

Novel forms of contracting in the Digital Economy (CoDE) AI- enabled autonomous contracting

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2025

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<https://joint-research-centre.ec.europa.eu>

JRC145138

Bruxelles: European Commission, 2025

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How to cite this report: Amaral-Garcia, S., Duch Brown, N., Navajas Cawood, E. and Pogorzelska, K., *Novel forms of contracting in the Digital Economy (CoDE) AI-enabled autonomous contracting*, European Commission, Bruxelles, 2025, JRC145138.

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Abstract

The digital transition is one of the key areas of the European Commission's (EC) policymaking. Digital technologies are already shaping the way European Union (EU) citizens interact, underpinning innovation across almost all productive sectors and becoming increasingly critical to economic growth. Over recent years, global markets have been following a trajectory towards digitalisation. Artificial intelligence stands out prominently among the technologies that are driving this digital transformation. In a business setting, contracting is a common activity, and enterprises need to keep track of a large number of contracts, thus facing potential issues such as lack of uniformity and difficulties in managing and updating contracts. In e-commerce and algorithmic trading, where transactions are to a large extent automated, AI allows for knowledge integration into decision-making into making an offer of buying-selling transaction.

To scrutinise more specific implementations of AI in contracting, the EP has launched and financed a Pilot Project "Novel forms of contracting in the digital economy." The project aims to contribute to the transition towards the digital economy and to promote the roll-out of AI technology in contracting and to support companies, Small and medium-sized enterprises (SMEs) and start-ups, in deploying business models using AI in contracting, while preserving the rights of all users and ensuring the enforceability.

The objective of this study is to contribute to the EP Pilot Project by shedding light on the adoption of AI systems for the automation of contracting, in particular on the AI-enabled autonomous contracting. Whereas the analysis of selected case studies provides evidence of business applications using AI to automatise different stages of the contractual process, the adoption of AI in contracting is not widespread, and, at present, little is known about the characteristics of adopters of AI in contracting. Having an overall characterization of AI adopters in general, and adopters of AI in contracting in particular, is relevant to understand which types of enterprises are the first adopters of AI technologies, and which ones are lagging. Additionally, exploring the potential economic impact of AI in contracting is important to understand the expected implications it will have for businesses, and how it will shape contractual relationships. The study provides evidence and analysis identifying the main factors of AI adoption in contracting and assessing its potential implications, namely in terms of costs and benefits, and barriers to AI adoption in contracting faced by firms.

Acknowledgements

We are grateful to Eleni Anna Liasidou, Carlo Reggiani, Simona Staikova-van Bommel and Diana Ursuleanu for useful comments and suggestions. Adrian Moreno and Sebastian Miguez provided excellent research assistance.

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Executive Summary

This report is structured into several sections that provide a comprehensive overview of the use of Artificial Intelligence (AI) in the digital economy, particularly in the context of contracting. First, a set of **Glossary and key terms** defines important terms and acronyms used throughout the document. Then, the document discusses the **Policy background** and the European Commission's approach to the digital transition, highlighting the importance of data-driven economy and AI. It outlines the EC's vision based on human-centric values, data privacy rights, and competitive digital markets. The section also touches on regulatory initiatives like the AI Act. The following section presents the **Rationale**, explaining the motivation behind the study, which is to shed light on the adoption of AI systems for automating contracting processes. It acknowledges the transformative impact of AI across various domains and the need for legal frameworks to adapt to AI-enabled contracting. The scope and general approach define the scope of the analysis, mostly encompassing economic transactions, focusing on offer generation, pre-contractual stage, contract conclusion, and performance. It also discusses the potential economic impact of AI in contracting and the challenges related to adoption, such as scalability and data management. Next, the section on **Automated contracting** explores the use of technology in contracting, particularly the role of automated decision making and AI systems in automating outputs like predictions, recommendations, and decisions. The following section on **Automation and AI systems** provides a look at the evolution of ICT and its role in automating digital processes, an in-depth description of the concepts underpinning the functioning and outcome of AI systems, such as decision, autonomy, and human oversight. The report then explores **Evidence on the General Adoption of AI**, reviewing studies and data sources on AI adoption by enterprises, such as AI Watch, OECD AI dashboards, and the Eurostat ICT Usage in Enterprises survey, and presenting findings on the prevalence of AI use across different enterprise sizes and sectors. The next section on **AI Adoption and Market Characterisation** analyses characteristics of enterprises that are likely adopters of AI in contracting, considering factors like enterprise size, age, sector of activity, and the role of complementary assets. It also discusses potential risks and benefits associated with AI adoption in contracting. This is followed by an **Empirical analysis** which provides an empirical assessment of the adoption and barriers of AI in contracting within the EU27, using data from the "European enterprise survey on the use of technologies based on artificial intelligence" (Ipsos-iCite, 2020) and Eurostat data. In order to provide additional insight into business applications and current instances of this new technology, several **Uses cases** are described and analysed, exploring how AI solutions are applied to automate contracting stages in economic transactions, such as Forex markets, programmatic advertising, e-commerce retail sale, supply chain management, and renewable energy trading. Finally, the **Conclusions** summarise the findings of the study, emphasizing the role of intermediaries in the AI ecosystem, the importance of policies fostering fair access to AI systems, and the need for a level playing field for all market participants.

Each section provides detailed insights into the integration of AI in contracting processes, the challenges and opportunities it presents, and the current state of adoption across various industries and business models.

1. Glossary and Key Terms

Ad impression – ad view: refers to an instance where an advertisement appears on a user's screen within an ad inventory of a visited website.

Ad inventory – place on the publisher's website where advertisements are displayed.

ADM – Automated –Decision-Making: computational process, including AI techniques and approaches that are fed by inputs and data received or collected from a wide range of sources, including databases, text, images, speech or sensors, among others, and can generate, given a set of pre-defined objectives, outputs in a wide variety of forms (content, ratings, recommendations, decisions, predictions, etc.).

AdX (Advertising Exchange) – marketplace for the advertisement exchange.

AI – Artificial Intelligence; in this study used interchangeably with “AI system” (see entry below).

AI contracting – AI-enabled contracting: covers the situations where software programs based on AI are used by the contracting parties at different stages of contractual cycle, including pre- and contractual phases.

AI ecosystem – interplay of people, and organisations and technology providers enabling the development of AI and its application to innovative solutions.

AI lifecycle – an AI system lifecycle typically involves four specific phases. The design, data and models phase is a context-dependent sequence encompassing planning and design, data collection and processing, as well as model building and interpretation. This is followed by verification and validation, deployment, and operation and monitoring. These phases often take place in an iterative manner and are not necessarily sequential. The decision to retire an AI system from operation may occur at any point during the operation and monitoring phase.

AI solution – application or functionality based on AI system(s).

AI system – machine-based system that is designed to operate with varying levels of autonomy and that can, for explicit or implicit objectives, generate outputs such as predictions, recommendations, or decisions, that influence physical or virtual environments. Depending on the underlying technical approach applied to build an AI system, it can be classified into two broad categories: Symbolic and Statistical models. The former uses logical representations to infer outputs as a response to given inputs, and generally encode complex and highly sophisticated human expert knowledge. The latter are developed over vast amounts of data, aiming to identify patterns effectively extracting and representing knowledge, rather than explicitly applying defined causal relations between inputs and outputs. Statistical models include neural networks and genetic algorithms, for example. In particular, generative AI is based on neural networks which identify patterns and structures within existing data to generate new and original content.

API – Application Programming Interface, a software interface that allows two applications or computer programs to communicate to each other, therefore enabling interoperability between them while keeping the two systems (internal design and the operation) independent.

Application – complete software solution designed for end-user-oriented tasks and purposes, often accessible through a user-friendly interface.

Automation – the use of technology to design a process or a system that, under specified conditions, operates with a relatively low degree of human intervention.

B2B – Business-to-Business: commercial relation that exists between businesses.

B2C – Business-to-Consumer: commercial relation that exists between business and consumer.

BIS – Bank for International Settlements: international financial institution that supports central banks' pursuit of monetary and financial stability through international cooperation, and acts as a bank for central banks.

C2C – Consumer-to-Consumer: commercial relation that exists between consumers.

Decision – final output of a subset of AI systems that may influence the physical or virtual environment. It may also entail legal consequences.

Delivery mode – the way AI solution is delivered to the end-user; delivery mode differs depending on provision modality, type of provider, and readiness to use.

Distributed Ledger Technology (DLT) – a decentralized data storage technology that can perform data sharing, synchronisation and enable redundancy in a network of multiple nodes, i.e. multiple physical addresses or multiple organizations.

DMP – Data Management Platform: platform responsible for aggregating, storing, and analysing the cookie data of online users.

DSP – Demand Side Platform: platform enabling management of advertising campaigns and providing features for advertisers to buy ad impressions online.

EA (Expert Advisor) – tool automating trading (for example in Forex).

E-commerce (electronic commerce) – digitally enabled consumption of goods or services. Ecosystem – network of people, organisations and technologies that interplay with each other in coordinated way to create value for all participants.

EULA – End User Licence Agreement: a legal contract between a software supplier and an end-user specifying in detail the rights and restrictions which apply to the use of the software.

Functionality – specific capability of a given software.

Forex (FX) – Over-the-Counter foreign exchange market for currency trading.

Human oversight – overall human influence oversight over of AI systems exercised during development, deployment or use of AI. It includes human intervention and human supervision.

Human oversight helps ensure that an AI system does not undermine human autonomy or causes adverse effects. Under the AI Act, human oversight is defined specifically for high-risk AI systems with the stated purpose of “preventing or minimising the risks to health, safety, fundamental rights or environment that may emerge when a high-risk AI system is used in accordance with its intended purpose or under conditions of reasonably foreseeable misuse” (Article 14(2)).

IaaS – Infrastructure as a Service: a cloud-based model of service in which infrastructure such as computing capacity is provided via internet and hosted in a cloud.

ICT – Information and Communication Technologies: all technical means used to handle information and communication.

Intermediary (or provider of online intermediation service) - any natural or legal person which provides, or which offers to provide, online intermediation services to users.

Intervention – form of human oversight exercised as an input during the course of the automated process, i.e. before an output is produced, generally at specific points of the decision cycle of the AI system operation.

LLM – Large Language Models – Generative AI that processes vast amounts of text data in order to generate new content.

M2M (Machine to Machine) – the automated exchange of information between any type of technologies or devices.

Marketplace – e-commerce – platform enabling commercial transactions where sellers sell their products directly to buyers.

ML (Machine Learning) – One of the existing AI building techniques, ML is based on the idea that the solution for a specific task can be obtained by accessing data sufficiently representative of such a task and using a training procedure that allows fitting a mathematical model to such data.

Monitoring (in this study used interchangeably with supervision) – form of human oversight exercised over the performance of AI systems so that signs of anomalies, dysfunctions and unexpected performance can be detected and addressed as soon as possible; informs and enables intervention.

Online intermediation service – information society service and business model that facilitates transactions between multiple buyers and multiple sellers in exchange for a fee or data.

OTC (Over-the-counter) – bought and sold directly between two participants rather than on a single exchange rate.

P2P (Peer to Peer) – direct technology-enabled relation between the market participants without depending on an intermediary.

PaaS (Platform as a Service) – type of a cloud-based service in which computing platform can be utilised remotely over the Internet via cloud computing.

PAYG (Pay As You Go) – a payment system of meeting costs as they arise.

Platform – business model in the digital economy that enables the interaction between people and organisations, favouring ecosystem building.

Prediction – output of AI ADM that informs a human decision by providing a potential development of a situation in relation to the set of data analysed by the AI system, normally reflecting past and current indicators.

Recommendation – output of AI ADM that informs and recommends a decision to a human.

Repricer – tool automating pricing in e-commerce operations.

Reseller platform – platform enabling commercial transactions by buying from sellers and reselling to buyers.

RTB (Real Time Bidding) – advertising offers auction where decision-making is fully automated (programmatic advertising).

SaaS (Software as a Product) – refers to a traditional distribution of software applications in which software is developed and sold to customers as a one-time product purchase, typically with a perpetual software license.

SaaS (Software as a Service) – a cloud-based model of service in which full software applications are hosted in a cloud and are provided to users over the internet as a service, often on a subscription basis. Instead of purchasing and installing software on individual devices or servers, users access and use the software through web browsers or dedicated application interface.

Scalability (system scalability) – the property of a system to adapt to growing (or decreasing) demand, as a way to optimise resources (investment costs, resources, consumption).

Service – means any Information Society service, that is to say, any service normally provided for remuneration, at a distance, by electronic means and at the individual request of a recipient of services.

Smart contracts – originally defined as a protocol for computerised transactions in order to execute the terms of a contract, the terms has evolved and is now often closely associated with distributed ledger technology (DLT) systems, where “smart contracts” are used to automate transactions on a distributed ledger based on a program that encodes the rules for specific actions in a way that can be validated, and triggered when conditions are met.

SMEs (Small and Medium Enterprises) – the category of micro, small and medium-sized enterprises.

SSP (Supply Side Platform) – platform managing the supplied ad inventory on behalf of content providers, publishers and other websites.

Supervision – in the context of this study used interchangeably with monitoring.

Symbolic AI – logic- and knowledge-based AI approaches.

Terms and conditions (T&C) or ‘Terms of Service (ToS) – all terms and conditions or specifications, irrespective of their name or form, which govern the contractual relationship between the provider of online service and its users and are unilaterally determined by the provider of online service.

Tool – application designed to perform a specific function within a specific software environment.

User and end-user (in the context of AI) – any natural or legal person, public authority, agency or other body using an AI system under its authority, or in the course of a personal non-professional activity.

VA – Virtual Assistant: software that can process demands, tasks or questions, including those based on audio, visual, written input, gestures or motions, and that, based on those demands, tasks or questions, provides access to other services or controls connected physical devices.

2. Introduction

2.1 Motivation for the study

The objective of this study is to contribute to the EP Pilot Project by shedding light on the adoption of AI systems for the automation of contracting, in particular on the AI-enabled autonomous contracting.

Over recent years, global markets have been following a trajectory towards digitalisation.¹ Artificial intelligence stands out prominently among the technologies that are driving this digital transformation.² AI's analytical and learning capabilities allow for handling great volumes of heterogeneous data. This allows for pattern recognition or knowledge extraction, which leads to the optimisation of various processes resulting in more precise problem-solving, increased speed, lower error rate, etc. Although AI is not a new field of study,³ its extensive applications have only been showcased by relatively recent technological advancements in the field; garnering attention for its transformative impact across various domains.⁴ Since AI technology is emerging as a competitive advantage,⁵ many companies, institutions, individuals and entire markets adopt AI solutions to enhance their efficiency.⁶

In a business setting, contracting is a common activity, and enterprises need to keep track of a large number of contracts, thus facing potential issues such as lack of uniformity and difficulties in managing and updating contracts. In e-commerce and algorithmic trading, where transactions are to large extent automated, AI allows for knowledge integration into decision-making into making an offer of buying-selling transaction. AI in contracting refers to situations where software solutions

¹ COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: Shaping Europe's digital future, COM(2020) 67 final.

² C. Dirican, The impacts of robotics, artificial intelligence on business and economics, *Procedia Social and Behavioral Sciences*, 195 (2015), pp. 564-573, 10.1016/j.sbspro.2015.06.134.

³ Vivek Kaul, Sarah Enslin, Seth A. Gross, History of artificial intelligence in medicine, *Gastrointestinal Endoscopy*, Volume 92, Issue 4, 2020, Pages 807-812, ISSN 0016-5107, <https://doi.org/10.1016/j.gie.2020.06.040>. (<https://www.sciencedirect.com/science/article/pii/S0016510720344667>); S.F. Huin, L.H.S. Luong, K. Abhary, Knowledge-based tool for planning of enterprise resources in ASEAN SMEs, *Robotics and Computer-Integrated Manufacturing*, 19 (2003), pp. 409-414, 10.1016/S0736-5845(02)00033-9.

⁴ EC JRC AI Watch: https://ai-watch.ec.europa.eu/index_en; Samoili, S., Righi, R., Cardona, M., López Cobo, M., Vázquez-Prada Baillet, M. and De Prato, G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106; Righi, R., Pineda León, C., Cardona, M., Soler Garrido, J., Papazoglou, M., Samoili, S. and Vázquez-Prada Baillet, M., AI Watch Index 2021, López Cobo, M. and De Prato, G. editor(s), EUR 31039 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-53602-4, doi:10.2760/921564, JRC128744; H. Min, Artificial intelligence in supply chain management: Theory and applications, *Int. J. Logist. Res. Appl.*, 13 (2010), pp. 13-39, 10.1080/13675560902736537; F.J. Martínez-López, J. Casillas; Artificial intelligence-based systems applied in industrial marketing: An historical overview, current and future insights; *Industrial Marketing Management Special Issue on Applied Intelligent Systems in Business-to-Business Marketing*, 42 (2013), pp. 489-495, 10.1016/j.indmarman.2013.03.001; M.H. Jarrahi, Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making, *Business Horizons*, 61 (2018), pp. 577-586, 10.1016/j.bushor.2018.03.007.

⁵ L. Thow-Yick, T. Huu-Phuong, Management expert systems for competitive advantage in business, *Inf. Manage.*, 18 (1990), pp. 195-201, <https://www.scopus.com/record/display.uri?eid=2-s2.0-0039357853&origin=inward&txGid=a58c27d76a64d3a2c0daa79b8193f44c>.

⁶ M. Kohtamäki, V. Parida, P. Oghazi, H. Gebauer, T. Baines, Digital servitization business models in ecosystems: A theory of the firm, *Journal of Business Research.*, 104 (2019), pp. 380-392, doi: 10.1016/j.jbusres.2019.06.027.

using AI (*i.e.*, AI systems) are used to automate different stages of contracting, including the conclusion of contracts, as well as the pre-contractual and implementation stages. The use of AI can result in efficiency gains in different steps of contracting. AI can bring benefits in the clarification of the content, renegotiation of terms, decrease contract disputes and increase the overall volume of negotiated and executed contracts⁷. Against this backdrop, traditional contract law concepts and rules, both at national and EU level, might need to be adapted to contracts concluded and/or implemented autonomously by AI systems. One key question in autonomous contracting is, whether all the conditions necessary for the conclusion of a contract are met. This relates to the question of whether the actions of the AI system can be attributed to the natural or legal person using the system, and how it can be assured (as well as under which conditions) that the person using AI for contracting becomes legally bound by the agreement, so that the contract can be considered concluded and the relevant commercial transaction performed. It may also be necessary to identify how national legal frameworks deal with avoidance of contract because of errors/mistakes that take place in the machine-run contractual process. A virtual shopping assistant may for example order a wrong product (e.g. a decorative pumpkin instead of an edible pumpkin) or order too much or not enough of a certain product. It is therefore likely that humans want to retain a certain level of control in the machine-run contractual process for such a technology to be rolled out successfully, but it remains unclear under which conditions a party that has used autonomous AI to conclude contracts on their behalf can get out of the concluded contract.

In addition to possible issues in national laws, requirements in the EU law may need to be adapted, namely in the context of the e-Commerce Directive (ECD) and the Consumer Rights Directive (CRD). For example, certain pre-contractual information requirements might not be, in their present state, adapted to a contractual process run by autonomous AI systems.

There is therefore a need to examine whether the existing legal framework allows for novel forms of contracting and provides sufficient legal certainty for the deployment of AI in this setting; or whether differing national rules cause legal fragmentation in the EU internal market for the cross-border use of these new forms of contracting.

While it is not within the scope of this study to answer these legal questions or provide legal analysis, the conceptual approach of the study is developed in a way to inform future research (including legal and economic) on key aspects of autonomous AI contracting, and review selected case studies providing insight to the current application of AI in the contract lifecycle.

Whereas the analysis of selected case studies provides evidence of business applications using AI to automatise different stages of the contractual process, **the adoption of AI in contracting is not widespread, and, at present, little is known about the characteristics of adopters of AI in contracting**. Having an overall characterization of AI adopters in general, and adopters of AI in contracting in particular, is relevant to understand which types of enterprises are the first adopters of AI technologies, and which ones are lagging. Additionally, exploring the potential economic impact of AI in contracting is important to understand the expected implications it will have for businesses, and how it will shape contractual relationships. **The study tries to provide**

⁷ See Rich, Beverly (2018). "How AI is changing contracts", Harvard Business Review, for more details on potential advantages of AI in contracting.

evidence and analysis identifying the main factors of AI adoption in contracting and assessing its potential implications, namely in terms of costs and benefits.

2.2 Scope and General Approach

Contractual relations are ubiquitous. Contracts are horizontal legal tools used by individuals, public institutions and businesses to shape their relations within the applicable legal framework. AI systems are also horizontal: they can support many processes across the whole range of sectors. The combination of these two horizontal tools opens up a potentially broad range of AI solutions in contracting. However, in the recent uptake of AI, the profoundly innovative nature of its underlying technology and its application means that its adoption is still at a very early stage. In addition, there is scant evidence on the way businesses are currently using AI for critical contractual steps (namely contract negotiation and contract conclusion). Therefore, this study is not a mapping exercise, and the scope of the analysis is limited to B2C and B2B economic transactions. It focuses on offer generation, pre-contractual stage, conclusion as well as contract performance and termination. Special attention is paid to the conclusion of contracts.

This study approaches ‘contracting’ as an umbrella term for the contract life cycle including **1) offer generation, 2) pre-contractual stage, 3) contract conclusion and 4) contract performance, including termination**. Technology can support different stages of the contract life cycle. From the perspective of automation, every contracting stage may be approached as a single process or bundled into other processes. The *offer generation* stage includes the generation of a legal offer as well as the process leading to it, namely negotiations and pricing strategies. The *pre-contractual stage* may include product and pre-contractual information discovery, negotiations, requirement specifications, placing of orders, etc. *Contract conclusion* involves a decision-making on, for example, buying, i.e. evaluation of the relevant information that ends up with a decision on buying or not. Finally, *contract performance and termination* encompass processes such as: checkout, payment, invoicing, enabling access, delivery processes and tracking and ultimately contract termination.

Beyond the legal implications of implementing autonomous solutions in this domain, AI in contracting represents a disruptive technological innovation that encounters challenges typical of broader technological advancements, particularly in relation to achieving widespread adoption. Generally, when a new technology becomes available in the market, not all enterprises adopt it, and the adoption of new technologies might be concentrated among certain types of enterprises. Some enterprises’ characteristics are likely to be linked to the adoption of new technologies such as enterprise size, enterprise age, and sector of activity. This chapter also considers whether evidence from previous AI adoption in terms of enterprises’ characteristics can be potentially extended to AI in contracting.

Additionally, exploring the potential economic impact of AI in contracting is important to understand the expected implications it will have for businesses, and how it will shape contractual relationships. Given the lack of specific enterprise-level data on AI adoption in contracting, the study relies on evidence about adoption and use of AI in general and, subsequently, draws considerations relevant to AI in contracting. As is typically the case with new technology adoption, there is a potential for increasing productivity and leading to higher economic growth. Nevertheless, there are also costs to be considered not only in terms of technology adoption but also in terms of its influence on the nature and balance of contractual engagements.

For instance, the deployment of AI in contracting may disproportionately benefit larger enterprises with the resources to harness extensive data sets, potentially exacerbating existing disparities in bargaining power. Smaller enterprises may find themselves at a competitive disadvantage, facing steeper relative costs to initiate AI utilization and negotiate terms against data-rich, AI-empowered counterparts. The asymmetry in data access and analytical capabilities could lead to a reinforcement of the dominant market positions of larger enterprises, as they leverage AI to optimise contract terms in their favour.

Furthermore, the economic impact of AI adoption is likely to be heterogeneous, with variables like enterprise size playing a critical role. Small and medium-sized enterprises (SMEs) might encounter not only higher relative costs but also barriers to entry when adapting to AI-driven contracting landscapes, related to their capacity to obtain and leverage essential data, infrastructure, and expertise. Such technological divide could result in reduced competitiveness and a stratified market where only the most technologically adept can thrive.

Moreover, the implementation of AI in contracting demands a cautious approach due to the risks inherent in AI systems, such as the generation of spurious or 'hallucinated' outputs, and the management of sensitive data. Missteps in these areas can lead to significant reputational damage, legal liabilities, and erosion of trust in AI solutions.

This study also analyses a set of use cases where AI solutions are applied to automate contracting stages in the context of economic transactions. The selection of the use cases is based on the extensive desk research of the AI solutions already available on the market and a subsequent analysis of the user communities and applications, as a proxy for the assumed adoption. Based on this approach, the final selection of the use cases aims to present a heterogeneous range of use cases, in order to cover a wide scope of potential issues arising from the use of AI in the automation of contracting. The specific cases analysed are: Forex markets (FX), programmatic advertising, e-commerce retail sale, supply chain management and renewable energy trading. The actual analysis of each use case considers AI automation in general, but mainly focuses on detecting instances where autonomous contracting is technically already enabled, i.e., where there are AI solutions on the market capable of operating with very low degree of human oversight. This approach does not aim to discover the actual level of adoption of AI in contracting in the relevant sectors, as this would require access to data that is unavailable or still inexistent. Moreover, the study does not definitely conclude if, for a given use case, specific contracts (transactions) are concluded in an autonomous way. In fact, for contracting to be considered autonomous, apart from the technical capability of AI system, deployment-dependant and user-dependant aspects would also need to be taken into account. These aspects influence the overall control over the solution and underpin the distribution of control between the stakeholders. As they are specific to every usage experience, the possible autonomy would need to be approached with a different methodology to be scrutinised.

3. Policy Background

The digital transition is one of the key areas of the European Commission's (EC) policymaking.⁸ Digital technologies are already shaping the way European Union (EU) citizens interact, underpinning innovation across almost all productive sectors and becoming increasingly critical to economic growth.

In order to foster a successful transformation and make the EU fit for the digital age, the Commission has outlined a vision⁹ based on three main pillars to steer policy initiatives: a human-centric vision, the protection of EU values (including data protection rights), and fair and competitive digital markets. Recent technological developments, particularly the increasing role of data in the provision of services (both digital and offline), and the dramatic improvement in applications based on Artificial Intelligence (AI), challenge many aspects of the current legislative framework and underline the need for a consistent approach at EU level, also taking into account the cross-border nature of digital markets.

Against this background, the European Data Strategy puts forward a comprehensive approach to promote data-driven economy,¹⁰ which leverages on enabling technologies like AI to reap the benefits of the digital transformation. A well-functioning digital economy avails both businesses and consumers. As recognised in the Europe's Moment Communication¹¹, it is important to 'make it easier for companies, especially small and medium enterprises (SMEs), to use digital tools' and 'to reduce red tape through digital solutions, for example for contracts'. The Council Conclusions on the New Consumer Agenda adopted in 2021¹² highlight the need to ensure a reliable, safe, and fair digital environment for consumers, through adequate policies and legislation and the need to address consumer concerns into other sectoral EU policies, such as the ones linked to the green and digital transitions.

The advent of AI systems brings both opportunities and challenges. As laid down in the Commission's White Paper on AI adopted in February 2019, AI can have a beneficial impact in our society if its development and deployment are based on European values.¹³ Accordingly, the Commission has proposed two major regulatory initiatives aiming at a responsible use of AI systems, while promoting the uptake of this novel technology. On the one hand, the AI Liability

⁸ European Commission, Directorate-General for Communication, Leyen, U., Political guidelines for the next European Commission 2019-2024 – Opening statement in the European Parliament plenary session 16 July 2019; Speech in the European Parliament plenary session 27 November 2019, Publications Office of the European Union, 2020, <https://data.europa.eu/doi/10.2775/101756>.

⁹ COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: Shaping Europe's digital future, COM(2020) 67 final.

¹⁰ COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A European strategy for data, COM(2020) 66 final.

¹¹ COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Europe's moment: Repair and Prepare for the Next Generation, COM(2020) 456 final.

¹² Council of the EU, Council Conclusions on the New Consumer Agenda, 6364/21.

¹³ WHITE PAPER On Artificial Intelligence – A European approach to excellence and trust, COM(2020) 65 final.

Directive Proposal¹⁴ lays down uniform rules for certain aspects of non-contractual civil liability for damage caused with the involvement of AI systems. On the other, the AI Act¹⁵ sets harmonised rules for the development, placement on the market, and use of AI systems in the Union following a proportionate risk-based approach.

With these initiatives, the EU is leading the global legislative effort to regulate artificial intelligence, aiming to set a comprehensive framework that fosters the uptake of novel AI applications while ensuring that this new technology is developed in a safe and trustworthy way.

To scrutinise more specific implementations of AI in contracting, the EP has launched and financed a Pilot Project “Novel forms of contracting in the digital economy.” The project aims to contribute to the transition towards the digital economy and to promote the roll-out of AI technology in contracting and to support companies, Small and medium-sized enterprises (SMEs) and start-ups, in deploying business models using AI in contracting, while preserving the rights of all users and ensuring the enforceability. The PP assesses especially fully or highly autonomous solutions, namely AI systems that take decisions in an autonomous, i.e. not deterministic way, where the only human intervention may consist of starting the program or not disabling the necessary features, and able to adapt to dynamic environments making sometimes complex decisions that are not predetermined, contrary to those applications that operate solely automatically. Such autonomous solutions, capable of self-learning and foreseeing future contracting needs, are more likely to cause contract law issues, while fully pre-programmed automatic actions are likely already covered by current legal frameworks.

¹⁴ Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on adapting non-contractual civil liability rules to artificial intelligence (AI Liability Directive), COM(2022) 496 final.

¹⁵ Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT) AND AMENDING CERTAIN UNION LEGISLATIVE ACTS, COM(2021) 206 final.

4. Automated Contracting

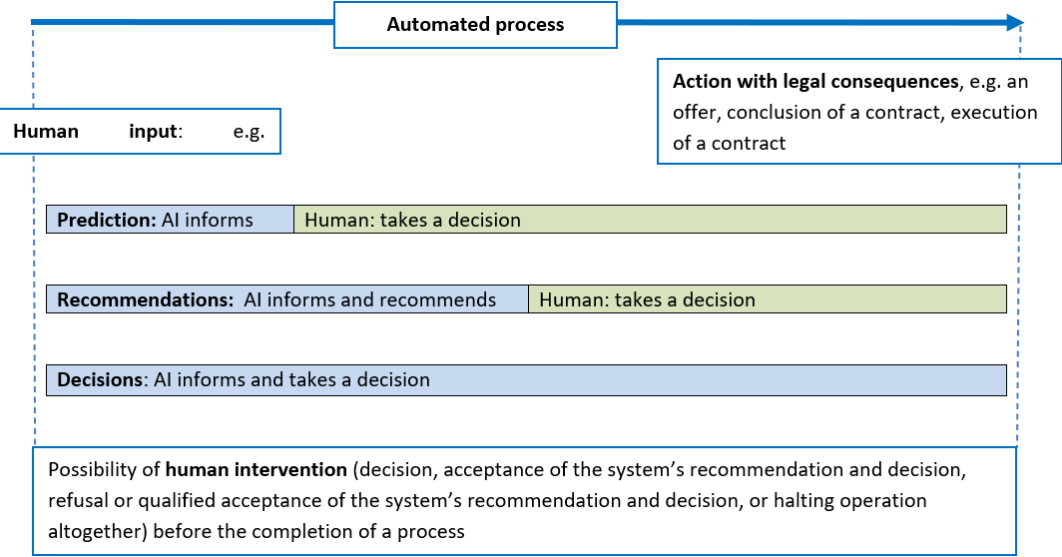
Technology in contracting can be used to automate different stages of the contractual cycle or to make decisions autonomously, with low degrees of human supervision, and in some cases, fully unsupervised. There is a growing awareness on the need to understand the transformational effect of AI in automation of contracting and to anticipate the possible issues brought up by these systems. At the same time, there is a rudimentary legal framework applicable to the automated contracting at the EU level. As the automated contracting is largely conducted in e-commerce, it is a subject to e-commerce and general contract law rules. In this context, the United Nations Commission on International Trade Law (UNCITRAL), at its 51st session (2018), tasked Working Group IV (Electronic Commerce) to revise and develop relevant provisions on automated contracting.¹⁶ As a result of this endeavour, the UNCITRAL adopted the Model Law on Automated Contracting, at its 57th session in July in 2024. The model law provides ‘a legal framework to enable the use of automation in international contracts, including through the deployment of artificial intelligence techniques and “smart contracts”, as well as in machine-to-machine transactions’. It is intended to complement and supplement existing laws on electronic transactions, in particular those based on other UNCITRAL electronic commerce texts, which have been enacted in over one hundred jurisdictions worldwide. The Model Law is the first legislative text to result from exploratory work conducted by UNCITRAL on legal issues related to the digital economy and digital trade, with work on data contracts and distributed ledger technology ongoing. Under Article 1(a). Definitions, ‘*“Automated system” means a computer system that is capable of carrying out actions without the necessary review or intervention of a natural person;*’. Another initiative concerning AI contracting is carried out by the European Law Institute (ELI). ELI tackles it under Automated Decision-Making (ADM). ADM is defined as: ‘*a computational process, including AI techniques and approaches that fed by inputs and data received or collected from the environment, can generate, given a set of pre-defined objectives, outputs in a wide variety of forms (content, ratings, recommendations, decisions, predictions etc).*’¹⁷ Automated contracting is considered a type of ADM.

In the context of contracting, the outputs of an automated decision-making may be a *prediction*, *recommendation* or *decision*. The three types of output differ on the level of human input required over the automated process. In the context of this study, only decisions are considered as actions with direct legal consequences.

¹⁶ UNCITRAL Working Group IV (Electronic Commerce), Draft guide to enactment of the Model Law on Automated Contracting (2024) A/CN.9/WG.IV/WP.185, para 17.

¹⁷ European Law Institute, *Guiding Principles for Automated Decision-Making in the EU* – ELI Innovation Paper (ELI, 2022), p.8.

Figure 1: Conceptual diagram of three types of automation output: predictions, recommendations and decisions



Source: Own elaboration.

5. Automation and AI systems: discussion

Over the past decades, technological progress and mass production and deployment of information and communication technologies (ICT) have fostered the adoption of new tools and applications aiming at improving efficiency in the economy in general, and the workplace in particular. ICT developments have been critical in technology-intensive sectors, but outside technological and scientific professions, ICT have been mostly used to support repetitive tasks, improve many aspects relating to documentation and information management (processing, storage, retrieval and exchange), as well as introduce new possibilities for communication. ICT have enabled the automation of many digital processes, facilitating the digital transformation of various sectors and altering the way relationships (including contractual ones) are established among different entities. E-commerce, for example, has flourished thanks to the automation of processes relating to buying and selling, such as product discovery, recommendation and payment, to name a few. Over time, ICT have become significantly more powerful, driven by a combination of reinforcing trends (pervasive digital communications fuelling a steep growth in data generation and sharing, a massive increase in processing and storage capacity, and a paradigm shift in programming techniques). The progressing digitalisation has been changing the way of acquiring and using information. The big data has become new source of knowledge, and the actual extraction of this knowledge become only possible with the development of new AI systems. Many decision-making processes that used to be fully handled by humans could be automated thanks to these systems. As a result, digital applications and software have acquired new functionalities, and, at their most sophisticated form, these evolved systems are now able to tackle highly specialised and complex tasks without human intervention. This ability is considered a defining feature of AI.¹⁸

Although there is not a widely accepted single definition for AI, partially due to the rapidly evolving nature of the underlying technology and the wide scope of current and potential applications, there is a need to outline the main features of AI systems in order to formulate policies able to take on the challenges raised by the uptake of these applications. In a recommendation adopted in 2019, the Organisation for the Economic Co-operation and Development (OECD) defined an AI system as “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”¹⁹, aiming to set the first intergovernmental standard on AI. In light of the continuing innovation in the field, the broadening scope of AI applications and the increasing pervasiveness of this technology, the OECD recently updated its definition of AI system as “a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and capability to adapt to new inputs after deployment.”²⁰ The AI Act aligns the definition of AI

¹⁸ Current AI systems are “able to perform individual tasks in specialized, well-defined domains, such as speech recognition, image recognition, and translation.” In contrast, “the long-term goal of general AI is to create systems that exhibit the flexibility and versatility of human intelligence in a broad range of cognitive domains, including learning, language, perception, reasoning, creativity, and planning. Broad learning capabilities would provide general AI systems the ability to transfer knowledge from one domain to another and to interactively learn from experience and from humans.” *National Artificial Intelligence Research and Development Strategic Plan*, Networking and Information Technology Research and Development Subcommittee (2017).

¹⁹ OECD, Recommendation of the Council on Artificial Intelligence, OECD/LEGAL/0449.

²⁰ See <https://oecd.ai/en/ai-principles>, as released in November 2023.

systems²¹ with the latest approach adopted by the OECD, and departs from the original proposal of the EC mentioning 'software', while the Council's proposal referred to a 'system' and the EP version to a 'machine-based system' (in line with the finally adopted OECD definition). Both 'system' and 'machine-based' encompass not only the software (like a computer program), but also the hardware that integrates the software. They also consider potential cases in which AI systems might solely rely on hardware (e.g., digital logic circuits²²).

Within this framework, the concepts of 'decision' and 'autonomy' are pivotal, yet they currently lack a comprehensive definition. As laid down in these legal texts, a decision involves an action on the part of AI systems with the potential to affect the current status of a physical or virtual setting at a given moment. However, a critical aspect that is not explicitly addressed is whether the choices made by an AI system are based on a predefined set of actions or responses determined during the design and development phases. This set of actions is typically programmed or trained into the system, guiding its decision-making process²³. However, the degree of flexibility can vary among AI systems, and some advanced systems, especially those using machine learning (ML), may exhibit a degree of adaptability and learn from data to make decisions beyond predefined actions.²⁴ The term 'autonomous' has started being used relatively recently in the context of highly complex machines and computational processes designed in ways that preclude unequivocal human prediction relating to the outputs. This term is considered by part of the technical community as referring to certain degree of self-government and self-directed behaviour²⁵. However, it should be clarified that the interpretation of "autonomous" as self-governance, in opposition to independent of user commands or user requirements, is not commonly accepted²⁶. Nevertheless, the Council conclusions on the Charter of Fundamental Rights from 21 October 2020²⁷ cited a 'certain degree of unpredictability and partially autonomous behaviour' among the characteristics of AI systems that might warrant close monitoring in order to ensure their compatibility with fundamental rights and to facilitate the enforcement of legal rules. In this context, the issue of human oversight stands as a crucial concept so as to define the level of autonomy and understand the implications of autonomous AI systems.

²¹ See Article 3 Definitions "AI system" means a machine-based system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.

²² A set of instructions hardcoded in a circuit, i.e., a series of logic gates (transistors) that implement by electronic means Boolean operations.

²³ Established AI system designs based on symbolic AI include "logical representations to deduce a conclusion from a set of constraints. It requires that researchers build detailed and human-understandable decision structures to translate real-world complexity and help machines arrive at human-like decisions". OECD, *Artificial Intelligence in Society*, doi:10.1787/eedfee77-en.

²⁴ See discussion below on relevant technical aspects underpinning the classification of AI systems.

²⁵ EU-U.S. Terminology and Taxonomy for Artificial Intelligence, First Edition, 2023. URL: <https://digital-strategy.ec.europa.eu/en/library/eu-us-terminology-and-taxonomy-artificial-intelligence>; SAE International, '(R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles', J3016 202104, 2021.

²⁶ See entry 3.15 on 'autonomy' and 'autonomous' in ISO/IEC DIS 22989(en) 'Information technology — Artificial intelligence — Artificial intelligence concepts and terminology'; For further details we direct the reader to the discussion presented in Section 3.2 in Fernandez Llorca, D. and Gomez Gutierrez, E., *Trustworthy Autonomous Vehicles*, EUR 30942 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-46055-8, doi:10.2760/120385, JRC127051.

²⁷ Council of the European Union, *Presidency Conclusions, 21 October 2020*, 11481/20, available at: <https://www.consilium.europa.eu/media/46496/st11481-en20.pdf> [accessed September 2024].

The AI Act requires that high-risk AI systems are developed and provided in a way that ensures human oversight during the use of the system. Human oversight,²⁸ as introduced by the AI Act, refers broadly to the possibility of human influence over the AI system. It encompasses the capability to monitor, understand and interpret the overall activity of the system, the ability to decide not to use the system in any particular situation, as well as to intervene on the systems' operation or interrupt the system.

5.1 Automation (and Autonomy) of AI systems: a design feature

When we speak about “*automation*” or “*automated decision making*” (ADM) we broadly refer to the use of technology to design a process or a system that, under specified conditions, operates with a low degree of human oversight (including the absence of human intervention). The “*level of automation*” is usually inversely proportional to the degree of human involvement needed and the term “*autonomous*” usually refers to high levels of automation. The terms “*automated*” and “*autonomous*” are in principle *technology neutral*, as they simply reflect a design decision regarding the level of human oversight. For example, we refer to an “*automated car*” when a backup driver is required, therefore providing supervision and ready to resume manual control when needed (intervention), while we refer to an “*autonomous car*” when no standby driver is needed (all occupants of the car are mere passengers)²⁹. While the underlying technology enabling such vehicle could be the same, the main difference between the two is the design decision regarding the level of human oversight in each case. From the technical perspective therefore, *autonomy*, may be understood as “the capability to perform with an absent or low degree of external influence or human involvement”.³⁰

The processes or tasks that can be automated can be both physical and cognitive tasks. They can be implemented using a simple set of rules or a hard-coded formula combining a finite number of parameters, or by using a very complex deep learning model/neural network involving millions of learned parameters. As a general rule, we can assume that the more complex the task to be automated and the higher the level of automation sought, then the more complex the technology required will be. However, we cannot assume that an automated system is not based on very advanced AI. This is because systems may be considered automated (and not autonomous) due to the higher level of human oversight built into the system due to the external requirements and not linked to the system's capability, such as for example legal requirements. In such case, although systems will not work in an autonomous way, the technology used may still be very complex and advanced.

5.2 Human oversight

The degree of human oversight in AI systems capable of making and implementing decisions is usually a design variable. That is a choice made by the developer, with the exception of those cases

²⁸ Estevez Almenzar, M., Fernández Llorca, D., Gómez, E., Martínez Plumed, F., Glossary of human-centred artificial intelligence, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/860665, JRC129614.

²⁹ Fernandez Llorca, D. and Gomez Gutierrez, E., Trustworthy Autonomous Vehicles, EUR 30942 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-46055-8, doi:10.2760/120385, JRC127051. 15

³⁰ Estevez Almenzar, M. et al. (2022) “Glossary of human-centric artificial intelligence”. EUR 3113 EN, Publications Office of the European Union, Luxembourg, JRC129614.

where due to their complexity or legal requirements, a system cannot be fully automated. For example, we can have a very advanced AI system that is only recommending or informing the user about a possible decision and humans can implement the decision by performing the required actions or just ignore them. On the other hand, we can also have systems that do not ask for human intervention before making and implementing a decision.

The design-enabled human oversight is fundamental for trustworthy AI. As provided in "Ethics guidelines for trustworthy AI" adopted by the High-Level Expert Group on AI appointed by the European Commission,³¹ trustworthy AI should be lawful (respecting all applicable laws and regulations), ethical (respecting ethical principles and values) and robust (both from a technical perspective while taking into account its social environment). It is important to note that human agency and oversight is the first out of seven key requirements for trustworthy AI systems. It recognises that 'proper oversight mechanisms need to be ensured, which can be achieved through human-in-the-loop, human-on-the-loop, and human-in-command approaches.' The remaining requirements deal with (a) technical robustness and safety, (b) privacy and data governance, (c) transparency, (d) diversity, non-discrimination and fairness, (e) societal and environmental well-being, as well as (f) accountability.

More specifically, the AI Act includes a requirement (Art. 14) on human oversight measures for high-risk AI systems. Human oversight includes in particular the possibility of human intervention. In this context, human oversight measures should "guarantee that the system is subject to in-built operational constraints that cannot be overridden by the system itself and is responsive to the human operator, and that the natural persons to whom human oversight has been assigned have the necessary competence, training and authority to carry out that role". As previously mentioned, Article 14(3) AI Act, obliges the provider to enable human oversight. One of the forms of oversight referred to in the Article 14(3)(e) AI Act is "intervention" on the operation of the high-risk AI system or interruption of the system through a "stop" button or a similar procedure. The possibility of intervention indirectly implies necessity of monitoring (term often used interchangeably with 'supervision') the operation and performance of AI systems. Monitoring informs and enables the intervention itself.

In this sense, "intervention" does not cover the initial human input made before the automation of a process is initiated. However, in the context of this study, the forms of human intervention include, *inter alia*, validation of the output and notification with an option to cancel, change or interrupt the automated task, and human oversight applies to any AI system under consideration, rather than limited to high-risk AI systems. In fact, human oversight is considered a general requirement of a trustworthy AI system³².

As long as automation of different contracting stages is considered (including conclusion of contracts with AI), we can assume that, if sufficient data is available, current state-of-the-art autonomous systems can be applied without any human supervision or intervention. This means that, the AI system could go beyond recommending or informing about possible contract decisions, and could actually make and implement the decision without human supervision or potential intervention.

³¹ High-Level Expert Group on AI. "Ethics guidelines for trustworthy AI", 2019.

³² High-Level Expert Group on Artificial Intelligence, *Ethics Guidelines for Trustworthy AI*, 2019.

5.3 Non-AI, symbolic AI and Machine Learning

Defining AI automated systems with respect to non-AI automated systems has been the subject of considerable debate³³. In both cases we refer to computational or machine-based programs/systems. For *non-AI automated* systems, we usually refer to those computer programs in which the designer explicitly implements the instructions needed to solve a particular problem. In this way, the operation of a *non-AI* computer program can be traced back to an earlier human decision to create such a program and to deploy it to perform a specific task. When applying it to conclude a contract, all the information required can be considered as pre-programmed in the form of computing software.

On the other hand, when we refer to *AI automated systems*, we need to introduce at least two categories. First, the so called “*symbolic AI*”, also known as logic and rule-based, or Good Old-Fashioned AI (GOFAI), which is a type of AI in which human knowledge is transferred into symbols and rules. It is an example of deterministic AI system. This form of AI attempts to explicitly represent human knowledge in a declarative form (e.g., a knowledge base). It uses symbols and symbolic expressions to represent the world and uses algorithms to manipulate these symbols and reason about them (e.g., inference engines). Expert systems and logic-based AI are examples of *symbolic AI*. Given that *symbolic AI* involves human experts to develop the main reasoning capabilities, they are closer to traditional computer programs than the second category of AI (*machine learning*) is.

Machine learning (ML) is to a large extent a non-deterministic algorithm at the core of many AI systems. ML approaches are based on the idea that the solution for a specific task can be obtained by accessing data sufficiently representative of such a task and using a training procedure that allows fitting a mathematical model to such data. In other words, machine learning is a subset of AI where systems learn from data. These approaches have been greatly benefited by the availability of massive data and improved computing power, which has enabled the use of increasingly complex models capable of solving increasingly sophisticated problems. In addition, this approach allows for continuous adaptation and improvement of the system throughout its life cycle as more data, experience of use, and interaction become available, making it a very powerful methodology.

In the context of contract law, and the automation of some of the tasks in the contracting workflow, if we focus on *symbolic AI*, we can assume that there is expert knowledge specifically encoded in the implementation of the system, whereas for *machine learning*, we need to consider that a sufficient and representative amount of data is available to train a model tailored to the specific task.

While this distinction is important for the developers and providers it may be less relevant for the end users of the systems, *i.e.*, contracting parties. Developers and providers are required to ensure appropriate level of human oversight in order to mitigate the risk to fundamental rights, hence the capabilities of AI system will need to be taken into account by them. Moreover, there are other

³³ Samoil, S., Lopez Cobo, M., Delipetrev, B., Martinez-Plumed, F., Gomez Gutierrez, E. and De Prato, G., AI Watch. Defining Artificial Intelligence 2.0, EUR 30873 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-42648-6, doi:10.2760/019901, JRC126426.

obligations foreseen for the providers where distinguishing between the systems used matters: such as an obligation to ensure robustness of the systems that continue to learn after being placed on the market (Art.15 AI Act) or obligation of post-market monitoring that need to be proportionate to the nature of AI technology (Art. 72 AI Act). On the level of the contracting parties, however, it is rather difficult or even not feasible to distinguish between the symbolic or machine learning AI and even between AI and non-AI. Some authors consider that, from a contract law perspective, the complexity of the automation technology may be irrelevant or at least inconsequential.³⁴ Also, UNCITRAL proposes the same principles for automated contracting whatever the system used in the recently adopted Model Law on Automated Contracting.³⁵ Nevertheless, in such case the legal umbrella of the automated contracting should be broad enough to cover issues specific to the use of AI systems. Even if human oversight is ensured and deemed proper as well as executed by users according to the provider's information, the risk of unintended outcomes still exists. This is due to the specific features of AI systems such as black-box architecture. On the other hand, AI models that exhibit the best predictive accuracy, and therefore are the most powerful and effective, seem to be, paradoxically, those with the most opaque black-box architectures.³⁶

5.4 Specific features of certain AI systems

As AI advances, there is growing concern about the risks it may pose to legally protected values, like physical integrity, property or other fundamental rights that its adoption may entail. These risks arise mainly from intrinsic characteristics of certain AI systems such as lack of causality, opacity, unpredictability, or the uncertainty derived from self and continuous learning capabilities, as well as other features such as bias.³⁷

In a nutshell we can group the specific AI features in **two main blocks**.

First, the features linked to the way AI systems are developed (or function) that may lead to unpredictability, non-deterministic and unexpected outcomes or behaviours. For example, when the data used for training is not sufficiently representative of the task, when the model has been over-fitted to the data, or due to the difficulties when learning causal relationships that inform the outputs, such as decisions in contracting. The unexpected outcomes, even in case if they can be linked to the specific development issues, are inherently difficult to be avoided.

The second block of AI-specific features refers to opacity, also known as the black-box problem. In this context, opacity arises due to extrinsic variables, such as task complexity or dimensionality, but it is mainly due to the intrinsic complexity of state-of-the-art machine learning systems, which defies human-scale reasoning and understanding. Complexity is a broad concept related to the whole system (number of interconnected elements, complexity of the supply chain,

³⁴ Mik, Eliza. "Much ado about artificial intelligence or: the automation of contract formation", *International Journal of Law and Information Technology*, 2022, 30, 484-506. <https://doi.org/10.1093/ijlit/eaad004> 486

³⁵ Annex IV: UNCITRAL Model Law on Automated Contracting (A/79/17 94 V.24-13025), available at: [mlac_en.pdf \(un.org\)](https://www.un.org/development/delap/artifical/mllaw/) . For the announcement of the formal adoption, please see notice of 15th July 2024, UNIS/L/362.

³⁶ Carabantes, M. Black-box artificial intelligence: an epistemological and critical analysis. *AI & Soc* 35, 309–317 (2020). <https://doi.org/10.1007/s00146-019-00888-w>.

³⁷ The impact of these features of certain AI systems on liability or product safety regimes has been widely studied before. See for example: Fernandez Llorca, D. et al. "Liability Regimes in the Age of AI: a Use-Case Driven Analysis of the Burden of Proof", *Journal of Artificial Intelligence Research*, Vol 76 (2023) 613-644.

etc.) and to the operating environment (number and type of agents, interactions, structure of scenarios, etc.). On the one hand complexity is a main factor contributing to opacity, on the other hand, the high complexity and capabilities of some AI systems allow to deal with complexity in other contexts contributing to the implementation of solutions that perform tasks and make decisions with increasing autonomy. It is reasonable to assume that, with the current state-of-the-art technologies, only complex and advanced AI systems can be autonomous.

5.5. Delivery mode of AI solutions

The delivery mode of AI solutions to the market and eventually to the user affects the contracting parties' control over the selected tool and is the result of the combination of three main aspects: *provision modality*, *type of provider* and the solution's *readiness to use*.

5.5.1 Provision modalities

AI solutions can be provided in two basic modalities: as AI products and AI services.

AI product is a complete licence-based software solution that can be downloaded in the form of desktop or mobile application. It can be subject to various updates to function in an optimal manner.

AI service is the most common way of provision of AI solutions to a user. AI services can be accessible via application interface (desktop or mobile) or directly via a website. The service provider may choose between two main types of services: cloud-based services and on-premise services.

Cloud computing further offers different variants of services to be included into the development and provision of AI solutions:³⁸

- Infrastructure-as-a-service (IaaS): IaaS refers to the delivery of infrastructure such as computing capacity. Also known as hardware-as-a-service, IaaS encompasses all the physical computing resources that support delivery of applications as a service;
- Platform-as-a-service (PaaS): PaaS is a method by which an entire computing platform can be utilised remotely over the Internet via cloud computing. PaaS refers to a broad collection of application infrastructure, including operating systems, application platforms and database services;
- Software-as-a-service (SaaS): SaaS is a software model that incorporates the delivery and management of a software application to a remote client via the Internet. SaaS relies on the centralised hosting of a software application that is typically accessed via a web browser application.³⁹

With cloud computing, participants in the ecosystem have the opportunity to leverage a variety of digital technologies, including artificial intelligence, blockchain, the Internet of Things (IoT), and even autonomous delivery solutions like drones or robots, to enhance and automate the e-commerce

³⁸ OECD (2019), *Going Digital: Shaping Policies, Improving Lives*, OECD Publishing, Paris, <https://doi.org/10.1787/9789264312012-en>.

³⁹ OECD (2019), *Going Digital: Shaping Policies, Improving Lives*, OECD Publishing, Paris, <https://doi.org/10.1787/9789264312012-en>.

processes. The key differences between the on-premise services and cloud-based services are presented below:

Table 1: On-premise service and Cloud-based service

| | On-premise service | Cloud-based service |
|----------------------------|--|---|
| Costs of service provision | High upfront costs, low ongoing costs | No/low upfront cost, high ongoing costs |
| Performance | Good performance (the provider is responsible for the overall settings of the system) | Depends on configurations, cloud type, specialist skills, internet connectivity, etc. |
| Scalability | Difficult to scale-up | Scaling-up or down occurs almost instantly and on-demand |
| Customisation | Provider has a full control over the system which makes it easier for the provider to control relation with a user and customisation options | Customisation options are dependent on a broader ecosystem of players |
| Security | Provider has full control over the security of the system | Control and security distributed among players of the ecosystem |

Source: Own elaboration.

The services can be accessed via different payment modes. Subscription-based and pay-as-you go (PAYG) models represent a large shift towards flexible, seamless, digitally driven access to AI services. Therefore, we notice a departure from a product to a service model that is underpinned by cloud computing and flexible payment modes.⁴⁰

5.5.2 Types of providers

AI solutions can be delivered to a user by different types of providers. In principle this is possible due to the fact that interactions among different types of participants are facilitated by a platform. Platforms provide technical infrastructure⁴¹ upon which other applications, processes or technologies can be developed and shared.⁴²

In general, AI solutions are enabled by a platform environment and can be provided as a platform functionality or an independent tool that plugs into a platform. The provider to the user may be a contracting party, intermediary or external provider.

⁴⁰ OECD (2019), Unpacking E-Commerce: Business Models, Trends and Policies, OECD Publishing, Paris, <https://doi.org/10.1787/23561431-en>.

⁴¹ Chenxing Wang, Sayed Fayaz Ahmad, Ahmad Y.A. Bani Ahmad Ayassrah, Emad Mahrous Awwad, Muhammad Irshad, Yasser A. Ali, Muna Al-Razgan, Yasser Khan, Heesup Han, An empirical evaluation of technology acceptance model for Artificial Intelligence in E-commerce, *Heliyon*, Volume 9, Issue 8, 2023, <https://doi.org/10.1016/j.heliyon.2023.e18349>.

⁴² See, for example: Parker, G., and Van Alstyne, M. (2005). Two-sided network effects: A theory of information product design. *Management Science*, 51(10), 1494–1504, Cennamo, C., and Santalo, J. (2013). Platform competition: Strategic trade-offs in platform markets. *Strategic Management Journal*, 34(11), 1331–1350, Zhu, F., 2019. Friends or foes? Examining platform owners' entry into complementors' spaces. *Journal of Economics & Management Strategy*, 28(1), pp.23-28, and Guilherme Brittes Benitez, Antonio Ghezzi, Alejandro G. Frank, When technologies become Industry 4.0 platforms: Defining the role of digital technologies through a boundary-spanning perspective, *International Journal of Production Economics*, Volume 260, 2023, 108858, <https://doi.org/10.1016/j.ijpe.2023.108858>.

In the context of transactions and therefore pertaining to the focus of this study, one of the **contracting parties** may provide AI solutions for the other party to use. The AI solution can also be delivered by an **intermediary** (a platform) that enables interaction between the contracting parties but is independent from them. In such a case the platform providers are often companies that specialise in the technical ecosystem building and solutions in the specific sector. Finally, the AI solution provider may be an **external provider**, independent from both the contracting parties and platform provider. As platforms facilitate the ecosystem-building of different actors, AI solutions can often be developed and provided in the form of a tool that can be used within the dedicated environment. For example, the users (contracting parties) of Amazon marketplace (intermediary) may choose between the pricing tool provided by the Amazon platform or use the third-party tools (external provider) compatible with Amazon.

5.5.3 Customisation capacity

The delivered AI solutions also differ on the customisation capacity. Depending on the customisation capacity, the influence of the user over the tool may reach different level. We can distinguish the following degrees of the customisation capacity:

- Off-the-shelf solutions (ready-to-use AI solutions) – user can control the settings to the extent ensured by the provider in the design of the system delivered to the client, as far as mandatory design requirements do not apply under the AI Act (for example, for high-risk systems).
- Customised solutions (AI solutions can be customised by a provider based on user's requirements or be delivered in a form that supports customisation by a user) – user can use coding skills to alter the tool and ways to control it,
- Solution-builder tools (such solutions come in the form of a toolbox that can be used by a user to build its own custom-made AI solution) – user creates its own tool.

The fully automated contracting does not necessitate human intervention, but could include it, alongside other forms of human oversight, or any other form of human control exercised before or after the course of the automated process.

6. Evidence on the General adoption of AI

In recent years, some data sources emerged on the adoption and use of AI by enterprises. Typically, these data tend to consider the adoption of AI in general, with a few exceptions on more specific types of usage (*e.g.*, robots). Nevertheless, there is currently no data source focusing on the adoption of AI in contracting as far as we are aware of.⁴³ Scant data is available on how different sectors are accessing and using a new technology that is, at its core, a general tool with a great potential for adaptability, albeit not yet mature enough to overcome barriers inherent to innovations: dynamic (not-consolidated) markets, difficult risk assessment, high investment costs, need for specialised skills or infrastructure, *etc.* (Bergek *et al.*, 2008).

Existing studies on the use of AI by firms are mainly based on three data sources: i) firm-level surveys; ii) job posting data with information on AI skills demand; and iii) information contained in intellectual property (IP) records, in particular on patents. Most of these studies are country-specific with many relying on data for the United States. In this section, we present some of the main findings from the most extensive studies publicly available on AI adoption. The results are not generally comparable between studies as they tend to be based on different samples and analyse different time periods. As an example, the Eurostat ICT Usage in Enterprises survey (2023) considers EU firms with 10 or more employees and self-employed people that were using at least one AI technology. Other studies, such as the Ipsos-iCite (2020), consider micro firms as well (*i.e.*, defined as firms with 5-9 employees). Additionally, in case diverse AI technologies are considered, they are not typically the same. Therefore, performing comparative analysis according to types of AI technology, even when possible, remains challenging.

This report refers to the following studies:

- i) “AI Watch TES Analysis of AI Worldwide Ecosystem” (Samoili *et al.*, 2020);
- ii) “AI Watch Index 2021” (Righi *et al.*, 2022);
- iii) “A portrait of AI adopters across countries: Firm characteristics, assets’ complementarities and productivity” (Calvino and Fontanelli, 2023). We also include a brief description of the OECD AI dashboards;
- iv) “The AI Index 2024 Annual Report” (Macej *et al.*, 2024).

Additionally, an important data source on AI adoption by EU enterprises is the Eurostat ICT Usage in Enterprises survey (2023). While this is not a report, it is a key representative data source for the EU and EU enterprises. The main results of this survey regarding AI adoption were published in an Eurostat article “Eurostat Use of artificial intelligence in enterprises (2024)”. The information provided by the Eurostat is also described in more detail below (Section 6.4 The Eurostat ICT Usage in Enterprises survey).

⁴³ This consideration arises from literature review, data available from the Eurostat and information received by statistical offices.

6.1 AI WATCH

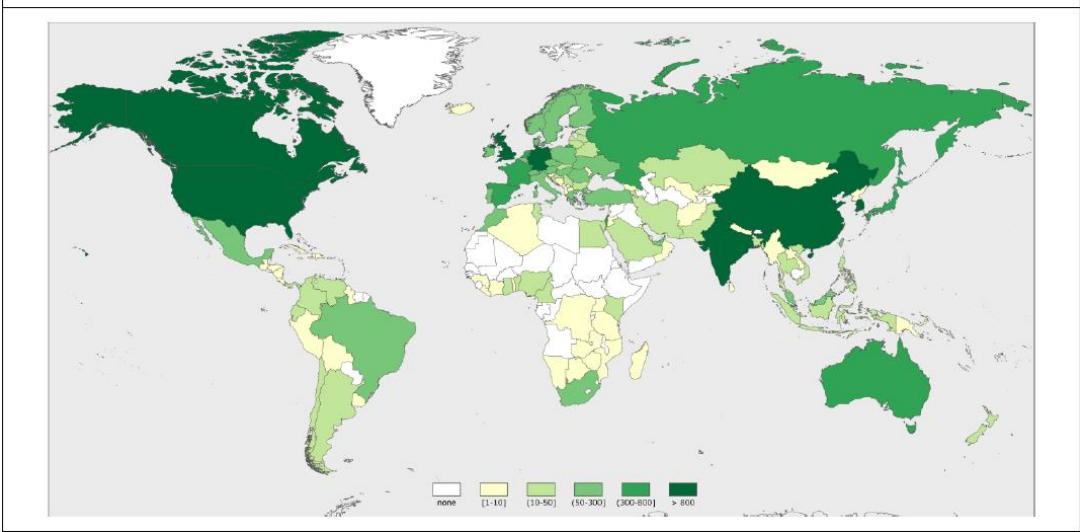
AI Watch is the initiative of the European Commission's Joint Research Centre (JRC) that monitors the development, uptake and impact of Artificial Intelligence for Europe (Samoili et al., 2020; Righi et al., 2022) and is a component of the EU's larger plan to track and evaluate the advancement and application of AI technology within the EU. It entails careful monitoring, analysing, and reporting on changes related to artificial intelligence (AI), including improvements in technology, market trends, and regulatory developments. The purpose of AI Watch is to supply timely and thorough information to researchers, industry stakeholders, policymakers, and the general public in order to support responsible and ethical development of AI within the EU and aid in decision-making. Some informative studies on AI were performed based on AI Watch (*e.g.*, Samoili et al., 2020; Righi et al., 2022), and we include a short description of their main findings in the next subsections.

6.1.1 EC JRC Report on the AI Worldwide ecosystem

The JRC Technical Report "AI Watch TES Analysis of AI Worldwide Ecosystem" (Samoili et al., 2020) is one of the first attempts to describe the AI Worldwide Ecosystem. It analyses and compares countries and regions in the evolving international industrial and research landscape of AI. The evidence presented is based on a unique database covering the years 2009-2018. The database has been specifically built from a multitude of sources to provide scientific evidence and monitor the AI landscape worldwide. Companies, universities, research institutes and governmental authorities with an active role in AI are identified and analysed in an aggregated fashion. The report presents a wide variety of indicators, such as the size of the AI ecosystem globally and at the country level; the main global competitors of the EU; the level of industrial involvement per country; the enterprises' demographics, profiling of economic agents according to their strengths in innovation and take-up of AI, including their patenting performance; and the degree of internal and external collaborations between EU and non-EU enterprises and research institutions. Subsequently, the report uses the indicators to build a country ranking on the adoption of AI.

Based on the total number of active players in AI, the United States, China, India, South Korea, the United Kingdom, and Germany are the primary players in the AI Worldwide Ecosystems with more than 800 active players each (**Figure 2**- from Samoili et al., 2020). Nonetheless, the remainder of the EU is not far behind, with an average of 300–800 active players in nearly every member state (Samoili et al., 2020).

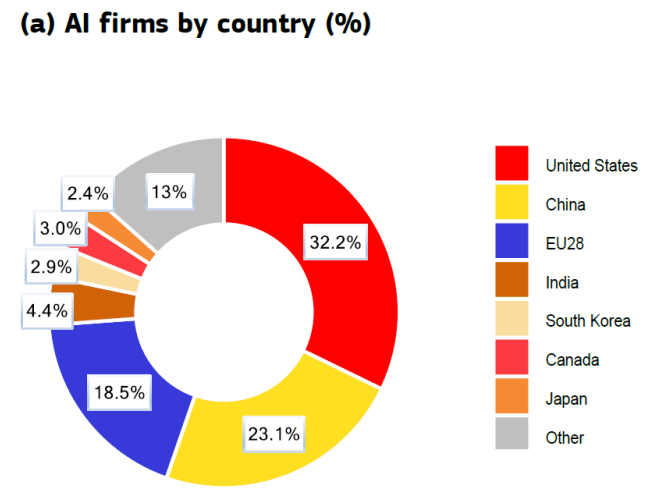
Figure 2: Worldwide distribution of players active in AI at the country level, 2009-2018.



Source: Samoili et al., 2020.

The percentage of AI enterprises by country is displayed in Figure 3 (from Samoili et al., 2020)⁴⁴: the US dominates with 32% of enterprises being AI adopters, China comes second with 23%, and the EU28 comes third with 19%.

Figure 3: Overview of firms involved in AI related processes, 2009-2018



Source: Samoili et al., 2020.

⁴⁴ This report considers data from 2009-2018, when the UK was still part of the EU.

6.6.2 AI Watch Index 2021

The JRC Technical Report “AI Watch Index 2021” (Righi et al., 2022) provides an analysis of multiple indicators related to the positioning and performance of the EU along different AI indicators. Table 2 presents a summary of the AI Watch Index indicator, which is organised in five dimensions: i) global view on the AI landscape, ii) industry, iii) research and development (R&D), iv) technology, and v) societal aspects. Righi et al. (2022) highlight that the AI domain has spread after very active years of technological development, both in hardware and software terms; and this phenomenon can be noticed everywhere in the economy and society, because more AI-supported tools and applications are used in both working environments and in the personal sphere.

Table 2: Summary of AI Watch Index Indicators by dimension

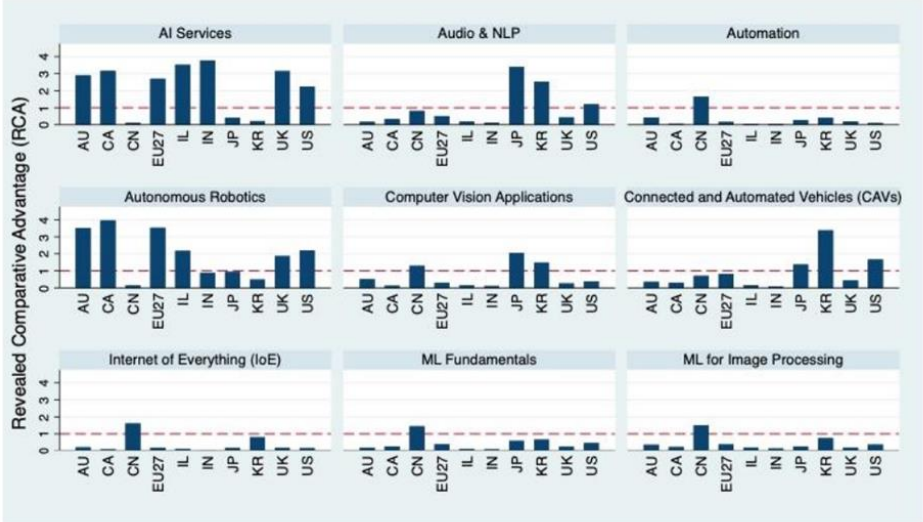
| AI Watch Index dimension | AI Watch Index sub-dimension | Indicator name |
|--|------------------------------|---|
| G – Global view on the AI landscape | AI activity | G1: AI economic players G2: AI player intensity |
| | AI areas of strength | G3: AI areas of specialisation: comparative advantage in AI thematic areas G4: AI thematic hotspots G5: EU's comparative advantage in industrial robotics trade |
| | AI investments | G6: AI investments in the EU |
| I – Industry | Industry | I1: AI firms' profile I2: Robotics start-ups in the EU |
| R – Research and development | R&D activity | R1: AI players in AI R&D R2: AI R&D activity score |
| | Network of collaborations | R3: AI R&D collaborating countries R4: Peer-to-peer collaborations R5: Strategic position in the network of collaborations |
| T – Technology | Performance of AI | T1: Performance of AI research |
| | Standardisation | T2: Standardisation activity engagement |
| S – Societal aspects | Diversity in research | S1: Gender diversity index S2: Geographic diversity index S3: Business diversity index S4: Conference diversity index |
| | Higher education | S5: AI in university programmes in the EU S6: University places with AI content in the EU S7: AI intensity in university places in the EU |

Source: Righi et al., 2022.

Since more AI-supported tools and applications are being used in both personal and professional settings, the AI domain has expanded as a result of years of intense technological development in both hardware and software (Righi et al., 2022). This phenomenon is evident throughout the economy and society, namely via a notable surge in AI investment in the EU between 2018 and 2019, both from the public and private sectors (from Righi et al., 2022).

The use of AI varies widely across sectors, and it is informative to know AI areas of specialisation among different geographical areas. The revealed comparative advantage (RCA) provides this information as it measures a country’s specialisation in a thematic area in comparison with the global average specialization for that thematic area.⁴⁵ The areas of specialization as a comparative advantage between nations or regions are displayed in Figure 4 (from Righi et al., 2022). It is noteworthy that China ranks among the first in many thematic areas, with the exception of autonomous robotics, where the EU, Canada, and Australia predominate, and AI services, where all nations/regions rank higher than the three Asian nations. The European Union (EU) enjoys a comparative advantage in AI services, emphasizing the role of its AI players in the provision of services between enterprises (B2B) or to the end-consumers (B2C) (Righi et al., 2020). The advantage of the EU is also particularly strong in Autonomous Robotics. The data is consistent with an OECD report that used enterprises from 11 different nations to show how common AI use is in ICT and professional services (Calvino and Fontanelli, 2023).

Figure 4: AI areas of specialisation: comparative advantage in AI thematic areas. Top worldwide countries and the EU (2009-2020)



Note: AU: Australia, CA: Canada, CN: China, EU27: European Union as of 2020, IL: Israel, IN: India, JP: Japan, KR: South Korea, UK: United Kingdom, US: United States.

Source: Righi et al., 2022.

Lastly, it should be noted that AI is advancing rapidly outside of the industrial sector as well. In the field of education, the proportion of studies related to artificial intelligence has experienced a significant increase. AI is evolving in university curricula for both bachelor’s and master’s degrees. Since the need for professional skills connected to artificial intelligence is growing, this is a critical component of the anticipated expansion in industrial sectors (Maslej et al., 2023). Also, complementary assets, including ICT skills, high-speed digital infrastructure, and the use of other

⁴⁵ To be more precise, the RCA is calculated in the following way: 1) sum of activities of a country in a thematic area divided by the sum of activities of a country in all areas; 2) sum of worldwide activities in a thematic area divided by the sum of worldwide activities in all areas; 3) share calculated in 1) divided by the share calculated in 2).

digital technologies, which are significantly related to the use of AI, appear to play a critical role in the productivity advantages of AI users (OECD, 2023).

6.2 OECD portrait of AI adopters

In 2023, the OECD published a report titled “A portrait of AI adopters across countries: Firm characteristics, assets’ complementarities and productivity” (Calvino and Fontanelli, 2023). This report analyses the use of AI in firms across 11 countries. In terms of methodology, the analysis was conducted using a distributed microdata approach based on a harmonised statistical code developed by the OECD – in the context of the AI diffuse project – and executed in a decentralised manner on official firm-level surveys.

Some of the main findings include:

- the use of AI is prevalent in ICT and Professional Services;
- the use of AI is more widespread across large – and to some extent across young - firms;
- AI users tend to be more productive, especially the largest ones;
- complementary assets, including ICT skills, high-speed digital infrastructure, and the use of other digital technologies, which are significantly related to the use of AI, appear to play a critical role in the productivity advantages of AI users.

6.2.1 OECD AI dashboards

Legal instruments and policies can be important for new technologies such as AI: they can protect citizens while enabling the adoption of AI technologies by companies. AI developments are being made at a fast pace, making it difficult for policymakers and regulators to keep track of all developments and ensure that the right policies and government frameworks are established. The OECD AI dashboards⁴⁶ aim at contributing to the understanding and mapping of AI policies worldwide. Moreover, tackling AI-challenges requires a joint effort and cooperation among different actors and countries. Therefore, mapping AI policies worldwide can provide very valuable information. The OECD AI dashboards provide a live repository of over 800 AI policy initiatives from 69 countries, territories and the EU, which can also be a good proxy for the adoption of AI. At the European Union level, the OECD AI dashboards report a total of 63 policies, which were categorised according to different policy instrument types: AI enablers and other incentives (15 policies); financial support (11 policies); guidance and regulation (21 policies); governance (24 policies).⁴⁷

EU enterprises can benefit from policies that support the use of new technologies as it is the case of AI, with the aim of accelerating the uptake of new technologies and reinforce its impact on the

⁴⁶ OECD.AI (2021), powered by EC/OECD (2021), database of national AI policies, last accessed on 10/10/2024, <https://oecd.ai/en/dashboards/overview>.

⁴⁷ <https://oecd.ai/en/dashboards/countries/EuropeanUnion>, last accessed on 10/10/2024. The categorisation might overlap, and therefore one policy can be part of more than one category.

European economy (Moreno María et al., 2023). In fact, the EU is lagging behind the US in some key technologies such as AI (EIB, 2023).

6.3 Stanford University AI Index

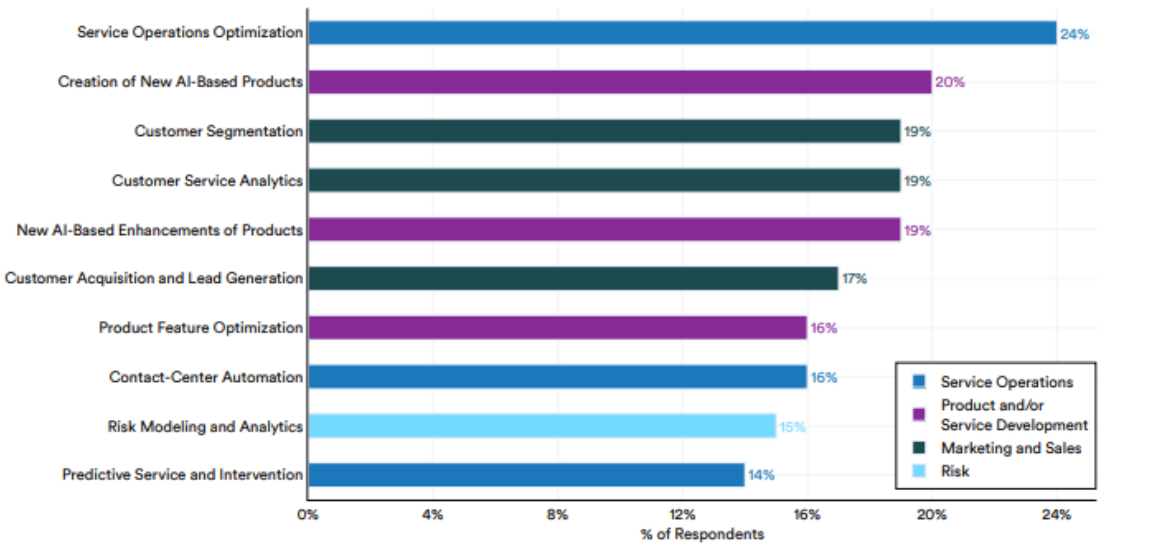
The AI Index 2023 of the Stanford University (Maslej et al., 2023) sheds more light on the adoption of AI based on a set of indicators. The report focuses mainly on the US, but it also covers the EU in areas such as private investment, research and development (among others, on AI journal publications, AI journal citations, AI conference publications, AI repository publications, significant machine learning systems). The report aggregates analyses done by third parties (often non-institutional consultancy companies). Some of the main takeaways from the report include the following:

- industry races ahead of academia in terms of released machine learning models. This has been a reality since 2014: before this year, most significant machine learning models were released by academia;
- AI is both helping and harming the environment;
- the number of incidents concerning the misuse of AI is rapidly rising (*e.g.*, related to deep-fakes);
- for the first time in the last decade, year-over-year private investment in AI decreased in 2022;
- while the proportion of companies adopting AI might have temporarily plateaued, the companies that have adopted AI continue to perform better than those that have not, presenting significant cost decreases and revenue increases;
- policymakers' interest in AI is on the rise and an AI Index analysis of legislative records of 127 countries shows that the number of bills containing "artificial intelligence" that were passed into law grew: while there was only 1 in 2016, in 2022 they reached a total of 37.

Maslej et al. (2023) acknowledge that with the developments throughout 2022 and the beginning of 2023, AI has moved into a new phase of deployment. They highlight that is mainly due to new large-scale AI models that have been released every month. These models, such as ChatGPT, Stable Diffusion, Whisper, and DALL-E 2, are capable of an increasingly broad range of tasks, from text manipulation and analysis, to image generation, to unprecedentedly good speech recognition. They recognise that these systems demonstrate capabilities that outperform the state-of-the-art on many benchmarks, old and new. However, they are prone to issues such as hallucination⁴⁸, the results might be routinely biased, and can be tricked into serving nefarious aims.

⁴⁸ Hallucinations refer to incorrect or misleading results that AI models generate. These results can be due to incorrect assumptions made by the model, insufficient training data or biases in the data to train the model. A more detailed description is provided while discussing potential risks of AI in contracting.

Figure 5: Most commonly adopted AI use cases by function, 2022



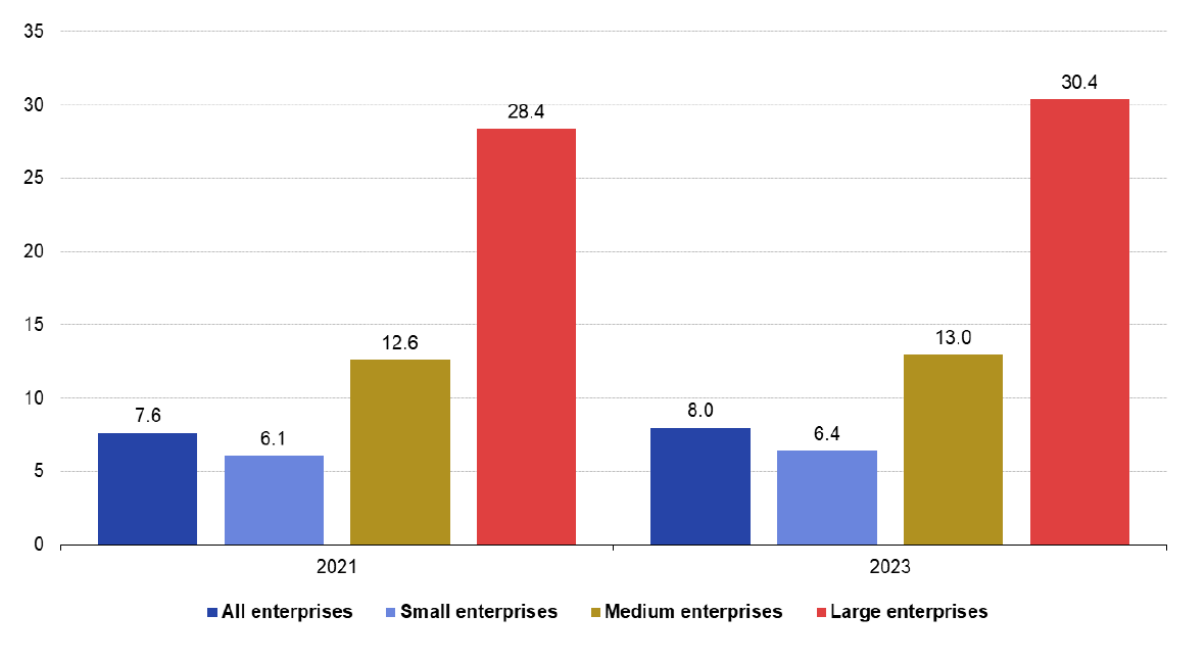
Source: Macej et al., 2023.

6.4 The Eurostat ICT Usage in Enterprises survey

The Eurostat ICT Usage in Enterprises survey (2023) provides relevant information about AI adoption by EU enterprises, which was analysed in the Eurostat article “Use of artificial intelligence in enterprises (2024)”. According to the Eurostat, in 2023, 8% of EU enterprises with 10 or more employees and self-employed people were using at least one AI technology.

When considering the size of enterprises using AI (Figure 6), large enterprises are those using AI technologies more: while only 6.4% of small enterprises were using some form of AI technology, the proportion of AI users increases to 13% of medium enterprises and 30% of large enterprises.

Figure 6: Enterprises using AI technologies by enterprise size, 2023 (% of enterprises)



Source: Use of artificial intelligence in enterprises (Eurostat, 2024).

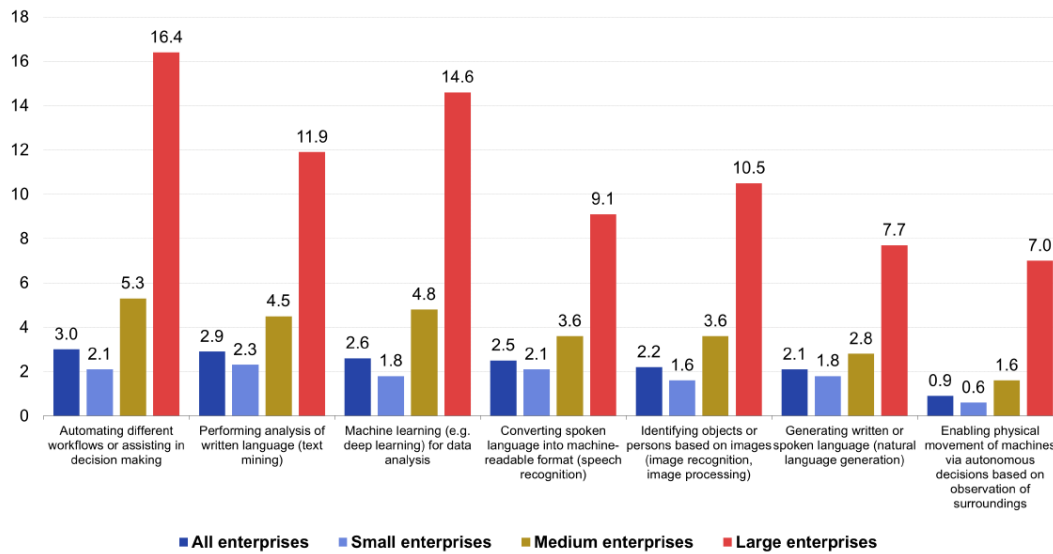
The use of AI presents differences in terms of economic activity: enterprises in the Information and Communication sector; and in Professional, scientific and technical activities were the top users of AI technologies, with almost 30% and 19% of enterprises using AI technologies, respectively. The sectors with a lower proportion of AI adopters are Transportation and storage (approximately 5%), and Construction (approximately 3%). At the EU country level, the top 3 AI adopters are Denmark (15.2%), Finland (15.1%) and Luxembourg (14.4%). Romania, Bulgaria, Poland and Hungary presented the lowest proportions (1.5%, 3.6%, 3.5% and 3.5%, respectively). Therefore, AI adoption at the EU country level ranged from 1.5% to 15.2%.

The Eurostat ICT Usage in Enterprises survey (2023) considered also different AI technologies, which were the following:

- Automating different workflows or assisting decision making (AI based software robotic process automation)
- Performing analysis of written language (text mining)
- Machine learning (e.g., deep learning) for data analysis
- Converting spoken language into machine-readable format (speech recognition)
- identifying objects or people based on images (image recognition, image processing)
- generating written or spoken language (natural language generation)
- enabling physical movement of machines via autonomous decisions based on observations of surroundings

For each AI technology, large enterprises are those using them more (Figure 7). A total of 16.4% of large companies use AI for automating different workflows or assisting in decision making, followed by 14.6% for machine learning and 11.9% for text mining. Use of these AI technologies by medium enterprises tends to be approximately 1/3 lower, with even lower values for small enterprises.

Figure 7: EU Enterprises using AI technologies by type of AI technologies and size class, 2023 (% of enterprises)

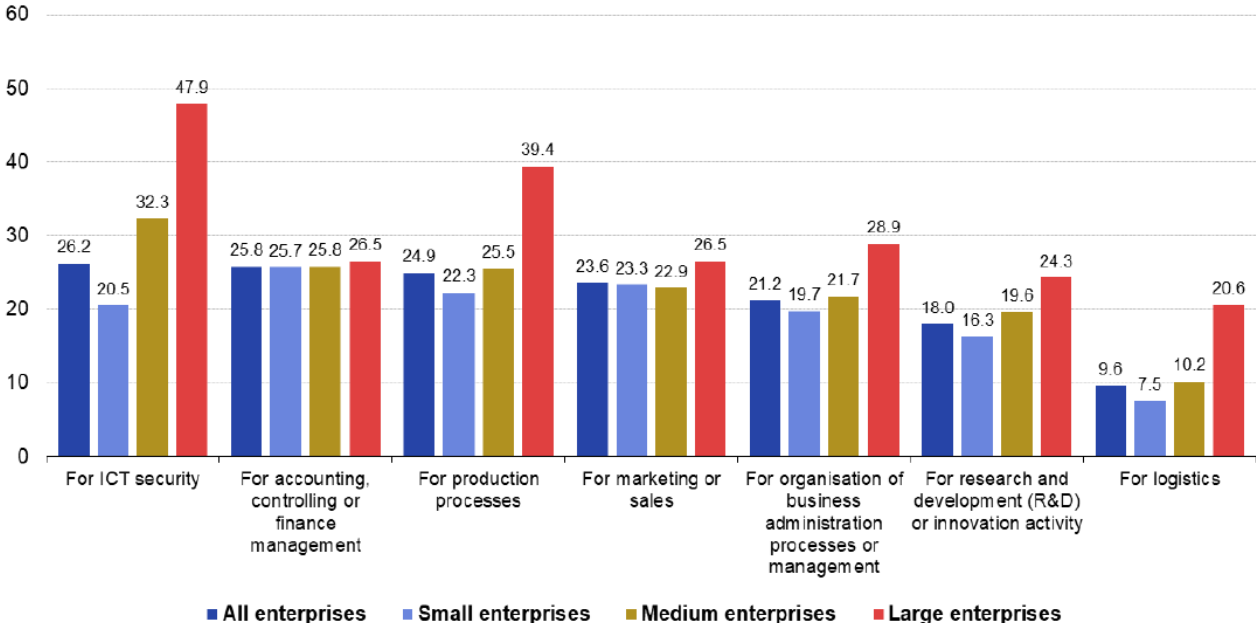


Source: *Use of artificial intelligence in enterprises (Eurostat, 2024).*

Additionally, the Eurostat ICT Usage in Enterprises survey (2023) asked enterprises for which purposes they were using AI technologies, among the following purposes:

- ICT security
- Accounting, controlling or finance management
- Production processes
- Marketing or sales
- Organisation of business administration processes or management
- Research and Development (R&D) or innovation activity
- Logistics

Figure 8: EU enterprises using AI technologies by type of purpose and size class, 2023 (% of enterprises using at least one AI technology)



Source: Use of artificial intelligence in enterprises (Eurostat, 2024).

For some purposes such as ICT security, and production processes and logistics, there is a large difference in terms of use by enterprise size: large enterprises use it more widely than small and medium enterprises. For instance, the percentage of large enterprises using AI technologies for ICT security is more than double that of small enterprises using these technologies for the same purpose, even though the gap is lower between medium and large enterprises. For other purposes such as marketing or sales or accounting, controlling or finance management, there are no large differences according to enterprise size.

7. AI Adoption: Market characterisation

AI-enabled autonomous contracting is still an emerging application but can evince a widespread adoption in a short time, with potentially significant implications for enterprises and the economy/society at large⁴⁹. Enterprises can use AI technologies in different steps of the contract life cycle such as offer generation, pre-contractual stage, contract conclusion and contract execution (see Section 3.1 “Motivation of the study” for a more detailed description). At first, the tendency was to consider software related to one phase for the management of the life span of a contract. Overtime, the trend became to offer and consider solutions for the entire contractual life cycle (Messori, 2022).⁵⁰ In terms of AI technologies used, many enterprises rely on machine learning (ML) and natural language processing (NLP) to make contracting more efficient (Ebers, 2022). This type of data-driven technologies requires the ability of computers to “understand, analyse, manipulate, and potentially generate human language” which means that successful AI applications require substantial data-learned knowledge (Ebers, 2022). In the case of contracts, this entails providing several contracts to the AI system so that the system can understand and classify the data accurately. The data should be related and relevant. As an example relating to contract drafting as such, suppose that an enterprise wants to adopt AI for the purpose of drafting supply chain management contracts. In this case, it is important that the AI system is fed with previous contracts on supply chain management. This enables the system to learn the structure, clauses, and other relevant information which can then be used on new contracts. In contrast, feeding the system with contracts on an unrelated topic such as car leasing, even if the contracts are well written or are of a high-volume, would not be very informative for supply chain management contracts.

Additionally, and also related to the importance of data feeding of AI models, it is detrimental to consider that the law changes continuously. Therefore, and “unless an administrator continuously feeds the system with new clauses that have been recognized and allowed by the court, while removing non-enforceable clauses,” the AI system might take time to adapt to the legal changes (Ng, 2017).

Except for companies with a core business on contracts, it is reasonable to consider that enterprises adopting AI in contracting tend to start by implementing AI technologies for broader purposes than contracts. In other words, these enterprises adopt AI technologies with the aim of using them not only for AI in contracts but also for other uses⁵¹.

Having this setting in mind, we now consider the literature on the adoption of AI in general and elaborate on which enterprises might be more likely to adopt AI in contracting. We consider enterprise characteristics that are relevant for the analysis of enterprise dynamics and adaption of new technologies such as enterprise size, enterprise age and sector of activity. Subsequently, we address issues that are specific to AI adoption and adoption of AI in contracting. Finally, we consider potential risks and effects of AI adoption. By doing so, the aim is to provide a market

⁴⁹ In opposition, drafting contracts that follow a standard contract template and that are simple is a practice that exists for long (*e.g.*, Ng, 2017).

⁵⁰ Messori (2022) provides a list of providers according to the contract lifecycle.

⁵¹ Recent business surveys include questions on specific uses of AI technologies, and we include a detailed description of potential uses in the Empirical Section. So far, there is no question related to AI in contracts.

characterisation of adopters of AI in contracting that serves as a framework to assess the potential effects of AI-enabled autonomous contracting.

7.1 Adopters of AI vs Adopters of AI in contracting

When new technologies became available in the market, enterprises have the opportunity of adopting them in their business activities. Considering that it typically entails costs, skills, and the need to readjust business processes, not all enterprises adopt new technologies and, among those that adopt them, some enterprises adopt them faster and to a wider extent than others. The rise of adoption of AI technologies by firms has captured interest and the opportunity to understand not only which types of enterprises adopt AI but also its corresponding economic effect. In terms of general AI-adoption, evidence points to heterogeneous adoption rates of AI by enterprises depending on different enterprises' characteristics, with differences across countries. With respect to costs, AI adoption typically requires an initial fixed cost of acquisition, and subsequent variable costs depending on, among others, the usage; enterprises' level of digitalization, including access to software, computing power⁵²; and human capital (ICT skills of employees manipulating them). Costs might differ depending on whether the enterprise outsources AI technologies to another enterprise, or whether it produces the technology in-house. Benefits can vary as well depending on many different factors such as the proportion of low vs high-skilled workers, or the complexity level of production.

Characterizing adopters of AI and the impact of AI technologies requires data on AI adoption by enterprises, which typically comes from business surveys that include questions about the adoption and use of AI technologies. While currently some business surveys include questions about AI adoption and use, namely about specific AI technologies⁵³, these surveys do not include specific questions on AI in contracting. Therefore, and to our knowledge, there is no characterisation of assumed adopters of AI in contracting. This Section aims at filling this gap.

Enterprise Size

Enterprise size is a characteristic that might be correlated with different outcomes and market dynamics. Larger enterprises tend to have better access to financing, access to a greater network of professionals, and higher bargaining power in comparison with their smaller counterparts, to name a few. Moreover, large incumbent enterprises might even be able to fund their own innovations. In practice, they are typically in a better position to succeed and survive competition. Smaller enterprises face greater barriers to entry and financial constraints, which might jeopardise their success and survival. This is a particular reason for concern because the majority of EU enterprises⁵⁴ are SMEs.

⁵² The *Communication on boosting startups and innovation in trustworthy artificial intelligence* (COM (2024) 28 final, 24.1.2024), aims at providing access to supercomputers by startups. As mentioned in the document, the use of supercomputers in AI can provide two relevant competitive advantages to startups: i) reduce significantly the time required to train large AI models from "typically six to nine months on average to just a few weeks"; ii) millions of euros of cost benefits due to the savings of accessing a supercomputer model instead of having to use commercial cloud platforms.

⁵³ The types of questions will be described in more detail in the empirical analysis section.

⁵⁴ SMEs represent 99% of all businesses in the EU: https://single-market-economy.ec.europa.eu/smes/sme-definition_en, last access 28 February 2024.

Enterprise size is expected to have a role in the use and adoption of new technologies. When new technologies become available in the market, larger enterprises tend to have an advantage in earlier adoption of the new technologies, namely because they are better equipped to bear the costs and risks of large and risky investments (Tirole, 2017). There is evidence that larger enterprises are more likely to adopt new technologies in comparison with smaller enterprises. For instance, Koch et al. (2022) find that larger enterprises are significantly more likely to adopt robots. Larger enterprises are more likely to increase investment than SMEs, to innovate more and to implement multiple technologies at the same time (EIB, 2023).

When considering whether enterprise size is relevant for AI adoption, evidence points to a higher AI adoption rate among larger enterprises as well. The Eurostat Use of artificial intelligence in enterprises (2024) shows that, in 2023, among surveyed enterprises, 30.4% of large enterprises use AI technologies, while only 6.4% of small enterprises and 13% of medium enterprises do so. Calvino and Fontanelli (2023) analyse data from the AI diffuse project which includes several OECD countries and show that, at the national level, there can be relevant differences among the various countries, depending on the size class of enterprises. For instance, Belgian enterprises with more than 250 employees report an AI use of approximately 40%, while this proportion is below 8% for enterprises with 10-19 employees. Czarnitzki et al. (2023) use data on the German contribution to the Community Innovation Survey (CIS) of the European Commission and find that approximately 7% of all enterprises are AI users. Acemoglu et al. (2023) explore why enterprises adopting advanced technologies are larger and focus on two main explanations. One is that the adoption of advanced technologies causally expands employment, which would imply that these technologies contribute to employment growth. In other words, the increase in employment is due to the adoption of new technologies and not the other way around (i.e., it is not employment that leads to the adoption of new technologies). Another is that enterprises that are already growing fast for other reasons are also better at adopting these technologies, which would be in favour of a selection explanation. They find evidence of the selection interpretation, as AI adopters were already large before the new technology adoption.

Larger enterprises might benefit from scale advantages and therefore their relative costs of AI adoption might be lower than the costs entailed by their smaller counterparts. Calvino and Fontanelli (2023) argue that this might be due to several reasons such as lower financing constraints, a larger amount of data to leverage AI applications and more endowments of intangibles, or capabilities to use intangibles or other assets which are needed to leverage the AI potential.

Overall, the empirical evidence so far considers whether enterprise size is relevant to explain general AI adoption and there is evidence that larger enterprises are generally more likely to adopt AI. Considering the specific case of adoption of AI in contracting, a few considerations can be provided, which are the following:

- i) The adoption of AI in contracting requires specific AI technologies such as machine learning (ML) and natural language processing (NLP). Having these technologies in-house might require large investments and, in this case, larger enterprises are typically in a better position to invest and bear the costs of risky and costly technologies. Therefore, larger enterprises might be more likely to adopt AI in contracting when costly investments are required.
- ii) Some AI technologies that are needed for contracts (such as ML and NLP) are currently easily accessible to smaller enterprises and at a low cost. This possibility arises due to, for instance, cloud computing and open source. If enterprises do not need to implement

costly AI solutions in-house and can rely on free or low-cost external solutions, they might be in a good position of adopting AI in contracts. Therefore, smaller and larger enterprises might be equally likely to adopt AI in contracts when cloud computing and open source are available.

- iii) AI in contracting requires data-learned knowledge and feeding AI models with data. If enterprises want to adopt AI in contracts, then models must be fed with contracts so that the model can learn. Some of these data might be confidential and enterprises might need to rely only on previous contracts in which the enterprise was one of the parties involved. Larger enterprises have higher business volumes and a larger number of contracts performed in the past. Therefore, they are expected to be in a better position of feeding data to AI solutions. Concomitantly, they might also face more stringent confidentiality clauses which might prevent them from easily using data from previous contracts.

All in all, enterprises that adopt new technologies tend to be larger (Acemoglu et al., 2023). Nevertheless, there are some specificities about AI in contracting, namely in terms of data needs, confidentiality, and types of AI technologies, elements which are not necessarily linked to the size of the enterprise. For example, as regards Marketing and Sales as a purpose of use relevant to AI contracting, the percentage of small and medium enterprises using AI technologies is very similar to the percentage of large firms (Eurostat, 2024). For logistics, the difference is large in terms of enterprise size. However, for logistics the Eurostat survey included specifically autonomous machines, which have a higher level of adoption by larger firms. Therefore, it is not straightforward to predict whether larger enterprises will be clearly more likely to adopt AI in contracting than smaller enterprises.

Enterprise Age

Enterprise age is another important characteristic for assessing enterprise dynamics, even though the evidence so far is not straightforward (Coad et al., 2018). Older enterprises have their activities established in the market for many years and can have an advantage in AI adoption, but younger enterprises might be more innovative and therefore might be more likely to bring new and disruptive technologies to the market or to implement them. It is however possible that younger enterprises face relatively higher costs of AI adoption, namely because these enterprises tend to face more financial constraints. Older firms have their activities established in the market for many years and can have an advantage in AI adoption, but younger firms might be more innovative and therefore might be more likely to bring new and disruptive technologies to the market or to implement them. R&D investments of young leading innovators in the EU are more likely to be hampered by access to finance (Cincera et al., 2015). Additionally, young small leading innovators are the most likely to be credit constrained (Ferrando et al., 2019).

Some recent studies investigate whether enterprise age is associated with AI adoption. McElheran et al. (2024) consider early adoption and diffusion of five AI technologies, which are the following: automated-guided vehicles, machine learning, machine vision, natural language processing, and voice recognition. They find that, conditional on size and industry, younger enterprises were more likely to use AI than older enterprises. This is an important result because younger enterprises are relevant players for innovation, even though they are more likely to die – or, in other words, less likely to survive (Decker et al., 2014). When considering the case of IT investments, which are typically needed for AI adoption, Jin and McElheran (2019) find evidence that younger enterprises in

the manufacturing sector face greater difficulties in financing the fixed costs of their IT investments.

Enterprise age can affect the adoption of AI in contracting in two opposing ways. On the one hand, younger enterprises might be less likely to adopt new technologies due to financial constraints or because they have less data available to feed in AI systems. On the other hand, younger enterprises might be more willing to rely on cloud computing or open source due to their typically lower costs, which facilitates the adoption of AI in contracting.

Sector of activity and other technologies

The adoption of new technologies can vary not only according to enterprise size and enterprise age, but also depending on the sector of activity in which enterprises operate. There are relevant differences between sectors of activity which also translate in different technological needs. The Eurostat (2024) considers 11 different economic activities⁵⁵ and finds that Information and Communications is the leading sector in terms of percentage of enterprises using AI technologies: almost 30% of enterprises in this industry use AI technologies. The sector Professional, scientific and technological activities is the second top adopter, where almost 18% of enterprises use AI technologies. Transportation and storage, and Construction, are the sectors with the lowest proportion of AI adopters (5% and approximately 2.5% respectively).⁵⁶ Similar evidence was found for OECD countries, with both the ICT and the Professional Services⁵⁷ sectors tending to be leading AI adopters in several OECD countries (Calvino and Fontanelli, 2023). The higher adoption rates in these sectors are related to the fact that they are, on average, better prepared not only in terms of IT infrastructure and digitalization, but also have skilled labour to deal with new technologies. For the US, McElheran et al. (2024) find that Manufacturing is a leading AI adopter, while this sector ranks 6th in the EU in 2023 (Eurostat 2024).

With respect to IT infrastructure and digitalization, enterprises that already adopted other forms of new technologies might show higher AI adoption rates. We can expect enterprises that adopt AI-enabled autonomous contracting to have already a high digitalization level, a good IT infrastructure, and to have adopted AI for broad purposes, not necessarily only for contracting. According to the Eurostat (2024), the proportion of enterprises adopting AI technologies is higher among enterprises with high digital intensity index than among enterprises with a low digital intensity index. If enterprises already use AI for performing analysis of written language, process or equipment optimisation, machine learning, automating workflows, forecasting, recommendations, among

⁵⁵ The categories considered by Eurostat (2023) are the NACE rev 2, that are commonly used. These are the following: Information and Communication; Professional, scientific and technical activities; Electricity, gas, steam and air conditioning supply, water supply, sewerage, waste management and remediation activities; real estate activities; Administrative and Support service activities; Manufacturing; Wholesale and retail trade, repair of motor vehicles and motorcycles; Accommodation; Retail trade, except of motor vehicles and motorcycles; Transportation and storage; Construction.

⁵⁶ A recent NACE revision 2 update 1 (NACE rev. 2.1) was adopted in 2022 and to be used from 2025. For an updated and complete list of sectors of activity, see Commission Delegated Regulation (EU) 2023/137 of 10 October 2022 amending Regulation (EC) No 1893/2006 of the European Parliament and of the Council establishing the statistical classification of economic activities NACE Revision 2 (Text with EEA relevance).

⁵⁷ According to the NACE categorisation, Professional & Scientific Activities includes sector codes 69-75. It includes specialised professional, scientific and technical activities. These activities require a high degree of training, and make specialised knowledge and skills available to users. Examples: head offices; management consulting; advertising and market research; legal and accounting; scientific research and development; engineering activities.

others, they might be more likely to use the already existing technologies and extend them to AI in contracting.

Delivery modes of AI solutions

When enterprises decide to adopt AI solutions, there are different possibilities with respect to how to incorporate the new technologies. The delivery mode of AI solutions can be framed as a combination of three main aspects: provision modality, type of provider and the solution's readiness to use (see Section on "Delivery modes of AI solutions" for a detailed description). Adopting a new technology, in particular a new enterprise software, typically requires not only adaptations to software but also changes to the organization itself.

According to the Eurostat (2023), in the EU in 2021, 52.5% of AI adopters used AI technologies that were commercial software or systems ready to use, 38% relied on AI technologies developed or modified by external providers, 27.6% used AI technologies developed by own employees, 28% were commercial software or systems modified by own employees. Only 22% of AI adopters were using open-source software or systems modified by own employees.

Hoffreumon et al. (2024) provide one of the first empirical evidence on how EU firms adopt AI in terms of technology sourcing. The authors use a sample of surveyed EU firms and consider whether firms purchase commercial readymade software, if they develop or customise solutions in-house, or a combination of both. While readymade software can reduce barriers to adopting AI namely as it facilitates knowledge sharing, it can also be ineffective and require complementary investments by firms (Bresnahan 2019; Hoffreumon et al., 2024). Readymade software is standardized, and its purpose is not to fit the unique needs of firms. Therefore, in case enterprises need customized options, readymade software will require complementary investments by firms. Developing or customizing solutions in-house can be expensive, even though it can be better aligned with the firm's needs. Readymade software can be easily accessed, but it is more rigid. Hoffreumon et al. (2024) find that readymade software is common, with 58% of AI adopters reporting that they use readymade applications. A survey performed in 2023 finds that the majority of the survey respondents acquire AI as a product or service (65%) while only 35% attempt to build their own solutions in-house (Deloitte 2022). Moreover, the results of the survey points to the fact that the majority of the respondents opts in an initial stage for off-the-shelf solutions. Larger enterprises are generally in a better capacity of doing both.

Additionally, software can be developed on premises or using cloud computing (see section on Provision Modalities). In recent years, cloud computing⁵⁸ became a fundamental service for many enterprises and can be relevant for AI technologies. Cloud computing allows enterprises to have access to IT services via "pay as you go" subscriptions without having to incur into large sunk investments in hardware and software. The advantages of cloud computing have been documented in recent empirical works, and evidence suggests that young enterprises are likely to benefit from it. Jin and McElheran (2019) find that young enterprises benefit from cloud computing. DeStefano et

⁵⁸ "Cloud technologies offer a model of on-demand data storage and processing, both in centralised data centres and in distributed connected devices close to the user (at the 'edge' of the network). As cloud technologies are faster, cheaper and more flexible than conventional computing methods, many of our everyday services are based on the cloud, such as web-based email, entertainment systems, and public services including health and transportation", <https://digital-strategy.ec.europa.eu/library/cloud-and-edge-computing-different-way-using-it-brochure>, last access 01 July 2024.

al. (2024) find that cloud adoption has positive effects on enterprise performance, in particular for younger enterprises.

7.2 Potential risks and effects of AI in contracting

Legal uncertainty and negative consequences

The initial adoption of AI for autonomous contracting might bring legal uncertainty. Typically, legal uncertainty is considered to have a negative impact on the economy (Baker and Raskolnikov, 2017). Moreover, the relationship between AI-enabled autonomous contracting and legal mistakes is difficult to assess. While there is a large potential of legal technologies to perform better than humans when analysing large texts, there is no agreement that AI can lead to better decisions than human decision-making (e.g., McKendrick and Thurai, 2022; de Véricourt and Gurkan, 2023). However, as large amounts of data become available for AI technologies to analyse, it is possible to reach better decisions over time.

The use of AI in contracting can result in negative consequences as a result of unintended or unexpected outputs. One concern relates to the algorithm used for AI in contracts, which can be a black box and can produce unexpected outcomes. As an example, Calvano et al. (2020) discuss the potential for AI algorithms to collude, leading to higher prices for consumers, which is a negative outcome. In other settings such as loan approvals or credit assessments, one serious potential risk to consider is that of algorithm discrimination, which can result in erroneous or biased AI-assisted decisions, a fundamental concern of the AI Act. The AI Act explicitly classifies prohibited AI practices (Chapter II), and defines high-risk AI systems (Chapter III) and their corresponding requirements and obligations. It further introduces transparency obligations for providers and deployers of certain AI systems (Chapter IV).

In the case of AI in contracting, biased or erroneous algorithms might lead to undesirable outcomes, which might take a long time until being detected. The algorithm used for AI in contracts can be a black box, and the lack of human supervision can lead to unintended consequences. Moreover, the outcomes are expected to depend on the data used to train the AI system. If the data is biased, then the AI system learns from it and might produce biased outcomes as well. Therefore, there is the risk of negative economic consequences in particular for the parties to the contract. The consequences of unintended outputs for the contractual parties are not always clear, as there is still a significant level of legal uncertainty.

Hallucinations in LLMs

Large language models (LLMs) are AI systems that are designed to understand and generate text like humans and rely on vast amounts of data to train them.⁵⁹ They are being used by firms, including chatbots, and can be applied to contractual texts (Arbel and Hoffman, 2024). Therefore, they are one type of AI technology which is relevant for AI in contracts.

LLMs are however susceptible of hallucinations in the sense that they can create information that seems accurate and reliable, even though it is false. The presence of these hallucinations in real-

⁵⁹ See <https://www.ibm.com/topics/large-language-models> for a detailed description of LLMs (last access on 10/10/2024).

world cases, including court cases, shows the need of monitoring the information provided by LLMs. Otherwise, there is the risk that these models can lead to harmful and inaccurate legal advice or decisions (Dahl et al., 2024).

Data and Privacy

As described previously, when enterprises use AI technologies for contracts there is a need of feeding the system with data as successful AI applications require substantial data-learned knowledge (Ebers, 2022). For AI in contracts, this requires feeding the AI system with relevant data for the contractual stage – e.g., contracts with information about contract terms or dynamic indicators on pricing, which could enable generation of dynamic offers based on real time developments in pricing on the market. Additionally, it is also important that the types of contracts feed to the AI system are related to the types of contracts that the system aims to develop. A potential risk that might emerge while providing data is the use of confidential data. For instance, some contracts that are relevant for the AI system to learn might contain data that is confidential. This is a concern that also arises when using cloud services, as it requires the transmission of information on the cloud.

Considering the specific case of AI in contracts, it is unclear which type of enterprises would be more susceptible of facing higher risks due to privacy concerns related to the need of data sharing. When considering the size and age of the enterprises, smaller and younger enterprises might rely more on AI solutions offered by third parties and can therefore be at a higher risk of exposure. Larger and incumbent enterprises are better positioned to afford and implement their own solutions in-house and apply different layers of security. While this might delay the daily business activities, it also provides higher security levels.

Overall, concerns about data and privacy when feeding AI systems might relate more to the specific business activity that enterprises perform and whether these require the use of confidential data.

Expected Benefits for enterprises adopting AI in contracting

One reason for enterprises to adopt new technologies is to achieve productivity gains, namely by a reduction in production costs. In terms of general AI adoption, AI will unequivocally enhance productivity, but there is the risk that it might also increase inequalities (Agrawal et al., 2022). While there is no empirical evidence on the potential gains due to the adoption of AI in contracting, there are studies that consider the effect of AI on contract drafting in terms of quality of the outcome and time. Choi et al. (2024) consider the effect of AI assistance on human legal analysis. They asked law students to perform different legal tasks, one of which consisted in drafting a contract. Access to AI increased the performance of students, not only in terms of time saving but also in terms of quality. Moreover, the lowest-skilled participants achieved the largest improvements in terms of quality, which provides evidence of heterogenous benefits depending on different characteristics such as skills.

The benefits resulting from the adoption of AI in contracting might be heterogeneous depending on the enterprise size. Scale advantages can result in greater benefits for larger enterprises that typically have larger volumes of business and contracts, and now have the possibility of automating diverse stages of contracting. However, depending on the possibility of relying on cloud services or open source, smaller enterprises can potentially adopt AI in contracts as well. A relevant variable is access to relevant data to provide to the AI system.

In terms of long-term overall net benefits for adopters of AI in contracting according to enterprise size, there are different potential scenarios:

- i) **Widening the gap:** larger enterprises are at an advantageous position in terms of adoption of AI in contracting and the adoption of AI in contracts is concentrated mostly among these companies. In this case, Small and Medium Enterprises will struggle, and the adoption of the new technologies will result in a larger gap between large enterprises and SMEs in terms of business outcomes.
- ii) **Closing the gap:** the adoption of AI in contracting is concentrated among SMEs which reach productivity gains due to the adoption of the new technologies. In this scenario, the use of AI in contracting will allow to close the gap between SMEs and large enterprises.
- iii) **Maintain the status quo:** in this scenario, the future adoption rate of AI in contracting is equally distributed across enterprises in terms of enterprises size. There can be an upward shift in the productivity of both types of enterprises, but the gap would be maintained in this case.

8. Empirical analysis

The aim of this section is to provide an empirical analysis of assumed adopters of AI in contracting in the EU27. As described above, currently there is no specific data available on the adoption and use of AI in contracting. However, there are two main sources of general data on the use of AI which are particularly relevant:

- i) the Eurostat ICT Usage in Enterprises survey (2023);
- ii) the “European enterprise survey on the use of technologies based on artificial intelligence” (Ipsos-iCite, 2020).⁶⁰

The Eurostat article “Use of artificial intelligence in enterprises (2024)” uses data on AI adoption from the Eurostat ICT Usage in Enterprises survey (2023) and provides valuable information on the use of AI technologies by European enterprises in 2023 (a more detailed description can be found on Section 6.4 The Eurostat ICT Usage in Enterprises survey). Nevertheless, the Eurostat provides aggregated data and therefore it is not possible to perform an empirical assessment with such level of aggregation. For example, it is possible to compute tables for the percentage of enterprises using one specific AI technology, but it is not possible to do the same exercise for the simultaneous use of two or more AI technologies which are relevant for AI in contracting. For this reason, the analysis that can be performed is limited. Hence, we consider in more detail the EU enterprise survey (Ipsos-iCite, 2020), as it includes micro-level data. In this case, each observation is an enterprise, and several variables for each enterprise are included. This is necessary to compute many of the calculations we show and to perform regression analysis. Overall, both data sources are considered and, when possible, comparisons are made.

8.1 Data description

This section considers mostly data provided by the “European enterprise survey on the use of technologies based on artificial intelligence” (Ipsos-iCite, 2020) to perform an empirical assessment of the adoption and barriers of AI in contracting. This is one of the first EU-wide surveys, along with the Eurostat ICT Usage in Enterprises survey, on the uptake of artificial intelligence technologies among enterprises and one of the main motivations was the recognition of limited data on the uptake of new technologies by enterprises at the Member State level, despite its relevance.⁶¹ This survey was performed in 2020 in the EU27, Norway, Iceland and the UK, with a sample of 9640 enterprises. Of these, 8661 were from the EU27,⁶² and the survey included enterprises of all sizes: micro enterprises (5-9 employees), small enterprises (10-49 employees), medium enterprises (50-249 employees) and large enterprises (more than 250 employees). Different questions were included about AI awareness, current AI adoption, plans of AI adoption, AI acquisition path, and barriers to the adoption of AI.

While the survey aimed at having a representative sample of EU27 enterprises, it is important to consider that it did not aim at a representative sample of each different AI technology covered.

⁶⁰ For a matter of simplification, we refer to this survey as the “EU enterprise survey”, or the Ipsos-iCite survey (2020).

⁶¹ Measuring the level of AI adoption is a challenge, even for official statistics, because this topic is multifaceted, heterogeneous and difficult to be defined (Perani, 2023).

⁶² The empirical analysis presented in this section using data from the Ipsos-iCite (2020) considers the EU27. This allows a more accurate comparison with the Eurostat (2023), when possible.

Therefore, the results at the AI technology level should be interpreted with caution. Nevertheless, it provides a useful snapshot of the landscape of enterprises adopting AI technologies in the EU at that point in time. In addition, by identifying the technologies that can be more directly associated to contracting, it also allows to make reasonable assumptions on the number of enterprises that are potential users of AI in contracting.

The Eurostat surveyed 150400 of the 1.47 million of enterprises in the EU (2023). It considered small enterprises (10-49 employees), medium enterprises (50-249 employees) and large enterprises (more than 250 employees). Micro enterprises, which have fewer than 10 employees, were not included. These enterprises were included in the Ipsos-iCite survey (2020).

8.2 Identification of AI technologies relevant for AI in contracting

To provide a measure of the level of AI adoption by enterprises, the European enterprise survey (Ipsos-iCite, 2020) asked respondents about their current state of adoption of 10 different AI technologies, which are the following:

- Speech recognition, machine translation or chatbots, also known as **natural language processing**.
- Visual diagnostics, face or image recognition, also known as **computer vision**.
- Fraud detection or risk analysis, also known as **anomaly detection**.
- Analysis of emotions or behaviours, also known as **sentiment analysis**.
- Forecasting, price optimisation and **decision-making** using machine learning algorithms.
- Process or equipment optimisation using artificial intelligence.
- **Recommendation and personalisation engines** using artificial intelligence to produce customised recommendations, via matching algorithms or information retrieval.
- **Process automation** using artificial intelligence, including warehouse automation or robotics process automation (RPA).
- **Autonomous machines**, such as smart and autonomous robots or vehicles.
- **Creative and experimentation activities**, such as virtual prototyping, data generation, artificial music or painting.

The total number of enterprises adopting each type of AI technology can be found in Table 3. The leading adopted AI technologies are Anomaly detection (adopted by 13.4% of the enterprises), Process/equipment optimisation (adopted by 13% of the enterprises), and Process automation (adopted by 12.5% of the enterprises). The sum of the number of enterprises adopting each type of AI technology is greater than 8661, the total number of surveyed enterprises, because enterprises can adopt several AI technologies at the same time.

Table 3: Enterprises adopting AI technologies.

| Type of AI Technology | Number of enterprises | Percentage |
|-----------------------------------|-----------------------|------------|
| Natural Language Processing (NLP) | 856 | 9.9 |
| Computer vision | 786 | 9.1 |
| Anomaly detection | 1160 | 13.4 |
| Sentiment analysis | 220 | 2.5 |
| Decision-making | 910 | 10.5 |
| Process/equipment optimisation | 1123 | 13 |
| Recommendation engines | 779 | 9 |
| Process automation | 1078 | 12.5 |
| Autonomous machines | 816 | 9.4 |
| Creative industries | 615 | 7.1 |

Note: The sum of the column "Number of enterprises" is greater than the total number of surveyed enterprises because enterprises can adopt multiple AI technologies at the same time. Source: Own calculations using the Ipsos-iCite survey (2020).

The Eurostat ICT Usage in enterprises survey (2023) also considers which types of AI technologies are used by enterprises and includes seven categories, which are the following:

- Automating different workflows or assisting decision making (AI based software **robotic process automation**)
- Performing analysis of written **language (text mining)**
- **Machine learning** (e.g., deep learning) for data analysis
- Converting spoken language into machine-readable format (**speech recognition**)
- Identifying objects or people based on images (**image** recognition, image processing)
- Generating written or spoken language (**natural language generation**)
- Enabling physical movement of **machines** via autonomous decisions based on observations of surroundings.

A mapping of each AI technology in the Eurostat ICT Usage in enterprises survey (2023) to the AI technologies in the Ipsos-Cite survey (2020) was made. According to the research we performed, the following correspondence emerges:

Table 4: Mapping AI technologies in the Ipsos-iCite (2020) and in the Eurostat ICT Usage in Enterprises survey (2023)

| Ipsos-iCite: % of adopters | Eurostat: % of adopters |
|--|---|
| 1. Speech recognition, machine translation or chatbots, also known as natural language processing : 9.9% | Converting spoken language into machine-readable format (speech recognition): 2.5% |
| | Generating written or spoken language (natural language generation): 2.1% |
| 2. Visual diagnostics, face or image recognition, also known as computer vision : 9.1% | Identifying objects or people based on images (image recognition , image processing): 2.2% |
| 3. Fraud detection or risk analysis, also known as anomaly detection : 13.4% | - |
| 4. Analysis of emotions or behaviours, also known as sentiment analysis : 2.5% | - |
| 5. Forecasting, price optimisation and decision-making using machine learning algorithms: 10.5% | Machine learning (e.g., deep learning) for data analysis: 2.6% |
| | Performing analysis of written language (text mining): 2.9% |
| 6. Process or equipment optimisation using artificial intelligence: (13%) | - |
| 7. Recommendation and personalisation engines using artificial intelligence to produce customised recommendations, via matching algorithms or information retrieval: 9% | - |
| 8. Process automation using artificial intelligence, including warehouse automation or robotics process automation (RPA): 12.5% | Automating different workflows or assisting decision making (AI based software robotic process automation): 3% |
| 9. Autonomous machines , such as smart and autonomous robots or vehicles: 9.4% | Enabling physical movement of machines via autonomous decisions based on observations of surroundings: 0.9% |
| 10. Creative and experimentation activities , such as virtual prototyping, data generation, artificial music or painting: 7.1% | - |

Source: Own elaboration, based on the Ipsos-iCite (2020) and in the Eurostat ICT Usage in Enterprises survey (2023).

A few takeaways emerge from this table. Firstly, there is not a one-to-one correspondence between the two sources of data in terms of AI technologies. In some cases, the designation is similar and includes some of the same words; in other cases, there are two AI technologies from the Eurostat

ICT Usage in Enterprises survey that correspond to one AI technology from the Ipsos-iCite survey. Secondly, the Ipsos-iCite survey includes a wider range of AI technologies. Thirdly, the percentage of AI adopters is lower in the Eurostat survey than in the Ipsos-iCite survey. One potential explanation might be that the Ipsos-iCite asked specifically for the questionnaire to be replied by someone who has a good knowledge about the technologies being used in the enterprise. This is in line with the findings of Perani (2023), who compares data from the Istat Business Census on the level of AI adoption by Italian enterprises and compares it with the results provided by the Eurostat ICT Survey. According to the results the rate of AI adoption among enterprises in Italy with 10 or more employees was estimated to be more than three times higher than the Eurostat ICT Usage in Enterprises survey (21% vs 6%). Some possible explanations for the differences relate to the structure and coverage of the two surveys, which differ. Regarding the structure of the survey, while the Eurostat ICT Usage in Enterprises survey filtered by AI technologies and then asked about uses, the Istat Business Census (2020) did not include a first filter, and asked only about uses. With respect to coverage, the Eurostat ICT Usage in Enterprises survey included almost all sectors except banking and insurance, while the Istat Business Census included all sectors.

In terms of methodology, the first step is to identify which AI technologies included in the survey are related to AI in contracting. While in recent years some national statistics offices and the Eurostat ICT Usage in Enterprises survey started including questions on AI adoption by enterprises, none of them includes questions specific to AI in contracting. The same holds for the EU enterprise survey (Ipsos-iCite, 2020). Therefore, the methodology that we develop considers each of the 10 AI technologies included in the EU enterprise survey. We analyse these AI technologies and identify the most relevant for AI in contracting:

- Natural language processing (**NLP**);
- Forecasting, price optimisation and **decision-making** using machine learning algorithms;
- **Recommendation and personalisation** engines using artificial intelligence to produce customised recommendations, via matching algorithms or information retrieval;
- **Process automation** using artificial intelligence.

While the use of these technologies separately does not necessarily identify AI in contracting, the joint use of some of these AI technologies is meaningful and necessary for AI in contracting. We then consider as proxy for the use of AI in contracts two different approaches:

- i) **Flexible approach:** enterprises using decision-making in combination with NLP, Recommendation/personalisation, or Process automation are assumed adopters of AI in contracting.
- ii) **Conservative approach:** enterprises that use at least three of the relevant AI technologies for contracts are considered assumed adopters of AI in contracting. In other words, we consider enterprises that adopt AI in contracting those enterprises that adopted three or four AI in contracting technologies.

Hence, we are able to provide an approximation to the set of enterprises –by country, sector and size- that are potentially using AI technologies in their contracting processes. It is not possible to provide a meaningful comparison using the Eurostat ICT Usage in Enterprises survey according to the type of AI technology because it is not possible to use the Eurostat website and extract the percentage of enterprises using jointly the AI technologies associated with AI in contracts. The same

holds when considering the type of purpose. Nevertheless, we include information on the Eurostat ICT Usage in Enterprises survey on both AI technologies and purposes, and compare the results.

All in all, and considering the data available, the results provided should be interpreted with caution and as an upper bound for enterprises eventually using AI in contracting.

Box 1: Definitions of AI technologies for AI in contracting

1) Adopter of AI:

A firm that adopts at least one of the 10 AI technologies. The adoption of any AI technology is enough to be categorised as an Adopter of AI. For the purpose of this study, Adopters of AI can be divided in two groups: Assumed adopters of AI in contracting, and Other AI adopters (their definitions can be found below).

2) Assumed adopter of AI in contracting

AI technologies relevant for contracting are the following:

- i) Natural Language Processing (**NLP**)
- ii) Forecasting, price optimisation and decision-making (**Decision-making**)
- iii) Recommendation and personalisation engines (**Recommendation/personalisation**)
- iv) Process automation

2.1 Flexible Approach

Firms adopting Decision-making and an additional AI technology relevant for contracting are categorised as Assumed adopters of AI in contracting according to the Flexible Approach. Therefore, it can be considered that Assumed adopters of AI in contracting are firms that adopted:

- Decision-making and NLP
- Decision-making and Recommendation/personalisation
- Decision-making and Process automation
- Decision-making, NLP and Recommendation/personalisation
- Decision-making, NLP and Process automation
- Decision-making, Recommendation/personalisation and Process automation

2.2 Conservative Approach

Firms adopting three or four AI technologies relevant for contracting are categorised as Assumed adopters of AI in contracting according to the Conservative Approach.

Therefore, it can be considered that Assumed adopters of AI in contracting are firms that adopted the four AI technologies relevant for contracting or a combination of three AI technologies relevant for contracting which, in this case, can be one of the following combinations:

- NLP, Decision-making and Recommendation/personalisation
- NLP, Decision-making and Process automation
- NLP, Recommendation/personalisation and Process automation
- Decision-making, Recommendation/personalisation and Process automation

3) Other AI adopter

Firms that adopt AI technologies that are not related to AI in contracting.

Source: Own elaboration.

Table 5 shows the total number of enterprises potentially adopting AI technologies for contracting, with a distinction according to the type of approach, Conservative vs Flexible. According to the

Conservative approach, it is possible to identify 246 assumed adopters of AI in contracting, while this number more than doubles according to the Flexible Approach: 576 firms.

Table 5: Total number of enterprises adopting AI technologies for contracting (2020).

| Type of Approach | Number of enterprises |
|------------------|-----------------------|
| Conservative | 246 |
| Flexible | 576 |

Source: Own calculations using the Ipsos-iCite (2020) dataset.

The Ipsos-iCite survey (2020) does not allow us to distinguish between intensities of AI adoption, as the questions are framed to collect information solely about adoption (“We currently use it: Yes or No”), but not levels of adoption (e.g., we use it in all contracting stages). Information about AI adoption intensity would allow a better understanding of how much the technology is used by the enterprises and to categorise enterprises according to levels of AI adoption.

8.3 Adoption of AI technologies for contracts

The current section starts by providing relevant summary statistics on enterprises adopting AI technologies related to contracts. Subsequently, regression analysis is performed to account jointly for different enterprise’s characteristics.⁶³

8.3.1 Summary Statistics

Enterprises adopting AI in contracting technologies: There is considerable heterogeneity among surveys and studies with respect to the percentage of enterprises adopting AI in general. For instance, according to the Ipsos-iCite survey (2020), a total of 42% of EU enterprises adopts at least one AI technology as of 2020. The Eurostat ICT Usage in Enterprises survey finds that, in 2023, 8% of EU enterprises use AI technologies. Perani (2023) finds that 21% of Italian enterprises are AI adopters. McKinsey (2022) reports that 50% of respondents adopt AI in at least one business area. The differences in the percentage of AI adopters can be due to different reasons which are outside the scope of this work. We now consider the focus of this work: adopters of AI technologies relevant for contracts.

Considering the methodology described above, according to the Conservative approach almost 3% of surveyed enterprises in the Ipsos-iCite survey (2020) are assumed adopters of AI technologies for contracts. However, according to the Flexible Approach, this percentage is almost 7%.

While this is a small proportion of enterprises, it is not surprising considering the initial stages of AI in contracting adoption. For instance, as a comparison, approximately 9% of EU enterprises adopted

⁶³ It is not possible to perform this type of analysis using the Eurostat ICT Usage in Enterprises survey (2023) because the data is aggregated.

Autonomous Machines (AM), a technology that is at more advanced stages of adoption (Moreno Maria et al., 2023).

For this metric, it is not possible to perform a direct comparison in terms of use of AI technologies with the Eurostat ICT Usage in Enterprises survey because it only provides the percentage of users for each individual AI technology. Therefore, it is not possible to consider a similar methodology and compute the percentage of users of AI technologies related to AI in contracts.

Considering the wide range of results in terms of the percentage of AI adopters and the fact that the scope of this work is on AI in contracts, it is more appropriate to focus on the percentage of assumed adopters of AI technologies for contracts among AI adopters. If we consider the subsample of AI adopters, then a total of approximately 8% of AI adopters are assumed adopters of AI in contracting according to the Conservative approach (*i.e.*, 246 enterprises out of 3624 AI adopters), and a total of 16% of AI adopters are assumed adopters of AI in contracting according to the Flexible approach (*i.e.*, 575 enterprises out of 3624 AI adopters).

The Eurostat Use of artificial intelligence in enterprises (2024) reports the percentage of AI adopters using AI technologies by types of purpose, which are the following:

- for ICT security (26.2%)
- for accounting, controlling or finance management (25.8%)
- for production processes (24.9%)
- for marketing or sales (23.6%)
- for organisation of business administration process or management (21.2%)
- for research and development (R&D) or Innovation activity (18%)
- for logistics (9.6%)

The types of purposes listed are broader than AI in contracts. Therefore, it would be difficult and would lack accuracy to draw conclusions in terms of assumed adopters of AI in contracts based on this information. However, the types of purposes more closely related to AI in contracts are marketing and sales; logistics; production processes; and organisation of business administration process or management. It is also not possible to use the Eurostat statistics tool to obtain the percentage of AI adopters using AI technologies, for instance, for marketing and sales and for logistics.

Table 6: Combinations of AI technologies by assumed adopters of AI in contracting: Flexible Approach (as of 2020)

| AI technologies for contracts | Number of enterprises |
|---|------------------------------|
| Decision-making and NLP | 84 |
| Decision-making and Recommendation/personalisation | 130 |
| Decision-making and Process automation | 160 |
| Decision-making, NLP and Recommendation/personalisation | 32 |
| Decision-making, NLP and Process automation | 64 |
| Decision-making, Recommendation/personalisation and Process automation | 54 |
| Decision-making, NLP, Recommendation/personalisation and Process automation | 51 |
| Total | 575 |

Note: Own calculations using the Ipsos-iCite (2020) dataset.

Technologies can have a complementary nature and enterprises might benefit from joint adoption of technologies (e.g., Lambert et al., 2015). Assumed adopters of AI in contracting tend to adopt AI technologies jointly (Table 7). Moreover, this pattern also emerges when comparing assumed adopters of AI in contracting with Other AI adopters: the proportion of assumed adopters of AI in contracting that adopt multiple AI technologies is greater than the proportion of Other AI adopters doing so.

Table 7: Total number of AI technologies by Assumed adopters of AI in contracting and Other AI adopters

| Number of AI technologies adopted | Assumed Adopters of AI in contracting (Flexible approach) | | | Other AI adopters | | |
|-----------------------------------|---|---------------------------|-----------------------|-----------------------|---------------------------|-----------------------|
| | Number of enterprises | Percentage of enterprises | Cumulative percentage | Number of enterprises | Percentage of enterprises | Cumulative percentage |
| 1 | - | - | - | 1480 | 48.5 | 48.5 |
| 2 | 94 | 16.35 | 16.35 | 814 | 26.7 | 75.24 |
| 3 | 105 | 18.26 | 34.61 | 420 | 13.78 | 89.01 |
| 4 | 153 | 26.61 | 61.22 | 226 | 7.41 | 96.43 |
| 5 | 105 | 18.26 | 79.48 | 67 | 2.2 | 98.62 |
| 6 | 64 | 11.13 | 90.61 | 19 | 0.62 | 99.25 |
| 7 | 24 | 4.17 | 94.78 | 15 | 0.49 | 99.74 |
| 8 | 14 | 2.43 | 97.22 | 6 | 0.2 | 99.93 |
| 9 | 13 | 2.26 | 99.48 | 2 | 0.07 | 100 |
| 10 | 3 | 0.52 | 100 | - | - | |
| Total | 575 | | 100 | 3049 | 100 | |

Note: Other AI adopters are enterprises that adopted AI, excluding AI technologies for contracting. Source: Own calculations using the Ipsos-iCite (2020) dataset.

Sector of activity: The adoption of AI technologies for contracts might differ by sector of activity, as some sectors might be more prone to adopt these technologies than others. Among AI adopters and within sector of activity, the proportion of assumed adopters of AI in contracts is the highest for the Trade sector, where almost 20% of its enterprises are assumed AI adopters in contracts. Subsequently, within the Manufacturing sector, 15% of the AI adopters are assumed AI adopters in contracting. Construction and IT/Finance follow. The sector ranking the lowest is Agriculture, as 10.7% of AI adopters in Agriculture are assumed AI adopters in contracting.

If we consider the sector of activity in the subsample of assumed enterprises adopting AI in contracting (Table 9), 38% of these enterprises operate in the Trade/Transport sector, 21% in the Manufacturing sector, and 18% in the IT/Finance sector.

Table 8: Sector of activity: Assumed Adopters of AI in contracting vs Other AI Adopters (Flexible Approach)

| Sector of Activity | Other AI Adopters | Assumed Adopters of AI in contracting | Total |
|-----------------------|-------------------|---------------------------------------|-------|
| Agriculture | 117 | 14 | 131 |
| (%) | 89.31 | 10.69 | 100 |
| Manufacturing | 674 | 121 | 795 |
| (%) | 84.78 | 15.22 | 100 |
| Construction | 422 | 72 | 494 |
| (%) | 85.43 | 14.57 | 100 |
| Trade/Transport | 885 | 217 | 1102 |
| (%) | 80.31 | 19.69 | 100 |
| IT/Finance | 631 | 104 | 735 |
| (%) | 85.85 | 14.15 | 100 |
| Education/HumanHealth | 320 | 47 | 367 |
| (%) | 87.19 | 12.81 | 100 |
| Total | 3049 | 575 | 3624 |
| (%) | 84.13 | 15.87 | 100 |

Source: Own calculations using the Ipsos-iCite (2020) dataset.

Table 9: Sector of activity among assumed adopters of AI in contracting

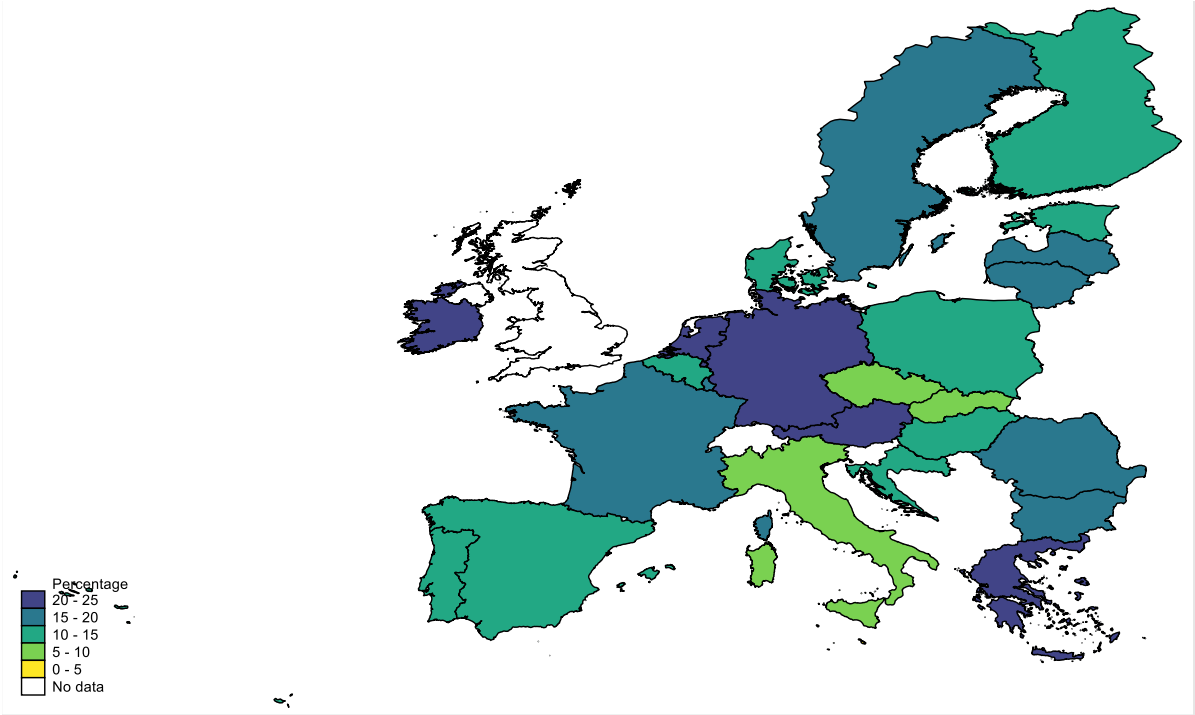
| Sector | Total of enterprises | Percentage |
|---------------|----------------------|------------|
| Agriculture | 14 | 2.4 |
| Manufacturing | 121 | 21.0 |
| Construction | 72 | 12.5 |
| Trade | 217 | 37.7 |
| IT/Finance | 104 | 18.1 |
| Education/HH | 47 | 8.2 |
| Total | 575 | 100 |

Source: Own calculations using the Ipsos-iCite (2020) dataset.

Location of assumed adopters of AI in contracting: The survey provides information about the enterprises’ location. There is some heterogeneity in terms of the proportion of assumed adopters of AI in contracting among AI adopters at the country-level: in some countries the proportion of AI in contracting adopters is small, while in others more than 10% of AI adopters are likely to be

adopters of AI in contracting (e.g., Germany, Austria, Portugal, and Slovenia). If we consider the percentage of adopters of AI in contracting among AI adopters (i.e., adopters of AI in contracting vs Other AI adopters), the percentage of adopters of AI in contracting is higher (Figure 9). Nevertheless, results at the national level in terms of AI technologies should be interpreted with caution because the survey aimed at having a representative sample of enterprises by country according to different characteristics such as enterprise size, but not according to the type of AI technologies adopted.

Figure 9: Percentage of assumed adopters of AI in contracting with respect to AI adopters.



Source: Own calculations using data from the Ipsos-iCite (2020).

Considering the data, a more accurate way of accounting for enterprises' location is to consider regions, defined for the purpose of this study⁶⁴: North, East, West and South (Table 10**Table 8**). The region with the highest proportion of assumed adopters of AI in contracting is the West (38.3%), followed by the East (26.3%). The same pattern emerges if we consider Other AI adopters, with 30.1% of enterprises located in the West region, 29.5% in the East, 20.7% in the North, and 19.7% in the South. As this can reflect the sample composition by region, we can consider instead the percentage of assumed adopters of AI in contracting among all AI adopters in a certain region. In the West, 19.3% of all AI adopters are assumed adopters of AI in contracting.

⁶⁴ North – Denmark, Finland, Sweden, Estonia, Latvia and Lithuania; East – Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia and Croatia; South – Greece, Spain, Italy, Cyprus, Portugal and Malta; West – Belgium, Germany, France, Ireland, Luxembourg, Netherlands and Austria.

Table 10: Location of AI adopters by region

| | Assumed Adopters of AI in contracting | Other AI adopters | Total by Location | % of Assumed Adopters of AI in contracting (with respect to all Assumed Adopters of AI in Contracting) | % of Other AI adopters (with respect to all Other AI adopters) |
|-----------------|---------------------------------------|-------------------|-------------------|--|--|
| North | 117 | 630 | 747 | 20.4 | 20.7 |
| (% among North) | 15.7 | 84.3 | 100 | | |
| East | 151 | 899 | 1050 | 26.3 | 29.5 |
| (% among East) | 14.4 | 85.6 | 100 | | |
| South | 87 | 602 | 689 | 15.1 | 19.7 |
| (% among South) | 12.6 | 87.4 | 100 | | |
| West | 220 | 918 | 1138 | 38.3 | 30.1 |
| (% among West) | 19.3 | 80.7 | 100 | | |
| Total | 575 | 3049 | 3624 | 100 | 100 |
| (%) | 15.9 | 84.1 | 100 | | |

Source: Own calculations using the Ipsos-iCite (2020) dataset.

Enterprise size: Enterprise size can be a relevant driver of technology adoption, namely AI (Section 7.1 Adopters of AI vs Adopters of AI in contracting). Larger enterprises can have an advantageous position compared to SMEs, namely because they have better access to finance. The likelihood of increasing investment, innovating more, and implementing multiple technologies is greater for larger enterprises than for SMEs (EIB, 2023).

The Ipsos-iCite survey (2020) includes information about the size of the enterprise which can be Micro (between 5 and 9 employees), Small (between 10 and 49 employees), Medium (between 50 and 249 employees), or Large (more than 250 employees). Table 11 shows that the percentage of assumed adopters of AI in contracting is higher among bigger enterprises: approximately 4.9% of micro and 6.2% of small enterprises are adopters of AI in contracting, while this proportion doubles for large enterprises. This corroborates previous findings that enterprise size can matter for technology adoption, with larger enterprises having an advantage.

Table 11: Enterprises assumed to have adopted AI in contracting by size.

| Size | Assumed adopters of AI in contracting (%) | Other enterprises (%) | Total (%) |
|---------------|--|------------------------------|------------------|
| Micro | 148 (4.9%) | 2896 (95.1%) | 3044 (100%) |
| Small | 189 (6.2%) | 2867 (93.8%) | 3056 (100%) |
| Medium | 158 (8.4%) | 1731 (91.6%) | 1889 (100%) |
| Large | 80 (11.9%) | 592 (88.1%) | 672 (100%) |
| Total | 575 (6.6%) | 8086 (93.4%) | 8661 (100%) |

Source: Own calculations using data from Ipsos-iCite (2020).

If only AI adopters are considered (*i.e.*, excluding enterprises that do not adopt AI), an interesting pattern emerges: the differences in the proportion of assumed adopters of AI in contracting according to enterprise size are small. Among AI adopters, 13% of micro enterprises are assumed adopters of AI in contracting, and 22% of large enterprises are assumed adopters of AI in contracting. Therefore, enterprise size is also a relevant factor for assumed adopters of AI in contracting, and similarly to the findings on broader technology adoption, larger enterprises have an advantage.

Table 12: Assumed adopters of AI in contracting vs Other AI adopters by enterprise size.

| Size | Other AI adopters (%) | Assumed adopter of AI in contracting (%) | Total (%) |
|-------------|------------------------------|---|------------------|
| Micro | 997 (87.1%) | 148 (12.9%) | 1145 (100%) |
| Small | 991 (84%) | 189 (16%) | 1180 (100%) |
| Medium | 773 (83%) | 158 (16.9%) | 931 (100%) |
| Large | 288 (78.3%) | 80 (21.7%) | 368 (100%) |
| Total | 3049 (84.1%) | 575 (15.9%) | 3624 (100%) |

Note: Own calculations using data from Ipsos-iCite (2020).

8.3.2 Regression Analysis: Predictors of adoption of AI in contracting

Some enterprise characteristics might be better predictors of the adoption of AI in contracting than others. Regression analysis can be useful as it allows to consider multiple firms' characteristics. We consider a probit⁶⁵ regression model in which the dependent variable is *assumed adoption of AI in contracting*. This is the main variable to be predicted, considering the values of other variables (the independent variables). Assumed adoption of AI in contracting takes the value of one if the firm adopts AI in contracting, and it takes the value of zero otherwise. The independent variables included in our model follow from the review of the literature, the market characterisation that we developed, and the analysis of the dataset. The previous section provided evidence on the relevance of firm size for firm dynamics and adoption of new technologies. Therefore, firm size is a relevant variable to be included. Sector of activity allows to consider sector specificities which are important for AI adoption as well. It is also relevant to control for country, as there is vast evidence showing that AI adoption is heterogenous at the EU member state level. Finally, total number of branches is included as a measure of firm geographic dispersion. On the one hand, enterprises with multiple branches can be geographically dispersed and might face greater barriers as the adoption of new technologies must take place in all locations. On the other hand, they can also benefit from economies of scale or can benefit from a learning effect (for instance, they can start by implementing the new technology in one location, understand how to better use it and only after adopting it in all the locations). The regression analysis aims at studying which variables are associated with the assumed adoption of AI in contracting and in which direction the relationship goes (positive or negative). Positive coefficients represent a higher likelihood of assumed adoption of AI in contracting, while negative coefficients indicate a lower likelihood of assumed adoption (Table 13; see the Appendix for full results).

Considering the sign of the coefficient is not enough, and it is important to consider whether the coefficient is statistically significant. For instance, if the coefficient for "Knowledge of AI" is positive, which would indicate that enterprises where employees know AI are more likely to adopt AI in contracting, is this due to chance, or can it be attributed to AI knowledge instead? If the effect is statistically significant and not random, the respective significance levels can be at the 10%, 5% or 1% level (indicated as *, **, or ***, with the highest significance level indicated by ***).

Enterprise Size: The regression analysis considers Micro enterprises as the baseline and, therefore, the coefficients for Small, Medium and Large should be compared with Micro enterprises.⁶⁶ The coefficients for Small, Medium and Large are positive and statistically significant. Moreover, the coefficients are of greater magnitude according to enterprise size. This indicates that Small enterprises are more likely of potentially adopting AI in contracting than Micro enterprises; Medium enterprises are more likely to adopt AI in contracting than Micro and Small enterprises, and Large enterprises are even more likely of doing so as the coefficient is positive and greater in magnitude.

Knowledge of AI: The variable "Knows AI" captures whether enterprise's employees have knowledge of AI. The coefficient is positive and statistically significant, and therefore enterprises with knowledge of AI have a greater likelihood of adopting AI in contracting than those enterprises where employees do not have such knowledge.

⁶⁵ In a probit model, the dependent variable is binary.

⁶⁶ A baseline category must be considered.

Sector of Activity: Surveyed enterprises operate in six activity sectors,⁶⁷ which are the following: i) Agriculture; ii) Manufacturing; iii) Construction; iv) Trade; v) IT; and vi) Education. Enterprises operating in the Manufacturing and Trade sectors are more likely to potentially adopt AI in contracting.

Number of branches: Enterprises with different branches and that are geographically dispersed are less likely to potentially adopt AI in contracting. This seems to confirm that enterprises geographically dispersed might face greater barriers of adopting new technologies.

Table 13: Summary of regression analysis (coefficients' sign and significance level)

| | (1) AI in contracting | (2) AI in contracting | (3) AI in contracting |
|------------------------|----------------------------------|----------------------------------|----------------------------------|
| Small enterprise | + ** | + ** | - |
| Medium enterprise | + *** | + *** | + *** |
| Large enterprise | + ** | + *** | + *** |
| Knows AI | + *** | + *** | + *** |
| Number of Branches | - *** | - *** | - *** |
| Manufacturing | + | + * | + * |
| Construction | + | + | + |
| Trade | + ** | + ** | + ** |
| IT/Finance | + | + | + |
| Education/Human health | + | + | + |
| Constant | - *** | - *** | - *** |
| Observations | 8661 | 8640 | 8640 |
| Country FE | NO | YES | YES |
| Robust SE | NO | NO | YES |

Note: The second column includes Country fixed-effects; the third column includes country fixed-effects and robust standard errors. Source: Own calculations using data from the Ipsos-iCite (2020).

⁶⁷ This is a standard categorisation. The full names of the activity sectors are: Agriculture, forestry and/or fishing; Manufacturing; Construction, waste management, water and electricity supply; Trade, transport, food/accommodation; IT, finance, real estate & other technologies; Education, human health & social work.

8.4 Barriers to the adoption of AI in contracting

Barriers to innovation (Revealed vs Deterring barriers): Enterprises might face barriers to the adoption or use of new technologies, which in practice can represent relevant barriers to innovation. There is evidence of a positive association between a firm's perception of obstacles and its innovation propensity (*e.g.*, Coad et al., 2016). Analyses of perceptions of barriers to innovation should distinguish between firms that do not innovate because they do not plan to do so and firms that try to innovate but fail to reach that outcome due to obstacles to innovation (Blanchard et al., 2013). In this context, D'Este et al. (2013) argue that it is necessary to distinguish between revealed barriers and deterring barriers. Revealed barriers reflect the degree of difficulty of the innovation process and the learning experience consequent on the firm engaging in innovation activity and, therefore, are barriers that firms face resulting from new technologies' adoption or during the process of adoption. They reflect difficulties encountered by an enterprise as a result of the technology adoption, or during this process. Deterring barriers are perceived obstacles that prevent enterprises from committing to innovation or, in other words, are obstacles to adopting new technologies.

The Ipsos-iCite survey (2020) asks enterprises if they are planning to use AI in the near future (*i.e.*, in the next 2 years). Therefore, in our analysis, we consider two sub-samples: a subsample composed of adopters of new technologies that face revealed barriers; and a sub-sample of non-adopters but potential innovators as they intend to innovate in the future, that face deterring barriers (Moreno Maria *et al.*, 2023).

Table 14 shows the proportion of AI adopters (Assumed adopters of AI in contracting⁶⁸ and Other AI adopters) that consider Liability/Reputation, Lack of access to Data, Adoption/adaptation costs, lack of skills, or complex algorithm as a revealed barrier. Therefore, these are perceptions of barriers that resulted from the adoption of the new AI technologies.

⁶⁸ As a reminder, the report uses the notation "assumed adopters of AI in contracting" to refer to those firms effectively adopting AI technologies related to AI in contracting.

Table 14: Revealed barriers according to enterprise size: Assumed Adopters of AI in contracting vs Other AI adopters.

| | Assumed Adopters of AI in contracting (%) | | | | |
|---------------------------------|---|-------|--------|-------|-------|
| | Micro | Small | Medium | Large | Total |
| Liability/Reputation | 79.7 | 72.7 | 75 | 74.3 | 75.4 |
| Lack of access to/internal Data | 76.1 | 81 | 75.6 | 77.6 | 77.9 |
| Adoption/adaptation Costs | 88.2 | 88.3 | 87.2 | 91 | 88.4 |
| Lack of skills | 95.2 | 95.6 | 94.3 | 89.3 | 94.3 |
| Complex algo | 75.6 | 69.6 | 69.7 | 78.8 | 72.5 |
| | Other AI adopters (%) | | | | |
| | Micro | Small | Medium | Large | Total |
| Liability/Reputation | 67.9 | 64.5 | 65 | 72.9 | 66.6 |
| Lack of access to/internal Data | 68.9 | 68.4 | 68.7 | 75.8 | 69.4 |
| Adoption/adaptation Costs | 84.4 | 84.4 | 85 | 84.5 | 84.6 |
| Lack of skills | 89.7 | 88.3 | 88.2 | 91 | 89 |
| Complex algo | 73.3 | 68.8 | 71.9 | 70.9 | 71.3 |

Note: Revealed barriers are those reported by enterprises already using the respective AI technologies; Deterring barriers are those reported by enterprises planning to adopt the respective AI technologies in the near future. Source: Own calculations using data from Ipsos-iCite (2020).

- *Lack of skills* is the revealed barrier reported by the highest percentage of enterprises, both assumed adopters of AI in contracting (94.3%) and Other AI adopters (89%). Among *Other AI adopters*, a somewhat similar proportion of micro, small, medium and large enterprises reported lack of skills as an obstacle. Among assumed adopters of AI in contracting, 94% of enterprises report lack of skills as a barrier, with a higher proportion of micro and small enterprises (approximately 95% for both types of enterprises), followed by medium (94%) and large (89%). Therefore, lack of skills is a greater obstacle for SMEs than for large enterprises.
- *Liability and reputation barriers* are a greater barrier for Assumed adopters of AI in contracting (75%) than for Other AI adopters (67%).
- A higher proportion of Assumed adopters of AI in contracting than Other AI adopters considers *data access* as a barrier to the adoption of AI (78% and 69%, respectively). Among assumed adopters of AI in contracting, this is a barrier even for larger enterprises.
- *Adoption/adaptation costs* are reported as a barrier by a higher proportion of assumed adopters of AI in contracting than Other AI adopters. Access to data is crucial for AI in contracts.
- *Complex algorithms* is reported by a similar proportion of Assumed Adopters of AI in contracting and Other AI adopters. Among Assumed Adopters of AI in contracting, the proportion of enterprises reporting it as a barrier was highest for Large enterprises (79% of large enterprises, followed by 76% of micro enterprises, and 70% of Small and Medium enterprises).

Deterring barriers, which are those reported by enterprises planning to potentially adopt AI in contracts in the near future, are also considered. Table 15 reports the types of barriers according to enterprise size.

Table 15: Deterring barriers according to enterprise size

| | Potential Future adopters of AI in contracting (%) | | | | |
|---------------------------------|--|-------|--------|-------|-------|
| | Micro | Small | Medium | Large | Total |
| Liability/Reputation | 80 | 81 | 76 | 85 | 80 |
| Lack of access to/internal Data | 80 | 84 | 74 | 81 | 79 |
| Adoption/adaptation Costs | 91 | 92 | 87 | 95 | 90 |
| Lack of skills | 95 | 93 | 86 | 97 | 93 |
| Complex algo | 80 | 76 | 70 | 82 | 77 |

Note: Deterring barriers are those reported by enterprises planning to adopt AI technologies for contracts in the near future. Source: Own calculations using data from Ipsos-iCite (2020).

A few patterns emerge:

- Liability for damage caused by AI and reputational risks linked to the use of AI, and Data Access, are perceived as a barrier to a similar proportion of SMEs and large enterprises. Future adopters of AI in contracting perceive liability/reputation as a greater risk than current AI adopters (both adopters of AI in contracting and Other AI adopters).
- *Lack of skills* is perceived as the deterring barrier reported by the highest percentage of enterprises (93%).

8.5 Delivery Modes

Enterprises can acquire AI software and systems via different sources. According to the Ipsos-iCite survey (2020), these can be developed in-house, modified commercial software or systems, modified open-source software or systems, purchased and ready to use, developed by external providers, or others. Enterprises can acquire AI software using one source or a combination of different types.

Table 16 shows that there is a higher proportion of Other AI adopters than assumed adopters of AI in contracting that use one unique delivery mode. Overall, adopters of AI in contracting seem to consider different delivery modes in terms of AI software and systems.

Table 16: Number of delivery modes

| Total Delivery Modes | Assumed Adopters of AI in contracting | | Other AI adopters | |
|----------------------|---------------------------------------|------------|-------------------|------------|
| | Number | Percent | Number | Percent |
| 1 | 212 | 36.9 | 1548 | 50.8 |
| 2 | 159 | 27.6 | 729 | 23.9 |
| 3 | 111 | 19.3 | 375 | 12.3 |
| 4 | 52 | 9.0 | 121 | 4.0 |
| 5 | 7 | 1.2 | 15 | 0.5 |
| NA | 34 | 5.9 | 261 | 8.6 |
| Total | 575 | 100 | 3049 | 100 |

Source: Own calculations based on data from the Ipsos-iCite survey (2020).

We also analyse which type of delivery mode is more used by assumed adopters of AI in contracting and by other AI adopters. Purchased software, and software developed by external providers are used in similar proportions by both types of firms. Nevertheless, there is a higher percentage of in-house, modified commercial, and modified open source by adopters of AI in contracting compared to other AI adopters (Table 17). This might suggest that AI in contracting requires AI software and systems that need to be readjusted and modified according to specificities of contracts which makes it more difficult to find and purchase software ready to use and which will be adapted to the needs of the specific contracting process.

Table 17: Types of delivery modes – Assumed adopters of AI in contracting vs Other AI adopters.

| Acquisition of AI Software/Systems | Other AI adopters | Assumed adopters of AI in contracting | Total AI adopters |
|------------------------------------|-------------------|---------------------------------------|-------------------|
| In-house | 570 | 157 | 727 |
| (%) | 18.7 | 27.3 | |
| Modified Commercial | 683 | 195 | 878 |
| (%) | 22.4 | 33.9 | |
| Modified Open-source | 554 | 154 | 708 |
| (%) | 18.2 | 26.8 | |
| Purchased | 1783 | 337 | 2120 |
| (%) | 58.5 | 58.6 | |
| External Providers | 1100 | 263 | 1363 |
| (%) | 36 | 45.7 | |
| Other | 246 | 28 | 274 |
| (%) | 8.1 | 4.9 | |

Note: In-house: developed by own employees; Modified Commercial: commercial software or systems modified by own employees; Modified Open-source: open-source software or systems modified by own employees; Purchased: commercial software or systems ready to use when purchased; External providers: external providers were contracted to develop or modify them. Source: Own calculations using data from the Ipsos-iCite survey (2020).

9. Use cases

AI systems and solutions for contracting purposes are horizontal tools that can support many processes across all sectors. From a technical perspective, this range of AI applications is only limited by the digital transformation of sectors and data availability.

The horizontal nature of contracts on the one hand and AI on the other hand potentially set the scope of our study to be very broad. As the study is not a mapping exercise, we limit the scope of the application of AI in contracting primarily to the B2B and B2C economic transactions, while the use-cases go beyond this scope to some extent (also covering peer to peer). We focus on the offer generation, conclusion and performance of contracts in economic transactions, as those bear the immediate legal consequences for the contracting parties.

The selection of the specific use cases is non-exhaustive. It is driven by the objective to shed light on the type of AI systems used, how they are delivered and how they are used. The analysis of these aspects can give way to further tackle legal issues related to the use of AI in contracting, such as issues linked to agency, error and mistake, intermediation, representation and attribution of actions, to name a few. While addressing these issues goes beyond the scope of this study, the description of the actual use cases already hints at the problems linked to the use of AI in contracting.

The analysis of the use cases also provides insight into many aspects common to emerging business practices. Nevertheless, due to the novel nature of AI approaches allowing for the automation of contracting and the rapid path of innovation taking place in the underlying tools and applications, data on market penetration and adoption for the particular use cases is still scant.

The following table presents use cases, further described in this section in relation to the contracting stages where automation is enabled by an AI system.

Table 18: Examples of use cases

| Use case | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
|--------------------------------|------------------|-----------------------|---------------------|--------------------------------------|
| Forex trading | | | X | x |
| Programmatic advertising | X | X | X | x |
| E-commerce: automated pricing | X | | | |
| E-commerce: virtual assistants | | X | X | x |
| Supply chain management | X | X | X | x |
| Renewable Energy trading | | | X | x |

Source: Own elaboration.

9.1 Forex

9.1.1 Nature of activity

Forex (FX) is the foreign exchange market for the trading of currencies. Forex allows for currency conversions, facilitating cross-border global trade, which can include investments, exchange of goods and services, and financial transactions. AI systems are used to fully automate buying and selling currencies, i.e. they facilitate conclusion and execution of transactions.

9.1.2 AI systems used

The automation of Forex trading is increasingly supported by online trading platforms. The automating tools are referred to as Expert Advisors (EAs), or more informally “trading bots”, or “trading robots”. These tools used to be based exclusively on the pre-determined logic therefore akin to *execution algorithms*. AI allowed the tools to evolve towards highly sophisticated and adaptive types based on machine learning techniques (deep learning) that respond to real-time changes in market conditions. AI techniques help to observe market tendencies on real time basis. AI-based techniques make it easier to handle big data, to understand and to compare different parameters using both historical and real-time data. In addition, AI makes it possible to identify the trends in different variables and to understand interactions of different parameters. As a result, advanced technologies are capable of fully automating trading decisions and increase the speed of the transactions.⁶⁹ The development of Large Language Models (LLMs) further influenced the use of AI in forex and other markets by allowing text-based trading. Therefore, apart from the AI-based analytical layer and automated execution of the transactions, AI can also be used as an interface enabling natural language conversations and placing trading instructions in plain language.

MetaTrader Platform

MetaTrader platforms (MT4 and MT5) are among the most common platforms for retail Forex. MT4 was released in 2005. The platforms software is licensed to Forex brokers who provide it to their customers. The platforms are the core component of the ecosystem. It is a downloadable desktop application that provides access to various financial markets (including Forex) commodities, indices, and more. In addition to the desktop version, MT4 is available as a mobile application and web-based platform, allowing traders to access their accounts and trade from anywhere.⁷⁰

One of the standout features of the platforms is their support for automated trading using Expert Advisors (EAs) often referred to as trading robots. Both terms are used to describe automated trading systems that can identify market patterns and generate trading signals. However, some sources may use the term EA to refer to a program that only provides trading signals, while a

⁶⁹ Miiikulainen, R., Liang, J., Meyerson, J. E., Rawal, A., Fink, D., Francon, O., Raju, B., Shahrzad, H., Navruzyan, Duffy, N. & Hodjat, B. (2019). Evolving Deep Neural Networks, Artificial Intelligence in the Age of Neural Networks and Brain Computing, 293-312.

⁷⁰ <https://www.metatrader4.com/en>; <https://www.metatrader5.com/>.

trading robot can also execute trades without any manual intervention. This distinction is not consistent, and many EAs are capable of both generating signals and performing trades.⁷¹

9.1.3 Human oversight and issues

Human oversight depends on the delivery mode of EAs. Users can choose from a full range of trading tools that suit different user's skills. EAs can be developed by a user and connected to the trading platform, they can also be provided by a platform or a third party. The EAs differ in both the *level of automation* and *level of the readiness to use*. The automation level can be often customised, depending on the user's preferences and skills to trade. The trading can be fully automated or automated under specific conditions, or specific stages of trading can be automated. Systems can be ready to use simply upon the introduction of the user's chosen settings.⁷² They can also be programmed in a way to give a user a possibility to further develop it.⁷³ There are also EA builders, a special software that allow for building a customised EA. The possibility to build an EA can be facilitated either by a trading platform, or by a third-party software developer.⁷⁴

The automation in forex facilitates high frequency trading. For this reason, user's intervention is impossible on the level of a single transaction (contract). At the same time, users may opt for full reliance on EA to make decisions relating to transactions. In such case, users have possibility to monitor the AI tool by direct real-time observation of the trends and indicators on the screen, by getting notifications in defined cases, or by setting rules on action in case when given conditions are met. They may also decide to stop using EA in any time. Nevertheless, the EAs providers highlight that fully relying on the EA brings better results as it removes the emotional bias that accompanies in particular inexperienced users. There are AI-based EAs that can adapt the executed trading strategy to the changing market in real time, in order to maximise profit. User's input in such case may be limited to the setting the level of acceptable financial risk. But experts advise to closely monitor fully automated adaptive EAs because the long-term performance of AI tool is not very well known. However, in case of an inexperienced user, the effective monitoring of fully automated and data-driven AI seems rather illusory. For this reason, unskilled users, in order to benefit from full automation in forex trading sometimes use third parties to monitor the tools they use. For example, they have an option to pay for services provided by dealers or intermediaries that offer 24 h monitoring of AI tools.

⁷¹ MetaTrader4: [Algorithmic trading and trading robots in MetaTrader 4](#); MetaTrader5: <https://www.metatrader5.com/en/automated-trading/robots-indicators>.

⁷² See for example: <https://3commas.io/blog/best-forex-trading-bot>.

⁷³ See for example: MetaTrader: <https://www.metatrader5.com/en/automated-trading/robots-indicators>.

⁷⁴ See for example: <https://tradersunion.com/interesting-articles/forex-trading-advisors/best-expert-advisor-builders/>; <https://www.mql5.com/en>.

9.1.4 Summary of the use of AI in retail Forex

Table 19: Summary of the use of AI in retail Forex

| B2C and B2B | | | | |
|--|-------------------------|------------------------------|---|--|
| Contracting stage | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
| Process automated with AI Automated process(es) | - | - | Automated decision on currency buying based on dynamic market analysis (action with legal consequences) | Automated execution of a buying/selling order (action with legal consequences) |
| Type of AI systems used (deterministic /non-deterministic) | - | - | Deterministic and non-deterministic | Determined by contract terms |
| Type of output: prediction, recommendation, decision | - | - | Decision | Decision |
| The automating tool(s) relevant for the use case | - | - | Expert Advisor (EA), Forex robot, trading robot | Expert Advisor (EA), Forex robot, trading robot |
| Provision modality | - | - | AI service, AI product | AI service, AI product |
| Types of provider | - | - | Contracting party, intermediary, external provider | Contracting party, intermediary, external provider |
| Customisation capacity | - | - | Full range | Full range |

Source: Own elaboration.

9.2 Programmatic advertising

9.2.1 Nature of activity

Programmatic advertising is a way of allocating advertising banners, in display advertising and beyond, where advertising impressions are sold in real-time bidding (RTB) auctions. This practice complements a more direct allocation through pre-negotiated contracts, known as reservation contracts, between publishers and advertisers.⁷⁵ Programmatic advertising started being used around the mid-2010s and gained wider popularity in 2014. AI has been considered an integral part

⁷⁵ SaS.Amin, *Real-Time Bidding in Online Display Advertising* (February 14, 2017). Available at SSRN: <https://ssrn.com/abstract=2916875> or <http://dx.doi.org/10.2139/ssrn.2916875>.

of programmatic advertising since its outset. Use of AI allowed the effective automation of marketing decisions and their execution.⁷⁶

AI in programmatic advertising today is correlated with enhanced knowledge-based automation of many processes performed on the Supply Side Platform (SSP), Demand Side Platform (DSP) and Ad exchange (AdX).

As long as contracting is considered, AI supports Real Time Bidding (RTB) in programmatic advertising. AI is used to bid for the available ad impressions, make a decision on the winning bid and finally to execute and display it. Multiple-level bidding and decision-making takes place on the DSPs accessed by advertisers before the final real time auction takes place on the Ad Exchange platform (AdX). In this final auction an AI system decides on the winning bid, hence on the selling of a specific ad impression to a specific advertiser. This ad impression buying and selling process followed by displaying an advertisement takes a fraction of a second.

9.2.2 AI systems used

AI-powered technologies are used throughout the process of programmatic advertising, enabling advertisers to reach their target audiences more precisely and optimise their ad placements.⁷⁷ To this end AI constantly integrates the changing data into the contracting.⁷⁸ The data includes advertiser's goals and objectives as well as user-based and context-based data. AI allows 'cookieless' targeting, which primarily do not rely on the user's consent but uses alternative methods like contextual or aggregated targeting to reach specific audiences anonymously.⁷⁹ Also AI-based predictive analytics is integrated into programmatic advertising. AI methods can predict user actions and campaign outcomes, allowing advertisers to adjust strategies proactively by continuously analysing conversion rates, click-through rates, and other relevant metrics relating to the bidding.

AI systems used in programmatic advertising are to large extent non-deterministic particularly due to the complexity, size and fluctuations in data that is integrated into the process.

Programmatic advertising is a complex ecosystem of players. Many important companies, such as Google and Amazon, among others, have tried to propose an integrated platform that provide a

⁷⁶ [A brief history of artificial intelligence in advertising \(econsultancy.com\).](https://www.econsultancy.com/insights/a-brief-history-of-artificial-intelligence-in-advertising)

⁷⁷ Li, Hairong. "Special section introduction: Artificial intelligence and advertising." *Journal of advertising* 48.4 (2019): 333-337; Vaibhav Shwetangbhai Diwanji, Jaejin Lee & Juliann Cortese (2022) Deconstructing the role of artificial intelligence in programmatic advertising: at the intersection of automation and transparency, *Journal of Strategic Marketing*, DOI: 10.1080/0965254X.2022.2148269; Busch, Oliver. "Programmatic advertising." *The Successful Transformation to Automated, Data-Driven Marketing in Real-Time*. Springer Cham (2016). DOI: <https://doi.org/10.1007/978-3-319-25023-6>.

⁷⁸ Choi and Lim identify machine learning techniques used in programmatic advertising. They categorise them as user- and content-centric approaches: A Choi, Kiho Lim, Identifying machine learning techniques for classification of target advertising, *ICT Express*, Volume 6, Issue 3, 2020, Pages 175-180, ISSN 2405-9595, <https://doi.org/10.1016/j.icte.2020.04.012>; Choi J.A., Lewis R. Culture and the star-power strategy: Comparing American and Korean response to Celebrity-Endorsed advertising *J. Glob. Mark.*, 30 (1) (2017), pp. 3-11.

⁷⁹ See for example: <https://blog.seedtag.com/how-ai-powered-contextual-advertising-will-replace-the-third-party-cookies#:~:text=Cookieless%20advertising%20methods%2C%20such%20as,complete%20picture%20of%20the%20user.>

one-stop solution for the demand and supply side of the advertising relation. Some of the players offering integrated solutions for programmatic advertising or specialise in selected components:

- **Google Marketing Platform** (formerly DoubleClick): offers a suite of tools that includes Google Ad Manager (SSP), Display and Video 360 (DSP), and Google Ad Exchange (AdX) for ad exchange services.
- **Amazon Advertising**: integrates demand and supply services with Amazon DSP and Amazon Publisher Services, allowing advertisers to buy and publishers to sell programmatically within the Amazon ecosystem.
- **Adform**: offers an end-to-end ad tech stack that includes SSP, DSP, and a cross-channel ad exchange.⁸⁰
- **MediaMath**: offers a comprehensive platform with DSP capabilities, supply connections, and ad exchange features.⁸¹
- **Microsoft Advertising** (former Xandr): provides a full-stack platform that includes both SSP and DSP capabilities.⁸²
- **Ad Pepper Media**: operates an ad exchange that provides programmatic solutions for online advertising across various formats and channels.⁸³

9.2.3 Human oversight and issues

In programmatic advertising, the AI oversight is performed by platforms that intermediate interactions between an advertiser and a publisher. Before the advertisement reaches a viewer, several platforms with their AI systems can interact in order to fulfil terms of the advertising campaign. It seems however that neither a publisher, an advertiser, nor an individual visiting a website can directly monitor AI systems used by intermediaries. They influence the AI performance by the relevant framework agreements dealing with advertising campaigns, i.e. by setting of the objectives, KPIs and potentially other boundaries of the AI performance. Individuals visiting websites can accept websites' ToS and manage their privacy settings, which can have an impact on the performance of AI systems in programmatic advertising.

Programmatic advertising is not without its drawbacks. The general issue of control over the campaign is already known, and there are attempts, including successful ones, to tackle it.⁸⁴ The next box highlights some well-known examples of campaigns gone wrong due to the lack of control.⁸⁵ With programmatic advertising, the lack of control over the buying of a specific ad inventory may actually lead to buying unwanted ad inventory. An example is when advertisements

⁸⁰ Adform: <https://site.adform.com>.

⁸¹ MediaMath: <https://www.mediamath.com/>.

⁸² Microsoft Advertising: <https://about.ads.microsoft.com/en-us/solutions/xandr/xandr-premium-programmatic-advertising>.

⁸³ Ad Pepper Media: <https://adpepper.com/en/>.

⁸⁴ See for example Qian Sang, Niklas Karlsson, Jiaxing Guo, Feedback control of event rate in online advertising campaigns, *Control Engineering Practice*, Volume 75, 2018, pp. 126-136, <https://doi.org/10.1016/j.conengprac.2018.03.010>.

⁸⁵ Further examples with the study of the economic effects and the policies on how to attenuate these risks can be found in: Madio, L., & Quinn, M. (2023). Content moderation and advertising in social media platforms. *SSRN Working Paper No. 3551103*.

can appear against unsavoury, inappropriate or illegal content. In 2017 advertisers on YouTube were found displayed on terror group websites and fake news sites.⁸⁶ Due to the unwanted and brand-damaging displays, there were advertisers (for example Johnson and Johnson) that paused their online advertising until the adequate control measures were put in place.⁸⁷

9.2.4 Summary of the use of AI in programmatic advertising

Table 20: Summary of the use of AI in programmatic advertising

| B2B | | | | |
|--|--|------------------------------|---|---|
| Contracting stage | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
| Process automated with AI Automated process(es) | Automated decision on pricing of ad inventory (Publisher) Automated generation of ad impression offer (automated bidding) (Advertisers) | Data and offer analysis | Real Time Bidding on the advertisers' offers on ad impressions related to a specific ad inventory made available by a publisher. The automated decision on the winning offer is driven by real time user- and content-related data. | Automated execution of ad impression placement as seen by a unique user. |
| Type of AI systems used (deterministic /non-deterministic) | Non-deterministic | Non-deterministic | Non-deterministic | Non-deterministic. Performance determined by auction results; the outputs from audience targeting AI algorithms on DSP are disseminated across ad networks via SSD) |
| Type of output: prediction, recommendation, decision | Decision | No output on this stage. | Decision | Decision |

⁸⁶ New York Times: <https://www.thetimes.co.uk/article/big-brands-fund-terror-knnxfgb98>.

⁸⁷ The New York Times: "AT&T and Johnson & Johnson Pull Ads From YouTube", <https://www.nytimes.com/2017/03/22/business/atamt-and-johnson-amp-johnson-pull-ads-from-youtube-amid-hate-speech-concerns.html>.

| | | | | |
|--|---|--------------------------------|--|---|
| The automating tool(s) relevant for the use case | Pricing tools available at SSP and DSP RTB tools enabling decision-making in multi-level auctions on DSPs aimed at selecting an offer that will enter the main auction on ADx with the prospect of the contract conclusion between an Advertiser and Publisher | RTB and pricing tools | RTB tools on AEx platform (main auction) | Automated advertisement dissemination tools across ad networks |
| Delivery mode of the AI system | Provided by platforms or external developers | Intermediaries (SSP, DSP, AEX) | Usually provided by a AEx platform | Provided by a SSD platform |
| Provision modality | Usually AI service | Usually AI service | Usually AI service | Usually AI service |
| Types of providers | Usually provided by intermediaries (SSPs and DSPs), but also by external developers | - | Provided by AEx platforms | Usually provided by platforms but also by external developers in the form of further optimisation tools |
| Customisation capacity | Off the shelf and customised solutions from the contracting parties perspective | - | Off the shelf | Off the shelf and customised solutions |

Source: Own elaboration.

9.3 E-commerce: automated pricing

9.3.1 Nature of activity

Electronic commerce implies the extensive use of digital technologies, including AI in facilitating processes relating to the online sale.⁸⁸ E-commerce is more generally enabled through the automation of different transaction stages, such as offer generation, product discovery, checkout, invoicing, the delivery processes.⁸⁹ Algorithms and AI also enable automated pricing by sellers, in the form of both: dynamic pricing and price personalisation.

The automation of pricing strategies came as a response to the growing amount of data reflecting market complexity on one hand and digital transformation of the markets on the other hand.⁹⁰ The parallel developments in algorithmic analysis and decision-making facilitated more innovative

⁸⁸ OECD (2019), Unpacking E-Commerce: Business Models, Trends and Policies, OECD Publishing, Paris, <https://doi.org/10.1787/23561431-en>.

⁸⁹ The study does differentiate between an 'offer' and 'invitation to treat.'

⁹⁰ See for example: P. Verhoef, T. Broekhuizen, Y. Bart, A. Bhattacharya, J. Qi Dong, N. Fabian, M. Haenlein, Digital transformation: A multidisciplinary reflection and research agenda Journal of Business Research, 122 (2021), pp. 889-901, <https://www.scopus.com/record/display.uri?eid=2-s2.0-85070896886&origin=inward&txGid=278158d956ca083113687d69c620e7e7>.

forms of automated pricing strategies tailored for digital markets.⁹¹ The adoption of innovative and automated pricing strategies is becoming a fundamental tool for numerous rapidly expanding companies.⁹²

The main examples of such technology-enabled strategies are automated *dynamic pricing* and *personalised pricing*. Both strategies imply that the prices can potentially vary.⁹³ Dynamic pricing is a strategy that allows businesses to change the price of a product or service *through time* based on supply and demand considerations.⁹⁴ Personalised pricing is a strategy where price is custom-tailored for a user.⁹⁵

9.3.2 AI systems used

Machine learning techniques and high computational power made possible to use predictive sale forecasting models based on large amounts or heterogeneous data collected through the years of the functioning of platforms. The retrieval of business knowledge from big data was enabled by machine learning. The forecasting models, which were not based on machine learning, but were linear statistical models, could not capture features commonly occurring in many actual time-series data, such as nonlinear patterns, asymmetric cycles and occasional outlying.⁹⁶ Unlike classical linear statistical models, AI methods usually perform well in cases where data that have large fluctuations

⁹¹ D. Nunan, M.L. Di Domenico, Value creation in an algorithmic world: Towards an ethics of dynamic pricing, *Journal of Business Research*, Volume 150, 2022, Pages 451-460, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2022.06.032>.

⁹² D. Nunan, M.L. Di Domenico, Value creation in an algorithmic world: Towards an ethics of dynamic pricing, *Journal of Business Research*, Volume 150, 2022, Pages 451-460, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2022.06.032>; Abdelnour, A., Bages-Amat, A., Moss, S., & Prabhu, M. (2021). Defying cost volatility: A strategic pricing response. McKinsey & Company: <https://www.mckinsey.com/business-functions/growth-marketing-and-sales/our-insights/defying-cost-volatility-a-strategic-pricing-response>; Castillo, J.C., Knoepfle, D. and Weyl, G., 2017, June. Surge pricing solves the wild goose chase. In *Proceedings of the 2017 ACM Conference on Economics and Computation* (pp. 241-242); and Guda, H. and Subramanian, U., 2019. Your uber is arriving: Managing on-demand workers through surge pricing, forecast communication, and worker incentives. *Management Science*, 65(5), pp.1995-2014.

⁹³ Price differentiation is often used interchangeably with price discrimination, despite the two concepts not always corresponding. Indeed, differentiated prices may not necessarily be discriminatory: for example, if a pack of 6 cans of beers costs half of a pack of 12 cans, the prices are different but there is no price discrimination. If the price of the large pack is less than twice, then there are quantity discounts, a type of price discrimination.

⁹⁴ W. Elmaghraby, P. Keskinocak, Dynamic pricing in the presence of inventory considerations: Research overview, current practices, and future directions, *Management Science*, 49 (10) (2003), pp. 1287-1309, 10.1287/mnsc.49.10.1287.17315; J. Wamsler, M. Natter, R. Algesheimer, Transitioning to dynamic prices: Should pricing authority remain with the company or be delegated to the service employees instead?, *Journal of Business Research*, Volume 139, 2022, pp. 1476-1488, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2021.10.067>; and Alderighi, M., Gaggero, A.A. and Piga, C.A., 2017. The hidden side of dynamic pricing: Evidence from the airline market. MPRA Working Paper 76977.

⁹⁵ Personalised pricing can be described as price differentiation for identical products or services at the same time based on information a trader holds about a potential customer. See, e.g., Rott, P., Strycharz, J., and Alleweldt, F., 2022, *Personalised Pricing*, Publication for the Committee on Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg: [https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU\(2022\)734008_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf), and . Esteves, R.B. and Resende, J., 2019. Personalized pricing and advertising: Who are the winners?. *International Journal of Industrial Organization*, 63, pp.239-282.

⁹⁶ L. Dong, H. Zheng, L. Li, L. Hao, Human-machine hybrid prediction market: A promising sales forecasting solution for E-commerce enterprises, *Electronic Commerce Research and Applications*, Volume 56, 2022, 101216, <https://doi.org/10.1016/j.elerap.2022.101216>.

is influenced by many factors.⁹⁷ Applications of machine learning approaches are particularly suitable for dynamic pricing⁹⁸ and price personalisation.⁹⁹

The off-the-shelf availability of the AI solutions (repricers)¹⁰⁰ suggests that many companies populating the marketplace track and dynamically adjust prices almost in instant time on marketplace sites like Amazon or eBay or on the flight platforms. There is indeed evidence that in nowadays online markets where enterprises' interactions often happen within milliseconds, both large and small e-commerce players monitor each other's website and can adjust their prices almost instantly.¹⁰¹

9.3.3 Human oversight and issues

Despite many benefits associated with the use of AI in pricing, there may be negative consequences for businesses using it, and for market competition in general.

First, AI may lead to setting up prices on unreasonably low level. For example, the so-called mistake or error airfares are a common issue and may be caused by technical glitches that happen in the complex systems that determine flight prices.¹⁰² In most cases, Airlines tend to honour such tickets, but they may also choose to cancel them.¹⁰³

Price differentiation may also have a negative impact on the perception of a business by its customers. It is often considered unfair by consumers,¹⁰⁴ in particular, in case of frequent price changes that may lead to customer confusion or dissatisfaction. If customers perceive a price as

⁹⁷ L. Dong, H. Zheng, L. Li, L. Hao, Human-machine hybrid prediction market: A promising sales forecasting solution for E-commerce enterprises, *Electronic Commerce Research and Applications*, Volume 56, 2022, 101216, <https://doi.org/10.1016/j.elerap.2022.101216>; T. Van Calster, B. Baesens, W. Lemahieu, ProfARIMA: A profit-driven order identification algorithm for ARIMA models in sales forecasting, *Appl. Soft Comput.*, 60, 2017, pp. 775-785.

⁹⁸ See, e.g., Wieting, M. and Sapi, G., Algorithms in the Marketplace: An Empirical Analysis of Automated Pricing in E-Commerce. NET Institute Working Paper No. 21-06.

⁹⁹ Amit Sharma, How Predictive AI Will Change Shopping, *Harvard Business Review*, 2016, [How Predictive AI Will Change Shopping \(hbr.org\)](https://hbr.org/2016/06/how-predictive-ai-will-change-shopping/)

¹⁰⁰ Only in case of a third-party services and tools that can be integrated into Amazon, the search in Google for "Amazon repricer/repricing" returns very large amount of the results. There are developers that develop automated pricing tools without AI, with AI, tools ready to use and tools that can be customised according to the level of user's expertise. Tools can be developed specifically for Amazon or be compatible with multiple platform marketplaces. Also see one of the many rankings of the pricing tools: <https://ecombalance.com/amazon-repricer-2/>.

¹⁰¹ Autoridade da Concorrência (2019). Digital ecosystems, Big Data and Algorithms; and Dastin J., 2017. Amazon trounces rivals in battle of the shopping `bots' www.reuters.com/article/us-amazon-com-bots-insight/amazon-trounces-rivals-in-battle-of-the-shopping-bots-idUSKBN1860FK

¹⁰² See for example: Forbes: <https://www.forbes.com/advisor/credit-cards/travel-rewards/how-to-find-mistake-airfares-and-save-hundreds/>.

¹⁰³ Euronews: [What are error fares? This airline was forced to sell flight tickets for less than €4 | Euronews](https://www.euronews.com/pt/2022/06/16/what-are-error-fares-what-airline-was-forced-to-sell-flight-tickets-for-less-than-4-euro).

¹⁰⁴ See for example: Priester, A.; Robbert, T.; Roth, S., "A special price just for you: effects of personalized dynamic pricing on consumer fairness perceptions", *Journal of Revenue and Pricing Management*. 19 (2): 99–112, 2020, doi:10.1057/s41272-019-00224-3. ISSN 1476-6930. S2CID 256510198; Alderighi, M., Nava, C.R., Calabrese, M., Christille, J.M. and Salvemini, C.B., 2022. Consumer perception of price fairness and dynamic pricing: Evidence from Booking. com. *Journal of Business Research*, 145, pp.769-783; and Vulkan, N. and Shem-Tov, Y., 2015. A note on fairness and personalised pricing. *Economics Letters*, 136, pp.179-183.

unfair or inconsistent, it may have reputational consequences for a business and decrease customer loyalty.¹⁰⁵

Price personalisation based on automated decision-making can be practiced under transparency conditions, in particular set out by the data protection laws¹⁰⁶ and the Consumer Rights Directive (CRD).¹⁰⁷ In general, the fairness of price personalisation has become associated with transparency: namely, the consumers' awareness of the way they are profiled, and how this information is used to adjust the price offers they receive.¹⁰⁸ Moreover, platforms must clearly indicate the use of such practices prior to the purchase, and consumers must also be informed about the ways their personal information affects prices. The use of AI may complicate the transparency requirements due to the opacity of AI systems. In 2022, after the Netherlands Authority for Consumers and Markets (ACM) had presented the transparency conditions to online platform Wish, it decided to stop using personalised pricing.¹⁰⁹

Another issue associated with automated pricing is algorithmic collusion.¹¹⁰ AI algorithms can enable price collusion. They can independently learn to set prices in a coordinated manner. Collusive behaviour facilitated by AI algorithms may be more difficult to detect and prove compared to traditional forms of collusion. AI algorithms capable of operating with low levels of human supervision may make it challenging for regulators to identify collusion. Algorithmic collusion may take a form of a tacit collusion but may also be unintentional.¹¹¹

¹⁰⁵ For example, Amazon experimented with price discrimination and experienced a public backlash that led its CEO to declare the experiment was a "mistake". CEO Jeff Bezos said "We've never tested and we never will test prices based on customer demographics." The prices in the experiment were allegedly varied randomly between customers. See Ennis, S. and Lam, W., 2021. Personalised Pricing and Disclosure. BEIS Research Paper Number 2021/008.

¹⁰⁶ R. Steppe, Online price discrimination and personal data: A General Data Protection Regulation perspective, *Computer Law & Security Review*, Volume 33, Issue 6, 2017, Pages 768-785, ISSN 0267-3649, <https://doi.org/10.1016/j.clsr.2017.05.008>.

¹⁰⁷ For the current legal framework applicable to personalised pricing see for example: Rott, P., Strycharz, J., and Alleweldt, F., 2022, Personalised Pricing, Publication for the Committee on Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, [https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU\(2022\)734008_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf).

¹⁰⁸ See for example: M. Hildebrandt, Profiling and the rule of law, *IDIS*, 2008, 1:55-70, doi: 10.1007/s12394-008-0003-1, <https://link.springer.com/article/10.1007/s12394-008-0003-1>.

¹⁰⁹ ACM, 2022, Following ACM actions, Wish bans fake discounts and blocks personalised pricing: <https://www.acm.nl/en/publications/following-acm-actions-wish-bans-fake-discounts-and-blocks-personalized-pricing>. Wish, a major American platform that sells items online to consumers in several European countries, and other regions, was applying price personalisation based on consumers purchasing behaviour and location, among other factors. The platform informed the public in an investor brochure that they use price personalisation in the US, but this practice was not clearly disclosed on the website to consumers.

¹¹⁰ OECD (2017), Algorithms and Collusion: Competition Policy in the Digital Age www.oecd.org/competition/algorithms-collusion-competition-policy-in-the-digital-age.htm.

¹¹¹ OECD (2017), Algorithms and Collusion: Competition Policy in the Digital Age www.oecd.org/competition/algorithms-collusion-competition-policy-in-the-digital-age.htm.

9.3.4 Summary of the use of AI in automated pricing

Table 21: Summary of the use of AI in automated pricing

| B2C, B2B | | | | |
|--|--|------------------------------|----------------------------|---|
| Contracting stage | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
| Process automated with AI Automated process(es) | Automated price generation, including personalised pricing and dynamic pricing | - | - | - |
| Type of AI systems used (deterministic /non-deterministic) | Non-deterministic | - | - | - |
| Type of output: prediction, recommendation, decision | Decision | - | - | - |
| The automating tool(s) relevant for the use case | Repricers | - | - | - |
| Provision modality | AI product and AI service | - | - | - |
| Types of providers | Provided by platforms or external developers | - | - | - |
| Customisation capacity | Mostly off the shelf solutions but also customised solutions | - | - | - |

Source: Own elaboration.

9.4 E-commerce: virtual assistants

9.4.1 Nature of activity

Virtual assistant is an umbrella term to describe technology that helps to process various tasks and can be used across different sectors. Within the EU acquis, the Digital Markets Act (DMA)¹¹² and the

¹¹² REGULATION (EU) 2022/1925 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2022 on contestable and fair markets in the digital sector and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Act).

Data Act¹¹³ define ‘virtual assistant’ as a software that can process demands, tasks or questions, including those based on audio, visual, written input, gestures or motions, and that, based on those demands, tasks or questions, provides access to other services or controls of connected products”¹¹⁴ In such understanding the virtual assistant’ is also used interchangeably with ‘digital assistant’.¹¹⁵ As such, VA can be embedded in a physical product that is not native for the digital ecosystem (for example a smart fridge, a watch, a speaker) or run on a computer or mobile in the form of application or be integral to the operating system.

AI in VA is used in two distinctive ways: first to enable natural language interaction, second to analyse vast amounts of fluctuating and heterogeneous data before making a shopping recommendation or perform a task relating to purchases and post-purchase services, such as item tracking and delivery. An automation of decision-making relevant for pre-contractual stage is making recommendations. The effective retrieval of knowledge from the data is made possible with the adoption of AI techniques that can predict, learn and adapt to the changing conditions. Making user-tailored recommendations is in particular enabled by AI systems. Recommendations require analysis of data relating to user preferences, purchase history, browsing behaviour, and demographic information. Based on the analysis of such data, AI algorithms can generate insights about individual shoppers and adapt to the changing user behaviour and market conditions. This allows shopping assistants to offer tailored product recommendations and suggestions that align with the user’s interests and needs.

9.4.2 AI systems used

There are VAs based on written input, audio and visual, as well as VAs that can process input from the sensors. Out of the all the VAs, chatbots are most broadly adopted in e-commerce.¹¹⁶

First shopping assistants in e-commerce used to come in the form of a simple rule-based text chatbots, which consumers found awkward. With the development of machine learning techniques, the conversation between a potential buyer and a VA started resembling a human-to-human conversation. Chatbots use Natural Language Processing (NLP) and sentiment analysis to communicate in human language by text or oral speech with humans or other chatbots.¹¹⁷ The possibility to have a human-like conversation increases trust in chatbots.¹¹⁸ Higher trust in chatbots

¹¹³ COM(2022) 68 final, Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on harmonised rules on fair access to and use of data (Data Act).

¹¹⁴ Article 2(12) DMA. ‘Virtual assistant’ has also a different meaning in the context of job market, where it refers to a person who works as an assistant *online* (see for example: <https://sg.indeed.com/career-advice/finding-a-job/personal-assistant-vs-virtual-assistant/>).

¹¹⁵ See for example: <https://whatfix.com/blog/digital-assistant/>.

¹¹⁶ R.M. Schuetzler, G.M. Grimes, J. Scott Giboney, The impact of chatbot conversational skill on engagement and perceived humanness J. Manag. Inf. Syst., 37 (2020), pp. 875-900; M. Adam, M. Wessel, A. Benlian, AI-based chatbots in customer service and their effects on user compliance Electron. Mark., 31 (2021), pp. 427-445, 10.1007/s12525-020-00414-7.

¹¹⁷ Khanna A., Pandey B., Vashishta K., Kalia K., Bhale P., Das T., A study of today’s A.I. through chatbots and rediscovery of machine intelligence International Journal of U- and e-Service, Science and Technology, 8 (2015), pp. 277-284.

¹¹⁸ Go E., Sundar S.S., Humanizing chatbots: The effects of visual, identity and conversational cues on humanness perceptions, Computers in Human Behavior, 97 (2019), pp. 304-316 (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85064447508&origin=inward&txGid=d2780cfdc2fba4ef576938988867c3c>) ; Wallace R.S., The anatomy of A.L.C.E., in Epstein R., Roberts G., Beber G. (Eds.), Parsing the turing test: philosophical and methodological issues in the quest

drives wider adoption of chatbots by sellers and their subsequent use by buyers.¹¹⁹ We see that the use of AI in chatbots has become so prevalent that sometimes it is even reflected on the level of definition. For example, Bansal & Khan (2018) define a chatbot as “an artificial intelligence program and a Human–computer Interaction (HCI) model.”¹²⁰

The development of AI in chatbots went another step further with the creation of voice assistants. Voice shopping assistants are gaining in popularity due to the convenience of hands-free commanding with voice. The most popular voice shopping assistants are Amazon Alexa and Google Assistant, on which we have a closer look.

Alexa

Alexa is an AI-powered virtual assistant developed by Amazon. It can assist users not only in pre-purchase phase but also add items to the shopping cart, place orders, and execute them via voice command. It provides order tracking information, facilitates communication between the buyer and the seller, and ensures delivery processes. It can also notify users about the status of their orders, estimated delivery times, and handle any necessary follow-up interactions. The tasks Alexa can perform are called skills.¹²¹ Alexa Skills are voice-activated apps or extensions that enhance the capabilities of Alexa. Amazon also allows third-party retailers and businesses to develop Alexa Skills that integrate with their websites or services to facilitate shopping on their websites. For example, Domino's Pizza allowed users to place pizza orders and track their deliveries via Alexa.¹²² Starbucks has integrated Alexa, enabling users to buy and check their Starbucks Card balance.¹²³ Ticketmaster developed an Alexa Skill that allows users to discover and purchase event tickets.¹²⁴

Alexa can also be integrated into various physical products.¹²⁵ Alexa-enabled devices include speakers, displays, smartphones, tablets, headphones, earbuds, smart home devices, kitchen appliances, car systems, smart watches, smart plugs, etc. Alexa-enabled devices include Amazon products (for example Amazon Echo Devices) or can be developed by third parties.

Google Assistant (GA) is another AI-powered virtual assistant available on various devices. Like Alexa, it can provide product recommendations, search for specific items, and help users complete purchases using natural language interactions.¹²⁶ GA is available on a wide range of devices,

for the thinking computer, Springer Netherlands, Dordrecht (2009), pp. 181-210; Go E., Sundar S.S., Humanizing chatbots: The effects of visual, identity and conversational cues on humanness perceptions, *Computers in Human Behavior*, 97 (2019), pp. 304-316 (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85064447508&origin=inward&txGid=d2780cfdc2fbae4ef576938988867c3c>); Wallace R.S., The anatomy of A.L.C.E., in Epstein R., Roberts G., Beber G. (Eds.), *Parsing the turing test: philosophical and methodological issues in the quest for the thinking computer*, Springer Netherlands, Dordrecht (2009), pp. 181-210.

¹¹⁹ T.M. Brill, L. Munoz, R.J. Miller, Siri, Alexa, and other digital assistants: a study of customer satisfaction with artificial intelligence applications, *J. Market. Manag.*, 35 (15–16) (2019), pp. 1401-1436.

¹²⁰ Bansal H., Khan R., A review paper on human computer interaction, *International Journal of Advanced Research in Computer Science and Software Engineering*, 8 (53) (2018).

¹²¹ Amazon: [Amazon.es: Alexa Skills](https://www.amazon.com/Alexa-Skills).

¹²² Amazon: <https://www.amazon.com/Dominos-Pizza-LLC/dp/B01B5G99CC>.

¹²³ Starbucks: <https://stories.starbucks.com/press/2017/starbucks-debuts-voice-ordering/>.

¹²⁴ Amazon: <https://www.amazon.com/Ticketmaster-L-L-C/dp/B07BFHJC6W>.

¹²⁵ See for example: <https://www.tomsguide.com/best-picks/best-alexa-compatible-devices>.

¹²⁶ Google: <https://support.google.com/assistant/answer/7540988?hl=en>.

including smartphones, smart speakers (such as Google Home), smart displays, and wearables. It is integrated into the Android operating system and is accessible through the Apple App Store as an application to download on iOS devices.¹²⁷ Google provides developer tools and APIs for creating Actions on Google, which are voice-powered applications and services that extend Google Assistant's capabilities.¹²⁸

9.4.3 Human oversight and issues

Virtual assistants are also used to automate buying processes by consumers. If granted permission and prompted, VAs can look for an item or offer and can execute transactions, including making payments, tracking and supervising delivery. The fully automated conclusion of transactions is not really embraced by the marketplaces and usually some form of buyer's intervention is requested before the transaction is concluded. Purchase confirmation remains the most practiced way to ensure human oversight. Having said that, we observe the development of technologies towards full automation. Amazon's Alexa can automatically conclude transactions (without user's confirmation) in case when the user activated a specific Alexa's features and entered required transaction specifications.¹²⁹

While VA are tools used by consumers, the actual recommendations made by them often automate the processes from the seller side and resemble marketing channel to reach users and persuade them to buy. VA can also automate offer discovery across various retailers online, which is a user-driven task. After providing results, the actual decision-making on whether to buy or not is still down to a user, and a VA by default will not proceed to buy.

Another issue is the possibility for a consumer to decide which virtual shopping assistant to use on a specific retail platform. In theory, some platforms may provide an open environment where third-party virtual shopping assistants can integrate with the platform or offer a selection of VA for a consumer to use. In practice, however we observe that while users can choose their preferred VA for general tasks on their devices, the shopping experience within a specific retailer's platform is usually determined by the retailer's chosen assistant or integration. The choice of VA and its performance is therefore controlled by a retailer or a platform. User oversight consist of possibility to enable or disable features, enter input, and intervene before the transaction is made.

VAs are still vulnerable to accidental or unauthorised purchases, in particular with voice commands because of issues relating to the AI voice recognition capabilities that, even if being much better than few years ago, are prone to mistakes. In such a case, disabling confirmation may result in purchases that are not intended.

¹²⁷ Google: <https://support.google.com/assistant/answer/7172657?hl=en&co=GENIE.Platform%3DiOS>; Apple: <https://apps.apple.com/us/app/google-assistant/id1220976145?ls=1>.

¹²⁸ Google: <https://developers.google.com/assistant>.

¹²⁹ Amazon: <https://www.aboutamazon.com/news/devices/try-these-new-convenient-ways-to-shop-with-alexa#:~:text=Just%20say%2C%20%E2%80%9CAlexa%2C%20buy,are%20the%20newest%20Alexa%20features%3F>.

9.4.4 Summary of the use of AI in Virtual Assistants

Table 22: Summary of the use of AI in Virtual Assistants

| B2C, B2B | | | | |
|--|-------------------------|---|--|---|
| Contracting stage | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
| Process automated with AI Automated process(es) | - | Automated interaction between VA and a user Automated information and knowledge retrieval on products and services Adding to the basket | Possibility of the automated conclusion of a contract under specific conditions and instructions as well as upon a user's permission | Automated checkout, tracking and delivery |
| Type of AI systems used (deterministic /non-deterministic) | - | Non-deterministic systems are used to enable natural language interaction between VA and a user | Deterministic and non-deterministic | Deterministic |
| Type of output: predictions, recommendations, decisions | - | Predictions and recommendations | Recommendations, Decisions Analysis results not conclusive if automated decisions are possible | Decision |
| The automating tool(s) relevant for the use case | - | VA | VA | VA |
| Provision modality | - | AI product and AI service | AI product and AI service | AI product and AI service |
| Types of providers | - | Provided by platforms or external developers (subject to compliance with platform's requirements) | Provided by platforms or external developers (subject to compliance with platform's requirements) | Provided by platforms or external developers (subject to compliance with platform's requirements) |
| Customisation capacity | - | Off the shelf and customised solutions | Off the shelf and customised solutions | Off the shelf and customised solutions |

Source: Own elaboration.

9.5 Supply chain management

9.5.1 Nature of activity

Supply chain management (SCM) is “the handling of the entire production flow of a good or service - starting from the raw components all the way to delivering the final product to the consumer.”¹³⁰ Different technologies are used and relied upon for enabling the integration of physical and digital dimensions in supply chains. These technologies include cloud, big data, the Industrial Internet of Services, IoT, 3D printing, augmented and virtual reality, blockchain as well as artificial intelligence and machine learning approaches.¹³¹

AI allows for the automation of many processes that take place across all parts of a supply chain.¹³² There are developed methodologies for the implementations of AI-based systems in supply chain management¹³³ and ready to use AI-powered tools for supply chain management in the framework of integrated software systems.¹³⁴ AI can be used to predict and anticipate future needs, hence to automatically place a purchase order with a supplier. Use of robots and sensors can also lead to the automatic order placements by a buyer. On the supplier side, AI may be used to automatically fulfil those orders.

A distinctive way of using AI for automation of processes in supply chain management is the negotiation of specific framework contract conditions between a supplier and buyer. When considering the stages of contracting relevant to smart warehouses, the most advanced stages in the context of the use of AI are contract negotiations, contract execution and management.

9.5.2 AI systems used

AI is particularly promising in predictive demand forecasting. Predictive analytics allows for precise forecast of future demand, enabling companies to fine-tune inventory levels, streamline supply

¹³⁰ IBM: <https://www.ibm.com/topics/supply-chain-management>; Rubio, S., Chamorro, A., & Miranda, F. (2008). Characteristics of the research on reverse logistics (1995–2005). *International Journal of Production Research*, 46(4), 1099–1120.

¹³¹ Michela Pellicelli, *The Digital Transformation of Supply Chain Management*, Elsevier, November 17, 2022; Baha M. Mohsen, *Developments of Digital Technologies Related to Supply Chain Management*, *Procedia Computer Science*, Volume 220, 2023, Pages 788–795, ISSN 1877-0509, <https://doi.org/10.1016/j.procs.2023.03.105>; (<https://www.sciencedirect.com/science/article/pii/S1877050923006403>).

¹³² Raphaël Oger, Frédéric Bénaben, Matthieu Lauras, Benoit Montreuil, *Towards Decision Support Automation for Supply Chain Risk Management among Logistics Network Stakeholders*, *IFAC-PapersOnLine*, Volume 51, Issue 11, 2018, Pages 1505–1510, ISSN 2405-8963, <https://doi.org/10.1016/j.ifacol.2018.08.287>, (<https://www.sciencedirect.com/science/article/pii/S2405896318314113>); Hisham O. Khogali, Samir Mekid, *The blended future of automation and AI: Examining some long-term societal and ethical impact features*, *Technology in Society*, Volume 73, 2023, 102232, ISSN 0160-791X, <https://doi.org/10.1016/j.techsoc.2023.102232>. (<https://www.sciencedirect.com/science/article/pii/S0160791X23000374>).

¹³³ George Kousiouris, Stylianos Tsarsitalidis, Evangelos Psomakelis, Stavros Koloniaris, Cleopatra Bardaki, Konstantinos Tserpes, Mara Nikolaidou, Dimosthenis Anagnostopoulos, *A microservice-based framework for integrating IoT management platforms, semantic and AI services for supply chain management*, *ICT Express*, Volume 5, Issue 2, 2019, pp. 141–145, <https://doi.org/10.1016/j.ict.2019.04.002>; Umamaheswaran Praveen, Ganjeizadeh Farnaz, Ghasib Hatim, *Inventory management and cost reduction of supply chain processes using AI based time-series forecasting and ANN modeling*, *Procedia Manufacturing*, Volume 38, 2019, Pages 256–263, <https://doi.org/10.1016/j.promfg.2020.01.034>.

¹³⁴ See for example: <https://www.supplychaindive.com/>.

chain processes, and mitigate the potential for stockout or overstocking. This level of automation in supply chain management is achievable solely through the integration of AI systems.¹³⁵ The results of the predictive demand forecasting can then be integrated into the decision making on placing purchase orders and orders fulfilment. In the case of contract negotiation, AI based on LLM was used to facilitate human-machine interaction.

Amazon fulfilment centres

Successful instances of the use of AI in supply chain can be observed in various industries. For example, Amazon has implemented AI-driven systems in its warehouses called “fulfilment centres.” These systems use machine learning algorithms to optimise inventory placement, automate picking and packing processes, and improve overall operational efficiency. This has enabled Amazon to handle a vast volume of orders. Amazon has been using AI to power its fulfilment centres for years now. The company’s robotics division, Amazon Robotics, has deployed more than 520,000 robotic drive units across its fulfilment and sort centres.¹³⁶ These robots help with stocking inventory, filling orders, and sorting packages for delivery. They follow directions provided by cloud-based algorithms and navigate along a grid of encoded markers.¹³⁷

Walmart case

Walmart introduced an AI system, namely a text-based chatbot, to negotiate specific contract terms with human suppliers on behalf of the company.¹³⁸ Like most organisations with large procurement operations, Walmart could not negotiate contracts with all of its 100,000-plus suppliers. It therefore deployed a chatbot that negotiated contracts on its behalf. The company that created the AI technology for this software was Pactum.¹³⁹ During the pilot project run in 2021 in Walmart Canada, the company tested the solution and refined it based on feedback from suppliers. Subsequently, the company implemented the solution in three additional countries, with plans to soon introduce the technology in more countries where Walmart operates. The pilot project lasted 3 months, for which Walmart International estimated a positive return on investment if 20% of the suppliers would close deals with the chatbot. The strategy was based on negotiating early payment discounts or extended payment without discounts, and in exchange Walmart would replace its right to terminate contracts immediately and without cause by a 30, 60, or 90 day written termination notice. Internal buyers created training scenarios for the machine-learning algorithm, which were used to create structured scripts for the negotiations. The chatbot managed to reach an agreement

¹³⁵ IEEE Computer Society: <https://www.computer.org/publications/tech-news/trends/ai-revolutionizing-supply-chain>.

¹³⁶ Amazon: [AI-Powered Inventory Management \(amazon.com\)](https://www.amazon.com), <https://www.amazon.science/latest-news/the-quest-to-deploy-autonomous-robots-within-amazon-fulfillment-centers>.

¹³⁷ [Amazon Inventory Management - 2023 Strategy & Automation - Jungle Scout](#).

¹³⁸ Van Hoek, R., DeWitt, M., Lacity, M., Johnson, T. (2022), ‘How Walmart automated supplier negotiations,’ Harvard Business Review. Available at: <https://hbr.org/2022/11/how-walmart-automated-supplier-negotiations>.

¹³⁹ Pactum: <https://pactum.com/>.

with 64% of the suppliers.¹⁴⁰ In the post-pilot feedback, 83% of suppliers liked the experience (easy to use, possibility for counteroffer, negotiations at their own pace - not in real time). Several suppliers would have still liked a face-to-face negotiations.¹⁴¹

9.5.3 Human oversight and issues

In most of the cases, the AI-based automation of placing purchase orders seems to be still performed with a human in the loop. Nevertheless, there are instances where physical infrastructures integrated within the IoT framework allow for almost full automation. In such cases, AI can 'sense' the stock and then this information is fed into AI system that further combine and analyse all different types of data, including demand forecasts, and takes a decision on placing an order. The supplier, on the other hand, can use automated fulfilment systems that effectively allow for fully automated execution of the transaction (Amazon). While we observe a technical readiness to fully automate the process of placing purchase orders and order fulfilment, the organisational reality of many companies does not allow for full M2M automation between the buyer and supplier.

A distinctive way of using AI for automation of processes in supply chain management is the negotiation of specific framework contract conditions between a supplier and buyer (Walmart case). The use case presents a step up in the use of AI in offer generation through negotiations as well as contract conclusion if a consensus is achieved. The case is a clear use of ML for enabling the machine-human interaction. What is not clear is if the AI system underpinning the decision-making on the conclusion of the contract was non-deterministic. The decision-making by AI seemed to be controlled by Walmart. While Walmart could not know what would be the result of negotiations with a specific supplier, the limited range of results were all in range acceptable and controlled by Walmart.

Most of issues linked to contracting in supply chain management is linked to errors in stock replenishments in cases when human oversight is not executed properly. While AI systems used in supply chain management are usually used to support human decisions, some companies like Amazon to some extent rely on full automation of placing orders with suppliers.

¹⁴⁰ Van Hoek, R., DeWitt, M., Lacity, M., Johnson, T. (2022), 'How Walmart automated supplier negotiations,' Harvard Business Review. Available at: <https://hbr.org/2022/11/how-walmart-automated-supplier-negotiations>.

¹⁴¹ Van Hoek, R., DeWitt, M., Lacity, M., Johnson, T. (2022), 'How Walmart automated supplier negotiations,' Harvard Business Review. Available at: <https://hbr.org/2022/11/how-walmart-automated-supplier-negotiations>.

9.5.4 Summary of the use of AI in supply chain management

Table 23: Summary of the use of AI in supply chain management

| B2B | | | | |
|--|--|---|--|--|
| Contracting stage | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
| Process automated with AI Automated process(es) | Chatbots for automated negotiations between a buyer and a supplier | Automated stocking inventory: filling of purchase orders Demand prediction to determine inventory levels | Automated conclusion of a contract in case of a negotiating chatbot. Automated fulfilment of orders | Automated release of products and services sorting packages, tracking and delivery |
| Type of AI systems used (deterministic /non-deterministic) | Non-deterministic systems are used to enable natural language interaction between VA and a user Deterministic systems, based on the instructions from a user is used to generate an offer | Deterministic and non-deterministic | Deterministic | Deterministic for the execution of orders, smart contracts are pushed to the market. Non-deterministic for tracking |
| Type of output: predictions/recommendations/decisions | Decision | Predictions and recommendations | Decision | Decision |
| The automating tool(s) relevant for the use case | Chatbots | Integrated supply chain management solutions | Integrated supply chain management solutions | Integrated supply chain management solutions |
| Provision modality | AI service | AI product and AI service | AI product and AI service | AI product and AI service |
| Types of providers | Contractual party | Contractual party | Contractual party | Contractual party |
| Customisation capacity | Off the shelf | Off the shelf and customised solutions | Off the shelf and customised solutions | Off the shelf and customised solutions |

Source: Own elaboration.

9.6 Renewable energy trading

9.6.1 Nature of activity

Renewable energy use is growing across Europe and worldwide.¹⁴² Over the past few decades, distributed energy resources (DERs) powered by renewable energy have been integrated into electrical grids. By the conclusion of 2016, approximately 25% of the world's electricity production was sourced from renewable energy.¹⁴³ In order to leverage all the benefits of growing number of DERs to meet policy targets towards decarbonisation a new kind of paradigm in energy trading has been emerging. One of the main propositions of the paradigm is decentralised peer-to-peer (P2P) energy trading and empowerment of prosumers.¹⁴⁴ Prosumers are individuals who consume and produce energy.¹⁴⁵

AI is a promising proposition to tackle the challenges linked to the management of more decentralised energy systems and infrastructures. The International Renewable Energy Agency (IRENA) highlights that AI helps optimising energy trading decisions, improving market efficiency, and facilitating the integration of renewable energy sources.¹⁴⁶ The combination of smart contracts with AI technology enables not only automated execution of transactions, but also automated decision-making on whether and when to buy or sell energy. AI allows for knowledge integration into the automated buying or selling decision.

9.6.2 AI systems used

The Port of Rotterdam, Netherlands

The Port of Rotterdam is an example of the implementation of microgrid combining smart contracts with AI.¹⁴⁷ In August 2020, the port launched a pilot program in microgrid trading. The project aimed

¹⁴² European Environment Agency, Energy prosumers in Europe Citizen participation in the energy transition, Luxembourg: Publications Office of the European Union, 2022, <https://www.eea.europa.eu/publications/the-role-of-prosumers-of>; Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, 2019, doi: 10.1109/JSYST.2019.2903172.

¹⁴³ P. Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, Sept. 2019, doi: 10.1109/JSYST.2019.2903172.

¹⁴⁴ P. Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, 2019, doi: 10.1109/JSYST.2019.2903172; IRENA (2020), Innovation landscape brief: Peer-to-peer electricity trading, International Renewable Energy Agency, Abu Dhabi.

¹⁴⁵ On energy prosumers in Europe see: European Environment Agency, Energy prosumers in Europe: Citizen participation in the energy transition, Luxembourg: Publications Office of the European Union, 2022.

¹⁴⁶ IRENA (2020), Innovation landscape brief: Peer-to-peer electricity trading, International Renewable Energy Agency, Abu Dhabi; See also: Pe Mahmoud M, Slama SB. Peer-to-Peer Energy Trading Case Study Using an AI-Powered Community Energy Management System. *Applied Sciences*. 2023; 13(13):7838. <https://doi.org/10.3390/app13137838>

¹⁴⁷ IEEE: <https://blockchain.ieee.org/verticals/transactive-energy/topics/blockchain-use-in-microgrids-applications-benefits-and-challenges>.

at reducing energy consumption and promoting the use of renewable energy.¹⁴⁸ The Port of Rotterdam microgrid seems to be one of the world's first high frequency decentralised energy markets.¹⁴⁹ The trade in microgrid was facilitated by platform called Distro,¹⁵⁰ jointly developed by S&P Global Platts (provider of energy and commodity information) and BlockLab (the Port of Rotterdam's blockchain innovation hub).¹⁵¹ The platform is a fully developed solution offered on the market, and leverages the capabilities of both artificial intelligence and blockchain. The platform furnishes each market participant with an AI-powered 'energy trading agent' tool, which learns and adapts to the user's energy requirements, preferences, and behaviours. This tool analyses billions of real-time data points, autonomously and makes decisions on energy transactions at the optimal prices for the user.¹⁵² Blockchain smart contracts are a carrier of market rules. They validate transactions and manage identities to ensure reliability and anonymity in the dynamic trading environment.¹⁵³ This integration of AI and blockchain allowed commercial energy consumers in the port to engage in active trading of renewable energy sourced from solar and battery storage, empowering them to effectively control and manage their power consumption.

9.6.3 Human oversight and issues

Users can access specialised trading platforms designed for energy trading. These platforms provide real-time data, analytics, and trading tools to help users monitor market trends, execute trades, and manage their energy portfolios efficiently. In principle, users can monitor real-time energy prices, available supply and demand, and historical trading data to make informed trading decisions. In case of AI-driven fully automated renewable energy trading, AI system learns and adapts to the user's energy requirements, preferences, and behaviours. The overarching goal is to optimise the use of renewable energy on the more aggregated scale. In the example of full automation of conclusion and execution of contracts in the case of the Rotterdam microgrid, the human influence over AI was primarily exercised on the level of a system design and deployment. During the use of the system, although the supervision was enabled on the platform, the decisions on energy purchases and execution of transactions seemed to be fully relied on AI and smart contracts.

Overall, while AI can optimise energy management in renewable energy microgrids to meet the diverse needs of individual users, there may be situations where users need to compromise for the

¹⁴⁸ See for example: <https://www.ledgerinsights.com/port-of-rotterdam-renewable-energy-blockchain-pilot-is-a-money-saver/>; <https://apnews.com/article/business-technology-alternative-and-sustainable-energy-renewable-power-generation-electric-power-transmission-and-distribution-65439f92792c49b491bf314de2924db2>.

¹⁴⁹ See for example: <https://www.smart-energy.com/industry-sectors/new-technology/ai-blockchain-microgrid-pilots-renewables-trading-in-port-of-rotterdam/>; <https://apnews.com/article/business-technology-alternative-and-sustainable-energy-renewable-power-generation-electric-power-transmission-and-distribution-65439f92792c49b491bf314de2924db2>; <https://www.bloomberg.com/news/articles/2020-10-05/port-of-rotterdam-pilot-uses-ai-microgrid-to-trade-renewables>; <https://www.spglobal.com/commodityinsights/en/about-commodityinsights/media-center/press-releases/2020/051020-world-s-first-high-frequency-decentralized-energy-market-drive-port-of-rotterdam-energy-transition>.

¹⁵⁰ Distro: <https://www.distroenergy.com/#case-study>.

¹⁵¹ S&P Global: <https://www.spglobal.com/commodityinsights/en>.

¹⁵² S&P Global: <https://www.spglobal.com/commodityinsights/en>; <https://apnews.com/article/business-technology-alternative-and-sustainable-energy-renewable-power-generation-electric-power-transmission-and-distribution-65439f92792c49b491bf314de2924db2>.

¹⁵³ <https://www.spglobal.com/commodityinsights/en/about-commodityinsights/media-center/press-releases/2020/051020-world-s-first-high-frequency-decentralized-energy-market-drive-port-of-rotterdam-energy-transition>.

greater good of the microgrid or broader energy system. Balancing individual interests with collective goals may require careful consideration of fairness, equity, transparency on the design and implementation stage of AI-driven energy management systems.

9.6.4 Summary of the use of AI in renewable energy trading

Table 24: Summary of the use of AI in renewable energy trading

| P2P | | | | |
|--|-------------------------|------------------------------|---|---|
| Contracting stage | Offer generation | Pre-contractual stage | Contract conclusion | Contract performance and termination |
| Process automated with AI Automated process(es) | - | - | Automated conclusion of a contract based on the real-time data on energy availability and market conditions | Automated execution and money transfer |
| Type of AI systems used (deterministic /non-deterministic) | - | - | Mostly non-deterministic | Deterministic, also with use of smart contracts |
| Type of output: predictions/recommendations/decisions | - | - | Decision | Decision |
| The automating tool(s) relevant for the use case | - | - | Solution integrated into a trading platform | Solution integrated into a trading platform |
| Provision modality | - | - | AI service, integrated platform | AI service, integrated platform |
| Types of providers | - | - | Intermediary | Intermediary |
| Customisation capacity | - | - | Off the shelf | Off the shelf |

Source: Own elaboration.

10. Conclusions

AI systems are increasingly used as solutions to automate contracting. Decisions taken by autonomous AI systems used for automating contracting steps, and particularly, contract conclusion, raise most complex issues, notably the issue of human oversight over the chosen solution or unintended outcomes in the performance of the contract.

The adoption of AI in contracting is not widespread yet among enterprises but it is advancing. Currently, there is a lack of appropriate data to identify precisely enterprises adopting these new technologies in contracting. Therefore, this report developed a methodology to provide a proxy for identifying assumed adopters of AI in contracting (*i.e.*, enterprises already using AI in contracting). Two different approaches were considered: a conservative and a flexible approach. These steps allowed to take a rigorous approach to identify assumed adopters of AI in contracting.

Similarly to other cases of AI adoption, the likelihood of adopting AI in contracting is higher for larger enterprises. Nevertheless, differences in the percentage of adopters of AI in contracting by enterprise size are small. This seems to point to the fact that adopters of AI in contracting might be different than other AI adopters.

Enterprises face barriers to the adoption of new technologies, which can be categorised as revealed barriers (which companies experienced in practice) and perceived barriers (which companies are concerned about for the future). Lack of skills is the most common revealed and deterring barrier identified by enterprises independently of their size, but it is followed closely by several other barriers, notably adoption/adaptation costs and liability/reputation risks.

The study analysed a set of different use cases to understand how AI solutions are currently used by businesses and individuals to automate various stages of contracting: offer generation, contract conclusion, as well as contract performance and termination. The analysis of the use cases revealed that AI solutions for automating the various contracting stages are already available on the market, including AI systems that can take decisions on contract conclusion. The study looks at different cases where the use of AI for making transactions has been reported by users. The following cases have been scrutinised: Forex, programmatic advertising, automated pricing in e-commerce, virtual assistants in e-commerce, supply chain management and renewable energy trading.

AI solutions are delivered to the user as AI services and products, by one of the contracting parties, or by a third-party (e.g. intermediaries). The solutions can also vary on their customisation capacity. All these aspects determine the level of human oversight over AI solutions. The in-depth analysis of the use cases is a core element of this study.

The analysis of the use cases provides insight into many aspects common to emerging business practices, the role of intermediaries, and the interplay between the stakeholders in the ecosystem. Importantly, the role of intermediaries who deliver services by means of a platform model cannot be overstated in the ecosystem of players. Most of the time it is platform intermediaries who provide a foundation for users to develop, deploy, and manage AI solutions. Some platforms facilitate access to AI models, algorithms, and data by connecting AI developers with businesses seeking AI solutions. Other platforms facilitate use of AI in contracting in a specific sectorial context. Thanks to platforms, users willing to enter a contract can interact and automate the relevant steps. For example, a seller can use a chatbot to automate contract negotiations with a supplier (as shown in the Walmart case described in the supply chain management use section). Another example is that of a seller on the online marketplace automating offer generation with AI that analyses the

whole range of data to predict an optimal price for a given product, and sometimes for an individual buyer.

Non-deterministic AI solutions can be developed and used in the fully automated high frequency currency trading (Forex), where a single transaction, i.e. single contract, is concluded in a fraction of a second. AI can also make fully automated and to a very large extent real-time data-driven decisions on the winning offer for a specific advertisement impression in programmatic advertising. Finally, execution of a contract may also be carried out with AI, as in the case of renewable energy trading.

The use of AI in contracting is subject to the level of digitalisation, data availability, relevant human skills, and legal uncertainty. Therefore, creating the right conditions to ensure fair access to data and to AI systems (provided as a product or as a service), skills, reduced legal uncertainty and setting a level playing field for enterprises (including SMEs) and individuals are key factors for the adoption of AI systems in contracting.

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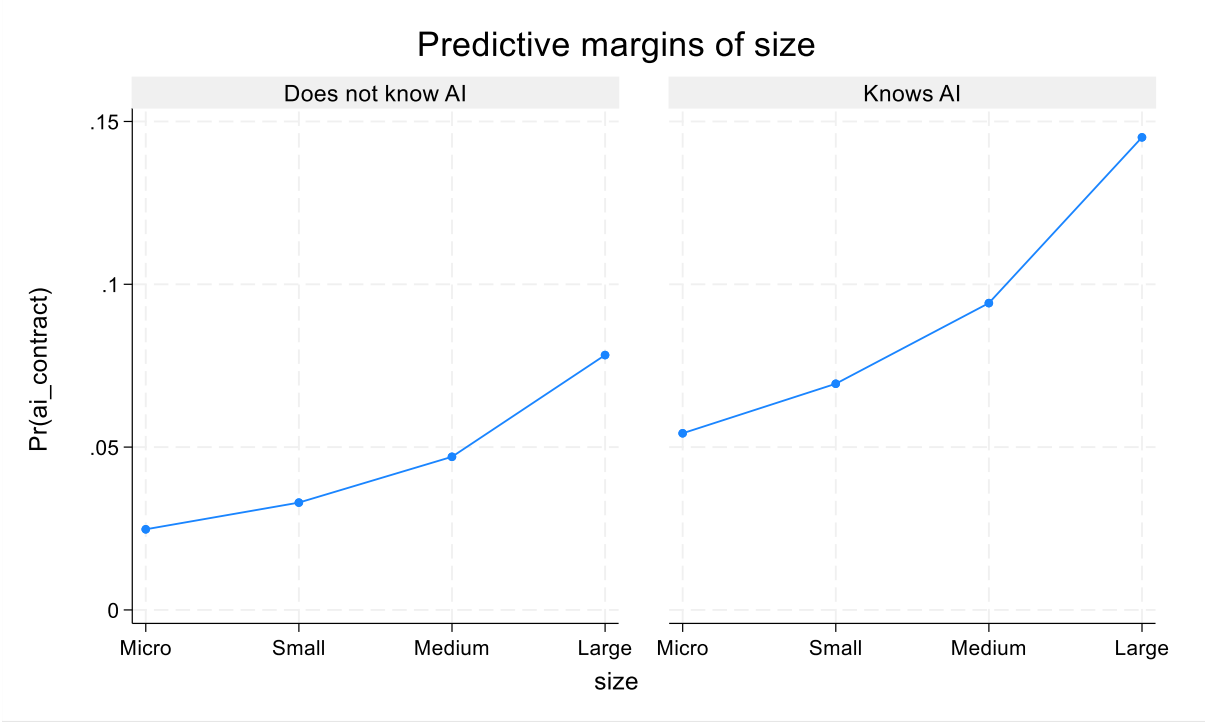
Annex I: Additional Figures and Tables

Table 25: Sector of activity: Non-Adopters of AI in contracting Vs. Assumed Adopters of AI in contracting (Conservative Approach)

| Sector of Activity | Non-Adopters of AI in contracting (Conservative approach) | Assumed Adopters of AI in contracting (Conservative approach) | Total |
|-----------------------|---|---|-------|
| Agriculture | 322 | 13 | 335 |
| (%) | 96.12 | 3.88 | 100 |
| Manufacturing | 1648 | 55 | 1703 |
| (%) | 96.77 | 3.23 | 100 |
| Construction | 1313 | 21 | 1334 |
| (%) | 98.43 | 1.57 | 100 |
| Trade/Transport | 2861 | 78 | 2939 |
| (%) | 97.35 | 2.65 | 100 |
| IT/Finance | 1527 | 46 | 1573 |
| (%) | 97.08 | 2.92 | 100 |
| Education/HumanHealth | 744 | 33 | 777 |
| (%) | 95.75 | 4.25 | 100 |
| Total | 8415 | 246 | 8661 |
| (%) | 97.16 | 2.84 | 100 |

Source: Own calculations based on the Ipsos-iCite survey (2020).

Figure 10: Probability of adopting AI in contracting by firm size and employee knowledge of AI



Source: Own calculations using data from the Ipsos-iCite (2020).

Table 26: Regression analysis: Predictors of adoption of AI in contracting

| | (1) AI in contracting | (2) AI in contracting | (3) AI in contracting |
|------------------------|--|--|--|
| Small | 0.122** (0.053) | 0.129** (0.054) | 0.129** (0.054) |
| Medium | 0.301*** (0.058) | 0.298*** (0.060) | 0.298*** (0.060) |
| Large | 0.549*** (0.078) | 0.564*** (0.081) | 0.564*** (0.079) |
| Knows AI | 0.350*** (0.060) | 0.349*** (0.064) | 0.349*** (0.061) |
| Branches Nbr | -0.031*** (0.009) | -0.026*** (0.009) | -0.026*** (0.008) |
| Manufacturing | 0.189 (0.134) | 0.250* (0.139) | 0.250* (0.131) |
| Construction | 0.104 (0.138) | 0.115 (0.143) | 0.115 (0.135) |
| Trade | 0.285** (0.131) | 0.318** (0.135) | 0.318** (0.128) |
| IT/Finance | 0.207 (0.135) | 0.211 (0.140) | 0.211 (0.132) |
| Education/Human health | 0.149 (0.145) | 0.203 (0.151) | 0.203 (0.143) |
| Constant | -2.141*** (0.138) | -2.175*** (0.177) | -2.175*** (0.167) |
| Observations | 8661 | 8640 | 8640 |
| Country FE | NO | YES | YES |
| Robust SE | NO | NO | YES |

Note: The dependent variable "AI in contracting" takes the value 1 if the firm potentially adopted AI in contracting and 0 otherwise. For firm size, the baseline category is Micro. For sector of activity, the baseline category is Agriculture. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Column (2) includes country fixed-effects; column (3) includes country fixed-effects and robust standard errors. Source: Own calculations using data from the Ipsos-iCite (2020).

Annex II: In depth analysis of use cases

1) Retail forex trading

Forex is the foreign exchange market for the trading of currencies¹⁵⁴. It is the largest and the most liquid market¹⁵⁵ in the world.¹⁵⁶ Forex allows for currency conversions, facilitating cross-border global trade, which can include investments, exchange of goods and services, and financial transactions. Forex is an over-the-counter (OTC) market, meaning that transactions are completed between two participants.¹⁵⁷ The OTC feature of Forex implies that there is no single exchange rate but rather a number of different rates (prices), depending on what currency the trader is trading, and where it takes place.

Forex is a market with two basic levels of access (tiers).¹⁵⁸ Most of the trade volume is realised in the primary market tier, called the interbank or interdealer market. It is only available for large financial institutions. This tier is also characterised by different levels of access and is not directly available to individual investors. The secondary market tier encompasses dealer-to-customer trades. It is known as *retail Forex*. The retail Forex segment enables participation of individual investors who can trade currencies as direct customers of dealers or via brokers. Dealers are considered market makers as they enable market access for individual investors, acting as a counter party to their transactions.¹⁵⁹ Individual investors do not make transactions directly with each other. Any time an individual investor sells or buys currency, he enters into a contractual relation with their dealer. There are also entities that can assume both roles: of a broker or of a dealer. When an individual investor places an order, a dealer can internalise it (make a match with a selling or a buying order of other customers) or externalise it (further trade it at the primary market).¹⁶⁰ All players in the Forex market are also referred to as traders.

¹⁵⁴ Encyclopaedia Britannica: [Foreign exchange market \(Forex, or FX, market\) | Britannica](#). See also: Neil Record, *Currency overlay*, Wiley 2003. For more recent articles see for example: (Kumar 2014) (Rinaldo and Somogyi 2021).

¹⁵⁵ Liquid market is “a financial market in which it is easy to buy and sell, and in which a lot of buying and selling takes place” (Cambridge Dictionary: [LIQUID MARKET | English meaning - Cambridge Dictionary](#)). In business, economics or investment, market liquidity is a market's feature whereby an individual or firm can quickly purchase or sell an asset without causing a drastic change in the asset's price ([Market liquidity - Wikipedia](#)).

¹⁵⁶ In October 2022 Global FX trading hit record \$7.5 trillion a day (Bank for International Settlement (BIS), *Triennial Central Bank Survey Results for Foreign Exchange and Derivative Markets*, 2022).

¹⁵⁷ See for example Amanda Nordström, Understanding the foreign exchange market, SVERIGES RIKSBANK ECONOMIC REVIEW 2022 no. 1, 2022, p. 48, available at: https://www.riksbank.se/globalassets/media/rapporter/pov/artiklar/engelska/2022/220314/2022_1-understanding-the-foreign-exchange-market_en.pdf.

¹⁵⁸ Amanda Nordström, Understanding the foreign exchange market, SVERIGES RIKSBANK ECONOMIC REVIEW 2022 no. 1, 2022, p. 48, available at: https://www.riksbank.se/globalassets/media/rapporter/pov/artiklar/engelska/2022/220314/2022_1-understanding-the-foreign-exchange-market_en.pdf.

¹⁵⁹ The clear division between two-tier Forex market structure has been *de facto* blurred with technology.

¹⁶⁰ Brokers that act as dealers are called broker-dealers or dealing desk brokers. When a broker-dealer acts as an agent, the trade is on behalf of the client (broker), and when acting as principal, the trade is on its own account (dealer) (Amanda, 2022)

Over the last decades, the Forex market has undergone large structural changes.¹⁶¹ It has also evolved from a market with a distinctive division between the two tiers, to a fast-paced and interconnected market with a growing number of participants (in particular, in the retail Forex).¹⁶² The Forex market has gradually built-up in complexity. While large banks and other institutional participants still constitute the largest part of traded volume in Forex,¹⁶³ participants have become more diverse, and trading venues multiplied.

The changes in Forex are to a large extent technology driven. Technical innovations have enhanced the speed of trading, and offered participants more choices relating to the choice of a dealer, platform, trading strategy, etc. Also, a growing number of individual investors is driven by technology developments, including the adoption of online platform business models and AI.¹⁶⁴ Up until the late 1990s, the Forex market was almost exclusively accessible to financial institutions.¹⁶⁵ The main shift towards wider accessibility to Forex came with the rise of dedicated trading platforms in the early 2000s, often provided by non-bank firms related to the booming tech sector.¹⁶⁶ At approximately the same time, dealer banks started introducing their own proprietary electronic platforms, so called *single-bank platforms (SBTs, also single-dealer platforms)*.¹⁶⁷ Non-dealer platforms are often multi-subject platforms where individual investors have access to many dealers or brokers, and brokers or dealers can pool from the large number of customers. Brokers and dealers are therefore pulled to most common retail Forex platforms so as not to miss out on individual investors accustomed to a specific technical interface.¹⁶⁸

Platforms and automation underpin - to a large extent - a new business model in Forex trading, where profits are generated from the high number of customers combined with high number of

¹⁶¹ Amanda Nordström, Understanding the foreign exchange market, SVERIGES RIKSBANK ECONOMIC REVIEW 2022 no. 1, 2022.

¹⁶² King M, C Osler and D Rime (2012): "Foreign exchange market structure, players and evolution", in Handbook of Exchange Rates, edited by I Marsh, J James, and L Sarno, Hong Wiley & Sons); Schrimpf, Andreas and Vladyslav Sushko (2019a), 'FX trade execution: complex and highly fragmented', article in *BIS Quarterly Review December 2019*, December;

¹⁶³ In 2016, it was reported that volume from retail foreign exchange trading represented 5.5% of the whole foreign exchange market or \$280 billion in daily trading turnover. Updates on this figure can be found in the latest triennial survey by the Bank for International Settlements and working papers (see for example <https://www.bis.org/publ/work1094.pdf>)

¹⁶⁴ King, Michael, Carol L. Osler and Dagfinn Rime (2013), 'The market microstructure approach to foreign exchange: looking back and looking forward', *Journal of International Money and Finance*, vol. 38, no. C, pp. 95–119.

¹⁶⁵ See note 158, p. 47. (Nordstrom).

¹⁶⁶ BIS, 2018.

¹⁶⁷ King, Michael, Carol L. Osler and Dagfinn Rime (2013), 'The market microstructure approach to foreign exchange: looking back and looking forward', *Journal of International Money and Finance*, vol. 38, no. C, pp. 95–119.

¹⁶⁸ MT4 and MT5 are the most common platforms. MetaTrader 4, also known as MT4, is an electronic trading platform widely used by online retail foreign exchange investors. It was developed by MetaQuotes Software and released in 2005. The software is licensed to foreign exchange brokers who provide the software to their customers. The software uses a proprietary scripting language, which enables traders to develop Expert Advisors, custom indicators and scripts. MT4 is designed to be used as a stand-alone system with the broker manually managing their position and this is a common configuration used by brokers. However, a number of third party developers have written software bridges enabling integration with other financial trading systems. Dozens of new automated trading applications appear in the MQL5 (MT4 and MT5 coding language) market every day: <https://www.mql5.com/>. Also, there are internet communities devoted to development of free open source software for MetaTrader (e.g. Yahoo! hosts a large group of over 12,000 members).

transactions, instead of more traditional profit based on price spreads and price speculations.¹⁶⁹ This business model drives the profitable Forex trading towards high frequency trading (HFT).¹⁷⁰ The Bank for International Settlements (BIS) describes the Forex market as a “fast-paced electronic market, a market where the price development predominantly occurs via electronic means, and which is characterised by a sizeable penetration of high-speed, algorithmic-driven order placements. Along with an increase in the use of electronic brokerages, the introduction of data aggregators and live price feeds has resulted in an increase in the updating frequency of data feeds.”¹⁷¹

Automation and AI in Forex

Retail Forex is a Forex segment that has seen the strongest rise in automation in recent years.¹⁷² Online platforms allowed for automation of trading steps, including the execution of buying and selling orders.

The automation of transactions conclusion in Forex trading is enabled through algorithms and is often referred to as algorithmic trading. The use of algorithms grew rapidly with the availability and improvement of data, becoming a tool for navigating an increasingly fragmented and complex market.¹⁷³ In addition, transparency requirements and regulations have increased the demand for traceable execution, which in turn has contributed to the growth of electronic and automated trading.¹⁷⁴ The current popularity of trading platforms largely stems from its support of algorithmic trading. Algorithmic trading in Forex is facilitated by software called Expert Advisor (EA), or more informally “trading bot”, or “trading robot”. These trading tools used to be based exclusively on the pre-determined logic to buy and sell currency pairs when specific signals are triggered by price action, an indicator, or whatever else the trader may choose. This type of an automating tool is akin to *execution algorithms* that use mathematical models and automated trading programs to create specific sets of trading rules and models, and then automatically execute orders and transactions. For example, traders commonly place limit orders using algorithms. When a pre-defined limit value is reached, the algorithm is programmed to automatically execute or cancel.

There are several ways to develop a trading strategy that will ultimately determine the decision-making on trading in Forex, including for individual investors. They can program their own algorithmic trading strategy and connect it to their trading account by means of an Application Programming Interface (API) or use robots available on a platform or provided by a third party. Leading trading platforms enable many features that are there for a customer to choose and determine their own strategy, as well as how to develop it. The available EAs or robots differ in both

¹⁶⁹ The revenue of the dealers often depend on the number of customers and number of transactions, where a dealer charges the transaction fee, transaction margin or fee for the use of the trading software. To gain a customer or software user, dealers offer inter alia low entry level in terms of funds necessary to start trading and the trading know-how and strategies built into the system.

¹⁷⁰ BIS, Markets Committee, “Monitoring of fast-paced markets”, 2018, <https://www.bis.org/publ/mkctc10.pdf>.

¹⁷¹ BIS, Markets Committee, “Monitoring of fast-paced markets”, 2018, <https://www.bis.org/publ/mkctc10.pdf>.

¹⁷² Schrimpf, Andreas and Vladyslav Sushko (2019a), ‘FX trade execution: complex and highly fragmented’, article in BIS Quarterly Review December 2019, December.

¹⁷³ Markets Committee, ‘FX execution algorithms and market functioning’, Markets Committee Papers no. 13, Bank for International Settlements, 2020.

¹⁷⁴ In principle, algorithms are used in many areas of trading, not only in Forex. They facilitate the execution of trades, statistical algorithmic trading and high-frequency trading. As executable liquidity is dispersed over a large number of venues, algorithms have also become a tool to source liquidity from many different venues simultaneously. SVERIGES RIKSBANK ECONOMIC REVIEW 2022 no. 1.

the *level of automation* and *level of the readiness to use*. The automation level can be often customised, depending on the user's preferences and skills to trade. The trading can be fully automated or automated under specific conditions, or specific stages of trading can be automated. The readiness to use is another feature that can be customised. Systems can be ready to use simply upon the introduction of the user's chosen settings.¹⁷⁵ They can also be programmed in a way to give a user a possibility to further develop it.¹⁷⁶ There are also EA builders, a special software that allow for building a customised EA. The possibility to build a trading robot can be facilitated either by a trading platform, or by a third-party software developer.¹⁷⁷ The choice of the adequate level of automation and level of readiness will ultimately depend on the user's skills to trade or code.

Unskilled individuals are also drawn to Forex trading by the possibility to follow other traders' strategy or social trading platforms. These ways of trading allow a user to fill up their knowledge gap relating to trading. The skilled traders can develop a particular trading strategy and share/provide resulting trading signals with less skilled platform users. MetaTrader platforms allow users to mechanically follow or copy the trades of Forex signal suppliers.¹⁷⁸ The social trading platforms bring together a community of traders, including both experienced and novice traders. Experienced traders can share their trading strategies and insights with others on the platform. Novice traders can follow or copy the trades of these experienced traders in real-time. It allows less experienced traders to benefit from the expertise of more skilled traders.¹⁷⁹

The use of AI-based trading tools is particularly efficient in automation of trading. AI-based techniques make it easier to handle big data, to understand and to compare different parameters using both historical and real-time data (see Miikulainen et al.¹⁸⁰ for a discussion on how AI techniques help to observe market tendencies on real time basis). In addition, AI makes it possible to identify the trends in different variables and to understand interactions of different parameters. As a result, advanced technologies are capable of fully automating trading decisions and increase the speed of the transactions. They have been more widely adopted recently, and now they are used not only by the largest institutional traders but also by individual traders. In such a case they may also fill up the knowledge gap of individual investors, opening the trading market to unskilled traders.

Since their introduction, trade-automating tools have also evolved from simple mechanical forms to highly sophisticated and adaptive types based on machine learning techniques that respond to real-time changes in market conditions.¹⁸¹ In Forex, as in finance in general, machine learning has been

¹⁷⁵ See for example: <https://3commas.io/blog/best-forex-trading-bot>.

¹⁷⁶ See for example: MetaTrader: <https://www.metatrader5.com/en/automated-trading/robots-indicators>.

¹⁷⁷ See for example: <https://tradersunion.com/interesting-articles/forex-trading-advisors/best-expert-advisor-builders/>;
<https://www.mql5.com/en>.

¹⁷⁸ See for example: <https://admiralmarkets.com/education/articles/automated-trading/best-Forex-trading-signal-providers>.

¹⁷⁹ See for example: <https://www.zulutrade.com/>.

¹⁸⁰ Miikulainen, R., Liang, J., Meyerson, J. E., Rawal, A., Fink, D., Francon, O., Raju, B., Shahrzad, H., Navruzyan, Duffy, N. & Hodjat, B. (2019). Evolving Deep Neural Networks, Artificial Intelligence in the Age of Neural Networks and Brain Computing, 293-312.

¹⁸¹ SVERIGES RIKSBANK ECONOMIC REVIEW 2022 no. 1; BIS Markets Committee, 'FX execution algorithms and market functioning', Markets Committee Papers no. 13, Bank for International Settlements, 2020; BIS Markets Committee, "Monitoring of fast paced electronic markets", 2018, ISBN 978-92-9259-193-9, <https://www.bis.org/publ/mkctc10.pdf>.

largely dominated by deep learning approaches.¹⁸² Deep learning¹⁸³ has continuously been the best-performing predictor class, not only across financial time series but also across a myriad of other disciplines.¹⁸⁴ Some empirical studies found that the neural networks and expert systems combined have increased the accuracy of forecasting and have performed well. However, these researches do not distinguish between the long-term and short-term periods. AI algorithms can make accurate short-term predictions as the investigations suggest, but they are also reliable for making long-term forecasts.¹⁸⁵

The use of neural networks in Forex gained a lot of attention in the technology-driven trading community after the 2007 Automated Trading Championship.¹⁸⁶ During this event hundreds of robots were competing against each other on one of the largest trading platforms. The winning robot was based on neural networks, and it outperformed the competitors spectacularly. At the time, many internet forums were flooded with topics related to neural networks and Forex trading.¹⁸⁷

The development of LLMs further influenced the use of AI in Forex and other markets. We observed the existence of the AI tools that allow for text-based trading. Therefore, apart from the AI-based analytical layer and automated execution of the transactions, AI can also be used as an interface enabling natural language conversations and placing trading instructions in plain language.¹⁸⁸ The use of AI as an interface does not determine whether the decision-making on the trades is done autonomously by AI.

¹⁸² Artur Sokolovsky, Luca Arnaboldi, A generic methodology for the statistically uniform & comparable evaluation of Automated Trading Platform components, *Expert Systems with Applications*, Volume 223, 2023, 119836, ISSN 0957-4174, <https://doi.org/10.1016/j.eswa.2023.119836>, (<https://www.sciencedirect.com/science/article/pii/S0957417423003378>); Ozbayoglu A.M., Gudelek M.U., Sezer O.B., Deep learning for financial applications: A survey *Applied Soft Computing*, 93 (2020), Article 106384, (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85084842457&origin=inward&txGid=a16b1ed16c5abc0e7557d7eacb3fbc67>); Sezer O.B., Gudelek M.U., Ozbayoglu A.M., Financial time series forecasting with deep learning: A systematic literature review: 2005–2019, *Applied Soft Computing*, 90 (2020), Article 106181, (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85079891275&origin=inward&txGid=59c145c37300be8df280ca4440d52450>).

¹⁸³ According to McKinsey&Company, Deep learning is broadly defined as ‘a type of machine learning that is more capable, autonomous, and accurate than traditional machine learning’ (<https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-deep-learning>). According to IBM, ‘Deep learning is a subset of machine learning that uses multilayered neural networks, called deep neural networks, to simulate the complex decision-making power of the human brain. Some form of deep learning powers most of the artificial intelligence (AI) applications in our lives today.’ ([What Is Deep Learning? | IBM](https://www.ibm.com/blogs/ai/2016/05/what-is-deep-learning/)).

¹⁸⁴ Artur Sokolovsky, Luca Arnaboldi, A generic methodology for the statistically uniform & comparable evaluation of Automated Trading Platform components, *Expert Systems with Applications*, Volume 223, 2023, 119836, ISSN 0957-4174, <https://doi.org/10.1016/j.eswa.2023.119836>, (<https://www.sciencedirect.com/science/article/pii/S0957417423003378>); Sezer O.B., Deep learning for financial applications: A survey *Applied Soft Computing*, 93 (2020), Article 106384, (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85084842457&origin=inward&txGid=a16b1ed16c5abc0e7557d7eacb3fbc67>).

¹⁸⁵ Alexandridis, A. K., Panopoulou, E. & Souropanis, I. (2018). Forecasting Exchange Rates: An Iterated Combination Constrained Predictor Approach, Working Paper No. 003; Yu, L., Lai, K. K. & Wang, S. (2005). Designing a Hybrid AI System as a Forex Trading Decision Support Tool. The 17th IEEE International Conference on Tools with Artificial Intelligence.

¹⁸⁶ <https://www.mql5.com/en/articles/1565>; <https://www.metaquotes.net/en/company/news/3504>.

¹⁸⁷ <https://www.mql5.com/en/articles/1565>; <https://www.metaquotes.net/en/company/news/3504>.

¹⁸⁸ See for example: <https://capitalise.ai/>.

MetaTrader Platform

MetaTrader platforms (MT4 and MT5) are among the most common platforms for retail Forex. MT4 was released in 2005. The platforms software is licensed to Forex brokers who provide it to their customers. The platforms are the core component of the ecosystem. It is a downloadable desktop application that provides access to various financial markets (including Forex) commodities, indices, and more. In addition to the desktop version, MT4 is available as a mobile application and web-based platform, allowing traders to access their accounts and trade from anywhere.¹⁸⁹

One of the standout features of the platforms is their support for automated trading using Expert Advisors (EAs) often referred to as trading robots, which are different types of tools on this platform. Both terms are used to describe automated trading systems that can identify market patterns and generate trading signals. However, some sources may use the term EA to refer to a program that only provides trading signals, while a trading robot can also execute trades without any manual intervention. This distinction is not consistent, and many EAs are capable of both generating signals and performing trades.¹⁹⁰

In principle, EAs are custom scripts or algorithms that can not only trade signals but also execute trades automatically based on predefined trading strategies. AI-based EAs can also automate the choice of strategy depending on the changing market conditions. Traders and developers can create their own EAs or choose from a vast library of pre-built EAs. Traders and developers can create custom EAs using AI algorithms and machine learning models to analyse market data, make automatic trading decisions, and execute them automatically. The EAs, including those developed by a third-party, are typically coded in programming languages like MQL4, which is specifically designed for MetaTrader platforms. This allows for seamless integration and full interoperability with the platforms. After AI-based EA is developed and tested, it can be deployed for live trading on MetaTrader platforms.¹⁹¹ Traders can set specific criteria for the EA to follow, such as entry and exit rules, risk management parameters, and other parameters.

Traders use MetaTrader platforms to execute trades, conduct technical and fundamental analysis, and manage their trading accounts. A number of third-party developers have written software bridges enabling the integration of EAs within other financial trading platforms. The MetaTrader ecosystem is very rich and enables wide participation of not only traders but also developers and providers of various ancillary services. Dozens of new automated trading applications appear in the MQL5 coding language on the market every day.¹⁹² Also, there are internet communities devoted to the development of free open-source software for MetaTrader.¹⁹³

¹⁸⁹ <https://www.metatrader4.com/en>; <https://www.metatrader5.com/>.

¹⁹⁰ MetaTrader4: [Algorithmic trading and trading robots in MetaTrader 4](#); MetaTrader5: <https://www.metatrader5.com/en/automated-trading/robots-indicators>.

¹⁹¹ MetaTrader: <https://www.metatrader5.com/en/search#!keyword=ea&page=3>.

¹⁹² <https://www.mql5.com>.

¹⁹³ For example, Yahoo! hosts a large community dedicated to sharing trading experiences. Also, the secure messaging channels exist to support the community: <https://finance.yahoo.com/news/metaquotes-released-mql5-channels-secure-134500449.html>.

AI-related issues

In general, most of the AI tools used in Forex are based on machine learning as these tend to perform better than humans in reacting to changing market conditions, in particular when a short-term perspective is considered. These algorithms can handle massive amounts of unstructured data and can sort, analyse and act upon it in fractions of the time it would take a human trader. Several major international dealer banks have launched adaptive machine algorithms – algorithms that self-adapt to the ongoing market conditions (see Greenwich Associates (2021)). Still, AI and machine learning techniques have only recently started to play an important role in transforming electronic Forex trading (see for example Refinitiv 2019 and Golden 2021)¹⁹⁴ and the magnitude of risk associated with their use is to be seen.

One of the risks related to automated tools in Forex is that changing market conditions can cause unexpected outcomes and result in high losses. As Forex trading robots can be continuously active, they can lead to a damaging impact to the trader's account, if left unattended. In May 2010, the US financial markets experienced what has become known as a major “Flash Crash”: within a few minutes the interaction of fully automated trading algorithms produced massive losses and left some market participants with the sense of the markets disappearing.¹⁹⁵

For this reason, traders are advised to monitor the AI-based EAs actively, i.e., not to leave them unattended even if it is technically possible. This is to ensure that EAs are functioning as intended when adapting to changing market conditions.¹⁹⁶ There are monitoring tools developed to monitor an active EA.¹⁹⁷ Checking upon a trading EA is also important in the context of software updates. AI-based EAs, as any other software, may also require periodic updates and adjustments to maintain their effectiveness.¹⁹⁸ Now some trading platforms offer human supervision in the form of managed accounts or private monitoring service to monitor automated trading on behalf of a trader.¹⁹⁹

Nevertheless, the use of machine learning adopts the idea that the automated machine learning trading system develops its trading rules independently from a trader.²⁰⁰ Borch (2022) argues that the shift from human-conceived to machine-learning-based trading is in need of scrutiny, as it changes the knowledge risks and principal-agent problems automated trading firms are facing.²⁰¹

¹⁹⁴ Refinitiv (2019), Refinitiv 2019 Artificial Intelligence / Machine Learning Survey Global Study; Golden, Paul (2021, July), Foreign Exchange Survey 2021: Fast forward to the future, Euromoney.

¹⁹⁵ Christian Borch, Machine learning, knowledge risk, and principal-agent problems in automated trading, *Technology in Society*, Volume 68, 2022, 101852, ISSN 0160-791X, <https://www.sciencedirect.com/science/article/pii/S0160791X21003274>.

¹⁹⁶ See for example: <https://www.ironfx.com/en/what-are-expert-advisors/>;

¹⁹⁷ See for example: <https://help.fxmonitor.online/en>, <https://softimotrade.com/en/signals/>.

¹⁹⁸ See for example threads on the community fora: <https://forums.babypips.com/t/mt4-updates/58187/4>.

¹⁹⁹ See for example: MetaTrader: <https://www.metatrader5.com/en/search#!keyword=monitoring>.

²⁰⁰ Bank of England, & The Financial Conduct Authority, *Machine Learning in UK Financial Services*, Bank of England and the Financial Conduct Authority, London (2019); Tony Guida (Ed.), *Big Data and Machine Learning in Quantitative Investment*, Wiley, Chichester (2019); Marcos López de Prado, *Advances in Financial Machine Learning*, Wiley, Hoboken, NJ (2018).

²⁰¹ Christian Borch, Machine learning, knowledge risk, and principal-agent problems in automated trading, *Technology in Society*, Volume 68, 2022, 101852, ISSN 0160-791X, <https://doi.org/10.1016/j.techsoc.2021.101852>.

2) Programmatic advertising

Advertising is the main financial engine of Internet nowadays. There are many types of online advertising, including search, display, and social media advertising. Display advertising refers to the ad banners that are hosted in content providers' and publishers' websites.

Programmatic advertising is a way of allocating advertising banners, in display advertising and beyond, where advertising impressions are sold in real-time bidding (RTB) auctions. This practice complements a more direct allocation through pre-negotiated contracts, known as reservation contracts, between publishers and advertisers.²⁰² Programmatic advertising started being used around the mid-2010s and gained wider popularity in 2014.

A burgeoning literature is developing on themes related to programmatic advertising, mostly focusing on the technical implementations (Korula et al., 2016²⁰³; Li et al., 2017²⁰⁴; Ford et al., 2023²⁰⁵) and its economic impacts (Goldfarb, 2014²⁰⁶; Blake et al., 2015²⁰⁷; Johnson et al., 2017²⁰⁸; Decarolis and Rovigatti, 2021²⁰⁹, inter alia). Programmatic advertising is also widely covered by practitioners and the sectoral press that promote it to potential client businesses. Figure 11 shows an increase in interest on Google for this practice in the mid of the past decade and a stable high interest since then.

Figure 11: Google Trends Index for "programmatic advertising", Worldwide, 2004-2023.



Source: Own elaboration.

²⁰² SaS.Amin, *Real-Time Bidding in Online Display Advertising* (February 14, 2017). Available at SSRN: <https://ssrn.com/abstract=2916875> or <http://dx.doi.org/10.2139/ssrn.2916875>.

²⁰³ N. Korula, V. Mirrokni and H. Nazerzadeh, *Optimizing Display Advertising Markets: Challenges and Directions*, *IEEE Internet Computing*, vol. 20, no. 1, pp. 28-35, Jan.-Feb. 2016, doi: 10.1109/MIC.2015.137.

²⁰⁴ J. Li, Y. Yuan, X. Zhao, F. Wang, *Research on Information Structure of Programmatic Advertising Markets*, *IFAC-PapersOnLine*, Volume 50, Issue 1, 2017, Pages 13587-13592, ISSN 2405-8963, <https://doi.org/10.1016/j.ifacol.2017.08.2377>

²⁰⁵ J. Ford, V. Jain, K. Wadhvani, D. G. Gupta, *AI advertising: An overview and guidelines*, *Journal of Business Research*, Volume 166, 2023, 114124, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2023.114124>.

²⁰⁶ Goldfarb, A., 2014. What is different about online advertising?. *Review of Industrial Organization*, 44, pp.115-129.

²⁰⁷ Blake, T., Nosko, C. and Tadelis, S., 2015. Consumer heterogeneity and paid search effectiveness: A large-scale field experiment. *Econometrica*, 83(1), pp.155-174.

²⁰⁸ Johnson, G.A., Lewis, R.A. and Nubbemeyer, E.I., 2017. Ghost ads: Improving the economics of measuring online ad effectiveness. *Journal of Marketing Research*, 54(6), pp.867-884.

²⁰⁹ Decarolis, F. and Rovigatti, G., 2021. From mad men to maths men: Concentration and buyer power in online advertising. *American Economic Review*, 111(10), pp.3299-3327.

Programmatic advertising is enabled by several technological developments that are the foundations of these advertising systems. As a result, there are numerous technical concepts associated with programmatic advertising.²¹⁰ Terms often used in this context, like "big data" and "data-driven display", encompass advanced data utilisation as the foundation for decision-making related to marketing. These large datasets, generated by a combination of internet users' web browsing and clicking data, demographic characteristics and beyond are fed into algorithms, referred to as "AI systems" and "machine learning solutions". These refer to the algorithmic processing of data and their statistical analysis to continuously generate empirical insights.²¹¹

Programmatic advertising therefore is a technology-enabled data-driven system that facilitates the cost-effective, real-time dissemination of selected marketing materials to target audiences via the internet. It is even considered a vital communication tool by a significant number of companies, most notably in retail sales.²¹²

AI in programmatic advertising

AI algorithms have been considered an integral part of programmatic advertising since its outset. When programmatic ad buying was popularised in 2014, it already included AI-based buying, effectively automating marketing decisions and their executions.²¹³ The sustained pace of research on machine learning algorithms in particular, is likely to drive fast and continuous change in the way programmatic advertising is developed and managed in online settings. In particular, RTB relies on the analytical ability of the AI system to determine prices dynamically and in real-time through auctions and automatically execute transactions. With an RTB model, any buyer can bid on the ad inventory in an open ad exchange instead of dealing with a single publisher. This allows advertisers to purchase advertisements on a case-by-case basis whenever a viewer visits a publisher's site.

Programmatic advertising is used to sell adverts in a wide range of forms (graphics, video, sound). It is delivered via various digital channels such as desktop or mobile displays on different websites and applications. Also, some traditional offline channels are becoming digitalised too. For example, there are offers of traditional outdoors channels advertising programmatically through digital screens on bus stations, shopping malls, and billboards.²¹⁴

²¹⁰ Busch, Oliver, "The Programmatic Advertising Principle" in *Programmatic advertising: The Successful Transformation to Automated, Data-Driven Marketing in Real-Time* (ed. Busch). Berlin (2016).

²¹¹ Anthony Samuel, Gareth R.T. White, Robert Thomas, Paul Jones, *Programmatic advertising: An exegesis of consumer concerns*, *Computers in Human Behavior*, Volume 116, 2021, 106657, ISSN 0747-5632, <https://doi.org/10.1016/j.chb.2020.106657>

²¹² Benady, D. "programmatic: Packed with potential and peril." *Catalyst, Chartered Institute of Marketing* (2015): 13-19.

²¹³ [A brief history of artificial intelligence in advertising \(econsultancy.com\)](#).

²¹⁴ See for example: E.C. Malthouse, E. Maslowska, J.U. Franks, *Understanding programmatic TV advertising* *Int. J. Advert. Rev. Mark. Commun.* 2018; Y. Deng, C.F. Mela, *TV Viewing and Advertising Targeting*, *J. Mark. Res.*, 55 (1), pp. 99-118 2018; J. Seitz, S. Zorn *Perspectives of programmatic advertising* in O. Bush (Ed.), *Programmatic Advertising the Successful Transformation to Automated, Data-driven Marketing in Real-time*, Springer, Switzerland, pp. 37-54, 2016; see also: [Programmatic outdoor advertising: a beginner's guide \(econsultancy.com\)](#).

How AI-based RTB works in programmatic advertising?

The process of programmatic advertising, culminating in a RTB auction comprises the following steps. The advertiser or its agency, demanding ad space, can deposit the insertion order plus advertisements²¹⁵ on a demand-side platform (DSP). This platform interacts with the supply-side platform (SSP), which manages the supplied ad space on behalf of content providers, publishers and other websites. Such interaction can only take place via the intermediation of an ad exchange, which enables the demand and supply side to meet and adverts to be placed.²¹⁶

The process on each side is facilitated by technical infrastructures supplied by intermediaries. Supply-side platforms (SSP) and demand-side platforms (DSP) are two fundamental types of intermediaries who establish connections with the corresponding contracting side through interfaces. As explained above, publishers connect with SSPs, while advertisers connect with DSPs. Interfaces of these platforms are accessed by publishers and advertisers to engage in programmatic advertising. Primary contracting partners are usually represented by specialised advertising agencies. SSP and DSP interact with each other via ad exchange platform (AdX) to display ad impressions.²¹⁷

In principle, a publisher and an advertiser may choose two different ways for the deployment of programmatic advertising. These ways correspond to the two selling channels and subsequently two types of contracts between a publisher and an advertiser:

1. Guaranteed selling channel: reservation contracts, or pre-negotiated contracts,
2. Non-guaranteed selling channel: real-time bidding auctions (RTB).

Reservation contracts are guaranteed selling channels where at least three main elements are specified:²¹⁸

1. Targeting. This element specifies which users of a specific website can see the ad. The criteria may include various data collected on users, such as demographics and behaviour.
2. Volume. This element usually refers to the number of ad impressions (in some cases clicks may be a goal of a contract).
3. Price. This element usually specifies how much the advertiser pays for a number of ad impressions and eventual penalties in case the number of ad impressions is lower.

²¹⁵ With the advent of generative AI, the practitioners in the field highlight that even the ad itself can be now generated by AI according to the user's profile and other data, see for example: <https://advertisingweek.com/ai-opportunities-in-ad-exchange-and-programmatic-advertising-not-only-chat-gpt/>.

²¹⁶ Holm Münstermann and Peter Würtenberger, "Programmatic Disruption for Premium Publishers" in *Programmatic advertising: The Successful Transformation to Automated, Data-Driven Marketing in Real-Time* (ed. Busch). Berlin (2016).

²¹⁷ Nitish Korula, Vahab Mirrokni, Hamid Nazerzadeh, Optimizing Display Advertising Markets Challenges and Directions, IEEE INTERNET COMPUTING, 1089-7801/16, 2016: <https://ieeexplore.ieee.org/document/7325200?reload=true>; Hana Choi, Carl Mela, Santiago R. Balseiro, Adam Leary, Online Display Advertising Markets: A Literature Review and Future Directions, 2019, <https://ssrn.com/abstract=3070706>; Sayedi, Amin, Real-Time Bidding in Online Display Advertising (February 14, 2017). Available at SSRN: <https://ssrn.com/abstract=2916875> or <http://dx.doi.org/10.2139/ssrn.2916875>; Yong Yua, Feiyue Wang, Juanjuan Li, Rui Qin, A Survey on Real Time Bidding Advertising, IEEE Xplore, 978-1-4799-6058-3/14, 2014: <https://ieeexplore.ieee.org/document/6960761>.

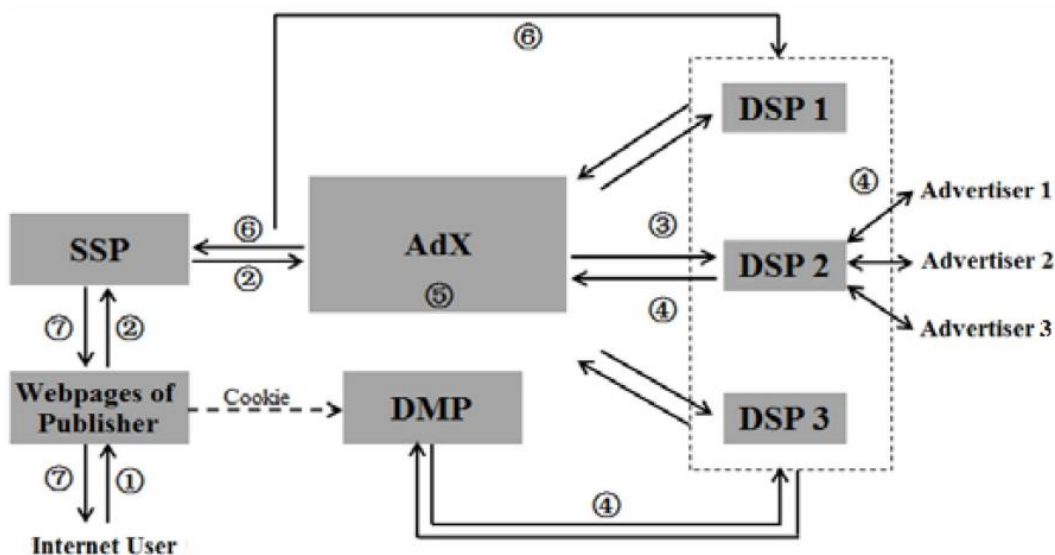
²¹⁸ Nitish Korula, Vahab Mirrokni, Hamid Nazerzadeh, Optimizing Display Advertising Markets Challenges and Directions, IEEE INTERNET COMPUTING, 1089-7801/16, 2016: <https://ieeexplore.ieee.org/document/7325200?reload=true>

In case of reservation contracts, these three elements are usually decided by the parties before the programmatic dissemination of advertisements takes place. Because guaranteed contracts are drawn in advance, both advertisers and publishers rely on the contractual conditions for future impressions and associated user characteristics.

RTB is a non-guaranteed selling channel. Originally, RTB was an auction for the remaining ad impressions. Publishers used to allocate all of their impressions to reservation contracts until those contracts were fulfilled, and only the leftover was available on RTB. Some publishers, however, adopt a so-called “header bidding” model, where all of their inventory available is for sale on RTB. Then for each impression, after receiving RTB bids, the publisher decides whether to allocate the impression to RTB or to reservation contracts.²¹⁹ In programmatic advertising most of the decisions are done programmatically via intermediaries facilitating adequate technical infrastructure.

RTB workflow for ad delivery

Figure 12: The typical process of RTB ad delivery.



Source: Yong Yua, Feiyue Wang, Juanjuan Li, Rui Qin (2014).

The key players in RTB workflow include the advertiser, DSP, AdX, SSP, DMP and publisher.²²⁰

Advertiser is the purchaser of ad impressions, and the corresponding audiences are the focal points. In real-time bidding (RTB) auctions, advertisers compete by submitting bids for ad impressions,

²¹⁹ Sayedi, Amin, Real-Time Bidding in Online Display Advertising (February 14, 2017). Available at SSRN: <https://ssrn.com/abstract=2916875> or <http://dx.doi.org/10.2139/ssrn.2916875>.

²²⁰ The presented RTB ecosystem is based on: Yong Yua, Feiyue Wang, Juanjuan Li, Rui Qin, A Survey on Real Time Bidding Advertising, IEEE Xplore, 978-1-4799-6058-3/14, 2014: <https://ieeexplore.ieee.org/document/6960761>

taking into account their marketing goals, financial resources, strategies, and other factors. The advertiser with the highest bid secures the ad impression.

DSP is an all-encompassing agency platform designed to assist advertisers in enhancing their ad management and delivery strategies. Leveraging extensive data analysis, precise audience targeting capabilities, as well as its RTB infrastructure and algorithms, the DSP facilitates advertisers in acquiring the most suitable ad impressions from AdXs through a streamlined, convenient, and unified approach.

AdX functions as an ad exchange marketplace, much like a stock exchange, where it pairs buyers and sellers for every impression. AdX employs standardised protocols to facilitate the exchange of ad requests and user data among various participants in the RTB ecosystem, with the objective of identifying the optimal alignment between advertisers and their desired audiences. As a result, AdX assumes a pivotal role within the RTB marketplace.

SSP is a publisher-centric platform that assists publishers in enhancing their ad inventory management and pricing strategies. This includes tasks such as determining optimal reserve prices, distributing ad impressions across various channels, and more.

DMP, or Data Management Platform, serves as a platform responsible for aggregating, storing, and analysing the cookie data of online users. Typically, DMPs offer paid services to DSPs and AdXs for the purpose of identifying and reaching their desired target audiences.

Publisher is the proprietor of an online website. Whenever a user visits a webpage owned by a publisher, it triggers the RTB process. The winning advertiser in the RTB auction for this impression will have their ad displayed on the publisher's webpages.

The process of ad delivery includes the following steps:

- 1- A user visits the webpages of a publisher.
- 2- When one or more ad inventories are available for sale in the RTB markets, the publisher will transmit an ad request to both the SSP and AdX. This request will include user information, details about the ad inventory, and often the specified reserve prices.
- 3- Following the reception of the ad request from the SSP, the AdX will proceed to transmit all pertinent information to eligible DSPs.
- 4- Each DSP then processes the information within the ad request, consults the DMP for the required user details (such as geographic location, gender, age, historical behaviour, shopping preferences, and intent), and initiates an auction to match advertisers. The winning advertiser's ad is sent back to AdX.
- 5- AdX initiates an auction among the winning advertisers from each DSP and identifies the highest bid among these victorious participants. If this bid falls short of the publisher's reserve price, the RTB process will be concluded with the ad inventory remaining unoccupied or potentially allocated to non-RTB channels. Conversely, if the highest bid meets or surpasses the publisher's reserve price, the advertiser with the highest bid will ultimately secure the ad impression.
- 6- AdX communicates the outcome of the auction to all DSPs and forwards the advertisements of the ultimate winning advertiser to the SSP
- 7- The SSP facilitates the display of the advertisements within the ad inventory on the publisher's webpages to reach the visiting users.

The whole process lasts 10 to 100 milliseconds.²²¹

RTB ecosystem

RTB based on AI seems to be currently a favoured way of delivering online advertising.²²² It can be seen in the fact that the RTB ecosystem is becoming more complex. In the RTB ecosystem, all the key players and their corresponding technical infrastructures multiply. Moreover, the core intermediaries are flanked by a broad ecosystem of supporting components and services. These platforms offer a whole range of tools, such as targeting tools, monitoring and validation tools, and advanced tracking and analysis features. But the DSPs and SSPs as well as ad exchanges are turning into multifunctional platforms where support components can be integrated from a third-party developer to achieve a whole spectrum of objectives relating to the processes run on the technical infrastructures of DSPs and SSPs. They also make it possible to plug in various third-party optimisation tools so that publishers and advertisers can test and use them in order to optimise a desired objective. In contrast to the major consolidation tendencies among core component providers, the number of support component providers has been growing.²²³

Apart from DSP and SSP, there are also data providers and data aggregators, who feed algorithms with information required for decision-making.

All these steps have to happen in reality almost instantly, while the webpage loads. For this reason, the process is highly automated, and the employment of AI solutions is crucial to its success and, as a result, to the commercial success of most of the companies and platforms of the current internet ecosystem.

Given the complexity and technicality of the process described above, some players have gained a particular prominence in the programmatic advertising market landscape. Indeed, many important companies, such as Google and Amazon, among others, have tried to propose an integrated platform that provide a one-stop solution for the demand and supply side of the advertising relation. Some of the players offering integrated solutions for programmatic advertising or specialise in selected components:

- **Google Marketing Platform** (formerly DoubleClick): offers a suite of tools that includes Google Ad Manager (SSP), Display and Video 360 (DSP), and Google Ad Exchange (AdX) for ad exchange services.
- **Amazon Advertising**: integrates demand and supply services with Amazon DSP and Amazon Publisher Services, allowing advertisers to buy and publishers to sell programmatically within the Amazon ecosystem.
- **Adform**: offers an end-to-end ad tech stack that includes SSP, DSP, and a cross-channel ad exchange.

²²¹ Yong Yua, Feiyue Wang, Juanjuan Li, Rui Qin, A Survey on Real Time Bidding Advertising, IEEE Xplore, 978-1-4799-6058-3/14, 2014: <https://ieeexplore.ieee.org/document/6960761>.

²²² Pepelyshev A., Staroselskiy Y., Zhigljavsky A. Adaptive targeting for online advertisement Proceedings of International Workshop on Machine Learning, Optimization and Big Data, Springer, Cham (2015), pp. 240-251

²²³ M. Pärssinen, M. Kotila, R. Cuevas Rumin, A. Phansalkar and J. Manner, "Is Blockchain Ready to Revolutionize Online Advertising?," in *IEEE Access*, vol. 6, pp. 54884-54899, 2018, doi: 10.1109/ACCESS.2018.2872694; Busch, Oliver, The Programmatic Advertising Principle" in *Programmatic advertising: The Successful Transformation to Automated, Data-Driven Marketing in Real-Time* (ed. Busch). Berlin (2016).

- **MediaMath**: offers a comprehensive platform with DSP capabilities, supply connections, and ad exchange features.
- **Microsoft Advertising** (former Xandr): provides a full-stack platform that includes both SSP and DSP capabilities.
- **Ad Pepper Media**: operates an ad exchange that provides programmatic solutions for online advertising across various formats and channels.

Furthermore, social media advertising has its own specificities. For example, Facebook possesses a cookie-based SSP known as Facebook Exchange, although log-in-based programmatic ad impressions are commonly exchanged directly between Facebook Marketing Partners (FMP) platforms and the interfaces of respective social media platforms. Initiatives to bridge the gap between these two programming domains are currently in progress. On one hand, there is an ongoing process of acquiring and integrating DSPs, FMPs, and search-bidding providers. On the other hand, Facebook offers anonymised usage data via its ATLAS Ad Server, accessible for advertisers through various devices. This enables the management and measurement of digital advertising across the Facebook platform, as well as external platforms.

These three core infrastructure components are now also flanked by a broad ecosystem of supporting components and services. The ecosystem includes data-management platforms, data and targeting offerings, monitoring and validation tools, and advanced tracking and analysis features. Advertisers, media or both can take advantage of such components to help them further develop and optimise their automated tasks. DSPs and SSPs interfaces make it possible to plug in various optimisation tools so that primary traders can test and use them. There is also a possibility to plug in an RTB optimiser from a third party.²²⁴ This means that DSPs and SSPs as well as ad exchanges are turning into multifunctional platforms where support components can be integrated from the third-party developers.

In contrast to the major consolidation tendencies among core component providers, the number of support component providers has been growing.²²⁵ The coexistence of very heterogeneous players in terms of size and capabilities may pose economic issues with respect to the trade-offs between the level of privacy protection and access to data, which deserve further investigation to guarantee that innovation and fair competition are preserved²²⁶

AI in programmatic advertising

AI in programmatic advertising today is correlated with enhanced knowledge-based automation of many processes performed on the SSP, DSP and Ad exchange platforms.

AI enables knowledge-based and data driven execution of the decision on pricing, bidding and subsequent contract conclusion between a publisher and advertiser. AI constantly integrates the

²²⁴ See for example: K. Ren, W. Zhang, K. Chang, Y. Rong, Y. Yu and J. Wang, "Bidding Machine: Learning to Bid for Directly Optimizing Profits in Display Advertising," in *IEEE Transactions on Knowledge and Data Engineering*, vol. 30, no. 4, pp. 645-659, 1 April 2018, doi: 10.1109/TKDE.2017.2775228.

²²⁵ M. Pärssinen, M. Kotila, R. Cuevas Rumin, A. Phansalkar and J. Manner, "Is Blockchain Ready to Revolutionize Online Advertising?," in *IEEE Access*, vol. 6, pp. 54884-54899, 2018, doi: 10.1109/ACCESS.2018.2872694; Busch, Oliver, *The Programmatic Advertising Principle* in *Programmatic advertising: The Successful Transformation to Automated, Data-Driven Marketing in Real-Time* (ed. Busch). Berlin (2016).

²²⁶ See: Year One Final Report, Observatory for the Online Platform Economy, 2023).

changing data on content and user into the contracting.²²⁷ AI adjusts prices and creative elements to meet the set goals and objectives. Advanced audience targeting AI algorithms analyse vast datasets of user's digital footprint to make patterns on user behaviour and preferences, enabling more precise audience targeting. AI-powered technologies are used extensively throughout the process of programmatic advertising, enabling advertisers to reach their target audiences more precisely and optimise their ad placements.²²⁸ AI also allows for 'cookieless' targeting, which primarily does not rely on the user's consent but uses alternative methods like contextual or aggregated targeting to reach specific audiences anonymously. Given their emphasis on the possibility to preserve individuals' privacy, these two solutions have already gathered attention from the stakeholders in the sector.²²⁹ AI is also used in predictive analytics. For example, AI methods can predict user actions and campaign outcomes, allowing advertisers to adjust strategies proactively by continuously analysing conversion rates, click-through rates, and other relevant metrics.

All the analytical outputs of AI-based analyses are integrated into the publisher's decision on the availability of ad inventory, offer making by an advertiser, and eventually fully automated decisions by AI systems on the conclusion of a contract between a publisher and advertiser during the ad inventory and offer matching in the RTB auction.

Issues with AI in programmatic advertising

Nevertheless, programmatic advertising is not without its drawbacks. The general issue of control over the campaign is already known, and there are attempts, including successful ones, to tackle it.²³⁰ The next box highlights some well-known examples of campaigns gone wrong due to the lack of control.²³¹

²²⁷ Choi and Lim identify machine learning techniques used in programmatic advertising. They categorise them as user- and content-centric approaches: A Choi, Kiho Lim, Identifying machine learning techniques for classification of target advertising, *ICT Express*, Volume 6, Issue 3, 2020, Pages 175-180, ISSN 2405-9595, <https://doi.org/10.1016/j.ict.2020.04.012>; Choi J.A., Lewis R. Culture and the star-power strategy: Comparing American and Korean response to Celebrity-Endorsed advertising *J. Glob. Mark.*, 30 (1) (2017), pp. 3-11.

²²⁸ Li, Hairong. "Special section introduction: Artificial intelligence and advertising." *Journal of advertising* 48.4 (2019): 333-337; Vaibhav Shwetangbhai Diwanji, Jaejin Lee & Juliann Cortese (2022) Deconstructing the role of artificial intelligence in programmatic advertising: at the intersection of automation and transparency, *Journal of Strategic Marketing*, DOI: 10.1080/0965254X.2022.2148269; Busch, Oliver. "Programmatic advertising." *The Successful Transformation to Automated, Data-Driven Marketing in Real-Time*. Springer Cham (2016). DOI: <https://doi.org/10.1007/978-3-319-25023-6>.

²²⁹ See for example: <https://blog.seedtag.com/how-ai-powered-contextual-advertising-will-replace-the-third-party-cookies#:~:text=Cookieless%20advertising%20methods%2C%20such%20as,complete%20picture%20of%20the%20user>

²³⁰ See for example Qian Sang, Niklas Karlsson, Jiaying Guo, Feedback control of event rate in online advertising campaigns, *Control Engineering Practice*, Volume 75, 2018, pp. 126-136, <https://doi.org/10.1016/j.conengprac.2018.03.010>.

²³¹ Further examples with the study of the economic effects and the policies on how to attenuate these risks can be found in: Madio, L., & Quinn, M. (2024). Content moderation and advertising in social media platforms, *Journal of Economics Management & Strategy*, 1-28, <https://doi.org/10.1111/jems.12602>.

With programmatic advertising, the lack of control over the buying of a specific ad inventory may actually lead to buying unwanted ad inventory. An example is when advertisements can appear against unsavoury, inappropriate or illegal content. In 2017 advertisers on YouTube were found displayed on terror group websites and fake news sites (see: New York Times: <https://www.thetimes.co.uk/article/big-brands-fund-terror-knnxfgb98>). Due to the unwanted and brand-damaging displays, there were advertisers (for example Johnson and Johnson) that paused their online advertising until adequate control measures were put in place ("The New York Times: "AT&T and Johnson & Johnson Pull Ads From YouTube", <https://www.nytimes.com/2017/03/22/business/atampt-and-johnson-amp-johnson-pull-ads-from-youtube-amid-hate-speech-concerns.html>).

3) E-commerce: retail sale

Electronic commerce (e-commerce) refers to digitally enabled trade and consumption of goods or services. According to the EU legislation, e-commerce can be defined as "the economic activity of selling or buying goods or services through electronic means, such as the internet or other information and communication technologies".²³² While e-commerce covers a wide range of online services, online retail sale of goods and services to consumers are the core of e-commerce.²³³

Electronic commerce implies the extensive use of digital technologies, including AI in facilitating online processes relating to sale as well as new business models.²³⁴ Technology-driven e-commerce facilitates two basic business models in retail sale: online-offline e-commerce and online platforms.²³⁵ The online-offline model includes modalities when firms sell online using offline services or facilities and when they add online functions to traditional offline business models.²³⁶ While this model used to prevail at the beginning of electronic commerce, the online platform model, which enables technical ecosystem building, collaboration and transactions,²³⁷ is often considered the future of e-commerce as it is tightly linked to the ongoing industry digital transformation.²³⁸ Platforms therefore facilitate all types of business interactions: B2B, B2C, C2B, C2C. As all these interactions may be intermediated by a technology (machine), the M2M mode can be embedded in all the types of interactions.

²³² E-Commerce rules in the EU | Shaping Europe's digital future. <https://digital-strategy.ec.europa.eu/en/policies/e-commerce-rules-eu>.

²³³ E-Commerce Directive | Shaping Europe's digital future. <https://digital-strategy.ec.europa.eu/en/policies/e-commerce-directive>.

²³⁴ OECD (2019), Unpacking E-Commerce: Business Models, Trends and Policies, OECD Publishing, Paris, <https://doi.org/10.1787/23561431-en>.

²³⁵ OECD (2019), Unpacking E-Commerce: Business Models, Trends and Policies, OECD Publishing, Paris, <https://doi.org/10.1787/23561431-en>.

²³⁶ OECD (2019), Unpacking E-Commerce: Business Models, Trends and Policies, OECD Publishing, Paris, <https://doi.org/10.1787/23561431-en>.

²³⁷ Wikipedia: 'Digital platform is a software-based online infrastructure that facilitates user interactions and transactions.' For the more thorough definition of 'platform' see sections below.

²³⁸ Heider Al Mashalah, Elkafi Hassini, Angappa Gunasekaran, Deepa Bhatt (Mishra), The impact of digital transformation on supply chains through e-commerce: Literature review and a conceptual framework, Transportation Research Part E: Logistics and Transportation Review, Volume 165, 2022, 102837, ISSN 1366-5545, <https://doi.org/10.1016/j.tre.2022.102837>, (<https://www.sciencedirect.com/science/article/pii/S1366554522002216>).

Figure 13: Platform-enabled interactions.

| | Business (M) | Consumer (M) |
|--------------|--------------------|--------------------|
| Business (M) | B(M) 2 B(M) | B(M) 2 C(M) |
| Consumer (M) | C(M) 2 B(M) | C(M) 2 C(M) |

Source: Own elaboration.

The largest firms in the world by capitalisation²³⁹ follow the so-called “digital platform business model”,²⁴⁰ however, ‘platform model’ is not a homogenous concept. Platforms face many design choices that determine their business model and, often, their commercial feasibility and success. Indeed, in presence of network externalities, business models can succeed by stimulating the participation of different agents on both sides of the market.²⁴¹ Digital technologies facilitated by platforms simplify the process of ordering items and services, including full automation of processes, eliminating transaction-related expenses, ultimately enhancing convenience for users. Similarly, companies can benefit from lower marginal costs, reduced frictions and long-term recurring revenue flows.²⁴²

Marketplaces

The specific types of platforms that enable commercial transactions are resellers and marketplaces. Resellers purchase products from suppliers and sell them to buyers. In marketplaces, sellers sell their products directly to buyers.²⁴³ The two models differ significantly on the allocation of control rights between independent suppliers and the intermediary over non-contractible decisions (prices, advertising, customer service, responsibility for an order fulfilment, and so on).²⁴⁴ Lefouili and Madio (2022) underline how a change in the liability regime of platforms may give them incentives to modify their business model to reduce their costs.²⁴⁵ Moreover, intermediate choices are possible and are becoming more common: for example, hybrid platforms, like Amazon, include both the characteristics of marketplaces and resellers.²⁴⁶

²³⁹ The largest companies by capitalisation in the S&P500 stock market index can be found, e.g., here: <https://www.slickcharts.com/sp500>. Between the top 10 are Amazon, Meta and Alphabet, whose core business relies on the platform business model, but also digital companies like Apple, Microsoft, Nvidia, and Tesla that equally benefit from a platform business organisation.

²⁴⁰ Aishwarya Ramasundaram, Neeraj Pandey, Yupal Shukla, Shirin Alavi, Jochen Wirtz, fluidity and the customer experience in digital platform ecosystems, *International Journal of Information Management*, Volume 69, 2023, 102599, ISSN 0268-4012, <https://doi.org/10.1016/j.ijinfomgt.2022.102599>; J.A. Fehrer, H. Woratschek, R.J. Brodie A systemic logic for platform business models, *Journal of Service Management*, 29 (4) (2018), pp. 546-568.

²⁴¹ See, for example, Belleflamme, P. and Peitz, M., 2021. *The Economics of Platforms*. Cambridge University Press.

²⁴² OECD (2019), *Unpacking E-Commerce: Business Models, Trends and Policies*, OECD Publishing, Paris, <https://doi.org/10.1787/23561431-en>.

²⁴³ Hagiu, A. and Wright, J., 2015. Marketplace or reseller?. *Management Science*, 61(1), pp.184-203.

²⁴⁴ Hagiu, A. and Wright, J., 2015. Marketplace or reseller?. *Management Science*, 61(1), pp.184-203.

²⁴⁵ Lefouili, Y. and Madio, L., 2022. The economics of platform liability. *European Journal of Law and Economics*, 53(3), pp.319-351.

²⁴⁶ See, for example, Anderson, S.P. and Bedre-Defolie, Ö., 2021. Hybrid platform model.

Marketplaces in particular facilitate the functioning of a more complex ecosystem of different types of users, not only buyers and sellers but also data providers, data aggregators, cloud services providers, advertisers and providers of supplementary or support services. From an economic perspective, a marketplace is therefore considered a multisided market,²⁴⁷ and since platforms, acting as an intermediary, can reach a very large size, they are also often examined in the context of their market power.²⁴⁸ Legal perspectives also consider platforms as intermediary services.²⁴⁹

Some marketplaces focus on B2C relations, while others choose to create a market for C2C relations. However, the lines between these typologies are rather blurred. For example, Amazon is a well-known marketplace and a re-selling platform that focuses on B2C, but also enables C2C transactions. Platforms where individuals can sell used items are typical C2C²⁵⁰. On the other hand, second-hand marketplaces also allow businesses to sell. A perhaps a more recent and less known case is that of B2B marketplaces.²⁵¹

In the context of platform economy, the term “peer-to-peer (P2P)” is also frequently encountered. However, this term is used to capture not the legal characteristics of the user, but the situation where a producer (usually an individual or small business) can reach out and sell to a wider buyer base without a professional business intermediary, but by using a platform service.²⁵² In legal terms, the EU Directive 2018/2001 defines P2P in the context of the renewable energy market as “the sale [...] through a contract with pre-established terms governing the automated execution and settlement of the transaction. This can occur either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator. The right to engage in the peer-to-peer trading shall not affect the rights and obligations of the involved parties in their roles as final customers, producers, suppliers, or aggregators.”

Internet and technological development enabled automation of the online buying and selling processes in e-commerce. The European regulator has cleared the way of the main legal uncertainties relating to the validity of contracts concluded by electronic means.²⁵³ The automation of contracting processes is, in fact, recognised as an integral part to e-commerce, albeit as a

²⁴⁷ B. Martens (2016) An Economic Policy Perspective on Online Platforms. Institute for Prospective Technological Studies Digital Economy Working Paper 2016/05. JRC101501; D. Thomé de Oliveira, M. Nogueira Cortimiglia, Value co-creation in web-based multisided platforms: A conceptual framework and implications for business model design, *Business Horizons*, Volume 60, Issue 6, 2017, pp. 747-758, <https://doi.org/10.1016/j.bushor.2017.07.002>.

²⁴⁸ Martens, B., An Economic Perspective on Data and Platform Market Power, SSRN, 2021: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3783297, Graef, I., 2015. *Market definition and market power in data: The case of online platforms*. *World Competition*, 38(4), Franck, J.U. and Peitz, M., 2023. *Market power of digital platforms*. *Oxford Review of Economic Policy*, 39(1), pp.34-46.)

²⁴⁹ DSA, Article 3(i) reads that “online platform’ means a hosting service that, at the request of a recipient of the service, stores and disseminates information to the public (...)”

²⁵⁰ For example Wallapop in Spain: <https://es.wallapop.com/>

²⁵¹ For some examples of these marketplaces, see: <https://www.shopify.com/enterprise/largest-b2b-marketplaces>.

²⁵² “Peer economy” or “shared economy” are other relating terms. OECD (2016), “Protecting Consumers In Peer Platform Markets: Exploring The Issues”, OECD Digital Economy Papers, No. 253, OECD Publishing, Paris, <https://doi.org/10.1787/5jlwvz39m1zw-en>.

²⁵³ DIRECTIVE 2000/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market (Directive on electronic commerce). Article 9 E-commerce directive obliged Member States to make sure that law “applicable to the contractual process neither create obstacles for the use of electronic contracts nor result in such contracts being deprived of legal effectiveness and validity on account of their having been made by electronic means”.

subset of electronic contracts that entails specificities and raises new issues, notably related to the limitation of human intervention and control.

The levels of automation in e-commerce transactions can vary on a scale, with autonomous non-deterministic AI systems marking the higher end of the scale, when deployed at different stage of the contractual process. To illustrate use-cases of automation of decision making in e-commerce contracting via automated means, we look at automated pricing used for offer generation and virtual assistants that are used for the partial automation of the contract conclusion.

Automated pricing

Although a product with a price on the digital marketplace may or may not amount to a contract offer, pricing is directly relevant to the decision-making on the contract conclusion. Algorithms are used to 'fill the gap' in a contract, which in this case is a price.²⁵⁴ In particular, this happens in cases where price is served on the take-it-or-leave-it basis.²⁵⁵ From the economic perspective, an adequate price is considered a very powerful factor in a buyer's decision-making. Pricing therefore plays a critical role, including in consumer decision-making, and the ability to effectively execute a pricing strategy remains a core factor in determining firm performance.²⁵⁶ The choice of a pricing strategy plays a central role in value creation and the effective functioning of markets.²⁵⁷ Prices can help to capture quality, value and willingness to pay.²⁵⁸ Indeed, the Boston Consulting Group²⁵⁹, famously advised its clients that: "A key step is to avoid average pricing. Pricing to specific consumer groups should reflect the true competitive value of what is being provided. When this is achieved, no money is left on the table unnecessarily on the one hand, while no opportunities are opened for competitors through inadvertent overpricing on the other. Pricing is an accurate and confident action that takes full advantage of the combination of customers' price sensitivity and alternative suppliers". Pricing is therefore both crucial and complex task.

The automation of pricing strategies came as a response to the growing amount of data reflecting market complexity on one hand and digital transformation of the markets on the other hand.²⁶⁰ The parallel developments in algorithmic analysis and decision-making facilitated more innovative

²⁵⁴ G. Alper, Contract law revisited: Algorithmic pricing and the notion of contractual fairness, *Computer Law & Security Review*, Volume 47, 2022, 105741, ISSN 0267-3649, <https://doi.org/10.1016/j.clsr.2022.105741>.

²⁵⁵ G. Alper, Contract law revisited: Algorithmic pricing and the notion of contractual fairness, *Computer Law & Security Review*, Volume 47, 2022, 105741, ISSN 0267-3649, <https://doi.org/10.1016/j.clsr.2022.105741>; L. H. Scholz, 'Algorithmic Contracts' (2017) 20 *STLR* 128, 141.

²⁵⁶ S. Dutta, M.J. Zbaracki, M. Bergen, Pricing process as a capability: A resource-based perspective *Strategic Management Journal*, 24 (7) (2003), pp. 615-630.

²⁵⁷ P. Kannan, H. Li, Digital marketing: A framework, review and research agenda *International Journal of Research in Marketing*, 34 (1) (2017), pp. 22-45, and Dutta, S., Bergen, M., Levy, D., Ritson, M. and Zbaracki, M., 2002. Pricing as a strategic capability. *MIT Sloan Management Review*, 43(3 (April 15, 2002)), pp.61-66.

²⁵⁸ W.B. Dodds, K.B. Monroe, D. Grewal, Effects of price, brand, and store information on buyers' product evaluations *Journal of Marketing Research*, 28 (3) (1991), pp. 307-319.

²⁵⁹ Varian, H.R., 1989. Price discrimination. *Handbook of Industrial Organization*, vol. 1, pp.597-654.

²⁶⁰ See for example: P. Verhoef, T. Broekhuizen, Y. Bart, A. Bhattacharya, J. Qi Dong, N. Fabian, M. Haenlein, Digital transformation: A multidisciplinary reflection and research agenda *Journal of Business Research*, 122 (2021), pp. 889-901, <https://www.scopus.com/record/display.uri?eid=2-s2.0-85070896886&origin=inward&txGid=278158d956ca083113687d69c620e7e7>.

forms of automated pricing strategies tailored for digital markets.²⁶¹ The adoption of innovative and automated pricing strategies is becoming a fundamental tool for numerous rapidly expanding companies.²⁶²

The main examples of such technology-enabled strategies are automated *dynamic pricing* and *personalised pricing*. Both strategies imply that the prices can potentially vary.²⁶³ Dynamic pricing is a strategy that allows businesses to change the price of a product or service *through time* based on supply and demand considerations.²⁶⁴ Personalised pricing is a strategy where price is custom-tailored for a user.²⁶⁵

Price differentiation is often considered unfair by consumers,²⁶⁶ in particular in a case of a frequent price that may lead to customer confusion or dissatisfaction. If customers perceive a price as unfair or inconsistent, it may have reputational consequences for a business and decrease customer

²⁶¹ D. Nunan, M.L. Di Domenico, Value creation in an algorithmic world: Towards an ethics of dynamic pricing, *Journal of Business Research*, Volume 150, 2022, Pages 451-460, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2022.06.032>.

²⁶² D. Nunan, M.L. Di Domenico, Value creation in an algorithmic world: Towards an ethics of dynamic pricing, *Journal of Business Research*, Volume 150, 2022, Pages 451-460, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2022.06.032>; Abdelnour, A., Bages-Amat, A., Moss, S., & Prabhu, M. (2021). Defying cost volatility: A strategic pricing response. McKinsey & Company: <https://www.mckinsey.com/business-functions/growth-marketing-and-sales/our-insights/defying-cost-volatility-a-strategic-pricing-response>; Castillo, J.C., Knoepfle, D. and Weyl, G., 2017, June. Surge pricing solves the wild goose chase. In Proceedings of the 2017 ACM Conference on Economics and Computation (pp. 241-242); and Guda, H. and Subramanian, U., 2019. Your uber is arriving: Managing on-demand workers through surge pricing, forecast communication, and worker incentives. *Management Science*, 65(5), pp.1995-2014.

²⁶³ Price differentiation is often used interchangeably with price discrimination, despite the two concepts not always corresponding. Indeed, differentiated prices may not necessarily be discriminatory: for example, if a pack of 6 cans of beers costs half of a pack of 12 cans, the prices are different but there is no price discrimination. If the price of the large pack is less than twice, then there are quantity discounts, a type of price discrimination.

²⁶⁴ W. Elmaghraby, P. Keskinocak, Dynamic pricing in the presence of inventory considerations: Research overview, current practices, and future directions, *Management Science*, 49 (10) (2003), pp. 1287-1309, 10.1287/mnsc.49.10.1287.17315; J. Wamsler, M. Natter, R. Algesheimer, Transitioning to dynamic prices: Should pricing authority remain with the company or be delegated to the service employees instead?, *Journal of Business Research*, Volume 139, 2022, pp. 1476-1488, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2021.10.067>; and Alderighi, M., Gaggero, A.A. and Piga, C.A., 2017. The hidden side of dynamic pricing: Evidence from the airline market. MPRA Working Paper 76977.

²⁶⁵ Personalised pricing can be described as price differentiation for identical products or services at the same time based on information a trader holds about a potential customer. See, e.g., Rott, P., Strycharz, J., and Alleweldt, F., 2022, Personalised Pricing, Publication for the Committee on Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg: [https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU\(2022\)734008_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf), and . Esteves, R.B. and Resende, J., 2019. Personalized pricing and advertising: Who are the winners?. *International Journal of Industrial Organization*, 63, pp.239-282.

²⁶⁶ See for example: Priester, A.; Robbert, T.; Roth, S., "A special price just for you: effects of personalized dynamic pricing on consumer fairness perceptions", *Journal of Revenue and Pricing Management*. 19 (2): 99–112, 2020, doi:10.1057/s41272-019-00224-3. ISSN 1476-6930. S2CID 256510198; Alderighi, M., Nava, C.R., Calabrese, M., Christille, J.M. and Salvemini, C.B., 2022. Consumer perception of price fairness and dynamic pricing: Evidence from Booking.com. *Journal of Business Research*, 145, pp.769-783; and Vulkan, N. and Shem-Tov, Y., 2015. A note on fairness and personalised pricing. *Economics Letters*, 136, pp.179-183.

loyalty.²⁶⁷ Nevertheless, price differentiation *per se* is not a negative phenomenon in a market economy.²⁶⁸

Dynamic pricing, as well as product recommendations, are widespread practices on marketplaces. Traditionally, firms dynamically adjust prices in many markets with perishable inventory. Examples range from seats on airplanes and trains, tickets for entertainment events, reservations for cruises, to inventory in retailing. In these markets, prices may adjust for a variety of reasons. First, prices reflect changing opportunity costs due to demand uncertainty—in the presence of scarcity, the cost of selling a unit of inventory today depends on a firm’s ability to sell it in the future. Second, demand may change over time in predictable ways. If consumers with high willingness to pay tend to arrive late, firms have an incentive to save inventory. Finally, in all aforementioned examples, prices may adjust in response to competitive interactions. This type of dynamic pricing based on historical data has been present since the 80’s.²⁶⁹

Price personalisation can be practiced under transparency conditions, in particular set out by the data protection laws²⁷⁰ and the Consumer Rights Directive (CRD).²⁷¹ In general terms, the fairness of price personalisation has become associated with transparency: namely, the consumers’ awareness of the way they are profiled, and how this information is used to adjust the price offers they receive.²⁷² Further, some scholars argue that GDPR enshrines the right to the impersonal price.²⁷³ Still, even if further transparency will be enforced and if consumers have the right to opt-out from profiling due the richness and complexity of online pricing, it is not clear that the competition will lead to welfare enhancing outcomes, for consumers and for the society as a whole.²⁷⁴ Indeed, from a practical perspective it is extremely difficult for outsiders, such as policy makers and researchers, to disentangle simple dynamic pricing from discriminatory price differentiation.

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- ²⁶⁷ For example, Amazon experimented with price discrimination and experienced a public backlash that led its CEO to declare the experiment was a “mistake”. CEO Jeff Bezos said “We’ve never tested and we never will test prices based on customer demographics.” The prices in the experiment were allegedly varied randomly between customers. See Ennis, S. and Lam, W., 2021. Personalised Pricing and Disclosure. BEIS Research Paper Number 2021/008.
- ²⁶⁸ See for example: S. K. Layson, Market Opening under Third-Degree Price Discrimination, *Journal of Industrial Economics*, Vol. 42, No. 3, 1994, pp. 335-340, <https://doi.org/10.2307/2950575>. Indeed, until recently economists and policy makers maintained that in presence of competition personalised pricing would make competition more intense, see, e.g., Thisse, J.F. and Vives, X., 1988. On the strategic choice of spatial price policy. *The American Economic Review*, pp.122-137 and Rhodes, A. and Zhou, J., 2022. Personalized pricing and competition. SSRN Working Paper 4103763. For an overview see, for example: OECD, Price discrimination, DAF/COMP(2016)15: [https://one.oecd.org/document/DAF/COMP\(2016\)15/en/pdf](https://one.oecd.org/document/DAF/COMP(2016)15/en/pdf) and Bourreau, M. and De Streel, A., 2018. The regulation of personalised pricing in the digital era.
- ²⁶⁹ J. M. Betancourt, A. Hortaçsu, A. Oery & K. R. Williams, *Dynamic Price Competition: Theory and Evidence from Airline Markets*, National Bureau of Economic Research, Working Paper 30347, DOI 10.3386/w30347, 2022.
- ²⁷⁰ R. Steppe, Online price discrimination and personal data: A General Data Protection Regulation perspective, *Computer Law & Security Review*, Volume 33, Issue 6, 2017, Pages 768-785, ISSN 0267-3649, <https://doi.org/10.1016/j.clsr.2017.05.008>.
- ²⁷¹ For the current legal framework applicable to personalised pricing see for example: Rott, P., Strycharz, J., and Alleweldt, F., 2022, Personalised Pricing, Publication for the Committee on Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg, [https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU\(2022\)734008_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf).
- ²⁷² See for example: M. Hildebrandt, Profiling and the rule of law, *IDIS*, 2008, 1:55–70, doi: 10.1007/s12394-008-0003-1, <https://link.springer.com/article/10.1007/s12394-008-0003-1>.
- ²⁷³ F. Esposito, The GDPR enshrines the right to the impersonal price, *Computer Law & Security Review*, Volume 45, 2022, 105660, ISSN 0267-3649, <https://doi.org/10.1016/j.clsr.2022.105660>.
- ²⁷⁴ See See Byungwan Koh; Sirinivasan Raghunathan; Barry R. Nault, ‘Is voluntary profiling welfare enhancing?’, *41 MIS Quarterly* 23, 2017.

Moreover, platforms must clearly indicate the use of such practices prior to the purchase, and consumers must also be informed about the ways their personal information affects prices. For example, in 2022, after the Netherlands Authority for Consumers and Markets (ACM) had presented the transparency conditions to online platform Wish, it decided to stop using personalised pricing.²⁷⁵

Algorithms enable both dynamic pricing and price personalisation on marketplaces. For example, there are professional companies specialised in providing information technology solutions to less technically capable market players in the platform ecosystem. These tools can be employed for monitoring rivals' prices and implementing optimal, best-response type of pricing strategies. One of these price tracking tools providers, BlackCurve, states “[p]rice tracking tools, such as BlackCurve, are commonly adopted where an online retailer has hundreds and even thousands of products. Price tracking tools will automatically find competitor matches for your products on the web, as well as automatically collect competitor prices each and every day, in order to provide competitor pricing insights.” The same company also provides tools for implementing pricing strategy, which “sets the objective of pricing decisions for an e-commerce company and how price changes will be implemented.”²⁷⁶

The off-the-shelf availability of this solution suggests that many companies populating the marketplace track and dynamically adjust prices almost in instant time on marketplace sites like Amazon or eBay. There is indeed evidence that in nowadays online markets, firms' interactions often happen within milliseconds. Both large and small e-commerce players monitor each other's website many times a day and can adjust their price almost instantly.²⁷⁷ This has led a number of researchers to identify algorithmic patterns in the dynamic pricing of firms operating on Amazon or similar sites.²⁷⁸

Algorithmic automation can potentially enable forms of price personalisation based on the characteristics of individual consumers and their behaviour.²⁷⁹ Algorithmic price personalisation

²⁷⁵ ACM, 2022, Following ACM actions, Wish bans fake discounts and blocks personalised pricing: <https://www.acm.nl/en/publications/following-acm-actions-wish-bans-fake-discounts-and-blocks-personalized-pricing>. Wish, a major American platform that sells items online to consumers in several European countries, and other regions, was applying price personalisation based on consumers purchasing behaviour and location, among other factors. The platform informed the public in an investor brochure that they use price personalisation in the US, but this practice was not clearly disclosed on the website to consumers.

²⁷⁶ See: <https://www.blackcurve.com/competitor-price-monitoring>.

²⁷⁷ Autoridade da Concorrência (2019). Digital ecosystems, Big Data and Algorithms; and Dastin J., 2017. Amazon trounces rivals in battle of the shopping `bots' www.reuters.com/article/us-amazon-com-bots-insight/amazon-trounces-rivals-in-battle-of-the-shopping-bots-idUSKBN1860FK

²⁷⁸ See, for example, Brown, Z.Y. and MacKay, A., 2023. Competition in pricing algorithms. *American Economic Journal: Microeconomics*, 15(2), pp.109-156; and Wieting, M. and Sapi, G. (2021). Algorithms in the Marketplace: An Empirical Analysis of Automated Pricing in E-Commerce. NET Institute Working Paper No. 21-06.

²⁷⁹ A European Parliament study recognises that price personalisation can take different forms: first-degree personalisation (based on personal characteristics of individual consumers), second-degree price personalisation (based on the quantity of products, e.g. when several bottles are sold in one package) and third-degree personalisation (based on membership in a market segment or consumer group, e.g. student rebate): Rott, P., Strycharz, J., and Alleweldt, F., 2022, Personalised Pricing, Publication for the Committee on Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg: [https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU\(2022\)734008_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf). See also Poort, J., and Zuiderveen Borgesius, F., 2019, Does everyone have a price? Understanding people's attitude towards online and offline price discrimination, Internet Policy Review 8. Available at: <https://policyreview.info/articles/analysis/does-everyone-have-priceunderstanding-peoples-attitude-towards-online-and-offline>.

typically operates in the following manner: an online store identifies a customer, often through methods such as cookies, IP addresses, or user login data. This distinct identification is usually not the ultimate objective but serves the purpose of enabling the retailer to either estimate the customer's willingness to pay for a specific product or to differentiate between broader categories, such as high-spending and low-spending consumers.²⁸⁰

When it comes to the foundation of decisions regarding personalised pricing, consumer data plays a pivotal role. A condition for personalisation is the retailer's ability to differentiate between customers, based on different data such as demographic information, information on consumers' device and location, their interests and preferences, services used, social networks and behaviour²⁸¹ allowing to determine the appropriate pricing for each consumer. Subsequently, a custom-tailored price offer can be shown to the consumer.

AI in pricing

The largest retail companies have been using AI and machine-learning approaches²⁸² to forecast demand and set prices for years.²⁸³ The beginning of the use of AI systems in e-commerce may be associated with the use of AI in sale forecasting models,²⁸⁴ which were employed to predict demand and subsequently adjust pricing. One of the first successful applications of AI in e-commerce, can be traced back to 1998, when Amazon and Netflix started to use recommender systems to suggest products or movies to their customers, based on their preferences and behaviour.²⁸⁵ In 2014, Amazon patented a predictive stocking tool that anticipated shipping before the purchase was actually completed. The "anticipatory shipping" is a method to start delivering packages even before customers click "buy."²⁸⁶

As stated in Section 9.3.2. AI systems used, the use of machine learning techniques and high computational power made possible to base sale forecasting models on large amounts or heterogeneous data collected through the years of the functioning of platforms. The retrieval of business knowledge from big data was enabled by machine learning. The forecasting models, which

²⁸⁰ Rott, P., Strycharz, J., and Alleweldt, F., 2022, Personalised Pricing, Publication for the Committee on Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg:

[https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU\(2022\)734008_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf).

²⁸¹ Searby, S., Personalisation — an overview of its use and potential, BT Technology Journal 21, 2003.

²⁸² Artificial intelligence techniques used for sale forecasting include: expert systems, fuzzy systems and neural network models such as feed-forward neural networks (FFNN), convolutional neural networks, recurrent neural networks (RNN) and long short-term memory (LSTM), and hybrid models (Z.X. Guo, W.K. Wong, M. Li, A multivariate intelligent decision-making model for retail sales forecasting Decis. Support Syst., 55 (1) (2013), pp. 247-255; Y. Li, Y. Yang, K. Zhu, J. Zhang, Clothing sale forecasting by a composite GRU–prophet model with an attention mechanism, IEEE Trans. Ind. Inf., 17 (12) (2021), pp. 8335-8344.

²⁸³ Amit Sharma, How Predictive AI Will Change Shopping, Harvard Business Review, 2016, [How Predictive AI Will Change Shopping \(hbr.org\)](#).

²⁸⁴ L. Dong, H. Zheng, L. Li, L. Hao, Human-machine hybrid prediction market: A promising sales forecasting solution for E-commerce enterprises, Electronic Commerce Research and Applications, Volume 56, 2022, 101216, <https://doi.org/10.1016/j.eierap.2022.101216>.

²⁸⁵ R. Fedorko, Š. Král and R. Bačík, Artificial Intelligence in E-commerce: A Literature Review, Proceedings of CIS vol. 2, 2021.

²⁸⁶ G. Bensinger, Amazon Wants to Ship Your Package Before You Buy It, The Wall Street Journal, 2014, [Amazon Wants to Ship Your Package Before You Buy It - WSJ](#). For an economic analysis, see: Agrawal, A., Gans, J. and Goldfarb, A., 2018. Prediction machines: the simple economics of artificial intelligence. Harvard Business Press.

were not based on machine learning, but were linear statistical models, could not capture features commonly occurring in many actual time-series data, such as nonlinear patterns, asymmetric cycles and occasional outlying.²⁸⁷ Unlike classical linear statistical models, AI methods usually perform well in cases where data that have large fluctuations is influenced by many factors.²⁸⁸

Applications of machine learning approaches are particularly suitable for dynamic pricing²⁸⁹ and price personalisation.²⁹⁰ ML allowed for real-time dynamic pricing and inclusion of more types of data, potentially allowing for more advanced personalisation. While dynamic pricing and personalised pricing strategies differ, they are already often integrated within one tool. There are dynamic pricing tools on the market that suggest the possibility of implementing a personalised pricing strategy.²⁹¹ In fact, these tools can assist companies to implement a wealth of strategies in pricing. Indeed, pricing tools can, to a more or less extent, be customised to the needs of the business user. They are customisable in the sense that businesses can use them to implement different kinds of pricing strategies, alter their strategies through time, use different degrees of automation, and in that users may also be able to integrate their own data into the tool.²⁹² To an extent, the availability and great selection of pricing tools on the market has somewhat shifted the managerial focus from the actual human manager-driven price discovery process to the choice of an algorithm to which to delegate it.²⁹³

We now turn to specific examples of large platforms enabling a marketplace in which pricing is to a large extent automated through Machine Learning algorithms.

Amazon

Selling on Amazon offers access to a consumer base that is interested in buying. One can sell on the Amazon marketplace via a “seller” channel or via a “vendor” channel.²⁹⁴ Amazon Seller Central (henceforth, ASC) is for sellers that want to sell directly to consumers. Amazon’s Vendor Central (henceforth, AVC) is for manufacturers or distributors to sell their products to Amazon, and then Amazon will offer its products on the platform. The manufacturer takes care of selling to Amazon

²⁸⁷ L. Dong, H. Zheng, L. Li, L. Hao, Human-machine hybrid prediction market: A promising sales forecasting solution for E-commerce enterprises, *Electronic Commerce Research and Applications*, Volume 56, 2022, 101216, <https://doi.org/10.1016/j.elerap.2022.101216>.

²⁸⁸ L. Dong, H. Zheng, L. Li, L. Hao, Human-machine hybrid prediction market: A promising sales forecasting solution for E-commerce enterprises, *Electronic Commerce Research and Applications*, Volume 56, 2022, 101216, <https://doi.org/10.1016/j.elerap.2022.101216>; T. Van Calster, B. Baesens, W. Lemahieu, ProfARIMA: A profit-driven order identification algorithm for ARIMA models in sales forecasting, *Appl. Soft Comput.*, 60, 2017, pp. 775-785.

²⁸⁹ See, e.g., Wieting, M. and Sapi, G., Algorithms in the Marketplace: An Empirical Analysis of Automated Pricing in E-Commerce. NET Institute Working Paper No. 21-06.

²⁹⁰ Amit Sharma, How Predictive AI Will Change Shopping, *Harvard Business Review*, 2016, [How Predictive AI Will Change Shopping \(hbr.org\)](https://hbr.org/2016/06/how-predictive-ai-will-change-shopping)

²⁹¹ See for example: <https://senkrondata.com/dynamic-pricing/>, stating that “Dynamic pricing can also help businesses improve customer satisfaction by offering personalized pricing options and more flexible pricing structures.”

²⁹² See, for example: https://www.wiser.com/price-optimization/?_bt=561180606842&_bk=dynamic%20pricing%20strategy&_bm=p&_bn=q&_bg=133358914967&_qclid=Cj0KCQjwpc-oBhCGARIsAH6ote8ONqO6jCLb0k7q4BAqrRZw1lqmiZLrsk70TtYIVuuMZ3M-cSo7Rz8aAkaqEALw_wcB; <https://pros.com/products/price-optimization-software/>;

²⁹³ D. Nunan, M.L. Di Domenico, Value creation in an algorithmic world: Towards an ethics of dynamic pricing, *Journal of Business Research*, Volume 150, 2022, Pages 451-460, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2022.06.032>.

²⁹⁴ <https://b2marketplace.com/resources/amazon-seller-and-vendor-central/>.

and getting its products to the logistics centre, while Amazon handles the rest of the process, including pricing and selling on the platform.²⁹⁵ In case of ASC, Amazon platform functions as a marketplace for the sellers. The products sold on Amazon are either sold by the third parties or by Amazon itself.²⁹⁶

In ASC sellers have control over pricing. In AVC Amazon has control over pricing to end consumers (subject to applicable ToS). Amazon also uses its own most advanced algorithms, including based on AI, to recommend products and to show the most relevant product searches from both channels to the consumers.²⁹⁷

Amazon sellers can choose to use tools available as a function on Amazon platform or a third-party pricing tool. Amazon offers to its sellers an advanced tool that automates pricing but is not based on AI.²⁹⁸ It also offers Amazon Personalize, a machine learning-powered tool that can be customised and used on other platforms or by a seller on Amazon platform.²⁹⁹ While Amazon Personalize and Amazon marketplace are designed to work independently, they can be integrated to provide a more personalised shopping experience for customers on the Amazon marketplace or any other e-commerce platform.³⁰⁰

As for the third-party services and tools that can be integrated into Amazon, the search in Google for “Amazon repricer/repricing” returns very large amount of the results. There are developers that develop automated pricing tools without AI, with AI, tools ready to use and tools that can be customised according to the level of user’s expertise. Tools can be developed specifically for Amazon or be compatible with multiple platform marketplaces.³⁰¹

Airbnb

Airbnb uses AI to suggest optimal prices to hosts³⁰² based on factors such as location, seasonality, amenities, etc. Airbnb also allows hosts to set their own prices or use other pricing tools. Like in case of Amazon, there are many third-party tools available for the hosts to use in their pricing strategy. The tools usually support hosts in pricing strategy (decision-making support), but hosts may also choose to automate pricing fully, i.e. rely on the tools for the price display to the customer.

²⁹⁵ To see how the selling format affects pricing and return of products under consumer fairness rules, see for example: Ying Zhao, Zhi-min Guan, Jun Zhang, Return freight strategies and selling formats in e-commerce supply chain: The perspective of consumer fairness concerns and online shopping returns, *Journal of Retailing and Consumer Services*, Volume 75, 2023, 103493, <https://doi.org/10.1016/j.jretconser.2023.103493>.

²⁹⁶ The fact that Amazon competes on its own marketplace against other sellers raises the questions of market power, and unfair competition. On recent developments see: Reuters: Amazon faces landmark monopoly lawsuit by FTC: <https://www.reuters.com/technology/us-sues-amazoncom-breaking-antitrust-law-harming-consumers-2023-09-26/>.

²⁹⁷ See for example: [How Amazon Uses AI in eCommerce – Two Use-Cases | Emerj Artificial Intelligence Research](#); <https://jaydevs.com/how-amazon-uses-ai-in-ecommerce-and-retail/>; [Here's How AI Powers Amazon's Success | Industrial Distribution \(inndist.com\)](#).

²⁹⁸ Amazon: <https://sell.amazon.com/tools/automate-pricing>.

²⁹⁹ <https://aws.amazon.com/personalize/>.

³⁰⁰ Amazon: <https://sell.amazon.com/tools/automate-pricing>.

³⁰¹ See for example one of the many rankings of the pricing tools: <https://ecombalance.com/amazon-repricer-2/>.

³⁰² For the definition and types of hosts, see here: <https://www.airbnb.com/help/article/1536>.

Adoption/impacts

Dynamic pricing seems to be no longer a niche strategy and it has a prospect to grow. A global survey by Bain & Company of 1,700 business leaders found that 85% of company management believe they need to make better pricing decisions. However, only 15% of companies have effective tools and dashboards in place to monitor prices.³⁰³

A large-scale global survey, conducted by the Massachusetts Institute of Technology (MIT) and the BCG Henderson Institute (BHI), revealed how successful AI-driven pricing transformations can be, and also how infrequently they are pursued. In the technology sector, for example, only 12% of the companies surveyed used AI to improve their pricing, but their initiatives succeeded twice as often as the efforts of companies that applied AI to other functional areas.³⁰⁴

Virtual assistants

VAs are used across many sectors, including for example healthcare³⁰⁵ and automotive sectors³⁰⁶ as well as for social interactions³⁰⁷. After considerations on more general and horizontal issues linked to VAs, this section focuses on the use of VAs in e-commerce, without exploring other sectors' specificities relevant for the use of VAs.

Virtual assistant is an umbrella term to describe technology that helps to process various tasks and can be used across different sectors. Within the EU acquis, the Digital Markets Act (DMA)³⁰⁸ and the Data Act³⁰⁹ define 'virtual assistant'. The latest definition under the Data Act, Article 2(31) defines it as 'software that can process demands, tasks or questions including those based on audio, written input, gestures or motions, and that, based on those demands, tasks or questions, provides access to other services or controls the functions of connected products.'³¹⁰ In such understanding the

³⁰³ SkyScanner: <https://www.skyscanner.net/terms-of-service>.

³⁰⁴ BCG, [AI Pricing Transformations | BCG](#).

³⁰⁵ Janice L. Krieger, Jordan M. Neil, Kyle A. Duke, Mohan S. Zalake, Fatemeh Tavassoli, Melissa J. Vilaro, Danyell S. Wilson-Howard, Sarah Y. Chavez, Eric B. Laber, Marie Davidian, Thomas J. George, François P. Modave, Folakemi T. Odedina, Benjamin C. Lok, A Pilot Study Examining the Efficacy of Delivering Colorectal Cancer Screening Messages via Virtual Health Assistants, *American Journal of Preventive Medicine*, Volume 61, Issue 2, 2021, Pages 251-255, ISSN 0749-3797, <https://doi.org/10.1016/j.amepre.2021.01.014>, (<https://www.sciencedirect.com/science/article/pii/S0749379721001136>).

³⁰⁶ Jediah R. Clark, David R. Large, Emily Shaw, Elena Nichele, Maria J. Galvez Trigo, Joel E. Fischer, Gary Burnett, Neville A. Stanton, Identifying interaction types and functionality for automated vehicle virtual assistants: An exploratory study using speech acts cluster analysis, *Applied Ergonomics*, Volume 114, 2024, 104152, ISSN 0003-6870, <https://doi.org/10.1016/j.apergo.2023.104152>, (<https://www.sciencedirect.com/science/article/pii/S0003687023001904>).

³⁰⁷ Rebecca Wald, Jessica T. Piotrowski, Theo Araujo, Johanna M.F. van Oosten, Virtual assistants in the family home. Understanding parents' motivations to use virtual assistants with their Child(dren), *Computers in Human Behavior*, Volume 139, 2023, 107526, ISSN 0747-5632, <https://doi.org/10.1016/j.chb.2022.107526>, (<https://www.sciencedirect.com/science/article/pii/S0747563222003466>).

³⁰⁸ REGULATION (EU) 2022/1925 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2022 on contestable and fair markets in the digital sector and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Act).

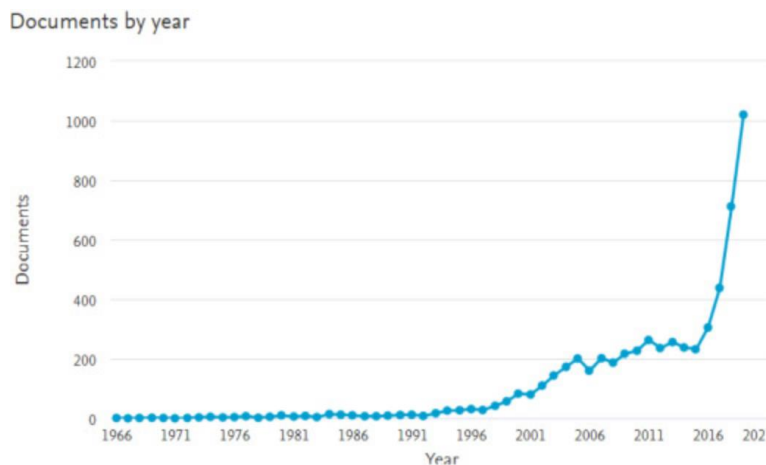
³⁰⁹ COM(2022) 68 final, Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on harmonised rules on fair access to and use of data (Data Act).

³¹⁰ Article 2(12) DMA. 'Virtual assistant' has also a different meaning in the context of job market, where it refers to a person who works as an assistant *online* (see for example: <https://sg.indeed.com/career-advice/finding-a-job/personal-assistant-vs-virtual-assistant>).

virtual assistant' is also used interchangeably with 'digital assistant'.³¹¹ As such, VA can be embedded in a physical product that is not native for the digital ecosystem (for example a smart fridge, a watch, a speaker) or run on a computer or mobile in the form of application or be integral to the operating system.

VAs can be approached as a type of interface that facilitates different ways to access a service. There are VAs based on written input, audio and visual, as well as VAs that can process input from the sensors. Text chatbots, where the interaction is via written input, are the oldest type of VAs.³¹² Along with the technological progress in AI techniques, they evolved from simple rule-based chatbots to chatbots that handle human way of conversation, which in turn, accelerated their adoption. Voice assistants or voice chatbots are examples of VAs based on audio input. They are technical solutions that, apart from handling conversations (as in case of text-based chatbots), include voice recognition technologies. An example of such an assistant is Amazon's Alexa. In general, both types of chatbots, text-based and voice-based, saw a steep rise in adoption since 2016. The developments in machine learning techniques facilitated faster adoption of chatbots and increased scholar interest in them.³¹³

Figure 14: Scholar interest in chatbots



Source: Adamopoulou and Moussiades (2020).

There are also assistants based on visual input. For example, in health sector there are solutions that support diagnosis based on the RTG scans. There are also VAs that can generate input themselves based on the sensors provided. For example, a prototype of a smart fridge includes installation of visual sensors capable to recognise food inside the fridge. As explained in the relevant sections below, developers already work on the possibility to use such input generated by

³¹¹ See for example: <https://whatfix.com/blog/digital-assistant/>.

³¹² Eleni Adamopoulou, Lefteris Moussiades, Chatbots: History, technology, and applications, Machine Learning with Applications, Volume 2, 2020, 100006, ISSN 2666-8270, <https://doi.org/10.1016/j.mlwa.2020.100006>, (<https://www.sciencedirect.com/science/article/pii/S2666827020300062>).

³¹³ Eleni Adamopoulou, Lefteris Moussiades, Chatbots: History, technology, and applications, Machine Learning with Applications, Volume 2, 2020, 100006, ISSN 2666-8270, <https://doi.org/10.1016/j.mlwa.2020.100006>, (<https://www.sciencedirect.com/science/article/pii/S2666827020300062>).

sensors automatically. The input from the sensors can subsequently be used to make a buying decision and potentially conclude a contract with a seller in fully automated way, i.e. without buyer's intervention in the form of a purchase validation, for example. In fact, many VAs can process more than one type of input, depending on the task. For example, doctor assistants can process text, photos, voice and input from the sensors. Driving assistants can rely on the car sensors as well as voice commands.

VAs tend to operate within the so called "knowledge domain" i.e. type of data to which a VA has access.³¹⁴ There are shopping assistants, travel assistants, health assistants, driving assistants, doctor and health assistants, recruitment assistants and so on. Within every domain, VAs can be used to perform different tasks. They can be used to either engage in a conversation relating to the knowledge domain, support humans in their decision or automate actions performed by humans within a specific domain. VAs that automate specific human actions, such as booking a room in a hotel, or making reservation in a restaurant, rely on the connection to other services, including platforms, booking systems, emails or telecommunication infrastructures. Widely understood interoperability between VAs and other services are crucial for the action-oriented VAs. Some of the actions performed by VAs may include automation of buying and selling processes that amount to contracting. For example, the use of a travel assistant includes searching for a flight and could include the actual booking of a flight. Similarly, a shopping assistant, after finding a desired item, could automatically proceed to buying stage, however currently it looks like all the purchases require user's confirmation.³¹⁵ The booking of a flight and buying an item online fall under contracting and involve automation of various processes such as decision-making on whether to buy or not and subsequent execution of a contract (if concluded) in the form of processing a payment, sending a ticket or delivering a purchased item. VAs can automate all these processes, given that access to other services is enabled.

Virtual assistants in e-commerce

Out of the all the VAs, chatbots are most broadly adopted in e-commerce. Chatbots are systems designed to communicate with human users and provide real-time customer services.³¹⁶ They can simulate human interaction through text chats or voice commands³¹⁷, and customers can communicate with chatbots to obtain information (e.g., product details) or assistance (e.g., solving technical problems, performing actions).³¹⁸

³¹⁴ Eleni Adamopoulou, Lefteris Moussiades, Chatbots: History, technology, and applications, Machine Learning with Applications, Volume 2, 2020, 100006, ISSN 2666-8270, <https://doi.org/10.1016/j.mlwa.2020.100006>, (<https://www.sciencedirect.com/science/article/pii/S2666827020300062>).

³¹⁵ In case of Alexa, however, there is a mixed message on if it can conclude contracts in fully automated mode. See the section on Alexa.

³¹⁶ R.M. Schuetzler, G.M. Grimes, J. Scott Giboney, The impact of chatbot conversational skill on engagement and perceived humanness, J. Manag. Inf. Syst., 37 (2020), pp. 875-900; M. Adam, M. Wessel, A. Benlian, AI-based chatbots in customer service and their effects on user compliance Electron. Mark., 31 (2021), pp. 427-445, 10.1007/s12525-020-00414-7.

³¹⁷ X. Luo, S. Tong, Z. Fang, Z. Qu, Frontiers: machines vs. Humans: the impact of artificial intelligence chatbot disclosure on customer purchases Mark. Sci. mksc.2019, 1192 (2019).

³¹⁸ M. Adam, M. Wessel, A. Benlian, AI-based chatbots in customer service and their effects on user compliance, Electron. Mark., 31 (2021), pp. 427-445; M. Song, X. Xing, Y. Duan, J. Cohen, J. Mou, Will artificial intelligence replace human customer service? The impact of communication quality and privacy risks on adoption intention, J. Retailing Consum. Serv., 66 (2022), Article 102900.

The chatbots in e-commerce are also referred to as ‘shopping assistants’, ‘personal shopping assistants’, ‘voice shopping assistants.’ They have started being used by marketplaces and online shops to improve consumer experience.³¹⁹ In general, their role is to answer questions that buyers would ask shop attendants in a brick-and-mortar markets. VAs facilitate single access point to the information relevant to the buying transaction, which is potentially very convenient for the consumers.

Apart from providing information, an increasing number of VAs used in e-commerce also include action-oriented tasks. They do not only provide information to a buyer but also make personalised offers, compare offers depending on a user’s profile, add items to a shopping cart, and monitor tracking and delivery services. Only, in case of Amazon’s Alexa, we came across the contract conclusion by VA without user’s confirmation, if specific conditions are met.³²⁰

With the adoption of AI techniques, we observed a steep rise in the use of VAs in online shopping. First shopping assistants in e-commerce used to come in the form of a simple rule-based text chatbots, which consumers found awkward. With the development of machine learning techniques, the conversation between a potential buyer and a VA started resembling a human-to-human conversation. Chatbots use Natural Language Processing (NLP) and sentiment analysis to communicate in human language by text or oral speech with humans or other chatbots.³²¹ The possibility to have a human-like conversation increases trust in chatbots.³²² Higher trust in chatbots drives wider adoption of chatbots by sellers and their subsequent use by buyers.³²³ We see that the use of AI in chatbots has become so prevalent that sometimes it is even reflected on the level of definition. For example, Bansal & Khan (2018) define a chatbot as “an artificial intelligence program and a Human–computer Interaction (HCI) model.”³²⁴

The development of AI in chatbots went another step further with the creation of voice assistants. Voice shopping assistants are gaining in popularity due to the convenience of hands-free

³¹⁹ Cuicui Wang, Yiyang Li, Weizhong Fu, Jia Jin, Whether to trust chatbots: Applying the event-related approach to understand consumers’ emotional experiences in interactions with chatbots in e-commerce, *Journal of Retailing and Consumer Services*, Volume 73, 2023, 103325, ISSN 0969-6989, <https://doi.org/10.1016/j.jretconser.2023.103325>, (<https://www.sciencedirect.com/science/article/pii/S0969698923000723>).

³²⁰ Amazon: <https://www.aboutamazon.com/news/devices/try-these-new-convenient-ways-to-shop-with-alexa#:~:text=Just%20say%2C%20%E2%80%9CAlexa%2C%20buy,are%20the%20newest%20Alexa%20features%3F>. See also the case of Alexa below.

³²¹ Khanna A., Pandey B., Vashishta K., Kalia K., Bhale P., Das T., A study of today’s A.I. through chatbots and rediscovery of machine intelligence *International Journal of U- and e-Service, Science and Technology*, 8 (2015), pp. 277-284.

³²² Go E., Sundar S.S., Humanizing chatbots: The effects of visual, identity and conversational cues on humanness perceptions, *Computers in Human Behavior*, 97 (2019), pp. 304-316 (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85064447508&origin=inward&txGid=d2780cfdc2fba4ef576938988867c3c>) ; Wallace R.S., The anatomy of A.L.C.E., in Epstein R., Roberts G., Beber G. (Eds.), *Parsing the turing test: philosophical and methodological issues in the quest for the thinking computer*, Springer Netherlands, Dordrecht (2009), pp. 181-210.; Go E., Sundar S.S., Humanizing chatbots: The effects of visual, identity and conversational cues on humanness perceptions, *Computers in Human Behavior*, 97 (2019), pp. 304-316 (<https://www.scopus.com/record/display.uri?eid=2-s2.0-85064447508&origin=inward&txGid=d2780cfdc2fba4ef576938988867c3c>) ; Wallace R.S., The anatomy of A.L.C.E., in Epstein R., Roberts G., Beber G. (Eds.), *Parsing the turing test: philosophical and methodological issues in the quest for the thinking computer*, Springer Netherlands, Dordrecht (2009), pp. 181-210.

³²³ T.M. Brill, L. Munoz, R.J. Miller, Siri, Alexa, and other digital assistants: a study of customer satisfaction with artificial intelligence applications, *J. Market. Manag.*, 35 (15–16) (2019), pp. 1401-1436.

³²⁴ Bansal H., Khan R., A review paper on human computer interaction, *International Journal of Advanced Research in Computer Science and Software Engineering*, 8 (53) (2018).

commanding with voice. The most popular voice shopping assistants are Amazon Alexa and Google Assistant, on which we have a closer look.

Alexa

Alexa is an AI-powered virtual assistant developed by Amazon. It can assist users not only in pre-purchase phase but also add items to the shopping cart, place orders, and execute them via voice command. It provides order tracking information, facilitates communication between the buyer and the seller, and ensures delivery processes. It can also notify users about the status of their orders, estimated delivery times, and handle any necessary follow-up interactions.

The tasks Alexa can perform are called skills. Alexa Skills are voice-activated apps or extensions that enhance the capabilities of Alexa. They are developed by Amazon as well as by individual and business software developers in order to make them available to the general public via Alexa Skills Store.³²⁵ These Skills can be developed using cloud-based Alexa Skills Kit.³²⁶ The kit is primarily a set of tools, APIs, and services provided by Amazon for developers to create and manage Alexa Skills.

Alexa's capability to make voice-enabled buying transactions, often referred to as "voice purchasing," is an AI-based feature developed by Amazon and is integrated into the core functionality of Alexa. It is not a separate third-party Alexa Skill. Amazon introduced this feature to enable users to make purchases from the Amazon platform. It is integrated with basic Alexa and does not require any additional third-party Skills to buy on Amazon. However, Amazon also allows third-party retailers and businesses to develop Alexa Skills that integrate with their websites or services to facilitate shopping on their websites. For example Domino's Pizza allowed users to place pizza orders and track their deliveries via Alexa.³²⁷ Starbucks has integrated Alexa, enabling users to buy and check their Starbucks Card balance.³²⁸ Ticketmaster developed an Alexa Skill that allows users to discover and purchase event tickets.³²⁹ Third-party retailers interested in using Amazon Alexa to enable voice-based shopping are typically required to enter into a developer agreement with Amazon, agree to specific technical arrangements and certification processes. If the skill involves transactions, such as e-commerce or payment processing, there may be additional legal and technical requirements to ensure secure and compliant transactions. This often involves integrating with Amazon Pay (Amazon's payment processing service).³³⁰

Alexa can also be integrated into various physical products.³³¹ Alexa-enabled devices include speakers, displays, smartphones, tablets, headphones, earbuds, smart home devices, kitchen appliances, car systems, smart watches, smart plugs, etc. Alexa-enabled devices include Amazon products (for example Amazon Echo Devices) or can be developed by third parties. There will be

³²⁵ Amazon: [Amazon.es: Alexa Skills](https://www.amazon.es/Alexa-Skills).

³²⁶ Amazon: <https://developer.amazon.com/en-US/alexa/alexa-skills-kit>.

³²⁷ Amazon: <https://www.amazon.com/Dominos-Pizza-LLC/dp/B01B5G99CC>.

³²⁸ Starbucks: <https://stories.starbucks.com/press/2017/starbucks-debuts-voice-ordering/>.

³²⁹ Amazon: <https://www.amazon.com/Ticketmaster-L-L-C/dp/B07BFHJC6W>.

³³⁰ The third party retailers that have enabled Alexa are for example: Domino's Pizza allowed users to place pizza orders and track their deliveries via Alexa (<https://www.amazon.com/Dominos-Pizza-LLC/dp/B01B5G99CC>); Starbucks had integrated with Alexa, enabling users to order a coffee and check their Starbucks Card balance (<https://stories.starbucks.com/press/2017/starbucks-debuts-voice-ordering/>); Ticketmaster had an Alexa Skill that allowed users to discover and purchase event tickets (<https://www.amazon.com/Ticketmaster-L-L-C/dp/B07BFHJC6W>).

³³¹ See for example: <https://www.tomsguide.com/best-picks/best-alexa-compatible-devices>.

relevant legal arrangements between Amazon and third-party manufacturer of the Alexa-enabled non-Amazon device. These arrangements typically cover licensing conditions, as well as arrangements on technical integration, compliance with Amazon guidelines for manufacturers, certification, marketing and branding.³³²

In order to buy an item with Alexa the device needs to be prompted to do so. For example, a user can say: “Alexa, buy [item name] for me.” Next, Alexa will provide details about the product, including its name and price, and ask the user to confirm the purchase. The user needs to verbally confirm the order. Subsequently Alexa will make a purchase. Alexa will use the default payment and delivery address from the user’s Amazon account to make the purchase. A user can ask Alexa to track the order status and estimate delivery.³³³ Alexa comes, with build in features, like voice recognition, to prevent unwanted Alexa voice purchasing, for example by kids or television. The user can cancel a purchase made through Alexa, according to a general cancellation policy.³³⁴

Amazon.com also informs its users about Alexa’s feature to send deal notification. It reads that Alexa can proactively notify a user up to 24 hours in advance of a deal becoming available for an eligible item on user’s wish list, shopping cart, or saved for later. Upon enabling the feature, a user can choose between getting a notification or, with user’s permission, Alexa can even order the item on behalf of a user when the deal is available. Alexa will use the default payment and delivery address in user’s Amazon account to make the purchase. The feature is advertised as helping user to make sure they never miss a great deal.³³⁵ We see that the product and conditions for a deal need to be specified by a user. The decision of Alexa in case of this feature seems to be primarily based on instructions (as opposed to based on the learning output), yet the level of instructions needed by Alexa to conclude a transaction is not clear. For this reason, the conclusion of a contract by Alexa can surely be classified as fully automated decision but it is difficult to consider it autonomus.

Google Assistant (GA) is another AI-powered virtual assistant available on various devices. Similar to Alexa, it can provide product recommendations, search for specific items, and help users complete purchases using natural language interactions.³³⁶ GA is available on a wide range of devices, including smartphones, smart speakers (such as Google Home), smart displays, and wearables. It is integrated into the Android operating system and is accessible through the Apple App Store as an application to download on iOS devices.³³⁷ Google provides developer tools and APIs for creating Actions on Google, which are voice-powered applications and services that extend Google Assistant’s capabilities.³³⁸

While it supports shopping and product searches, GA seems to be less retail-focused than Alexa. But, on the other hand, it seems that GA is intended to be interoperable with wider range of

³³² See: <https://developer.amazon.com/en-US/alexa/devices>.

³³³ CNET: [Alexa Shopping and Voice Purchasing: A Step-by-Step Guide - CNET](#).

³³⁴ Amazon: <https://www.amazon.com/gp/help/customer/display.html?nodeId=GSL37WQTJZUYA9QE>.

³³⁵ Amazon: <https://www.aboutamazon.com/news/devices/try-these-new-convenient-ways-to-shop-with-alexa#:~:text=Just%20say%2C%20%E2%80%9CAlexa%2C%20buy,are%20the%20newest%20Alexa%20features%3F>.

³³⁶ Google: <https://support.google.com/assistant/answer/7540988?hl=en>.

³³⁷ Google: <https://support.google.com/assistant/answer/7172657?hl=en&co=GENIE.Platform%3DiOS>; Apple: <https://apps.apple.com/us/app/google-assistant/id1220976145?ls=1>.

³³⁸ Google: <https://developers.google.com/assistant>.

retailers. Google partners with various retailers and brands to enable voice-based shopping experiences. Users can shop from partner retailers, such as Walmart, Target, and others, through GA. Retailers are not necessarily required to develop custom GA capabilities ('Actions' on Google) before users can shop with GA across multiple retail shops. GA offers a range of shopping capabilities, including integrations with various retailers and brands, that can be used by users without retailers developing custom Actions. Similarly to Alexa, Google Assistant can provide product details and ask the user to confirm the purchase verbally before completing the transaction. It requires a confirmation code for all purchases made through the GA. Users can link their payment information to Google Pay to make purchases. GA includes the possibility for a user to train GA to recognise its voice. Voice match is a way to verify a user before giving personalised results. It is also used as a security measure against unauthorised purchases.³³⁹ GA is primarily a cloud-based virtual assistant. While it has a presence on various devices and platforms, the core intelligence and processing of voice commands take place in the cloud. It utilises the power of cloud servers for voice recognition, natural language processing, analysis of data and delivering responses. Users typically interact with GA through the Google app on their smartphones or through dedicated applications on smart displays. The primary function of these applications is to provide a user an interface.³⁴⁰

Smart fridge

A smart fridge with embedded shopping assistant that can autonomously make purchases is a project that captures a lot of attention from home appliance manufacturers as well as from software developers. In June 2000, LG introduced the first internet-connected fridge. This 'smart fridge' was able to create grocery lists and link to mobile apps, allowing users to control the temperature remotely, be alerted if the door was left open and access online recipes based on their fridge contents.³⁴¹ In 2020, Samsung and LG unveiled fridges with added AI capabilities.³⁴² Both fridges include AI-equipped cameras that can identify food using deep learning and natural languages processing. The idea is that the cameras can scan products inside and let users know what items they are short on or make meal suggestions and provide recipes based on the ingredients they still have. The forthcoming smart fridge updates presented by Samsung and LG promise an opportunity to become intermediaries between consumers and grocers.³⁴³ There are Samsung's smart fridges with integrated features designed to simplify grocery management and ordering. These fridges are intended to be integrated with online grocery platforms, allowing users to link their accounts and seamlessly place orders for groceries directly from the fridge's interface. For example, the Samsung Family Hub series has a feature that lets to build a shopping list on the fridge panel and synchronise it with a phone.³⁴⁴ A user can also order groceries directly from the fridge using the SmartThings Cooking app.³⁴⁵ The built-in AI algorithms in the fridge are supposed to

³³⁹ Google: <https://support.google.com/assistant/answer/9071681?hl=en&co=GENIE.Platform%3DAndroid>.

³⁴⁰ Google: <https://developers.home.google.com/cloud-to-cloud>.

³⁴¹ Wikipedia: https://en.wikipedia.org/wiki/Internet_Digital_DIOS.

³⁴² [Samsung and LG go head to head with AI-powered fridges that recognize food - The Verge](https://www.theverge.com/2020/6/24/21344443/samsung-lg-ai-fridges), Wikipedia: https://en.wikipedia.org/wiki/Internet_Digital_DIOS.

³⁴³ [Samsung and LG Unveil Artificial Intelligence-Equipped Smart Fridges \(businessinsider.com\)](https://www.businessinsider.com/samsung-lg-ai-fridges)

³⁴⁴ Samsung: [Build a shopping list with your Samsung smart fridge](https://www.samsung.com/us/support/answer/ANS00088902/)

³⁴⁵ Samsung: <https://www.samsung.com/us/support/answer/ANS00088902/>.

learn and adapt to the user's preferences over time, improving the accuracy of their recommendations and possibly facilitating autonomous ordering in the future.³⁴⁶

Also, Whisk, a UK Startup, has developed an AI-powered fridge that identifies different food objects and suggests meals. It also helps users plan meals over the course of a week using both a web-scraping and classification model. Another recent example is Brezzl, a Munich-Based Startup that has developed a camera to put inside non-smart refrigerators. Their camera, Fridge-eye, can be attached to any fridge to take photos of the items inside. Moreover, the images are stored in an app using a classification model, which can later be used to remind users about the missing items.³⁴⁷

The most advanced in the process of building a fridge that can autonomously order food seems to be Amazon. It has been reported already in 2017 that Amazon was building its smart fridge with the purpose to order food.³⁴⁸ In 2017, Amazon filed two patents for smart fridge technology: the first described a fridge that uses machine vision to detect food spoilage,³⁴⁹ and the second described a fridge that utilised an electronic nose to detect food spoilage.³⁵⁰ Few years later, in 2021 the news on building a smart fridge by Amazon were shared by Business Insider and repeated over the news.³⁵¹ Amazon is aiming to bring some of its already existing technical solutions to its fridge. Compared to Samsung and LG, Amazon has the advantage of having built a device (Alexa) and service ecosystem as well as having a retail side with its very own grocery business. As company already invested in Alexa-powered smart devices in homes, locking them into its ecosystem of services, Amazon fridge is expected to also have Alexa built-in technology enabling voice orders. Although conceptually developed and highly expected, it is not clear when smart and autonomous fridges will be available on the market. At the moment, fully autonomous smart fridges are rather in the phase of experimenting and prototyping.

AI in virtual assistants

AI in virtual shopping assistants is used in two distinctive ways: first to enable natural language interaction, second to analyse vast amounts of fluctuating and heterogeneous data before making a shopping recommendation or perform a task relating to purchases and post-purchase services, such as item tracking and delivery. An automation of decision-making relevant for the pre-contractual stage is making recommendations. The effective retrieval of knowledge from the data is made possible with the adoption of AI techniques that can predict, learn and adapt to the changing conditions. Making user-tailored recommendations is in particular enabled by AI systems. Recommendations require analysis of data relating to user preferences, purchase history, browsing behaviour, and demographic information. Based on the analysis of such data, AI algorithms can generate insights about individual shoppers and adapt to the changing user behaviour and market

³⁴⁶ Samsung: <https://www.samsung.com/us/support/answer/ANS00086664/>.

³⁴⁷ <https://150sec.com/smart-fridges-set-to-get-smarter-with-iot-ai-functionalities/13576/#:~:text=Whisk%2C%20a%20UK%20startup%2C%20is,based%20on%20the%20food%20available>

³⁴⁸ <https://www.theverge.com/2017/1/18/14308352/amazon-echo-refrigerator-reorders-groceries>.

³⁴⁹ <https://www.freepatentsonline.com/y2017/0262973.html>.

³⁵⁰ <https://www.freepatentsonline.com/y2017/0263100.html>.

³⁵¹ Business Insider: <https://www.businessinsider.com/amazon-is-building-smart-fridge-that-monitors-your-buying-patterns-2021-10?r=US&IR=T>.

conditions. This allows shopping assistants to offer tailored product recommendations and suggestions that align with the user's interests and needs. While VA are tools used by consumers, the actual recommendations automate rather the processes from the seller side and resemble a marketing channel to reach a user. On the other hand, a VA can automate offer discovery across various retailers online, which is a user-driven task. After providing results, however, the actual decision-making on whether to buy or not is still down to a user, and a VA by default will not proceed to buy. Nevertheless, for example Amazon's Alexa can make purchases on Amazon without requiring a confirmation code if the user has enabled required features such as in case of Amazon's 'deal notification.' In this case, however, it is required that the user places an order on its wish list, in a shopping cart or saves it for later.

VAs are still vulnerable to accidental or unauthorised purchases, in particular with voice commands because of issues relating to the AI voice recognition capabilities that, even if being much better than few years ago, are prone to mistakes. In such a case, disabling confirmation may result in purchases that are not intended.

The ability for consumers to decide which virtual shopping assistant to use on a specific retail platform varies depending on the platform and its policies. In theory, some platforms may provide an open environment where third-party virtual shopping assistants can integrate with the platform or offer a selection of VA for a consumer to use. In practice, however we observe that while users can choose their preferred VA for general tasks on their devices, the shopping experience within a specific retailer's platform is usually determined by the retailer's chosen assistant. Currently, users do not seem to have an option to switch between different VAs while shopping on a single retailer's website or app.

4) Supply chain management

Supply chain management (SCM) is "the handling of the entire production flow of a good or service - starting from the raw components all the way to delivering the final product to the consumer."³⁵² Digitalisation revolutionised SCMs.³⁵³ The supply chains in the past primarily focused on the accessibility, transportation, and expenses associated with physical assets. Today's supply chains evolve toward digital ecosystems that rely on flows of data, services, and products integrated into comprehensive software solutions and tools.³⁵⁴ Different technologies are used and relied upon for enabling the integration of physical and digital dimensions in supply chains. These technologies include cloud, big data, the Industrial Internet of Services, IoT, 3D printing, augmented and virtual reality, blockchain as well as artificial intelligence and machine learning approaches.³⁵⁵

³⁵² IBM: <https://www.ibm.com/topics/supply-chain-management>; Rubio, S., Chamorro, A., & Miranda, F. (2008). Characteristics of the research on reverse logistics (1995–2005). *International Journal of Production Research*, 46(4), 1099–1120.

³⁵³ João Barata, The fourth industrial revolution of supply chains: A tertiary study, *Journal of Engineering and Technology Management*, Volume 60, 2021, 101624, ISSN 0923-4748, <https://doi.org/10.1016/j.jengtecman.2021.101624>; (<https://www.sciencedirect.com/science/article/pii/S0923474821000138>).

³⁵⁴ IBM: <https://www.ibm.com/topics/supply-chain-management>.

³⁵⁵ Michela Pellicelli, The Digital Transformation of Supply Chain Management, Elsevier, November 17, 2022; Baha M. Mohsen, Developments of Digital Technologies Related to Supply Chain Management, *Procedia Computer Science*, Volume 220, 2023, Pages 788-795, ISSN 1877-0509, <https://doi.org/10.1016/j.procs.2023.03.105>; (<https://www.sciencedirect.com/science/article/pii/S1877050923006403>).

AI allows for the automation of many processes that take place across all parts of a supply chain.³⁵⁶ There are developed methodologies for the implementation of AI-based systems in supply chain management³⁵⁷ and ready to use AI-powered tools for supply chain management in the framework of integrated software systems.³⁵⁸ The integrated systems include automated contract management tools, procurement automation tools, smart contracts and demand predictive tools based on AI. IBM, for example, provides a whole range of tools to automate and manage supply chains.³⁵⁹ Their tools allow for automated sending of the signal replenishment orders to manufacturers so retail shelves can then be restocked almost as quickly as a product is sold.³⁶⁰ IBM tools for the supply chain management promise the evolution of supply chain processes into intelligent workflows, where the use of AI and blockchain underpin automation of every step of the value chain – from demand planning to order orchestration and fulfilling.³⁶¹

In general, AI can provide robust optimisation capabilities essential for precise capacity planning, refined demand forecasting, increased productivity, reduced supply chain costs, and heightened output. Additionally, it contributes to fostering safer working conditions. The disruptions caused by the pandemic highlighted the significant influence of uncertainties on supply chains, emphasising the necessity for intelligent contingency plans to effectively navigate such uncertainties.³⁶² According to McKinsey, AI-powered forecasting can reduce errors by 20 to 50% in supply chain networks. The improved accuracy may lead up to a 65% reduction in lost sales due to inventory out-of-stock situations, warehousing costs decrease by 5 to 10% and administration costs by 25 to 40%.³⁶³ AI is particularly promising in predictive demand forecasting. Predictive analytics allows for precise forecast of future demand, enabling companies to fine-tune inventory levels, streamline supply chain processes, and mitigate the potential for stockout or overstocking. This level of automation in supply chain management is achievable solely through the integration of AI

³⁵⁶ Raphaël Oger, Frédérick Bénaben, Matthieu Lauras, Benoit Montreuil, Towards Decision Support Automation for Supply Chain Risk Management among Logistics Network Stakeholders, IFAC-PapersOnLine, Volume 51, Issue 11, 2018, Pages 1505-1510, ISSN 2405-8963, <https://doi.org/10.1016/j.ifacol.2018.08.287>, (<https://www.sciencedirect.com/science/article/pii/S2405896318314113>); Hisham O. Khogali, Samir Mekid, The blended future of automation and AI: Examining some long-term societal and ethical impact features, Technology in Society, Volume 73, 2023, 102232, ISSN 0160-791X, <https://doi.org/10.1016/j.techsoc.2023.102232>.

(<https://www.sciencedirect.com/science/article/pii/S0160791X23000374>).

³⁵⁷ George Kousiouris, Stylianos Tsarsitalidis, Evangelos Psomakelis, Stavros Koloniaris, Cleopatra Bardaki, Konstantinos Tserpes, Mara Nikolaidou, Dimosthenis Anagnostopoulos, A microservice-based framework for integrating IoT management platforms, semantic and AI services for supply chain management, ICT Express, Volume 5, Issue 2, 2019, pp. 141-145, <https://doi.org/10.1016/j.ict.2019.04.002>; Umamaheswaran Praveen, Ganjeizadeh Farnaz, Ghasib Hatim, Inventory management and cost reduction of supply chain processes using AI based time-series forecasting and ANN modeling, Procedia Manufacturing, Volume 38, 2019, Pages 256-263, <https://doi.org/10.1016/j.promfg.2020.01.034>.

³⁵⁸ See for example: <https://www.supplychaindive.com/>

³⁵⁹ [What is supply chain management? | IBM.](#)

³⁶⁰ IBM: <https://www.ibm.com/topics/supply-chain-management>.

³⁶¹ IBM: <https://www.ibm.com/topics/supply-chain-management>.

³⁶² See for example: Tariq, Muhammad Usman. (2023). Role of Artificial Intelligence in the Enabling Sustainable Supply Chain Management during COVID-19. 44. 115-135. 10.1504/IJSOM.2020.10036037. See also: <https://www.futureofbusinessandtech.com/business-ai/when-the-pandemic-disrupted-the-normal-supply-chain-ai-stepped-in/>; <https://www.reuters.com/technology/startups-apply-artificial-intelligence-supply-chain-disruptions-2022-05-03/>.

³⁶³ McKinsey: <https://www.mckinsey.com/capabilities/operations/our-insights/ai-driven-operations-forecasting-in-data-light-environments>.

systems.³⁶⁴ The results of the predictive demand forecasting can then be integrated into the decision making on placing purchase orders and orders fulfilment.

In most of the cases, the AI-based automation of placing purchase orders seems to be still performed with a human in the loop. Nevertheless, there are instances where physical infrastructures integrated within the IoT framework allow for almost full automation. In such cases, AI can 'sense' the stock and then this information is fed into AI systems that further combine and analyse all different types of data, including demand forecasts, and takes a decision on placing an order. The supplier, on the other hand, can use automated fulfilment systems that effectively allow for fully automated execution of the transaction (see Amazon example below). While we observe a technical readiness to fully automate the process of placing purchase orders and order fulfilment, the organisational reality of many companies does not allow for full M2M automation between the buyer and supplier.

A distinctive way of using AI for automation of processes in supply chain management is the negotiation of specific contract conditions (a framework agreement) between a supplier and buyer (see the section on Walmart case below). Framework agreements are commonly used in supply chain management. They are long-term agreements between a buyer and a supplier that establish the terms and conditions under which future purchases will be made.

Amazon fulfilment centres

Successful instances of the use of AI in supply chain can be observed in various industries. For example, Amazon has implemented AI-driven systems in its warehouses called "fulfilment centres." These systems use machine learning algorithms to optimise inventory placement, automate picking and packing processes, and improve overall operational efficiency. This has enabled Amazon to handle a vast volume of orders. Amazon has been using AI to power its fulfilment centres for years now. The company's robotics division, Amazon Robotics, has deployed more than 520,000 robotic drive units across its fulfilment and sort centres.³⁶⁵ These robots help with stocking inventory, filling orders, and sorting packages for delivery. They follow directions provided by cloud-based algorithms and navigate along a grid of encoded markers.³⁶⁶

When considering the stages of contracting relevant to smart warehouses, the most advanced stages in the context of the use of AI are contract negotiations, contract execution and management. AI technologies play a crucial role in automating order fulfilments processes, tracking inventory levels, and ensuring timely delivery of products. By leveraging AI, warehouses can efficiently manage contracts with suppliers, logistics providers, and customers, facilitating smooth operations and ensuring contractual obligations are met.

³⁶⁴ IEEE Computer Society: <https://www.computer.org/publications/tech-news/trends/ai-revolutionizing-supply-chain>.

³⁶⁵ Amazon: [AI-Powered Inventory Management \(amazon.com\)](https://www.amazon.com), <https://www.amazon.science/latest-news/the-quest-to-deploy-autonomous-robots-within-amazon-fulfillment-centers>.

³⁶⁶ [Amazon Inventory Management - 2023 Strategy & Automation - Jungle Scout](#)

Walmart case

Walmart introduced an AI system, namely a text-based chatbot, to negotiate specific contract terms with human suppliers on behalf of the company.³⁶⁷ Like most organisations with large procurement operations, Walmart could not negotiate contracts with all of its 100,000-plus suppliers. It therefore deployed a chatbot that negotiated contracts on its behalf. The company that created the AI technology for this software was Pactum.³⁶⁸ During the pilot project run in 2021 in Walmart Canada, the company tested the solution and refined it based on feedback from suppliers. Subsequently, the company implemented the solution in three additional countries, with plans to soon introduce the technology in more countries where Walmart operates. The pilot project lasted 3 months, for which Walmart International estimated a positive return on investment if 20% of the suppliers would close deals with the chatbot. The strategy was based on negotiating early payment discounts or extended payment without discounts, and in exchange Walmart would replace its right to terminate contracts immediately and without cause by a 30, 60, or 90 day written termination notice. Internal buyers created training scenarios for the machine-learning algorithm, which were used to create structured scripts for the negotiations. The chatbot managed to reach an agreement with 64% of the suppliers.³⁶⁹ In the post-pilot feedback, 83% of suppliers liked the experience (easy to use, possibility for counteroffer, negotiations at their own pace - not in real time). Several suppliers would have still liked face-to-face negotiations.³⁷⁰

The use case presents a step up in the use of AI in offer generation through negotiations and reaching agreement on contract conclusion. The case is a clear use of ML for enabling the machine-human interaction. What is not clear is if the AI system underpinning the decision-making on the conclusion of the contract was non-deterministic, i.e. data-driven as opposed to decision-making driven by algorithmic instructions hand-coded by a human. In the light of the approach adopted by this study, the distinction is important to consider a given AI decision-making process autonomous.

5) Renewable energy trading

Renewable energy use is growing across Europe and worldwide.³⁷¹ Over the past few decades, distributed energy resources (DERs) powered by renewable energy have been integrated into electrical grids. By the conclusion of 2016, approximately a quarter (25%) of the world's electricity production was sourced from renewable energy.³⁷² In order to leverage all the benefits of growing numbers of DERs to meet policy targets towards decarbonisation a new kind of paradigm in energy

³⁶⁷ Van Hoek, R., DeWitt, M., Lacity, M., Johnson, T. (2022), 'How Walmart automated supplier negotiations,' Harvard Business Review. Available at: <https://hbr.org/2022/11/how-walmart-automated-supplier-negotiations>.

³⁶⁸ Pactum: <https://pactum.com/>.

³⁶⁹ Van Hoek, R., DeWitt, M., Lacity, M., Johnson, T. (2022), 'How Walmart automated supplier negotiations,' Harvard Business Review. Available at: <https://hbr.org/2022/11/how-walmart-automated-supplier-negotiations>.

³⁷⁰ Van Hoek, R., DeWitt, M., Lacity, M., Johnson, T. (2022), 'How Walmart automated supplier negotiations,' Harvard Business Review. Available at: <https://hbr.org/2022/11/how-walmart-automated-supplier-negotiations>.

³⁷¹ European Environment Agency, Energy prosumers in Europe Citizen participation in the energy transition, Luxembourg: Publications Office of the European Union, 2022, <https://www.eea.europa.eu/publications/the-role-of-prosumers-of>; Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, 2019, doi: 10.1109/JSYST.2019.2903172.

³⁷² P. Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, Sept. 2019, doi: 10.1109/JSYST.2019.2903172.

trading has been emerging. One of the main propositions of the paradigm is decentralised peer-to-peer (P2P) energy trading and empowerment of prosumers.³⁷³ Prosumers are individuals who consume and produce energy.³⁷⁴ EU Directive 2018/2001 (part of the Clean Energy Package) aims to establish a level playing field for the prosumers. This directive defines P2P trading as "the sale of renewable energy between market participants through a contract with pre-established terms governing the automated execution and settlement of the transaction. This can occur either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator. The right to engage in peer-to-peer trading shall not affect the rights and obligations of the involved parties in their roles as final customers, producers, suppliers, or aggregators."³⁷⁵

The transactions between peers in P2P energy trading can therefore be intermediated by a third party or can happen directly between market participants. For example, an aggregator, energy producer, supplier, or a community group³⁷⁶ can assume the role of an intermediary. The small-scale decentralised energy sources are often too small to participate in energy or ancillary services markets. In such cases, intermediaries facilitate their participation in the market via enabling access to different marketplaces and energy trading schemes such as OTC trading, crowdsourced energy systems, or flexibility trading.³⁷⁷ Intermediaries also allow for building a trustworthy environment for the participants acting as an enabler or a validator of the transactions.³⁷⁸ While the access to different markets may need to be intermediated, transactions between peers, in particular between prosumers on the local level, can take the form of direct trading without relying on a third party. Distributed ledger technologies based on blockchain arise as the most promising solution to enable direct transactions between peers in the decentralised energy markets. Energy systems

³⁷³ P. Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, 2019, doi: 10.1109/JSYST.2019.2903172; IRENA (2020), Innovation landscape brief: Peer-to-peer electricity trading, International Renewable Energy Agency, Abu Dhabi.

³⁷⁴ On energy prosumers in Europe see: European Environment Agency, Energy prosumers in Europe: Citizen participation in the energy transition, Luxembourg: Publications Office of the European Union, 2022.

³⁷⁵ DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources, Article 2 (1).

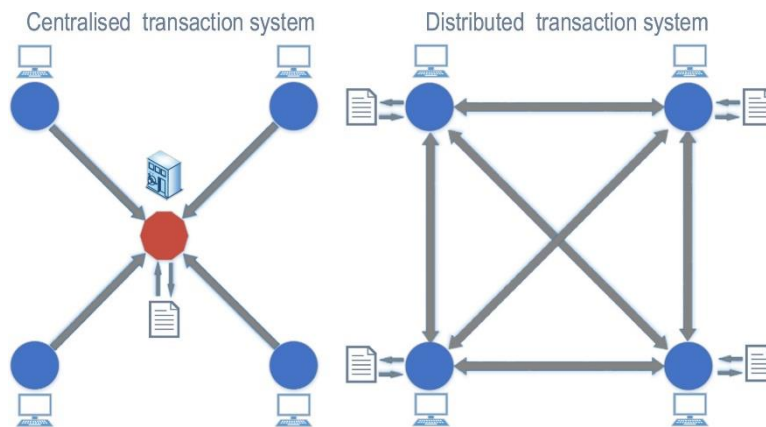
³⁷⁶ Saber Talari, Hosna Khajeh, Miadreza Shafie-khah, Barry Hayes, Hannu Laaksonen, João P.S. Catalão, The role of various market participants in blockchain business model, Editor(s): Miadreza Shafie-khah, *Blockchain-based Smart Grids*, Academic Press, 2020, Pages 75-102, ISBN 9780128178621, <https://doi.org/10.1016/B978-0-12-817862-1.00005-1>; J. Mattila, et al. 'Industrial Blockchain Platforms: An Exercise in Use Case Development in the Energy Industry 43, The Research Institute of the Finnish Economy (2016).

³⁷⁷ Saber Talari, Hosna Khajeh, Miadreza Shafie-khah, Barry Hayes, Hannu Laaksonen, João P.S. Catalão, The role of various market participants in blockchain business model, Editor(s): Miadreza Shafie-khah, *Blockchain-based Smart Grids*, Academic Press, 2020, Pages 75-102, ISBN 9780128178621, <https://doi.org/10.1016/B978-0-12-817862-1.00005-1>; S. Wang, A. Taha, J. Wang, Blockchain-assisted crowdsourced energy systems 2018 IEEE Power & Energy Society General Meeting (PESGM) (2018), pp. 1-5.

³⁷⁸ Stephan Koch, Chapter 2 - Assessment of Revenue Potentials of Ancillary Service Provision by Flexible Unit Portfolios, Editor(s): Pengwei Du, Ning Lu, *Energy Storage for Smart Grids*, Academic Press, 2015, ISBN 9780124104914, <https://doi.org/10.1016/B978-0-12-410491-4.00002-6>; P. Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 3454-3466, Sept. 2019, doi: 10.1109/JSYST.2019.2903172.

decentralisation and blockchain-based P2P have drawn much attention among researchers and prompted the creation of hundreds of start-ups.³⁷⁹

Figure 15: Centralised vs. distributed transaction system.



Source: Andoni et al. (2019)

In the context of local energy markets, the development of smart microgrids represent the shift from fully centralised energy markets towards more localised and distributed solutions in energy generation and sharing.³⁸⁰ Microgrids are small-scale power grids. As they can be managed locally, they cater to small geographical areas, populations, or communities that turn to different sources of energy, like renewable energy. Microgrids can operate independently or in conjunction with the main grid, in particular to exchange the excess energy.³⁸¹ The use of microgrids is seen as an alternative to fully centralised infrastructures, allowing for more optimised and sustainable energy use.

Smart contracts in P2P energy trading

As microgrids embrace the idea of P2P transactions, they become a testing ground for the use of blockchain-enabled *smart contracts* between prosumers.³⁸² A blockchain is a shared, immutable

³⁷⁹ Cali U., Çakir O. Energy policy instruments for distributed ledger technology empowered peer-to-peer local energy markets IEEE Access, 7 (2019), pp. 82888-82900, <https://ieeexplore.ieee.org/document/8740846>; on the systematic review of 178 peer-reviewed publications and 13 innovation projects that provide a thorough analysis of the strengths and weaknesses of smart contracts used in the energy sector see: Desen Kirlı, Benoit Couraud, Valentin Robu, Marcelo Salgado-Bravo, Sonam Norbu, Merlinda Andoni, Ioannis Antonopoulos, Matias Negrete-Pincetic, David Flynn, Aristides Kiprakis, Smart contracts in energy systems: A systematic review of fundamental approaches and implementations, Renewable and Sustainable Energy Reviews, Volume 158, 2022, 112013, ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2021.112013>, (<https://www.sciencedirect.com/science/article/pii/S1364032121012764>).

³⁸⁰ On the microgrid energy markets see: Esther Mengelkamp, Johannes Gärtner, Kerstin Rock, Scott Kessler, Lawrence Orsini, Christof Weinhardt, Designing microgrid energy markets: A case study: The Brooklyn Microgrid, Applied Energy, Volume 210, 2018, pp. 870-880, ISSN 0306-2619, <https://doi.org/10.1016/j.apenergy.2017.06.054>.

³⁸¹ See for example: Esther Mengelkamp, Johannes Gärtner, Kerstin Rock, Scott Kessler, Lawrence Orsini, Christof Weinhardt, Designing microgrid energy markets: A case study: The Brooklyn Microgrid, Applied Energy, Volume 210, 2018, Pages 870-880, ISSN 0306-2619, <https://doi.org/10.1016/j.apenergy.2017.06.054>; (<https://www.sciencedirect.com/science/article/pii/S030626191730805X>).

³⁸² P. Siano, G. De Marco, A. Rolán and V. Loia, "A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets," in IEEE Systems Journal, vol. 13,

digital ledger that records transactions and can be used to track assets, such as land, money, copyrights, intellectual property, and distributed energy resources. Blockchain networks can be public, where any party can participate, or private, where only authorised users can have access to.³⁸³Blockchain offers support to microgrids in multiple ways. Thanks to the immutability of the ledger, energy transaction data can be accurately tracked, confirming the precise timing and sequence of sales. Blockchain platforms can provide all parties with enhanced control and visibility over their energy usage, hence facilitating transactions.³⁸⁴

Users can integrate smart contracts into the blockchain network to facilitate energy trading. Smart contracts are sets of rules dictating when energy transactions can occur. They are algorithms used for the automated execution and settlement of the transactions once certain conditions are met.³⁸⁵ When smart contracts are implemented on a blockchain, they inherit its main features linked to transparency and tamper-proof way of operating. Smart contracts ensure that parties can trust that the agreed-upon value will be exchanged as specified in the contract, without the third-party transaction verification,³⁸⁶ significantly lowering the costs of verification and networking associated with transactions.³⁸⁷ Nevertheless, the use of smart contracts in the energy sector is still in its early stages as there are many open challenges related to security, privacy, scalability and billing.³⁸⁸

Brooklyn microgrid, US

A pioneering example of energy trading based on smart contracting is “Brooklyn Microgrid” in New York, US.³⁸⁹ The microgrid was launched in 2016 and facilitated by the LO3 Energy and Siemens. Brooklyn microgrid is an energy marketplace for locally-generated solar energy. It allows prosumers to sell the excess solar energy they generate to NYC residents who prefer using renewables.³⁹⁰ The

no. 3, pp. 3454-3466, Sept. 2019, doi: 10.1109/JSYST.2019.2903172; One of the first research addressing the use of blockchain in energy markets is M. Mihaylov, S. Jurado, N. Avellana, K. Van Moffaert, I.M. de Abril, A. Nowe Nrgcoin: virtual currency for trading of renewable energy in smart grids 2014 11th International conference on the European energy market (EEM), IEEE (2014), pp. 1-6.

³⁸³ IEEE: [Blockchain Use in Microgrids: Applications, Benefits, and Challenges - IEEE Blockchain Technical Community](#).

³⁸⁴ IEEE: [Blockchain Use in Microgrids: Applications, Benefits, and Challenges - IEEE Blockchain Technical Community](#).

³⁸⁵ Thibault Schrepel, Collusion by Blockchain and Smart Contracts, 33 Harv. J. L. & Tech. 118, 118 (2019). See also Massimo Bartoletti, A formal model of Algorand smart contracts, 1 (2021), <https://arxiv.org/abs/2009.12140v3>. (“Smart contracts are agreements between two or more parties that are automatically enforced without trusted intermediaries.”).

³⁸⁶ Haney, Brian, Defining Smart Contracts (2023); available at SSRN: <https://ssrn.com/abstract=4574563> or <http://dx.doi.org/10.2139/ssrn.4574563>; Merlinda Andoni, Valentin Robu, David Flynn, Simone Abram, Dale Geach, David Jenkins, Peter McCallum, Andrew Peacock, Blockchain technology in the energy sector: A systematic review of challenges and opportunities, Renewable and Sustainable Energy Reviews, Volume 100, 2019, pp. 143-174, ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2018.10.014>; (<https://www.sciencedirect.com/science/article/pii/S1364032118307184>); Riley T. Svikhart, Blockchain’s Big Hurdle, 70 STAN. L. REV. ONLINE 100, 101 (2017).

³⁸⁷ Catalini, C. and J. Gans (2017), “Some simple economics of the blockchain”, <http://dx.doi.org/10.2139/ssrn.2874598>.

³⁸⁸ Desen Kirli, Benoit Couraud, Valentin Robu, Marcelo Salgado-Bravo, Sonam Norbu, Merlinda Andoni, Ioannis Antonopoulos, Matias Negrete-Pincetic, David Flynn, Aristides Kiprakis, Smart contracts in energy systems: A systematic review of fundamental approaches and implementations, Renewable and Sustainable Energy Reviews, Volume 158, 2022, 112013, ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2021.112013>.

³⁸⁹ Brooklyn Microgrid: <https://www.brooklyn.energy/>. For the case study see: Esther Mengelkamp, Johannes Gärtner, Kerstin Rock, Scott Kessler, Lawrence Orsini, Christof Weinhardt, Designing microgrid energy markets: A case study: The Brooklyn Microgrid, Applied Energy, Volume 210, 2018, Pages 870-880, ISSN 0306-2619, <https://doi.org/10.1016/j.apenergy.2017.06.054>.

³⁹⁰ Brooklyn Microgrid: <https://www.brooklyn.energy/>.

initiative aims to network Brooklyn residents in a self-sufficient microgrid, which is a small electricity network with its own sources of supply capable to function independently of the main grid. In the microgrid, a dispersedly generated solar energy is traded amongst the neighbourhood using Ethereum-enabled blockchain technology.³⁹¹ Energy is generated, stored, and transacted locally via a decentralised transaction system without the need for the regular utility company to act as an intermediary.³⁹² While the electrical grid's maintenance remains the responsibility of the utility provider, the energy generation, storage, and local trading is managed by community members. Smart meters monitor the surplus energy generated, making it visible to potential buyers, while also keeping track of energy purchases by consumers. Meanwhile, blockchain technology facilitates secure, efficient, and intelligent transactions among prosumers.³⁹³

A couple years after its implementation the status of Brooklyn Microgrid was still a far cry from the LO3's ultimate vision.³⁹⁴ It has been reported that although participants could virtually trade electricity with one another, they were not physically connected by a microgrid, therefore in fact they could not transact electricity, because the utility had a monopoly over electricity sales. Instead, participants could only trade renewable energy certificates. As a result, the first iteration of the Brooklyn Microgrid did not provide resilience, cost, or sustainability benefits. The report highlighted challenges linked to the implementation of blockchain-enabled smart contracts in microgrids. The overarching challenge was that a blockchain ledger facilitating smart contracting is only one component of implementing a microgrid, and the success of microgrids is in principle determined by general energy market schemes.³⁹⁵

Project Quartierstrom, Switzerland

Project Quartierstrom is a microgrid initiative involving thirty-seven households in Switzerland.³⁹⁶ The Swiss Federal Office of Energy funded the project to explore possibilities of blockchain-powered microgrids to support local communities. In 2019, the Swiss community produced their own solar power locally. Prosumers configured smart contracts and consumers established their maximum prices using a digital portal. Each household received a computer with built-in electricity meters and blockchain software to facilitate energy transactions. Every fifteen minutes the energy usage per

³⁹¹ G. Kim, J. Park, and J. Ryou, "A study on utilization of blockchain for electricity trading in microgrid," in Proc. IEEE Int. Conf. Big Data Smart Comput. (BigComp), Shanghai, China, Jan. 2018, pp. 743–746.

³⁹² Martin Onyeka Okoye, Junyou Yang, Jia Cui, Zhenjiang Lei, Jingwei Yuan, Haixin Wang, Huichao Ji, Jiawei Feng and Chinenye Ezech, A Blockchain-Enhanced Transaction Model for Microgrid Energy Trading, *IEEE Access*, vol. 8, pp. 143777–143786, 2020, doi: 10.1109/ACCESS.2020.3012389.

³⁹³ Martin Onyeka Okoye, Junyou Yang, Jia Cui, Zhenjiang Lei, Jingwei Yuan, Haixin Wang, Huichao Ji, Jiawei Feng and Chinenye Ezech, A Blockchain-Enhanced Transaction Model for Microgrid Energy Trading, *IEEE Access*, vol. 8, pp. 143777–143786, 2020, doi: 10.1109/ACCESS.2020.3012389.

³⁹⁴ Council on Foreign Relations: https://cdn.cfr.org/sites/default/files/report_pdf/Discussion_Paper_Livingston_et_al_Blockchain_OR_0.pdf?_gl=1*ywg7y1*_ga*MTI10DA3NDU3Ny4xNjk3MTg5Nzgw*_ga_24W5E70YKH*MTY5OTQ1NzA2Mi4yLjAuMTY5OTQ1NzA2Mi42MC4wLjA.

³⁹⁵ Council on Foreign Relations: https://cdn.cfr.org/sites/default/files/report_pdf/Discussion_Paper_Livingston_et_al_Blockchain_OR_0.pdf?_gl=1*ywg7y1*_ga*MTI10DA3NDU3Ny4xNjk3MTg5Nzgw*_ga_24W5E70YKH*MTY5OTQ1NzA2Mi4yLjAuMTY5OTQ1NzA2Mi42MC4wLjA.

³⁹⁶ Quartierstrom: <https://quartier-strom.ch/index.php/en/homepage/>.

household would be assessed and energy bids would be put up for purchase and sale. As a result, consumers were able to participate in energy trading.³⁹⁷

The Port of Rotterdam, Netherlands

The Port of Rotterdam is an example of the implementation of microgrid combining smart contracts with AI.³⁹⁸ In August 2020, the port launched a pilot program in microgrid trading. The project aimed at reducing energy consumption and promoting the use of renewable energy.³⁹⁹ The Port of Rotterdam microgrid seems to be one of the world's first high frequency decentralised energy markets.⁴⁰⁰ The trade in microgrid was facilitated by platform called Distro,⁴⁰¹ jointly developed by S&P Global Platts (provider of energy and commodity information) and BlockLab (the Port of Rotterdam's blockchain innovation hub).⁴⁰² The platform is a fully developed solution offered on the market, and leverages the capabilities of both artificial intelligence and blockchain. The platform furnishes each market participant with an AI-powered 'energy trading agent' tool, which learns and adapts to the user's energy requirements, preferences, and behaviours. This tool analyses billions of real-time data points, autonomously and makes decisions on energy transactions at the optimal prices for the user.⁴⁰³ Blockchain smart contracts are a carrier of market rules. They validate transactions and manage identities to ensure reliability and anonymity in the dynamic trading environment.⁴⁰⁴ This integration of AI and blockchain allowed commercial energy consumers in the port to engage in active trading of renewable energy sourced from solar and battery storage, empowering them to effectively control and manage their power consumption.

Smart contracts and AI in P2P energy trading

AI is a promising proposition to tackle the challenges linked to the management of more decentralised energy systems and infrastructures. The International Renewable Energy Agency (IRENA) highlights that AI helps optimising energy trading decisions, improving market efficiency,

³⁹⁷ IEEE: <https://blockchain.ieee.org/verticals/transactive-energy/topics/blockchain-use-in-microgrids-applications-benefits-and-challenges>. For the final Report on the Quartierstrom Project see: <https://quartierstrom.ch/index.php/en/2020/08/17/final-report-on-project-quartierstrom/>.

³⁹⁸ IEEE: <https://blockchain.ieee.org/verticals/transactive-energy/topics/blockchain-use-in-microgrids-applications-benefits-and-challenges>.

³⁹⁹ See for example: <https://www.ledgerinsights.com/port-of-rotterdam-renewable-energy-blockchain-pilot-is-a-money-saver/>; <https://apnews.com/article/business-technology-alternative-and-sustainable-energy-renewable-power-generation-electric-power-transmission-and-distribution-65439f92792c49b491bf314de2924db2>.

⁴⁰⁰ See for example: <https://www.smart-energy.com/industry-sectors/new-technology/ai-blockchain-microgrid-pilots-renewables-trading-in-port-of-rotterdam/>; <https://apnews.com/article/business-technology-alternative-and-sustainable-energy-renewable-power-generation-electric-power-transmission-and-distribution-65439f92792c49b491bf314de2924db2>; <https://www.bloomberg.com/news/articles/2020-10-05/port-of-rotterdam-pilot-uses-ai-microgrid-to-trade-renewables>; <https://www.spglobal.com/commodityinsights/en/about-commodityinsights/media-center/press-releases/2020/051020-world-s-first-high-frequency-decentralized-energy-market-drive-port-of-rotterdam-energy-transition>.

⁴⁰¹ Distro: <https://www.distroenergy.com/#case-study>.

⁴⁰² S&P Global: <https://www.spglobal.com/commodityinsights/en>.

⁴⁰³ S&P Global: <https://www.spglobal.com/commodityinsights/en>; <https://apnews.com/article/business-technology-alternative-and-sustainable-energy-renewable-power-generation-electric-power-transmission-and-distribution-65439f92792c49b491bf314de2924db2>.

⁴⁰⁴ <https://www.spglobal.com/commodityinsights/en/about-commodityinsights/media-center/press-releases/2020/051020-world-s-first-high-frequency-decentralized-energy-market-drive-port-of-rotterdam-energy-transition>.

and facilitating the integration of renewable energy sources.⁴⁰⁵ The combination of smart contracts with AI technology enables not only automated execution of transactions, but also automated decision-making on whether and when to buy or sell energy. AI allows for knowledge integration into the automated buying or selling decision.

⁴⁰⁵ IRENA (2020), Innovation landscape brief: Peer-to-peer electricity trading, International Renewable Energy Agency, Abu Dhabi; See also: Pe Mahmoud M, Slama SB. Peer-to-Peer Energy Trading Case Study Using an AI-Powered Community Energy Management System. Applied Sciences. 2023; 13(13):7838. <https://doi.org/10.3390/app13137838>

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