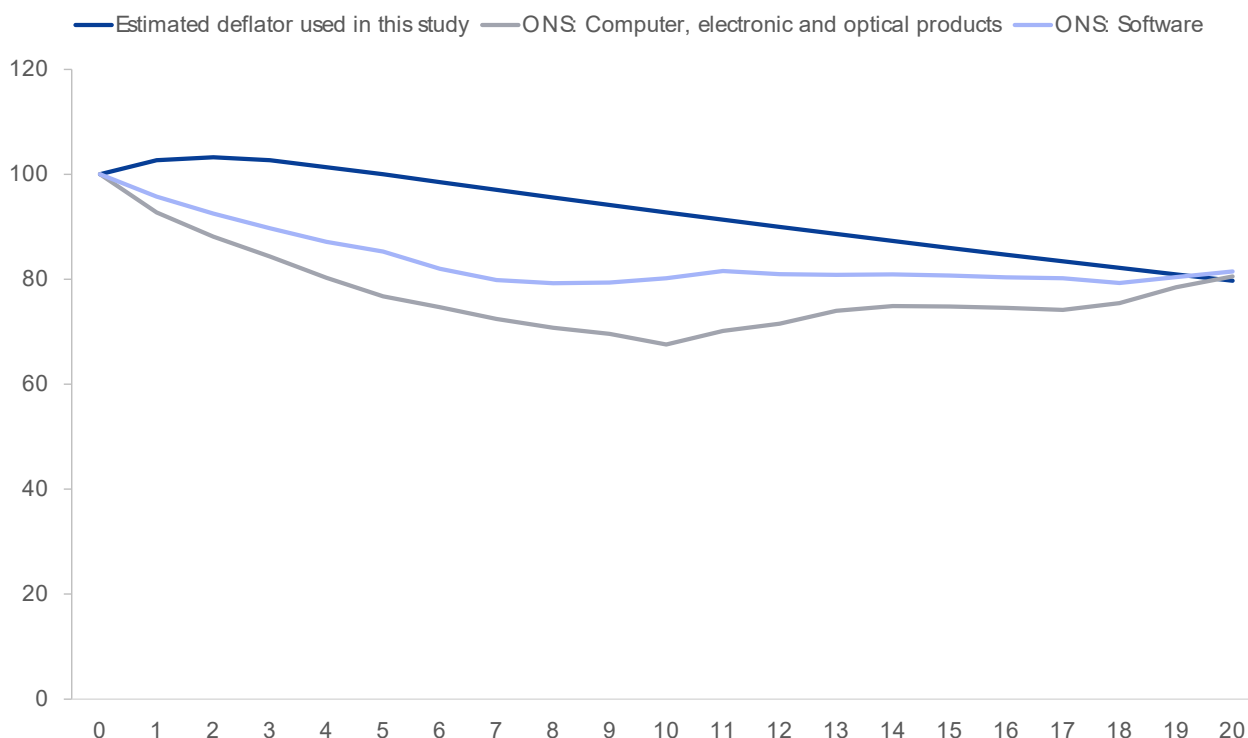
Notes: Start point is 2020 for the deflator of this study. For the ONS deflators for computer, electronic, and optical products as well as the deflator on software, the start year is 1997.
Source: ONS.[80]

In the downside scenario, with automation reaching around one fifth of its potential, total spending on AI technologies reaches £50.4 billion by 2040. This corresponds to an annual growth rate of 5.7%. Between 2020 and 2040, in this scenario, average expenditure of adopting firms on technologies still rises by around £7,000 to £45,600. Spending accounts for 1.8% of turnover of adopting firms in 2040, down from 2.4% in 2020. While individual business expenditure decreases as a share of turnover, partly driven by the fall in prices, overall spending continues to increase. (See Figure 4.3.)

In the upside scenario, the percentage of work hours automated reaches over 90% of its potential maximum on average. Consequently, average expenditure on technologies rises to £81,300 per adopting company over the period. Total spending equates to £127 billion in 2040, growing at a rate of 10.7% annually. As a result, expenditure on technologies as a share of turnover of adopting firms is 3.2% in 2040, an increase by around 0.8 percentage points from its 2020 value.

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[80] ONS (2021), *Investment in intangible assets in the UK*, Available at: https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/articles/experimentalestimatesofinvestmentinintangibleassetsintheuk2015/2018 [Accessed September 2021].

Figure 4.3: Expenditure on technology by scenario, 2020-2040 (£ billion)
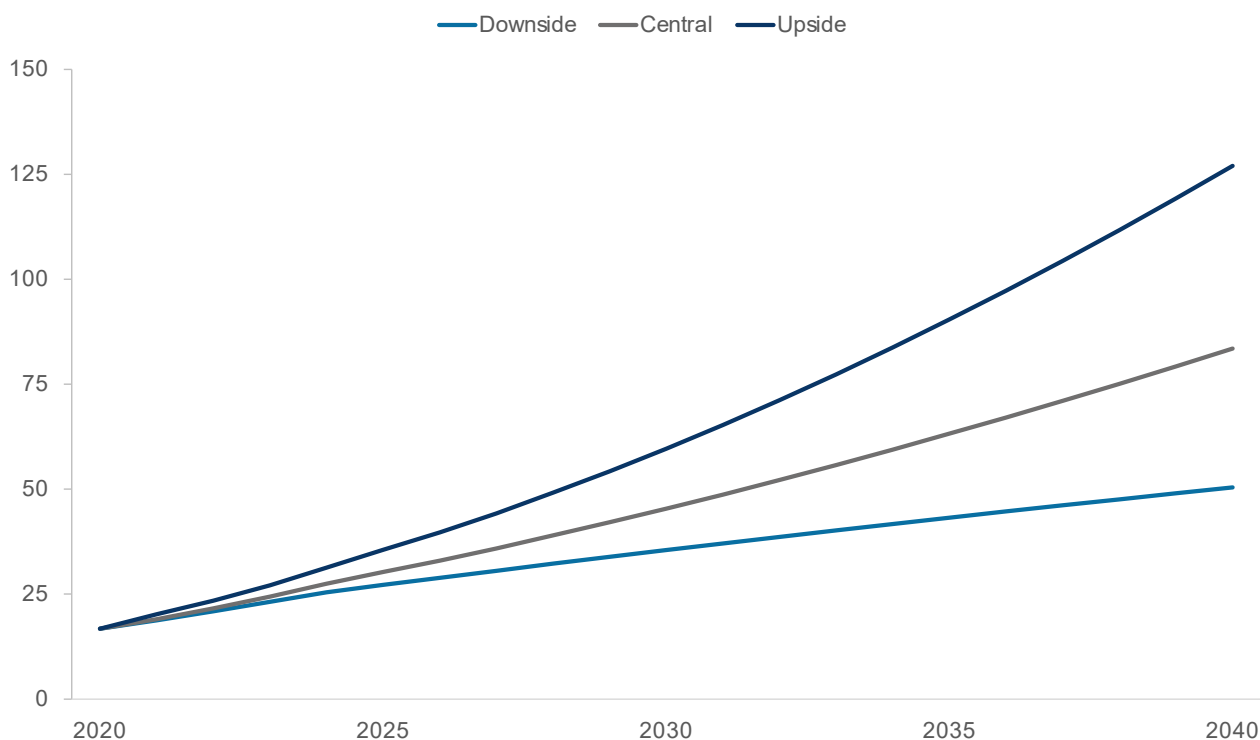
Source: Capital Economics analysis of YouGov survey.

Our labour cost scenarios are based on the ratio of AI related labour to AI technologies spend by business size.[81] Analysing data on software investment and employment in software related occupations as a comparator, suggests an increase in the ratio of labour spend to technologies spend over time. The rate of growth of software related employment outstripped the rate of growth in investment between 2004 and 2019.[82][83]

To generate conservative estimates, we assume that the ratio of labour spending related to AI to spending on AI technologies remains constant over time. We also adjust prices for increases in wages over time.

In our central scenario, labour costs rise from £46.0 billion in 2020 to £304.2 billion in 2040 at a compound annual growth rate of 9.9%, or to £216 billion at a compound annual rate of 8.0% in real terms. (See Figure 4.4.) By 2040, spending on labour costs related to the development, operation and maintenance of AI technologies represents 36% of adopting firms' total labour costs. It is important to note that these labour costs do not take into account any displacement effects of AI technologies adoption on labour. Given a lack of previous work in this area, it is difficult to benchmark the scale of these numbers to other estimates. However, the broad scale seems reasonable. As a comparison, assuming average total cost of an employee

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[81] The ratio for small firms is 2.6, 4.3 for medium-sized firms, and 1.9 for large companies.

[82] ONS (2021), *Annual Population Survey,* Accessed from Nomis (selected occupations).

[83] Between 2009 and 2019, employment in selected occupations grew by 3.5% and investment by 3.2%.

of £50,000, the total spend on occupations closely related to software in the UK was £74.8 billion in 2020, meaning AI related labour could account for half of these.[84]

The estimates of spending on labour related to the development, operation and maintenance of AI range from £185.2 billion (£130.5 billion in real terms) in the downside scenario to £456.0 billion (£329.0 billion in real terms) in the upside scenario. This equates to an annual growth rate between 7.2% and 12.1% (5.3% and 10.3% in real terms), or a range of 26.5% to 45.9% of AI adopting companies' labour costs.

Figure 4.4: Expenditure on labour by scenario, 2020-2040 (£ billion)
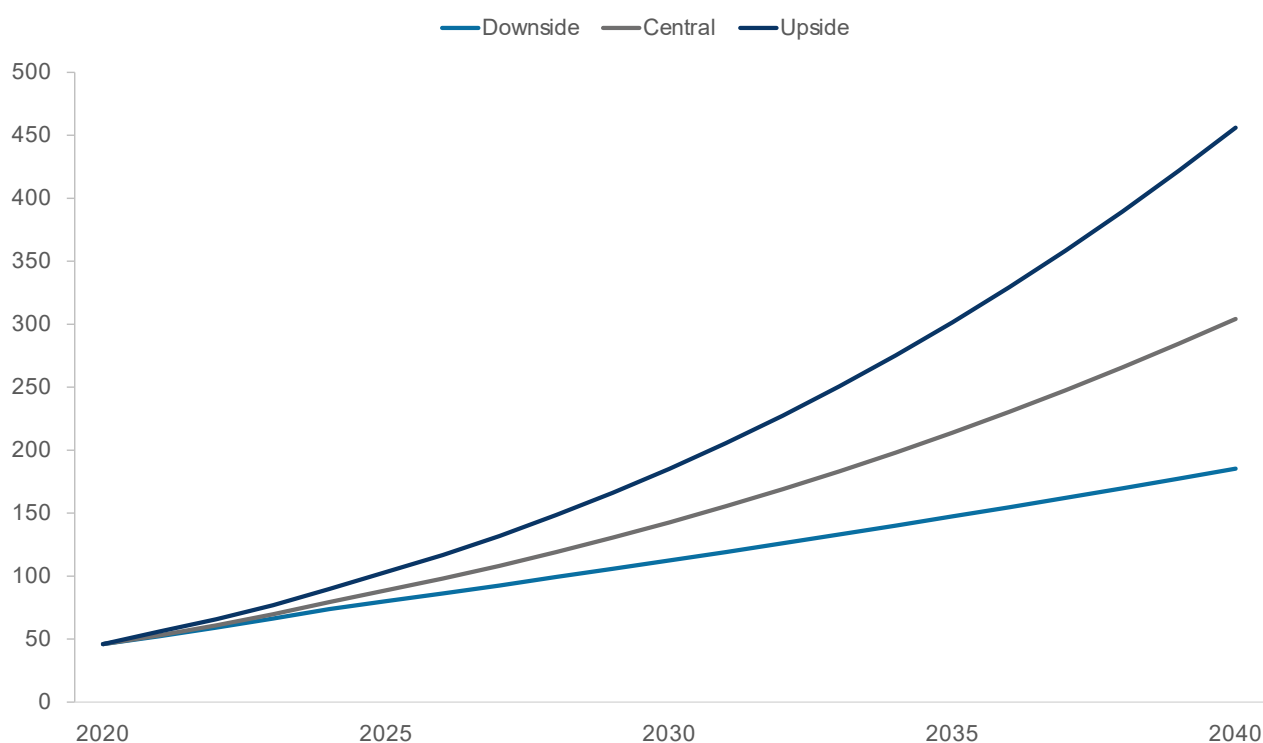
Source: Capital Economics analysis of YouGov survey.

Overall, spending on AI technologies and labour is projected to increase from £62.8 billion in 2020 to £387.7 billion in 2040 (£299.6 billion in real terms) at an annual growth rate of 9.5% in the central scenario. Growth is faster at the beginning of the period and then flattens off. Spending per adopting business grows from an average of £145,400 to £290,000 over the period. The net worth of the UK's AI supply sector was estimated at £15.6 billion in 2020 according to DataCity. If spending by businesses increases in line with our central scenario, there is considerable scope for growth in the value of the UK supply sector in the coming years.[85]

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[84] ONS (2021), *Annual Population Survey,* Accessed from Nomis (selected occupations)*.*

[85] DataCity (2020), *UK Artificial Intelligence analysis 2020,* Available at: https://thedatacity.com/insight/uk-artificial-intelligence-analysis-2020/ [Accessed September 2021].

Figure 4.5: Total expenditure on labour and technology by scenario, 2020-2040 (£ billion)
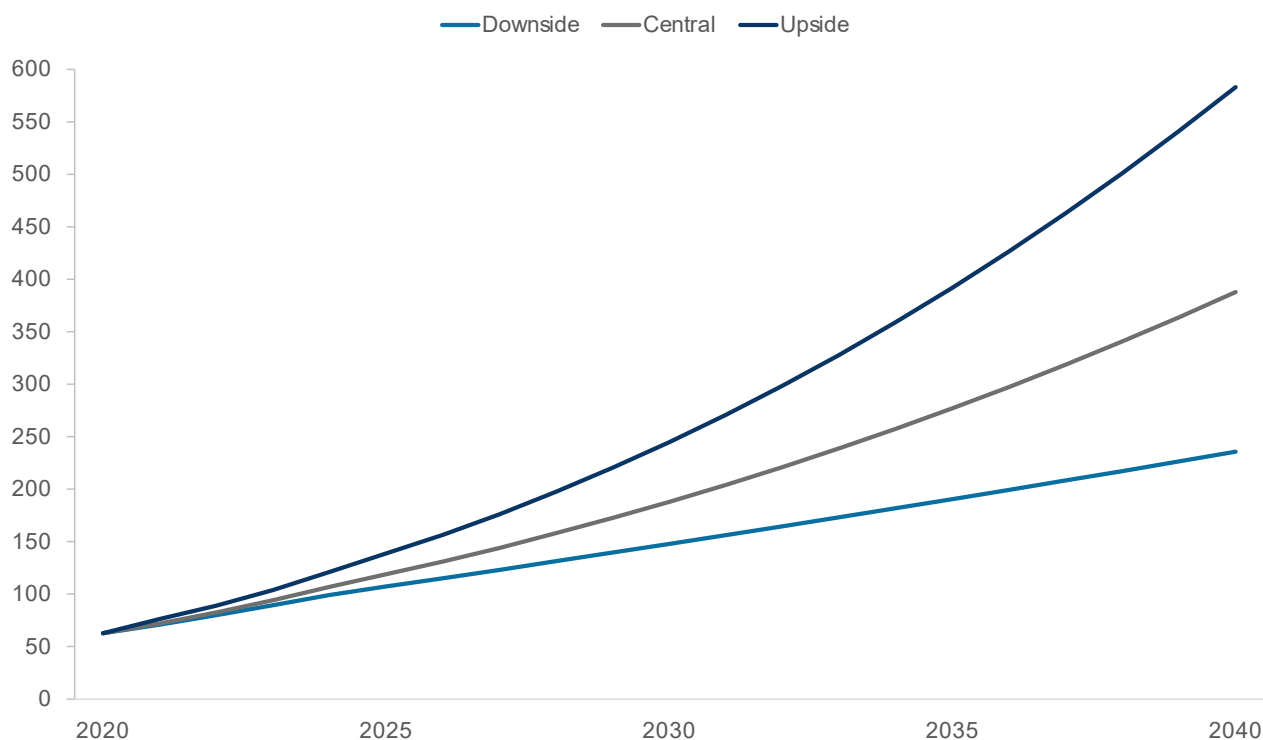
Source: Capital Economics analysis of YouGov survey.

Expenditure by size

Expenditure on AI technologies and labour related to AI shows considerable variation by business size. In the central scenario, we assume business' expenditure on AI grows by an annual rate of 8%, 10%, and 13% for small, medium, and large-sized businesses respectively between 2020 and 2025. These growth rates represent the average annualised five year growth rate for each business size from our survey.

As such, large companies could increase their expenditure on AI labour and technologies from £24.2 billion in 2020 to a total of £48.5 billion by 2025 in the central scenario. In this scenario, medium-sized businesses will spend around £45.6 billion on AI solutions by 2025, with small business' expenditure around 40% below this figure, standing at £24.9 billion.

For the upside and downside scenarios, the growth rates assumed for 2021 and 2021 to 2025 differ. In the upside scenario, we took the average reported spending increase rate for each business size from our survey results for 2021 and assumed these do come to pass. Large companies reported the highest anticipated spending increase on AI technologies and labour, of nearly 50% in 2021. This compares to small and medium business' average intended expenditure increase of around 35%. Between 2021 and 2025 in the upside scenario, we assume that spending grows 20% faster than in the central scenario. Consequently, large companies' expenditure on AI solutions grows at an annual rate of 19.5% until 2025, with the total annual expenditure equalling £58.9 billion by 2025. Small firms would increase spending by 14.9%annually to £28.0 billion, and medium sized firms' expenditure would grow at 16.1% to £51.7 billion in this scenario.

In the downside scenario, spending in 2021 is assumed to grow at a third of the rate applied in the central scenario, and at half the central scenario's rate between 2021 and 2025. As such, AI spending of small firms is £2.0 billion below that of the central scenario by 2025 – or £4.1 billion and £5.7 billion for medium and large-sized companies respectively.

Overall, annual spending on AI technologies and labour will likely range between £47.9 and £108.5 billion for small companies by 2040, between £91.8 and £213.7 billion for medium-sized companies, and £95.9 and £260.8 billion for large companies, depending on the scenario. In the central scenario, expenditure will have grown at an annual rate of 8.8% for small, 9.4% for medium, and 10.0% for large businesses between 2020 and 2040. These equate to total AI spending of £76.0 billion for small, £148.0 billion for medium, and £161.7 for large businesses in 2040.

Figure 4.6: Labour and technology expenditure by size, central scenario 2020-2040 (£ billion)
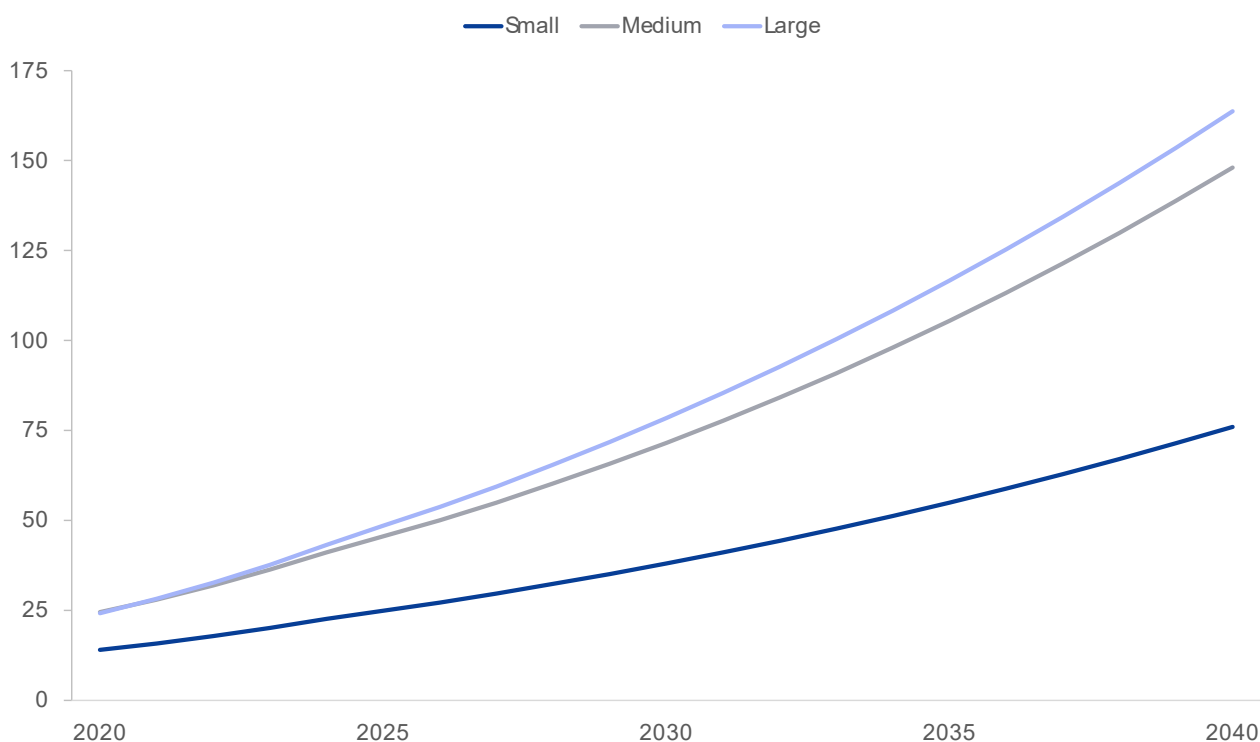
Source: Capital Economics analysis of YouGov survey.

5 CONCLUSION AND POLICY IMPLICATIONS

In this study, we have presented estimates of the current adoption rate of AI technologies and expenditure on AI in UK businesses, split by business size and sector. Overall, the modelling and analysis suggests that current adoption rates are slightly lower than other estimates imply. Meanwhile, our spending estimates are higher than others, but these are harder to benchmark given a lack of existing evidence. Our estimates suggest that there are 432,000 companies that do use AI technologies and the total annual expenditure related to this is over £62 billion in 2020. The scenario modelling shows that the scope for increasing adoption and expenditure is large but there are a wide range of possible outcomes.

Policy implications

It is not within the scope of this study to make recommendations for policy. Rather, we have highlighted some issues for consideration that emerge from our analysis:

- There is scope for a large increase in the number of companies adopting AI, with only 15% of firms (around 432,00 businesses) currently doing so.

- Medium sized businesses have been found to be most likely to develop AI solutions in-house, while small firms most frequently procure AI solutions externally through the purchase of ready-made systems.

- There are a total of 354,800 businesses in 2020 that are piloting (2%) or planning to adopt AI (10%), and an environment needs to be created that ensures these businesses do not face barriers which prevent them from doing so. A review of the current literature suggests that there are a range of barriers to adoption that span the supply and demand side, namely skills shortages, as well as funding difficulties, regulatory uncertainty, ethical considerations, cultural inhibitions, and uncertain returns on investment.

- Large firms are most likely to adopt AI technologies but there are innovative companies using AI across all business sizes with 414,400 small firms, 12,100 medium sized firms and 5,200 large firms currently using at least one AI technology.

- There is a wide variation in adoption rates between sectors. High tech sectors and high value services have the highest rates of adoption currently while some of the largest sectors with high potential for growth, such as retail, hospitality, construction and manufacturing, have some of the lowest rates of adoption.

- The sectors set for the largest increase in adoption rates by 2025 and by 2040 according to our central scenario based on survey results are IT and telecommunications (+29 percentage points by 2040), and legal (+28.8 percentage points by 2040) as well as media, marketing and sales (+24.8 percentage points by 2040).

- Total expenditure on labour related to the development, operation or maintenance of AI technologies is approximately 2½ times that of expenditure on AI technologies themselves; skills will be needed to sustain the increase in spend over time.

- With the right conditions, total AI expenditure could grow between 11% and 17% annually over the next five years.

- There is a wide range of potential outcomes for spending on AI technologies and labour, depending on progress to overall potential in the adoption and intensity of AI use, ranging from £236 billion by 2040 in the downside scenario to £583 billion by 2040 in the upside scenario.

Contribution to the literature

This report adds to the literature on the scale and nature of AI use in the UK. It supplements existing evidence on adoption with a large survey of over 2,000 businesses focused specifically on the UK, while providing breakdowns by business size, sector and technology type. Estimates of expenditure on AI by UK businesses are sparse, and this study provides new estimates with a breakdown by business size and by spending on technologies and labour. In addition, it includes three scenarios for the trajectory of AI spending over the next 20 years which is based on modelling using survey results, as well as a range of official statistics and other publications. These provide indicative estimates of the broad scale of increase that can be expected depending on the ability of firms and government to overcome barriers to adoption that currently exist. There are limitations to this study. There are a range of assumptions that underpin the calculations, which should all be treated as indicative estimates. (See Section A.4.)

There is more work that can be done on AI in the UK that would be useful additions to the literature and increase understanding of the subject area, including:

- Continuing to improve data collection on adoption and expenditure on AI technologies in the UK under a single definition of AI, and increasing access to this data

- Increased literature on policies that reduce the barriers to AI use by businesses

- An assessment of the net impact of AI adoption on employment and business expenditure

- An assessment of the economic impacts of the increased adoption of AI through productivity improvements

- Analysis on the economic impacts of the increased use of AI products by consumers

- Analysis of AI adoption and expenditure amongst UK public organisations

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APPENDIX - METHODOLOGY

This appendix sets out the methodology and key assumptions used in the modelling of AI adoption and spending in the UK.

A.1   Survey background

To gather data on AI adoption and spending to inform the modelling in this study a survey of private businesses was conducted in conjunction with YouGov.

The following four survey questions were asked to businesses:

1. **Does your business use any of the following Artificial Intelligence technologies or do you intend to do so?** (Technologies = machine learning, natural language processing and generation, computer vision/image processing and generation, data management and analysis, hardware, robotic process automation)
   [please tick one option for each technology]

   a.   Currently piloting
   b.   Used for over 3 years
   c.   Used for 1-3 years
   d.   Not used but planning to adopt in the next year
   e.   Not used but planning to adopt further into the future
   f.   Not used and no plans to adopt

2. **How did your business adopt the majority of the technologies you ticked in question one?**
   [Please tick one]

   a.   Developed in-house (fully, or by adapting existing software)
   b.   Through purchase of external software or ready-to-use systems
   c.   Out-sourced the development of AI applications to external providers

3. **How much has your business spent on artificial intelligence technologies and the labour related to these technologies?**
   [Please tick one in each column and estimate the total cost for all technologies identified in question one]

	Technology costs of AI over **past three years**	Labour costs relating to the development, operation, or maintenance of AI technologies **in the past twelve months**
< £10,000		
£10,000 – £50,000		
£50,000 – £100,000		
£100,000 – £500,000		
£500,000 - £1 million		
£1 – 10 million		
£10 – 20 million		
> £20 million		

4. **How much do you anticipate your total expenditure on the Artificial Intelligence technologies that you identified in question one will increase in the future?**
[Please tick one in each column]

	Next year	Next 5 years
N/A		
<10%		
10-25%		
25-50%		
50-75%		
75-100%		
100-150%		
>150%		

The total survey sample was 2,019 private businesses, including 1,127 small businesses (55.8%), 291 medium businesses (14.4%) and 601 large businesses (29.8%). Following standard categorisations of business size used in official statistics, businesses employing less than 50 employees were classified as small, those employing between 50 and 249 workers as medium, and firms with over 250 workers as large. Respondents spanned all regions of Great Britain and all private sectors. Businesses in Northern Ireland have thus not been surveyed. For the purposes of this study, which is concerned with AI adoption in the United Kingdom, it is assumed that behaviour of businesses in Northern Ireland reflects the behaviour of businesses in Great Britain, as derived from survey responses. After removing spurious responses, the identification process of which included an analysis of expenditure responses relative to firm size (in terms of turnover), the sample reduced to 2,008 quality responses. The 11 companies' responses removed from the sample were micro and small firms that had answered they had spent over £10 million on AI in the past three years.

In this study, AI is defined as highlighted in section 1.1. Survey participants were asked about their usage or planned usage of the following six technologies: robotic process automation (RPA), machine learning, natural language processing and generation, data management and analysis, computer vision and image processing, and hardware related to AI. Although information on robotic process automation is gathered, this is not included in our AI totals because it does not constitute AI as defined in this study. Instead, a respondent is classified as an AI adopter, if the business uses at least one of the remaining five technologies. In the survey,

respondents were asked about RPA as a way to ascertain that we capture valid responses. The inclusion of the RPA category helps respondents to not mistakenly attribute the use of this non-AI technology to the machine learning bucket, which is the broadest of the five. Expenditure responses from companies using RPA and AI have been adjusted to remove the effect of RPA spending. As an example, for a company who used two AI technologies and RPA, we allocated two thirds of their expenditure to AI technologies and discarded the remaining third in our analysis.

In the survey, businesses were asked to self-identify the sector in which they operate. This study's model is based on the YouGov sector breakdown which includes thirteen sectors.[86] However, as these sectors do not correspond exactly to the Office for National Statistics' Standard Industrial Classification (SIC) code breakdown, for scaling up responses to the UK business population sixteen SIC broad industry groups were mapped to these thirteen YouGov sectors. Where the SIC sector was broader than the corresponding YouGov sector, the SIC sector was split using four-digit Business Register and Employment Survey (BRES) employment data.

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[86] Manufacturing, construction, retail, finance and accounting, hospitality and leisure, legal, IT and telecommunications, media/ marketing/ advertising/ PR and sales, medical and health services, education, transportation and distribution, real estate, other.

Modelling current adoption of and expenditure on AI

The survey was used to model the adoption and expenditure on AI technologies in 2020. The overall approach taken was to scale the survey results by sector and business size. In cases where the sample size wasn't sufficient to do this, other approaches were taken. (See Figure A.1.)

Figure A.1: Overview of modelling 2020 adoption and spend
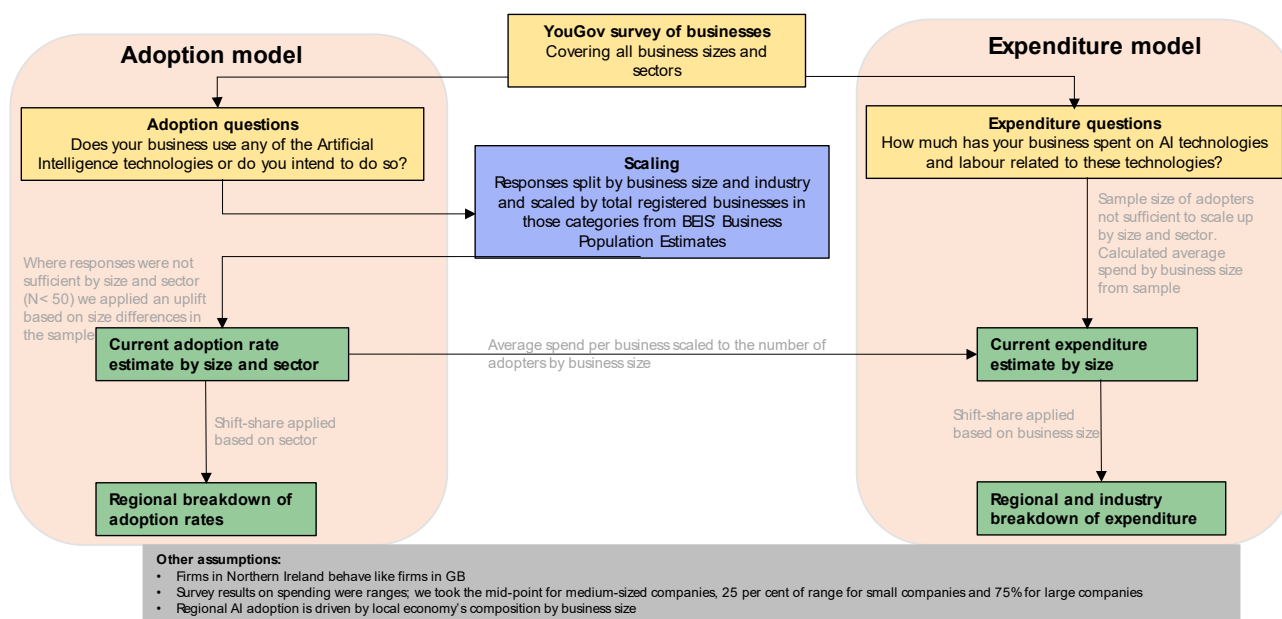
Note(s): Yellow = survey results; green = calculation; blue = data input; grey= assumption

Adoption

Objective: Estimation of the current number of businesses adopting, piloting, or planning to adopt AI technologies in the UK.

Scaling survey responses to UK estimates: to estimate the current number of private businesses in the UK that have either (i) adopted; (ii) are piloting; or (iii) haven't adopted AI, the survey responses were distributed proportionally to the total UK business population by size and in each sector. For example, the number of small companies in the finance industry. Using the same approach, the number of businesses that are piloting an AI technology but not currently using one were estimated, as well as the number of businesses that are not currently using AI but plan to do so in the future.

The scaling up of responses was undertaken using data from the Department for Business, Energy & Industrial Strategy's (BEIS) Business Population Estimates (BPE).[87] Only registered private businesses were considered, to ensure holding companies and other micro businesses that are unlikely to adopt AI are not taken into

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[87] BEIS (2020), Business Population estimates for the UK and regions, Available at: https://www.gov.uk/government/collections/business-population-estimates [Accessed August 2021].

account. Respondents who answered 'Don't know' to any of the four survey questions have been distributed proportionately to survey results.

Results on the number of businesses that have already adopted AI, those currently piloting, and those planning to adopt at least one AI technology in the future are broken down by size and sector. Given the three size bands and thirteen sectors, there are 39 categories.

Where the sample size in any given sector by size breakdown was less than 50 the average difference in adoption rates for small, medium, or large businesses across the entire sample were applied to size-bands within the sector that did have more than 50 responses. For two sectors, where no size-band had enough responses, total sample averages for adoption, piloting, and future adoption rates were used; these sectors are Transportation & Distribution and Real Estate.

For example, the survey contained responses of 36 medium-sized construction businesses. This was below the 50 response threshold required for robust results. For this reason, we took the adoption rate of small construction firms, 12.4%, and multiplied it by factor 2.4 to arrive at an estimated adoption rate for medium-sized firms. This factor was calculated by looking at how many more medium-sized firms have adopted any AI technology relative to small businesses across the entire sample.

Expenditure

Objective: Estimation of the expenditure on AI technologies and AI related labour of the number of businesses having already adopted AI technologies.

The estimation of current expenditure on AI was broken down by labour and technologies spend. Labour includes the expenditure on labour related to the operation, maintenance, or development of AI technology solutions. The survey asked for an estimate of spending on both separately, based on ranges (see tables in section A.1). These ranges have been converted into values based on the size of company responding. The midpoint of each range was used for medium firms, with small and large firms' values at the quarter and three-quarter point respectively. For example, a medium-sized firm that reported expenditure in the range of £1 million to £10 million would be noted as having spent £5 million. For a small company expenditure would be £2.5 million, and £7.5 million for a large business. Taking into consideration that companies might have acquired AI technologies more than a year ago, and to account for anomalies that may have resulted from the COVID-19 pandemic in 2020, respondents were asked about their technology expenditure in the last three years, which was then annualised for the modelling process.

Preliminary analysis showed that there were considerable differences in average spend by business size. Consequently, for modelling current expenditure a more granular size breakdown was used to separate out micro businesses (less than 9 employees). The weighted average of labour and technology expenditure by each business size was calculated across the sample and subsequently multiplied by the number of businesses of each size having adopted AI – as found in the adoption model detailed above.

The sample of adopting businesses was not sufficient to obtain reliable average spend estimates by sector, therefore spend estimates are based on business size. The spend by sector is then calculated by applying the average spend by business size to the total number of UK businesses of each size having adopted AI in each sector – as found in the adoption model detailed above.

A.2 Adoption and expenditure scenario modelling

To provide estimates of the broad scale of business investment in AI over the next twenty years we undertook scenario analysis, with a central, upside and downside projection. Figures are provided by sector and business size. Given that we have more robust information about likely growth in the near term, both adoption and expenditure models are split into two approaches for the near term and the medium/long term. The expenditure model distinguishes between labour related to AI and AI technologies expenditure. (See Figure A.2.)

The scenarios are based on the definition of AI illustrated in 1.1. For the purposes of this study, machine learning, natural language processing, computer vision, data management, and hardware are considered AI technologies. There are three implicit assumptions that underpin the scenario modelling. First, it is assumed that the definition of AI remains constant over the modelling horizons, i.e. no emerging technologies that do not exist in 2020 are taken into account. Second, the quality of the five AI technologies remains constant over time. Finally, the barriers to the adoption of these technologies also remain constant.

Figure A.2: Overview of modelling scenarios for 2020 to 2040
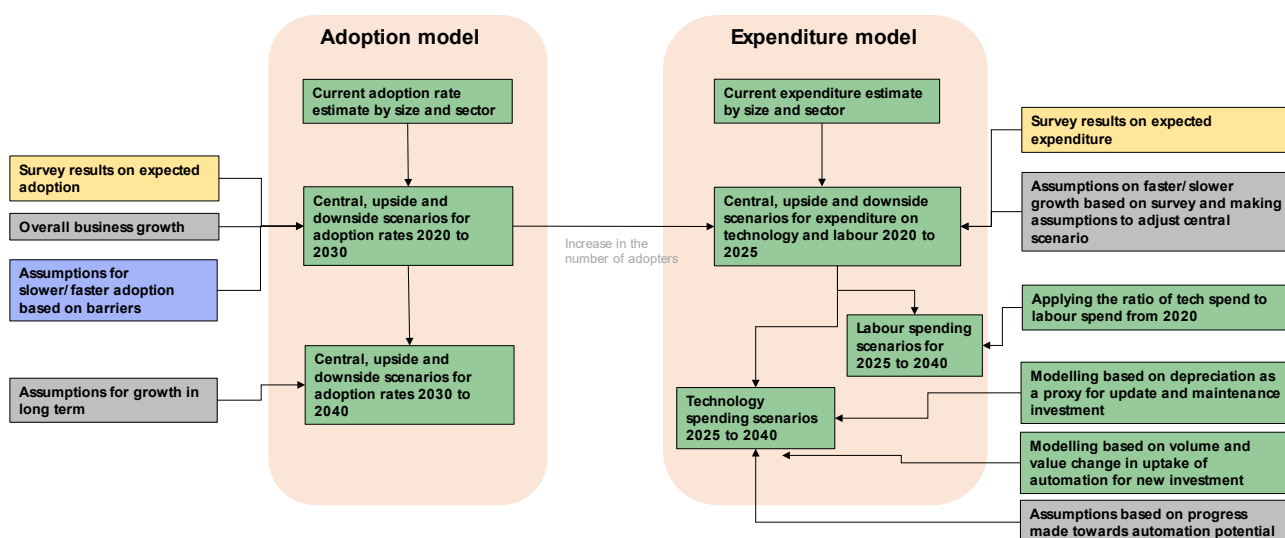
Note(s): Yellow = survey, green= model input, light blue= data input, grey = assumption.

Adoption scenario model

Objective: Estimation of the number of businesses adopting AI technologies over the period of 2020 to 2040 under three scenarios.

The number of AI adopting businesses by sector and size in 2020 from the adoption model are used as the starting point for the projections.

In all scenarios the overall growth in the number of businesses has been accounted for. The number of businesses grows between 2020 and 2040 at the same rate as the compound annual growth exhibited during

the period of 2000 and 2020. This growth rate has been calculated using BEIS Business Population Estimates figures for UK private businesses and is broken down by business size. (See Figure A.3).

For the first-year projection, 2021, the rate of uptake as indicated in the survey results which directly asked businesses whether they planned to adopt AI in the next year is taken.

For the period from 2021 to 2025, the projections differ reflecting the ability for firms and government to overcome or remove barriers to adoption. The European Commission's study containing a survey of firms that included detailed information on business' views on barriers to adoption was used to quantify this. [88] The top six barriers highlighted in the sample of 10,000 companies across Europe include internal barriers such as the cost of adoption and difficulties in hiring new staff, as well as external barriers. The latter encompass a lack of public/ external funding, the need for new laws or regulation, concerns about liability for damage caused by AI, and strict standards for data exchange. In the downside scenarios it has been assumed that out of the six barriers, the one with the highest share of companies considering it an obstacle, will be insurmountable for these companies. The remainder of companies will overcome this and any other obstacles and adopt AI. For the upside scenario, the barrier that the smallest share of firms considers to be an obstacle to AI adoption is taken, and it is assumed that all but these firms planning to adopt AI will overcome any constraints and adopt AI by 2025. The central scenario represents the midpoint between the two. See table A.2 below for the assumptions for percentage of firms already piloting or having indicated plans to adopt AI technologies, actually adopting by 2025 used for each sector. For example, amongst manufacturing companies in the EC survey, 58.6% considered hiring new staff the biggest barrier. For our downside scenario, we have hence assumed that the inverse, 41.4% of firms piloting or planning to adopt AI technologies will overcome this barrier, with the remaining 58.6% unable to do so.

Table A.2: Assumptions on the percentage of piloting or planning to adopt firms adopting AI by 2025, per cent

Scenarios, % of firms adopting by 2025:	Downside	Central	Upside
Manufacturing	41.4	58.7	75.9
Construction	46.1	61.3	76.5
Retail	45.5	60.3	75.0
Finance & Accounting	48.0	63.8	79.6
Hospitality & Leisure	43.1	60.5	77.9
Education	45.9	62.8	79.7
Legal	44.5	62.1	79.8
IT & Telecoms	41.4	60.0	78.6
Media/marketing/ advertising/ PR & sales	44.5	62.1	79.8
Medical & health services	40.1	58.4	76.8
Transport & distribution	44.1	60.1	76.1
Real estate	53.0	65.7	78.5
Other	44.5	62.1	79.8

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[88] European Commission (2019), *European enterprise survey on the use of technologies based on artificial intelligence*, Luxembourg: Publications Office of the European Union, doi:10.2759/759368.

In the central scenario, it is assumed that by 2030 all companies that indicated in the survey that either they are piloting or that they plan to adopt AI do so by 2030. For the downside scenario, it is assumed that only 80% of those that are currently piloting or plan to adopt do so by 2030. In the upside, some firms that don't currently have any plans to adopt do end up adopting by 2030, so we have assumed 120% of the firms that are piloting or plan to adopt actually do adopt AI by 2030.

Figure A.3: Assumptions for adoption scenarios

	Assumptions on:	Upside scenario	Central scenario	Downside scenario
Current adoption rate model	Adoption in 2020	Adoption model result		
Does your business plan to adopt any of the Artificial Intelligence technologies next year?	Adoption by 2021	Survey result on % increase expected in 2021		
European enterprise survey on the use of technologies based on AI • Top 6 barriers (external & internal) mentioned	% of businesses who plan to adopt that do so by 2025	X% of businesses are prevented from adoption by the least frequently cited barrier* (20-25%)	Midpoint (58-66%)	X% of businesses are prevented from adoption by the most frequently cited barrier* (47-60%)
• Does your business plan to adopt any of the Artificial Intelligence technologies further into the future? • Do you currently pilot AI?	% of businesses who plan to adopt that do so by 2030	120% of firms currently piloting, or planning to adopt AI, adopt AI	100% of firms currently piloting, or planning to adopt AI, adopt AI	80% of firms currently piloting, or planning to adopt AI, adopt AI
Best estimate	% of businesses without a near-term adoption plan that do adopt between 2030-40	15%	10%	5%

Other assumptions:
• We have accounted for growth in the total business population by assuming the number of businesses by business size grows in line with its average growth rate from 2000 to 2020

Note(s): Yellow = survey, green= model input, light blue= data input, grey = assumption.

Expenditure scenario model

Objective: Estimation of the expenditure on AI technologies and related labour by AI adopting companies over the period of 2020 to 2040 under three scenarios.

The projections for AI spending are based on a combination of the results from the survey of UK businesses and the adoption rate modelling in the near term. In the medium/long term proxies for the volume and value changes in AI activity are used to produce scenarios on AI technologies spending and the ratio of spending on labour to technologies is used for the labour spending scenarios. The approach taken reflects the need to account for the increase in intensity of spending by individual firms as well as the number of businesses that use AI. In addition, it accounts for the changing price of technologies over time. (See Figure A.4.)

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[89] *ibid.*

The spending figures presented are gross figures. For example, the spending on labour relating to AI does not account for any jobs lost as a result of the increase in automation and AI spending. This paper does not attempt to measure the net impact on labour spending. Other literature estimates that the net impact of automation on jobs could range from a net gain of 12 million jobs by 2025 to a net loss of 58 million jobs globally.[90]

All figures are presented in current prices and therefore include the impact of changing technology costs over time.

Figure A.4: Overview of expenditure scenarios modelling
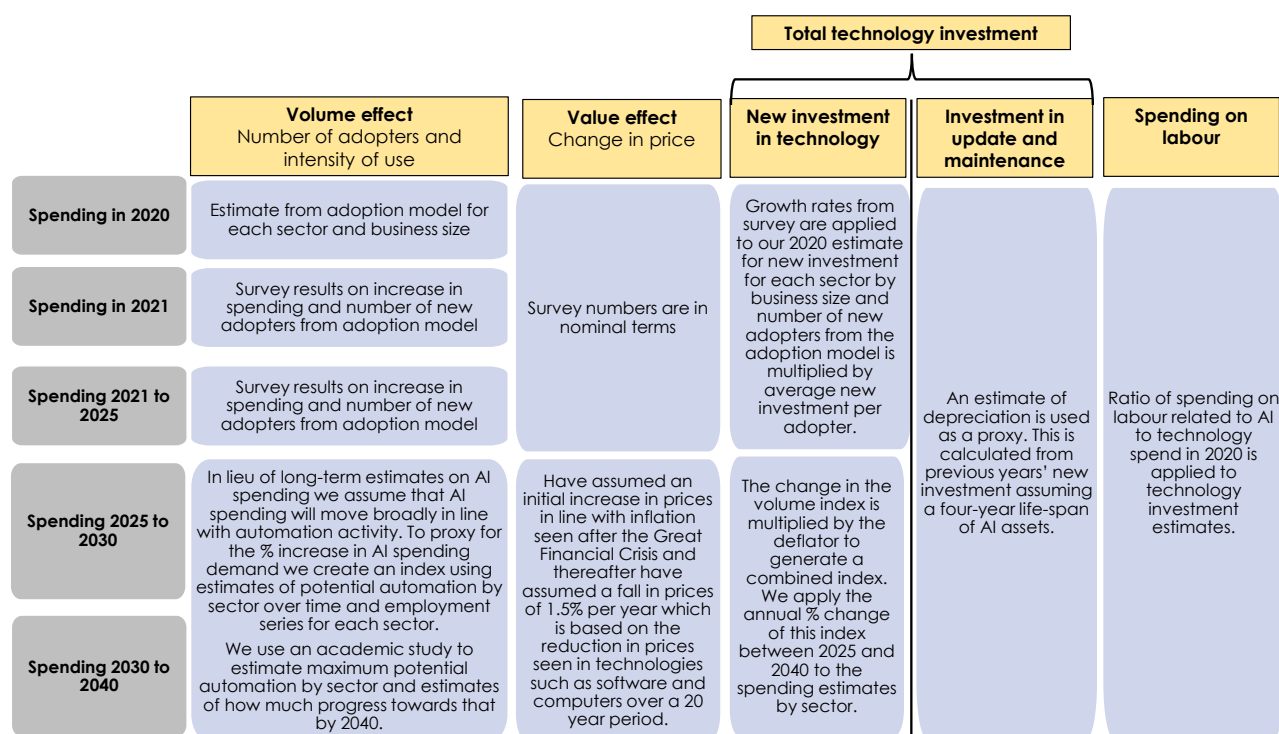
Source: Capital Economics

The approach taken splits spending on technology into new investments in AI technology and investment in the update and maintenance of existing AI technologies. To split the 2020 spending figure between these two we projected the total technology investment spend backwards by four years in order to estimate the depreciation costs in 2020. (See Figure A.4.) To project the 2020 figure backwards we assumed the same annual rate of growth as expected in the next five years in the central scenario to apply to the period 2016 to 2020.

90 World Economic Forum (2020), *The Future of Jobs Report,* Available from: http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf [Accessed September 2021].

New investment in technology

For 2021, survey respondents were asked directly about their intended increase in spending. They were also asked about their expected increase in spending over the next five years. The sample sizes for the spending questions were significantly smaller than that for adoption because it was only asked to those that currently use AI. As such, results were split by business size only and the same growth rates were applied to all sectors for a given business size.

The average increase in spend for 2021 from the survey responses was over 30% for all business sizes compared to an annual average growth rate of between eight and 13% over the next five years. As such, for 2021 we apply the survey estimates in the upside scenario only. In the central scenario we apply the average annual growth rate over the next five years and in the downside scenario we assume the increase in spending is one third of that in the central scenario.

For 2021 to 2025, the average annual growth rates for small, medium and large businesses were applied in the central scenario. In the upside scenario the growth rate was 20% higher and in the downside scenario the growth rates were half of those applied in the central scenario. Businesses will not necessarily have accurate figures for the next five years and the scenarios reflect that uncertainty. Applying the growth rates for the scenarios is more of an art than a science. However, we have looked at the difference in growth rates in investment in related assets over time in the United States, where there are more data available, which provides a guide to the sort of scale that is possible for different technologies. Investment in intellectual property products from software publishers grew around 20% more than investment in intellectual property products related to computer systems design and related services over the five year period leading up to 2020. Meanwhile, investment in own account software grew at half the latter's rate.[91]

In addition to the growth in spending of businesses already using AI, the average spend per business is assumed for the new adopters in each scenario from the adoption rate model.

For the period 2025 to 2040, the assumptions in each scenario were broadly based on estimates of the potential increase in automation activity from McKinsey's '*A future that works: Automation, Employment, and Productivity*' study that was based on work by Arntz, Gregory, and Zierhan from 2016 as well as an earlier paper by Frey and Osborne from 2013.[92][93][94] In this study they presented a range of projections for the increase in automation as measured by the percentage time spent on current work activities; this encompasses new businesses using AI and companies using more AI. Although we don't have the underlying data, we use approximate estimates from the graph to form the outlook for automation in our central, downside and upside scenarios. We don't include the increase in potential automation over time as our calculations are based on current technologies.

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[91] Bureau of Economic Analysis (2020), *Investment in Private Nonresidential Fixed Assets*, Available at: https://apps.bea.gov/itable/index_fa.cfm [Accessed September 2021].

[92] McKinsey Global Institute (2017), *A future that works: Automation, Employment, and Productivity*, Available at: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary [Accessed September 2021].

[93] Arntz, M. T. Gregory and U. Zierahn (2016), The risk of automation for jobs in OECD countries: a comparative analysis, OECD Social, Employment and Migration Working Papers No 189.

[94] Frey, C.B. and M.A. Osborne (2013), The Future of Employment: How Susceptible are Jobs to Computerization?, University of Oxford.

The key assumption is that AI spending will grow broadly in line with automation activity. We also made an assumption about the current rate of automation, for which we have assumed 3%, which was informed by the McKinsey study and PWC estimates. A volume series was created by multiplying estimates of the share of time spent on work activities that is automated in each sector between 2020 and 2040 by employment in those sectors. Employment was assumed to grow at an average 1.7% across sectors – its compound annual growth rate between 2000 and 2020.[95] The estimates of time spent on work activities that is automated took into account:

- The maximum potential automation with current technologies in each sector[96]

- The total level of adoption by 2040 in three scenarios[97]

- Sector variation in speed of uptake using results from the modelling on adoption rates of AI by 2040.

The annual change in the volume series is then deflated to account for the changing technology costs over time. For the decrease in technology costs, it is assumed that the price of AI will fall by 30% over the 20 years - this is based on historic falls in prices seen in other technologies. Current shortages in semiconductors and supply chain bottlenecks are captured in an initial increase in the price of technology until 2025, with technology prices decreasing from 2026 onwards. The temporary increase reflects the increase in the ONS' experimental deflators for Computer, electronic and optical products as well as Software for the period just after the financial crisis.[98] (See Table A.3.) The growth rates of the change in automated employment adjusted for falling technology prices for each sector are applied to the 2025 estimates of spending up until 2040.

Note that numbers between 2025 and 2040 have been smoothed to remove a jump in 2026 as the calculations move away from being based on survey results and to estimates of the volume and price changes by 2040.

Table A.3: Deflator series for technology cost reduction 2020-40

Year	Index
2020	100.0
2021	102.7
2022	103.2
2023	102.7
2024	101.3
2025	100.0

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[95] Office for National Statistics (2021), *JOBS05: Workforce jobs by region and industry,* Available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/workforcejobsbyregionandindustryjobs05 [Accessed September 2021].

[96] McKinsey Global Institute (2017), *A future that works: Automation, Employment, and Productivity*, Available at: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary [Accessed September 2021].

[97] McKinsey Global Institute (2017), *A future that works: Automation, Employment, and Productivity*, Available at: https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary [Accessed September 2021].

[98] ONS (2021), *Investment in intangible assets in the UK*, Available at: https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/articles/experimentalestimatesofinvestmentinintangibleassetsintheuk2015/2018 [Accessed September 2021].

2026	98.5
2027	97.0
2028	95.6
2029	94.1
2030	92.7
2031	91.3
2032	90.0
2033	88.6
2034	87.3
2035	86.0
2036	84.7
2037	83.4
2038	82.2
2039	80.9
2040	79.7

Source(s): ONS.

Update and maintenance investment in technology

To estimate the spending by businesses on updating and maintaining AI assets (software) estimates of depreciation were used to reflect the capital that needs to be replaced. A lifespan of four years was applied, based on a study by the National Institute of Economic and Social Research which suggested software has a lifespan of three to five years.[99] A linear depreciation has been assumed so the estimate for update and maintenance in a given year is calculated by summing the total investment over the past four years and dividing by four.

Spending on labour related to AI

Projections for labour spend are based on the ratio between spending on AI related labour and AI technology in the 2020 estimates, broken down by business size. This ratio is applied to technology spend in each of the three scenarios and the figures are inflated to reflect increasing wages. Growth in labour costs was assumed to grow at 3% throughout the period based on the compound annual growth rate of the labour cost index between 2000 and 2019.[100]

A.3   Limitations

This study adds new data and modelling to the literature on the use of artificial intelligence by providing estimates of the current and future adoption and expenditure of private businesses in the UK. There are several limitations to the analysis that should be acknowledged, and the findings should be viewed in the context of the limitations of the study:

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[99] NIESR (2017), *Academic review of asset lives in the UK*, IESR Discussion Paper No. 474 , Available at:
https://www.niesr.ac.uk/sites/default/files/publications/DP474.pdf [Accessed September 2021].
[100] Eurostat (2021), Labour cost index by NACE Rev. 2 activity, dataset: LC_LCI_R2_A [Accessed September 2021].

- Given the nature of the modelling employed and assumptions made the estimates presented are indicative of the broad scale of activity rather than precise figures.

- There is a higher level of confidence in the numbers for 2020 and between 2021 and 2025 as these have a stronger grounding in the survey data collected and uncertainty around the economic environment inevitably rises the longer the time horizon.

- The estimates are based on current AI technologies as defined in chapter 1. They do not account for new technologies that would increase the ability to automate current work activities, nor changes that would reduce the skills barrier for AI technologies operation.

- The modelling does not account for potential economic crises or downturns.

- The figures for expenditure are gross numbers; they do not account for any reduced spending on labour or capital as a result of using AI technologies.

- The sectoral and regional numbers are less robust than the totals and disaggregation by business size. Regional estimates are driven by the proportion of different business sizes in those economies. For adoption estimates, sectoral numbers are based on the survey but supplemented by assumptions using business sizes where sample sizes were insufficient. For expenditure estimates, the sectoral estimates are driven by the proportion of different business sizes in each sector.