EVIDENCE TO SUPPORT THE ANALYSIS OF IMPACTS FOR AI GOVERNANCE

Final Report

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Executive Summary

AI is a complex group of technologies that involve machines, particularly computer systems, simulating human intelligence processes. Governments around the world are grappling with how to harness the benefits AI can offer whilst mitigating the risks that AI poses.

The UK would like to assess what, if any, additional AI regulation is required to mitigate the risks of AI. The UK can approach AI regulation using several approaches, which may include, but are not limited to:

- relying on the current set of regulations already in place in the UK (not introducing AI-specific regulation),
- establishing a central AI governance regime,
- making changes to existing regulations to accommodate AI-specific risks (AI regulation through existing regulators).

Understanding the impacts of alternative regulatory options on both UK economic activity and the level of reduction in AI risks will assist the government in designing an appropriate and beneficial AI regulatory regime. This report sets out evidence to support the analysis of potential options for an AI regulatory framework in the UK.

Our analysis offers both a quantitative and qualitative assessment of options. The quantitative model developed for this work compares the impacts of two potential AI regulatory frameworks against no further AI-specific regulation as a baseline scenario. The regulatory scenarios considered are: [1] regulation by a central UK AI-specific regulator and [2] changes to current UK sectoral regulation to account for AI-specific risks. We consider the following impacts on AI businesses: (1) prohibition of certain AI systems; (2) AI businesses' reaction to regulatory compliance costs; (3) changes in consumers' trust and consequent impacts on the level of AI purchases and willingness to share data; and (4) the impact of regulation on market uncertainty on the level of investments in AI. We also consider UK government regulatory costs and costs incurred by non-AI firms that develop in-house AI products. Our qualitative assessment discusses the impact on trade and the extent to which regulatory divergence between jurisdictions will generate trade frictions. Lastly, we discuss the impact of alternative forms of AI regulation on preventing harmful outcomes, such as social manipulation and discrimination of protected characteristics.

We reach six main conclusions:

1. Decisions that prohibit AI systems should carefully target harmful outcomes to minimise the unintended removal of low-risk products and services: Our quantitative analysis shows that, while prohibition is the main regulatory tool for preventing harm from AI systems, its impact on the value of the AI market is expected to be significantly larger than the impact of other regulatory measures. Although it is not possible, at the moment, to quantify the benefits generated by the prevention of harm, it is clear that AI regulation should strike a balance

between maximising the prevention of harmful outcomes and minimising the negative impact of this prevention on the industry.

2. If regulation increases consumer trust, it could potentially offset some of the costs of AI regulation on the AI market: Our quantitative analysis shows that an increase in consumers' trust in AI could significantly mitigate the costs created by AI regulation. Information on this topic is limited, so this finding is indicative, and further research on this question is recommended.
3. Regulation should be targeted to avoid potential high compliance costs for non-AI firms developing AI products in-house: Our analysis shows that, since many firms (which are not AI-specific) have AI products developed in-house, AI regulation may create substantial additional cost to those firms. AI regulation should be clear about the firms that are in scope and balance the burden it creates with its effectiveness in removing harmful outcomes.
4. The overall impact of AI regulation may be higher than presented in this report: This report focuses only on the impact of AI regulation on: (1) the value of the AI market and (2) the costs to non-AI firms developing AI products. This may be an underestimate for three reasons. First, AI is thought to be associated with highly productive firms, so any loss of revenue from AI firms is likely to be associated with a productivity loss in the economy. Second, AI serves as an input to production for other sectors, therefore, the losses in terms of market value and productivity may be larger. Third, our model did not consider the impact that regulation might have on AI R&D in the UK and the wider economic impact that these R&D activities might have. This is another area where further research is recommended.
5. Regulatory asymmetry may cause trade frictions and have a further impact on the economy: There are two main ways in which AI regulation may impact trade. First, AI systems have the potential to reduce trade costs, and any reduction in the size and value of the AI market may reduce these opportunities. Second, divergence in AI regulation between the UK and other jurisdictions may create additional costs for firms that operate and trade AI systems across countries. Further research (for example, through gravity modelling) is recommended to understand better the impact of AI regulation on trade.
6. Quantitative and qualitative results of this analysis should always be considered together: Our analysis included quantitative estimation of impacts and qualitative discussions. It is tempting to only look at the quantitative analysis to draw conclusions, but a key benefit of regulating AI, which is the removal of harmful outcomes, is discussed in a qualitative way. As such, it is important to consider the quantitative and qualitative results together.

Our study was based on available academic and grey literature as well as insights from focused stakeholder engagements. This exercise revealed that many areas of interest for this type of analysis still lack in-depth understanding and sufficient evidence. As such, the results of this report should be considered as an indication of areas where the impact of AI governance may be greatest as well as what further research might be helpful. In particular, further research into the impact of AI regulation on consumers' trust and further exploration of the impacts of regulatory divergence on trade appear of particular interest. Other potential next steps for the government include a wider and more in-depth understanding of AI and non-AI firms' attitudes towards AI regulation through a wider survey or a qualitative analysis.

1 Introduction

The importance of artificial intelligence (AI) is rapidly growing, leading to conversations about the need for regulation. It is widely recognised that AI technologies can provide economic and consumer benefits, such as increased productivity and higher product quality, but they can also cause harm to consumers. The complexity of AI technologies makes them hard to understand and creates difficulties in ensuring risks are accounted for and mitigated. The rapid growth of AI and its quick penetration into various sectors further increase the potential risks AI can pose to the economy and consumers.

Various countries and jurisdictions are already designing and assessing new regulatory regimes for AI systems. For example, in 2019, the US published its "Guidance for Regulation of Artificial Intelligence Applications",[1] and in 2021, Japan published its Artificial Intelligence Governance Framework.[2] Presently, most of those conversations are theoretical, and only a few jurisdictions have started setting up regulatory requirements. One of the first jurisdictions to propose an overarching AI regulation was the European Union (EU). In 2021, the European Commission (EC) published its proposal for an AI regulatory regime (hereafter, EU AI Act). Early proposals set out aspects of central EU regulation and differentiated between AI services that would be prohibited and those considered high risk to consumers and bound to some regulatory assessments. It set out transparency requirements for AI systems interacting with a natural person,[3] a voluntary code of conduct for non-high-risk AI services, penalties for non-compliance and other regulatory aspects.

Before deciding on an AI regulatory regime, the UK government would like to understand the impacts of alternative options on the economy and consumer welfare. To answer this question, the Department for Digital, Cultural, Media and Sports (DCMS) commissioned Frontier Economics to undertake independent economic research to help inform the government of the benefits and costs of potential alternatives. This report summarises the analysis and its results.

[1] https://media.defense.gov/2019/Oct/31/2002204458/-1/-1/0/DIB_AI_PRINCIPLES_PRIMARY_DOCUMENT.PDF

[2] https://www.cpsec.aist.go.jp/achievements/aiqm/AIQM-Guideline-1.0.1-en.pdf

[3] Refers to systems that interact with a human. See Title IV of the EU AI Act. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0206&from=EN

2 Background

The Artificial Intelligence (AI) market is difficult to define and estimate. Definitions of AI can vary, sometimes classifying technological ability (e.g. the ability to self-teach) and, at other times, operational processes (e.g. machine learning).[4] AI technologies can also be hard to distinguish from other technologies as they are often integrated into other software or technological solutions. Estimating the AI market, spending on AI products or AI revenues requires an agreed definition of AI and isolation of the revenues attributed to each AI component relative to the product's total price. These challenges are reflected in the diversity of market estimates for the global AI market. Some sources estimate that the global revenues from AI software were $14.7bn in 2019,[5] while others estimate the total global spending on AI at $50bn in 2020, with potential growth of more than 50% by 2024 to a total of $110 bn.[6] Although this volatility shows the difficulties of AI definition, it also shows the importance of the AI market and its potential future expansion.

The UK, in particular, is considered a global leader in innovation, implementation, and investment in AI. The UK is ranked near the top of the Global AI Index, third only to the US and China.[7] The UK's third-place in the Nature Index reflects the high performance of UK-based universities and their contribution to AI research.[8] In light of this, it is not surprising that London is in the top 10 cities for AI talent globally[9] and supplies the AI sector[10] with over 35,000 employees working in over 1,000 AI firms across the UK.[11] The UK was also ranked third in private and government investment in 2019, with about £2.5 bn in total investment.[12] The UK's strong position in the market results from the creative and innovation-driven environment it fosters and the high levels of investments in the market, leading to estimated growth from an estimated £16.7 billion in 2020 to £30 billion in 2025 and up to £82.5 billion by 2040.[13]

The growth in the AI market reflects the significant potential benefits that AI development, adoption, and implementation can bring to the UK society and economy. The high processing speed at the heart of AI products can create substantial efficiencies and productivity gains,

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4 For a further and more detailed discussion about the complexity of AI definition, please see [AI act]

5 https://www.statista.com/statistics/607716/worldwide-artificial-intelligence-market-revenues/

6 IDC (2020), worldwide Spending on Artificial intelligence is expected.

7 https://www.tortoisemedia.com/intelligence/global-ai/

8 https://www.nature.com/articles/d41586-020-03409-8

9 The Data City, UK Artificial Intelligence analysis 2020 (2020).

10 Stakeholders indicated that talent availability plays a key role in deciding where to locate AI development.

11 https://hbr.org/2021/12/50-global-hubs-for-top-ai-talent

12 https://www.gov.uk/government/news/new-ten-year-plan-to-make-britain-a-global-ai-superpower

13 https://www.gov.uk/government/publications/ai-activity-in-uk-businesses/ai-activity-in-uk-businesses-executive-summary#:~:text=In%202020%2C%20the%20432%2C000%20companies,1.6%20million%20per%20large%20business.

leading to savings for individuals and businesses. One study found that AI could increase labour productivity 40% by 2035.[14] AI's ability to personalise and produce higher quality products driven by the processing of large datasets could further impact the economy. As quality improves, more customers interact and purchase AI services, which increases data sharing and further enhances the quality of AI products – creating a cycle of data sharing and quality improvement.[15] The benefits of AI go beyond productivity and higher product quality and may include quicker diagnoses, more effective energy allocation and resource usage, and increased cybersecurity capabilities.[16]

AI processes large amounts of data to learn. However, a lack of transparency around data processing raises questions about the potential harms these technologies could create. AI technologies are highly automated and produce results that cannot be easily (and at times never) traced back and audited: the 'black box' problem.[17] A lack of traceability and explainability raises concerns about computation errors that may accrue because of bias in the code (especially given the low diversity of the workforce producing programming code), an internal error, or an inherent bias in the datasets used to 'teach' the systems. These harms may have far-reaching impacts, such as social injustices and discrimination (e.g. women systematically being given a lower credit score[18]). Other risks relate to the application of AI and its results. For example, since AI can be implemented as part of another software, it is not always obvious when one interacts with an AI. This lack of transparency can lead to an invasion of consumers' privacy (e.g. if they are unaware they are sharing data with an AI) or social manipulation (e.g. where targeted advertisements (commercial and political) manipulate consumers' choices). The wide range of risks associated with AI systems raises questions, by both scholars and market participants, about whether governments can – and should – mitigate AI risks.[19]

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[14] https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/637967/EPRS_BRI(2019)637967_EN.pdf. We acknowledge this source is four-years-old which may indicate that the estimates are outdated. Given that we could not find a more recent estimation we use this source to show the potential impact of AI on the economy.

[15] https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/637967/EPRS_BRI(2019)637967_EN.pdf. https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf

[16] https://www.forbes.com/sites/forbestechcouncil/2020/03/20/ais-effect-on-productivity-now-and-in-the-future/?sh=5cfa0f8e7591

[17] https://jolt.law.harvard.edu/assets/articlePDFs/v31/The-Artificial-Intelligence-Black-Box-and-the-Failure-of-Intent-and-Causation-Yavar-Bathaee.pdf

[18] https://ssir.org/articles/entry/when_good_algorithms_go_sexist_why_and_how_to_advance_ai_gender_equity

[19] Such as concerns Elon Musk raised in 2017 about how the lack of AI regulation poses an "existential risk". https://www.npr.org/sections/thetwo-way/2017/07/17/537686649/elon-musk-warns-governors-artificial-intelligence-poses-existential-risk?t=1646845326263

3 Regulatory Context

Since 2016, authorities worldwide have begun proposing strategies and plans for AI. The UK established the UK AI Sector Deal in 2018, which set out a plan to support the UK in becoming "a global leader in this technology".[20] By the end of the 2020s, some countries also started publishing guidelines on AI risk mitigation. In 2019, the US published Guidance for Regulation of Artificial Intelligence Applications, setting up the main principles for US regulatory agencies to consider when undertaking AI regulations. The publication was met with several position papers by authorities such as the National Security Commission.[21] Singapore published the second edition of their Model AI Governance Framework in 2020[22] , and Japan published its Governance Guidelines for the Practice of AI Principles in 2022[23] as China passed a new set of regulations restricting algorithmic usage. However, no country has, so far, passed any overarching regulation to mitigate the risks of AI.

In April 2021, the EC published an outline of a potential regional AI regulatory regime[24] to mitigate AI risks.[25] The EC proposed: *"A horizontal EU legislative instrument following a proportionate risk-based approach, plus codes of conduct for non-high-risk AI systems*".[26] The requirements set in the proposed regulation would apply extraterritorially to public and private actors and affect providers, importers, distributors, and users. The proposed regulation, managed centrally by an AI regulator, is based on the distinction between four types of AI systems:

1. **Prohibited AI systems:** Are defined as those contravening EU values, for instance, by violating fundamental human rights. Examples include 'real-time' remote biometric identification systems in publicly accessible spaces for the purpose of law enforcement.
2. **High-Risk AI systems (HRS):** Are defined as those creating an adverse impact on people's safety or fundamental human rights. Those would be subject to a series of regulatory requirements.
3. **Limited-risk systems:** Are defined as non-HRS systems that interact with a natural human. And may pose a limited risk to fundamental human rights.
4. **Other AI systems:** these would be subject to a voluntary code of conduct.

[20] https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal

[21] https://media.defense.gov/2019/Oct/31/2002204458/-1/-1/0/DIB_AI_PRINCIPLES_PRIMARY_DOCUMENT.PDF

[22] https://www.pdpc.gov.sg/-/media/Files/PDPC/PDF-Files/Resource-for-Organisation/AI/SGModelAIGovFramework2.pdf

[23] https://iapp.org/news/a/japan-publishes-ai-governance-guidelines/

[24] The regulatory regimes we are considering in the context of this report relate to safety and risk mitigation from AI systems and not other regulatory regimes such as competition regulation.

[25] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0206&from=EN

[26] Option 3 + as defined in the impact assessment that was conducted by the Commission for five potential regulatory regimes.

The EU AI Act is still being debated in 2023, with the proposals subject to potential changes and amendments before the final regulation is passed by the European Union.[27]

In the 2021 National AI Strategy, the UK set a ten-year plan to make the UK a "global AI superpower". In addition to addressing the long-term needs for AI ecosystems and supporting the transition to an AI-enabled economy, the National AI strategy set out a third goal: "Ensure the UK gets the national and international governance of AI technologies right to encourage innovation, investment, and protect the public and our fundamental values".[28] The UK can approach AI governance and regulation using several methods: relying on the current set of regulations already in place in the UK (i.e. no introduction of AI-specific regulation); establishing a central AI governance regime, or making changes to existing regulation to accommodate AI-specific risks (AI regulation through existing regulators). All three options would be viable, and each would have different impacts on the level of innovation and economic activity in the UK and the level of protection from AI risks. The preliminary analysis of these options in the following sections is intended to inform policymakers about the impacts of each AI regulatory regime for the UK.

27 https://www.brookings.edu/blog/techtank/2022/02/01/the-eu-and-u-s-are-starting-to-align-on-ai-regulation/

28 https://www.gov.uk/government/publications/national-ai-strategy/national-ai-strategy-html-version

4 Approach to analysis

Understanding the impacts of potential AI regulation on the UK presents several analytical challenges. First, there is an infinite number of AI regulatory options that can be considered. Second, given the wide scope of the potential regulation, its impacts may be hard to untangle from other impacts on the economy. In many cases, the benefits would be indirect and realised only in the long term. Figure 1 shows the steps included in the analysis to overcome these challenges.

Figure 1 Analysis steps

Source: Frontier Economics

1. **Defining regulatory regime options:**
Although there are many AI regulatory options for the UK, only some aspects of the regulatory regime are likely to yield significant variations in the anticipated impacts on the economy and consumers. To keep the analysis tractable, we have restricted our analysis to two hypothetical regulatory scenarios : [1] regulation by a central UK AI-specific regulator; and, [2] changes to current UK sectoral regulation to account for AI-specific risks that vary according to aspects of the regulation most likely to be of substantive interest. We compare those to a baseline regulatory regime (the counterfactual). Section 5 below explains how we have defined the two regulatory regimes and the baseline for this work.

2. **Identifying the impact – the creation of logic models:**
For each option, we have followed the Magenta Book guidance and used logic models (or theory of change) to help identify the impacts of the regulation. These models help us trace the logical relationship between the activity (in this case, the specific regulatory aspects) to outcomes and, finally, impacts.[29] This exercise helps us understand the main outcomes the model should estimate, identifies the impacts we would like to evaluate and helps expose any assumptions made. The logic model is the framework for identifying the impacts and the "blueprint" for the model and analysis.

3. **Estimating the impacts – creating an analytical model:**

29 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879438/HMT_Magenta_Book.pdf. Section 2.2.1

Using the logic model, we build the analysis to estimate the impacts of each regulatory scenario. The analysis is split into quantitative and qualitative parts. The quantitative model estimates the main impacts, which have data and sources available and provides valuable insight - without extreme complexity. These include impacts such as consumers' trust, the size of the AI market and investment in AI. The qualitative part of the analysis investigates impacts valuable for supporting decision-making on AI regulation, which, given the limited availability of data and the context of these impacts, cannot be quantified. These include the impact on consumers' harm and trade frictions that can arise from the regulatory asymmetry between the UK and other regions. Section 6.1 below details modelling and results for each regulatory regime, whereas section 6.2 provides qualitative discussions about the non-quantifiable impacts.

4. **Comparison of impacts and conclusions:**
The quantitative model provides an overall estimate of the impacts and costs comparison between regulatory options. The comparison of each regulatory regime with the baseline regime shows the net benefits and costs of the new regime, providing the ability to see which option is quantitatively preferable. The qualitative analysis contributes to a wider consideration about which option best addresses harms and maximises benefits to consumers and might have wider trade implications. In section 7, we offer conclusions from the analysis, its limitations and suggestions for further research.

Section 5 below provides a more detailed description of the two hypothetical regulatory scenarios and a granular summary of the mechanisms through which these are expected to generate an impact on society and the economy.

5 Defining three potential regulatory options and their logic models

As mentioned above, the purpose of this analysis is to understand and appraise the costs, benefits, risks and opportunities of different hypothetical regulatory frameworks in the domain of AI. The sub-sections below describe the two regulatory scenarios analysed in this report (scenarios 1 and 2) and the baseline scenario against which they have been analysed. We further discuss the mechanisms and the impact anticipated from each scenario.

5.1 Baseline scenario: Counterfactual

Description of scenario

The UK does not implement any new AI regulation. There are no significant changes to regulatory frameworks in all other sectors (e.g. finance, product safety, medicine authority, etc.) in the UK. However, countries around the world begin to introduce AI regulation, starting with the EU AI Act.

The main mechanisms affecting this scenario are trade frictions generated by regulatory asymmetry between the UK and EU. As discussed in more detail below, trade frictions could also occur due to regulatory divergence with other major jurisdictions (e.g., the US). To simplify and account for future regulation uncertainty, we assume the regulatory frameworks in place in other countries to be the same in all three scenarios.

Mechanisms and impact of the scenario

We do not draw or describe a logic model for the baseline scenario, as it is the basis against which scenarios 1 and 2 are appraised in this analysis.

5.2 Hypothetical scenario 1: regulation by a central UK AI-specific regulator

Description of scenario

The UK implements new AI regulation and establishes a central AI regulator for its delivery. Central AI regulation provisions can be grouped into six main categories:

a Prohibitions: these are provisions that forbid the use of certain AI systems.

b Conformity assessment for high-risk systems (HRS): these require providers of HRS to verify that the established quality management systems comply with the specific requirements and that the design and development process of the AI system and its post-market monitoring are consistent with the technical documentation.

c Governance/management requirements for HRS: these are a series of requirements concerning record-keeping, accuracy, cybersecurity and robustness, technical documentation and risk management systems.

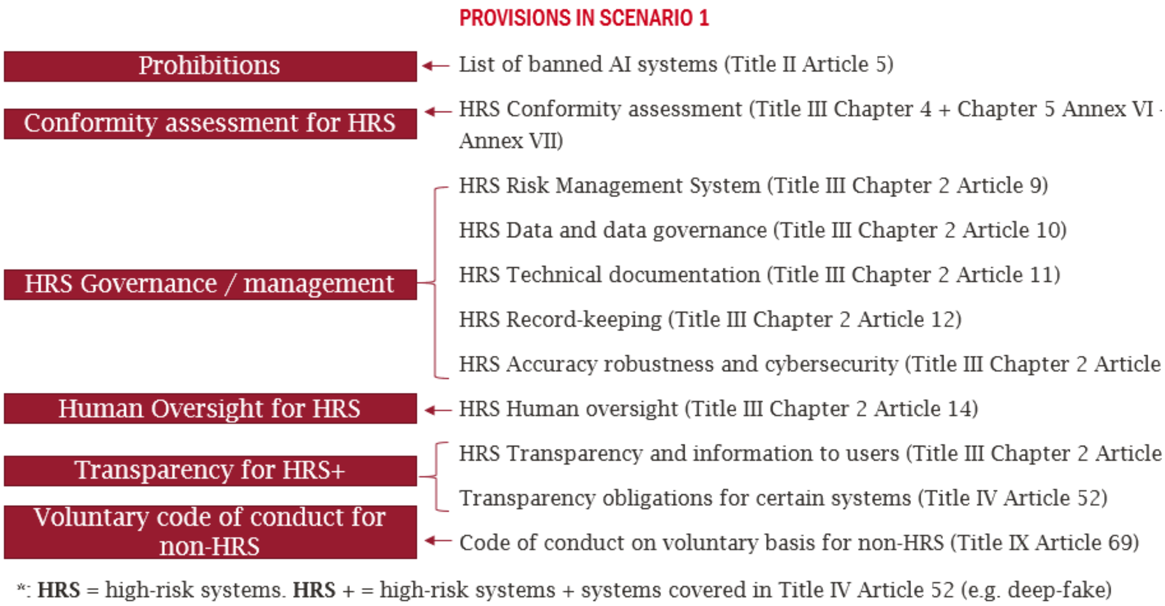
d Human oversight requirements for HRS: this is a requirement for HRS, which must be effectively overseen by natural persons while the AI system is in use.

e Transparency requirements for HRS and other systems: these are requirements for HRS, which must be sufficiently transparent to enable users to interpret the systems' output and use it appropriately. In addition, all AI systems intended to interact with natural persons must be designed and developed in a way that informs the natural persons they are interacting with an AI system.

f Voluntary code of conduct for non-HRS: this provision encourages and facilitates drawing up codes of conduct intended to foster the voluntary application to AI systems other than the high-risk AI systems listed above.

Figure 2, below, outlines how these provisions map onto the proposals for the EU AI Act.

Figure 2 Chart or graph etc



Source: Frontier Economics

Mechanisms and impact of the scenario

The first point that emerged from the literature review and the interviews with stakeholders is that most of these groups of provisions are expected to trigger similar activities, outputs and outcomes in the UK economy and society. Indeed, as shown in Figure 3 below, all the input groups (apart from the voluntary code of conduct for non-HRS) are expected to generate three types of activities within businesses:

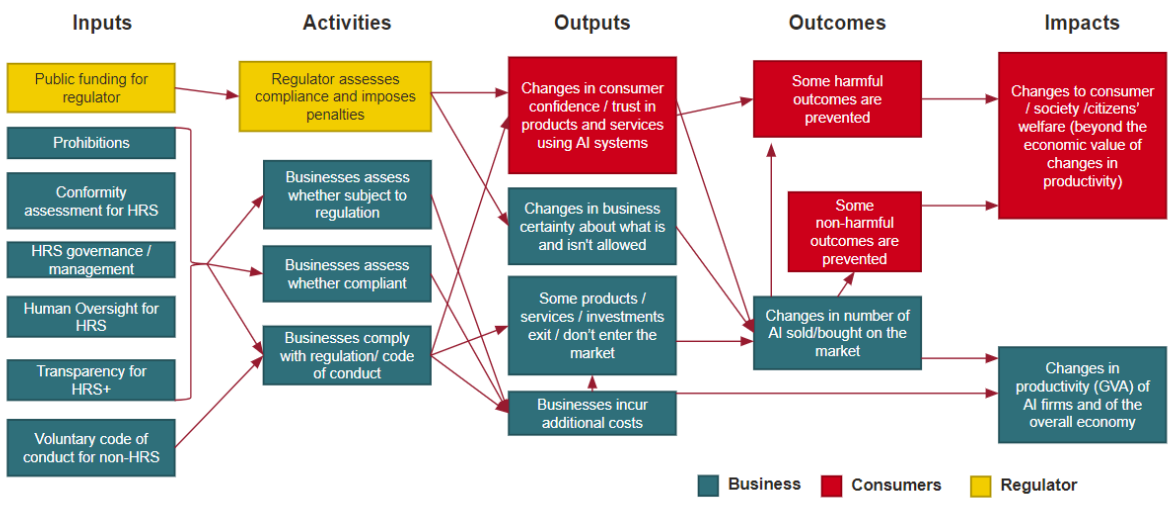
- **Scope:** Businesses will assess whether they are subject to the regulation (i.e. whether the systems they use/develop/sell can be classified as high risk or as prohibited);
- **Current compliance:** Businesses will assess whether the systems they currently use/develop/sell are compliant with the rules. This activity (which might look redundant in light of activity 1 above) is important because many businesses active in the AI space already have a series of mechanisms and operations in place that partially or fully overlap with the new regulation;
- **Future compliance:** Lastly, and most importantly, businesses will comply with the regulation in the areas each business is not already compliant. If unable to comply, they will leave the market or accept the risks. In case of non-compliance, they will face penalties.

As mentioned in the analysis section below, based on the evidence that emerged in the interviews with stakeholders, the first two mechanisms are expected to have a negligible impact on the overall cost structure of affected businesses. As a result, our modelling focuses on the last mechanism: complying with the regulation.

The only provision expected to generate a slightly different and simpler set of activities is the voluntary code of conduct for non-HRS, which, due to its voluntary nature, is not expected to trigger any assessment activity within the business.

From a government sector perspective (the yellow boxes in the diagram below), the main input is the funding required to create the AI regulator and to run/operate it over time. The main activities of this regulator will be to assess compliance and impose penalties (in case of non-compliance).

Figure 3 Theory of change in scenario 1



Source: Frontier Economics

On the business side (blue boxes in the diagram above), there are four main mechanisms at play:

- The presence of regulation and the activities of the regulator changes the level of legal certainty within the market.[30]
- The assessment activities[31] described above, as well as the activities needed to comply with regulation, generate additional costs.[32]
- Complying with certain provisions (in particular those related to prohibitions) leads to a direct reduction in the number of AI services/products in the market.
- The additional compliance costs described above will lead to an indirect change in AI investments and in the AI services and products developed (i.e. those that are not profitable, once the additional costs are taken into account, will leave or not enter the market).

From a business perspective, these changes will expectedly impact productivity by two main mechanisms:

- From a within-product and within-firm perspective, a change in the number of AI systems on the market and the number of consumers using these systems will impact their quality. This is because the volume of data underpinning an AI system has a direct impact on its quality.
- From an economy-wide perspective, a change in AI use is expected to have an impact on the overall productivity of a sector and the economy.[33] However, as highlighted in the analysis section below, we do not model this mechanism and focus exclusively on the dynamic described in the previous bullet.

On the consumer side (i.e. final consumers or businesses purchasing AI products B2B, red boxes in the diagram above), regulation is expected to change the confidence and trust of consumers in AI systems. Based on the literature reviewed,[34] this impact is likely to be positive since most evidence suggests that product regulation makes consumers feel safer. For example, trust and confidence might induce consumers to engage more frequently with certain

[30] Most of the interviewees we engaged with highlighted the positive relationship between regulation in the AI sector and the legal certainty needed to operate at scale and attract investments.

[31] As mentioned above, based on the evidence that emerged in the interviews with stakeholders, assessment activities are expected to have a negligible impact on the overall cost structure of affected businesses.

[32] Regulatory costs are the main focus of the impact assessment produced by the European Commission to appraise the impact of the proposed EU AI Act: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/694212/EPRS_BRI(2021)694212_EN.pdf

[33] https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf

[34] https://www.weforum.org/agenda/2020/08/consumer-trust-ai-potential/#:~:text=We%20are%20already%20seeing%20the,more%20loyalty%20to%20that%20company.
https://onlinelibrary.wiley.com/toc/15206793/2021/38/7
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7344323/

AI systems and share more data with them, increasing the level of quality and quantity of the AI market (see section 6.1.4 for more details on these mechanisms).

However, there is a possibility that regulation might make consumers more aware of certain technologies and therefore reduce their trust in AI systems,[35] or even that consumers will not change their levels of trust or their behaviours as a result of regulation. It is important to note that these changes in consumer confidence are expected to be driven by two main mechanisms. First, by the fact that regulation exists[36] and, second, by the fact that businesses comply with that regulation.

On the consumer side, the change in the nature and number of AI services on the market is expected to (see section 6.2 for more details):

- Prevent some harmful outcomes from emerging (e.g. an ML-powered credit scoring system will not be able to use gender or ethnicity to decide whether an individual is granted a loan). This will generate an increase in social welfare beyond the changes in prices and productivity generated on the business side and passed on, to a certain extent, to consumers
- Prevent some outcomes that are not necessarily harmful (e.g. a prohibited anti-money laundering algorithm is now unable to identify an illegal transaction). This will generate a decrease in social welfare beyond the changes in prices and productivity generated on the business side and passed on, to a certain extent, to consumers.

5.3 Hypothetical scenario 2: Changes to current UK sectoral regulation to account for AI-specific risks

Description of scenario

As shown in the table below, the main differences between scenario 1 and scenario 2 are:

- There is no central AI regulator proposed in scenario 2. Instead, each existing regulator will be responsible for regulating AI within their regulatory scope, with one or more existing institutions covering sectors without a dedicated regulator.
- In scenario 2 all AI systems (not just HRS) will undergo in-house self-assessments on conformity with regulation (ex-post), rather than an external conformity assessment before launching a product (ex-ante) as proposed in scenario 1.
- Systems will be regulated based on specific contexts rather than using blanket prohibitions.

[35] https://scholar.harvard.edu/files/shleifer/files/regulation_trust_qje.pdf

[36] Most of the literature reviewed associates regulation with an increase in consumer trust. See https://unctad.org/system/files/official-document/ser-rp-2021d15_en.pdf for a comprehensive review. However, some commentators have questioned the strength of this relationship: https://www2.itif.org/2018-trust-privacy.pdf

- HRS will be defined by each sector regulator, alongside other technologies and products. The definition will be based on the level of risk of the outcome/purpose and not the level of risk of the technology itself.
- All firms (not just HRS) will have to comply with a series of rules on transparency towards users.

Mechanisms and impact of the scenario

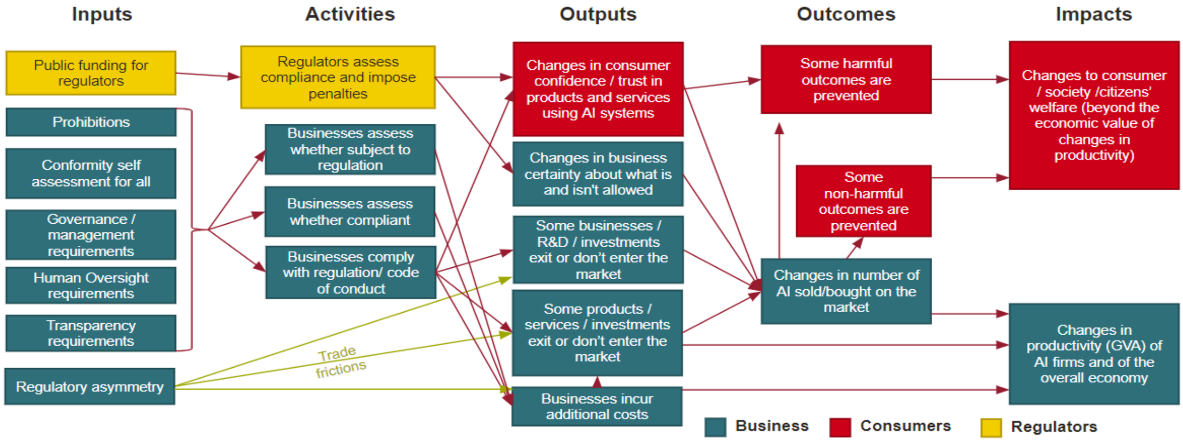
Figure 4 Main differences between scenario 1 and scenario 2

Regulatory body	• No new AI regulatory body that identifies high-risk services/products. • AI Coordinating function for existing regulators. Main responsibility is to align between the various regulators and address any AI-specific risks that might be new (or not covered by current regulators' High-risk assessment). • Any product that currently does not fall under any regulator would fall under a designated one (e.g. employment/recruitment AI software).
Ex-ante assessment requirements	• All AI systems before being placed on the market required to undertake a minimal assessment (less strict than the EU for HRS). • The assessment to be done individually **"in-house" without regulatory confirmation.** • Regulators to be required to investigate companies ex-post in light of complaints.
Levels of risk	Two: 1. Banned (decided by each regulator based on the context and purpose). 2. Other risk levels depending on individual sector regulators' assessments for the product as a whole (not AI-specific).
Geographical scope	• Mirroring the EU AI Act approach (all product/ services placed in the UK, regardless of the product development and creation location).
Risk-level basis	• Risk assessment done as part of an overall risk assessment conducted by individual regulators. • Risk is based on context and purpose not technology.
Required user disclaimers	• Compared to the EU AI Act: Higher number of business fall under requirements with less stringent features.

Source: Frontier Economics

- From a theory of change perspective, there is one main difference relative to scenario 1. Regulatory asymmetry between the UK and other jurisdictions might cause trade frictions. This can be considered as a cost of scenario 2 compared to scenario 1 or a benefit of scenario 1, although it should be noted that this analysis is primarily focussed on trade frictions between the UK and the EU. Regulatory asymmetry is also a feature of the baseline scenario, where hypothetically, the UK does not implement any new regulation whilst other jurisdictions proceed, including the EU AI Act. This difference between the baseline and scenario 1 will not be quantified in this analysis, but it is an important aspect to consider when comparing different regulatory scenarios.

Figure 5 Theory of change in scenario 2



Source: Frontier Economics

Although the mechanisms of change are very similar between scenario 1 and scenario 2, there will be material differences in the magnitude of the causal chains depicted in the figures above.

In particular, we expect the following differences to be relevant:

- In scenario 2, there are **more regulators** (sector regulators) **+ coordinating functions instead of a single central regulator**. This might impact the amount of funding needed to make the regulation work, as discussed more in detail in the section on regulatory costs.
- The **list of banned systems is expected to be different** and to apply to a different subset of firms and products, generating lower compliance costs in scenario 2.
- **Governance/management requirements** and **human oversight requirements** (i.e. HRS requirements) will be lower in scenario 2 compared to scenario 1 in terms of "regulatory burden" and will **apply to a different number of firms/products**.
- **Transparency requirements will also apply to a higher number of firms/products** in scenario 2 but are expected to be less burdensome and generate lower costs per product/firm.

In terms of outcomes, these differences are expected to generate the following divergence between scenarios 1 and 2:

- **Less stringent requirements in scenario 2** (e.g. shorter governance and risk-management procedures) might have a different impact on consumer trust (they might not be sufficiently visible to trigger a change in trust) and will have a different impact on compliance costs and, therefore, on the number of AI systems on the market.
- Requirements applying to a **larger spectrum of firms/products in scenario 2** might have a different impact on trust (i.e. through different levels of visibility from consumers) and will have a different impact on compliance costs as well as on business certainty since more businesses will be impacted.

- These differences will also have an impact on the **number of harmful outcomes** prevented by the regulation and on the societal benefits associated with it. This is because more businesses will be impacted, and different requirements will have a different success rate in preventing harmful outcomes.

For simplicity, we have depicted only trade frictions with the EU in scenario 2. In reality, trade frictions could occur in both scenario 1 and scenario 2 in relation to other major jurisdictions. In theory, they could be more impactful in scenario 1 if countries like the US or Japan implemented a regulatory regime similar to scenario 2 and materially different from the EU AI Act.

Similarly, in scenario 1, trade frictions might emerge over time if the UK implemented a central AI framework that was directly interoperable with the EU AI Act in the first instance and then deviated from it. We do not consider such divergence in our model as scenarios are assumed to be stationary.

As mentioned above, regulatory asymmetry will also be a feature of the baseline scenario. Similarly to scenario 2, for simplicity, we only depict divergence between the UK and EU, assuming that while the UK does not implement any new regulation and the EU's proceeds with the AI Act as set out in early proposals. This difference between the baseline and scenario 1 will not be quantified in this analysis, but it is an important aspect to consider when comparing different regulatory scenarios.

The diagrams depicted above for all scenarios do not account for any distributional impacts. It is clear that the same requirements will have a different impact on different types of firms (e.g. SMEs vs large firms).[37] Similarly, it might have different effects on different types of consumers (e.g. those who consume larger proportions of tech products and services).

[37] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712010/sme-growth-regulation.pdf

6 Analysis

Our analysis contains two parts: a quantitative assessment of impacts that could be measured at the time of the study and a qualitative discussion of other impacts where quantification was not feasible. Both parts aim to validate the impacts assumed in the logic model, understand their direction (increase/decrease) and provide tools to compare the final results between the two scenarios. Utilising both qualitative and quantitative methods allows us to consider a wider range of outcomes and impacts, provide a complete view of impacts, and allow for an evidence-based indication of the relative importance of different mechanisms through which regulation is likely to have an impact. This will support decisions about the preferred AI regulatory option for the UK. Below we detail the analytical approach for the quantitative and qualitative analyses.

The quantitative model

The quantitative model estimates the monetary values of impacts identified in the logic model, such as the value of the AI market and overall regulatory costs. This allows costs and benefits for our alternative regulatory scenarios, relative to the baseline, to be compared with each other. Monetary estimation allows us to effectively compare different regulatory regimes at an aggregate level, taking into account each regime's negative and positive effects. The model follows the flow from input to impacts set out in the logic models but takes a practical approach to the quantitative estimations by utilising available public data, academic literature, and wider grey literature to support the calculations across the model. Some assumptions were based on information gathered through a focused stakeholder engagement exercise conducted as part of this project.[38] In other cases, assumptions were made and agreed to be reasonable with the DCMS team. In annex A, we detail the methodologies, assumptions and sources used for the quantitative analysis.

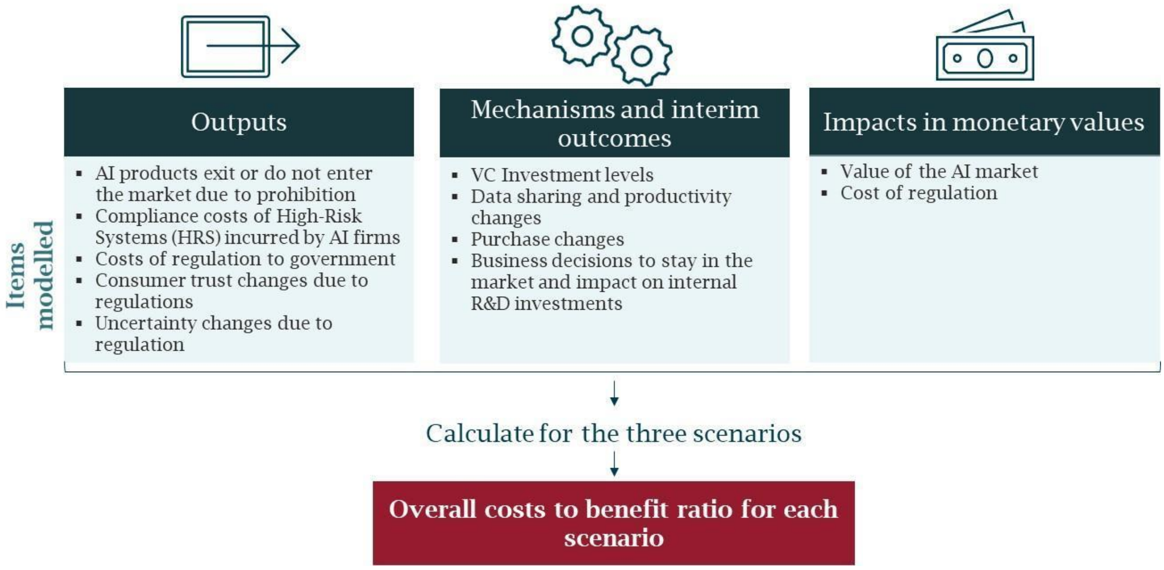
Since regulatory regimes may change in the future, we allow flexibility to change many of the current assumptions to ensure that the model continues to be useful. The model follows the definitions of the two scenarios defined in section 5 and provides flexibility, which allows the DCMS team to explore variants of scenarios in the future if they would like.

The overarching model structure follows the logic presented in Figure 6 (below). We first model the immediate changes (outputs) expected to result from the regulation, including the set of AI products that are prohibited from the market, the nature of HRS and resulting compliance costs, the costs involved in establishing an AI regulator, anticipated changes in consumer trust that may occur and changes to market uncertainty that the regulation may create. These

[38] We interviewed seven UK based AI businesses (developers) of various sizes and from a variety of sectors. In addition, we conducted a workshop with seven additional AI firms to gather further views. Lastly, we talked with one regulator and two AI experts. The conversations were kept anonymous and confidential to receive honest and helpful information, and as such, we do not include the summary of each conversation in the report. Annex B presents the takeaways gathered for the main discussion areas across interviews. We note which assumptions or decisions are based on information received from stakeholders.

outputs then interact with each other to lead to a series of further changes (outcomes), such as a set of businesses deciding to exit the market or consumers choosing to share more data because their trust in AI has grown. Lastly, those outcomes can be related to two main quantitative impacts: the impact on the value of the AI market and the cost to the regulator.

Figure 6 Overall quantitative model structure



Source: Frontier Economics

Sections 6.1.1 to 6.1.7 detail how we modelled each of the identified outputs, the mechanisms they interact with, and the effects each has on the final impacts. We then compare the cost-benefit ratios across the two scenarios. Section 6.1.6 compares the full impacts of the two scenarios, which is the basis for the conclusions discussed in section7.

The qualitative assessment

In addition to the quantitative model, we have undertaken a qualitative analysis to assess two potential outputs and the associated impacts, which we are not in a position to assess in a quantitative way - at this stage. Those are the regulations' effects on:

- **The harms and the benefits that AI systems could generate for consumers** (businesses or citizens consuming AI products and services). More specifically, AI regulation will remove (through prohibitions or through regulatory costs) some systems from the market. In some cases, harmful outcomes will be prevented by this mechanism (e.g. discrimination from an AI system). In other cases, consumers will lose the potential benefits/utility generated by AI systems that will not enter (or will leave) the market because of regulation. Distributional and equality outcomes are discussed in detail qualitatively in section 6.2.2.

- **Trade costs**: there are two mechanisms at play here. The first relates to the demonstrated potential of AI to reduce trade costs. This means that changes in the cost or quality of AI systems that might result from AI regulation could change the overall trade cost. The second mechanism relates to how regulatory asymmetry across areas (e.g. any divergence between the EU and the UK) could impose additional costs on businesses that serve both markets.

As explained in more detail in the analysis section, these impacts have not been assessed with a quantitative model due to data availability issues and the complexity of modelling some of the mechanisms behind these impacts. However, the fact that quantification has not been possible should not diminish the importance of considering these impacts alongside quantitative ones when comparing the scenarios. The sections on consumer and trade impacts also provide some insights into how these could be quantified through further research.

6.1 Quantitative analysis

This section details the methodology behind the calculations of outputs and their effect on final impacts in the quantitative model. We first explain the modelling of our counterfactual scenario, which forms the model's foundation and the basis from which we vary our assumptions to estimate the impacts of the two alternative regulatory scenarios. We then explain how each output (which includes impacts from prohibition, business costs from compliance, consumers' trust and market uncertainly changes) is modelled and how the outputs interact with different mechanisms and lead to ultimate impacts. Lastly, we present the results for each scenario and briefly discuss our conclusions.

Several overarching assumptions were made in the quantitative analysis presented below. The main ones include:

- We assume that all businesses comply with the regulation.[39]
- We apply regulation to businesses as a whole and not to specific products.[40]
- We assume a uniform distribution of revenues across the three business sizes considered in the analysis. [41]

These main assumptions are discussed in more detail in the sections below and in the relevant annexes, together with other more detailed and specific assumptions.

[39] We acknowledge that a certain proportion of businesses will not comply with the regulation. A subsection of those might also bare some penalties depending on the regulatory regime. Those were not considered in the scope of this analysis.

[40] Please see annex A.4.1 for further details about the methodology, assumptions, and sources.

[41] Please see annex A.7.2 for further details about the methodology, assumptions, and sources.

6.1.1 Modelling of the counterfactual and foundational aspects of the impact analysis

The baseline scenario is our counterfactual and the foundation for most calculations in the model. Where we subsequently vary the assumptions to capture the effects of the two alternative regulatory scenarios, these are applied to the estimates in our baseline. The only anticipated impact within the baseline counterfactual scenario in section 5 is modelled through the asymmetry between UK's existing legal and regulatory frameworks and the EU's AI Act proposals. Since trade frictions are discussed separately in the report's qualitative analysis, we do not account for trade frictions in the quantitative model. In order to offer an indicative quantified difference between scenarios 1 and 2, the baseline estimates are deducted from both scenarios. This means that the exclusion of trade friction impacts in the baseline does not have a material impact on the estimated impacts in the quantitative model.

Within our baseline, we model the following four key aspects of the AI market: the value of the AI market, the number of AI firms and products in the market, VC investment in UK AI firms, and SME ROI.

(a) The value of the AI Market:

We are interested in understanding the impact that regulation would have on the economy, and in line with the Green Book guidelines, we exclude any economic transfers from our analysis.[42] The value of the AI market is an indication of the economic value associated with AI products. We proxy the values of the AI market by using AI technology expenditure in the UK based on the AI Activity in UK Businesses report (DCMS, December 2021).[43] We use the same technology-based definition of AI as the paper and assume that AI products include five broad categories covering the most commonly used AI technologies. These are: (i) machine learning, (ii) natural language processing and generation, (iii) computer vision and image processing/generation, (iv) data management and analysis, and (v) hardware.

We make several adjustments to the AI expenditure estimated in the paper to align it more closely with what is needed for our modelling – the AI revenues generated by firms that develop and sell AI products.[44] First, we adjust the estimates by removing expenditure that relates to in-house AI development.[45] The impact of AI regulation on

[42] The Green Book - Central Government Guidance on Appraisal and Evaluation. Paragraph 6.7. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf.

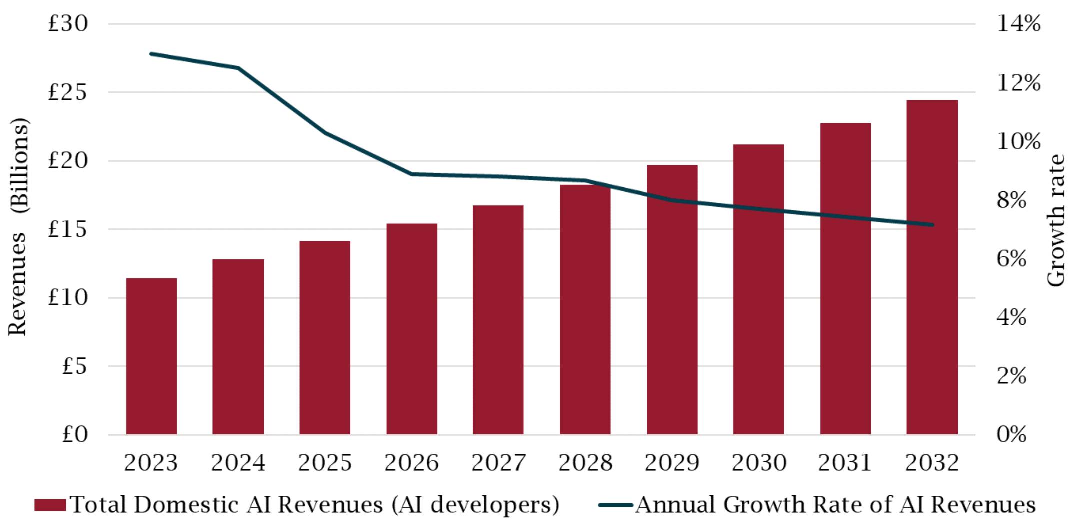
[43] AI Activity in UK Businesses report (DCMS, December 2021)

[44] We use the central scenario estimates in The AI Activity in UK Businesses report.

[45] The AI Activity in UK Businesses report looks at total expenditure on AI in the UK, which includes in-house AI development, out-sourced AI development, and purchases of external ready-to-use solutions. We are interested in the impacts of regulation of AI developers and, as such, remove expenditure attributed to in-house AI development which is estimated at 40% of total expenditure. The impact of regulation on in-house AI products is discussed further in section 6.1.8.

firms developing AI in-house is assessed separately in section 6.1.8. After this adjustment, we have an estimated amount of expenditure on AI products which is, in turn, a proxy for the revenues for AI developers from AI sales. Second, the paper provides projections until the year 2040. Since we assume that regulation will commence in 2023, we use the projected revenues up to the year 2032 for our 10-year evaluation horizon – a period recommended in the UK Green Book.[46] [47] Lastly, given that trade frictions are excluded from our quantitative analysis, we remove revenue related to imported AI products.[48] The result of these adjustments, which are presented in Figure 7 below, is a figure we use to proxy the value of the market for domestic AI developers in the UK every year up to 2032. Reduction in the AI revenues compared to the counterfactual is essentially the removal of the value that was put on those products.

Figure 7 Domestic AI revenues and the year-on-year growth rates



Source: Frontier Economics based on the AI Activity in UK Businesses report (DCMS, December 2021), central scenario

Note: Adjusted to remove an approximate amount of imports. See annex A.3.1 for further details.

(b) The number of AI developers and AI products in the market:

[46] The Green Book - Central Government Guidance on Appraisal and Evaluation. 5.14 page 42. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf

[47] Please see annex A.3.1 for further details about the methodology, assumptions, and sources.

[48] The AI Activity in UK Businesses report looks at the level of AI purchases in the UK. These purchases could be domestic or from imports, but it would not include exports (as those are not purchased by UK based consumers). We assume that 22% of the purchases relate to imports (based on GVA and imports of the tech sector in 2019). As such, we remove 22% from the total expenditure to get the domestic only purchases. Please see annex A.3.1 for further details about the methodology, assumptions, and sources.

Unlike in the AI Activity in the UK Businesses report, we are interested in the number of AI developers (referred to from now on as AI firms) instead of the number of businesses that purchase/deploy AI products and services. The main reason for this divergence is that we are interested in understanding how regulation would affect the decisions of businesses that directly incur regulatory costs and how those change the AI market. Decisions, such as exiting the market or not or passing through costs to consumers, are only possible to model if the regulatory cost is first applied to AI firms. We use the assumption that there were 1,506 AI firms in the UK in 2020.[49] Although the regulatory burden falls mainly on those firms, our model and discussion acknowledge that this burden is felt by others across the economy and not only by AI firms.

The number of firms is split by size within the model into small, medium (small and medium together referred to as SMEs) and large AI firms.[50] Stakeholder interviews indicated that some impacts might differ between SMEs and large AI firms. For example, compliance costs are expected to be proportionally higher for SMEs than for large businesses. Evidence also suggests that uncertainty in the market would not materially impact large firms but would affect SMEs.[51]

Modelling the impact of AI regulation also requires us to understand the number of distinct AI products present in the market. Our modelling of compliance costs (which is detailed in section 6.1.3) follows the Study to Support an Impact Assessment of Regulatory Requirements for Artificial Intelligence in Europe (from now Study to Support the EU AI Act Impact Assessment), which is based on "units" of AI: unique AI products that would undergo separate regulatory compliance assessments under the proposed EU regulation.[52] The total cost of compliance per business depends on the number of AI products sold by each business. To capture this dimension, we assume the typical level of AI products provided by each small, medium and large AI firm.[53]

The number of firms and AI products per business is projected over the next ten years to 2032. We use the growth rate of AI revenues, taken from the estimates in the AI Activity in UK Businesses report (DCMS, December 2021), and assume a proportion of the growth rate is from an increase in the number of products per business (i.e. growth of the AI firms already in the market), and the remaining proportion is due to growth in the number of new businesses.[54] At the end of this exercise, we have

[49] Based on Beauhurst estimates. For further details, please see annex A.3.2.

[50] For the assumption of the split and sources please see annex A.3.2.

[51] Dejuan-Bitria, D. Ghirelli, C. Economic policy uncertainty and investment in Spain. SERIEs 12, 351–388 (2021). Available at: https://link.springer.com/article/10.1007/s13209-021-00237-5

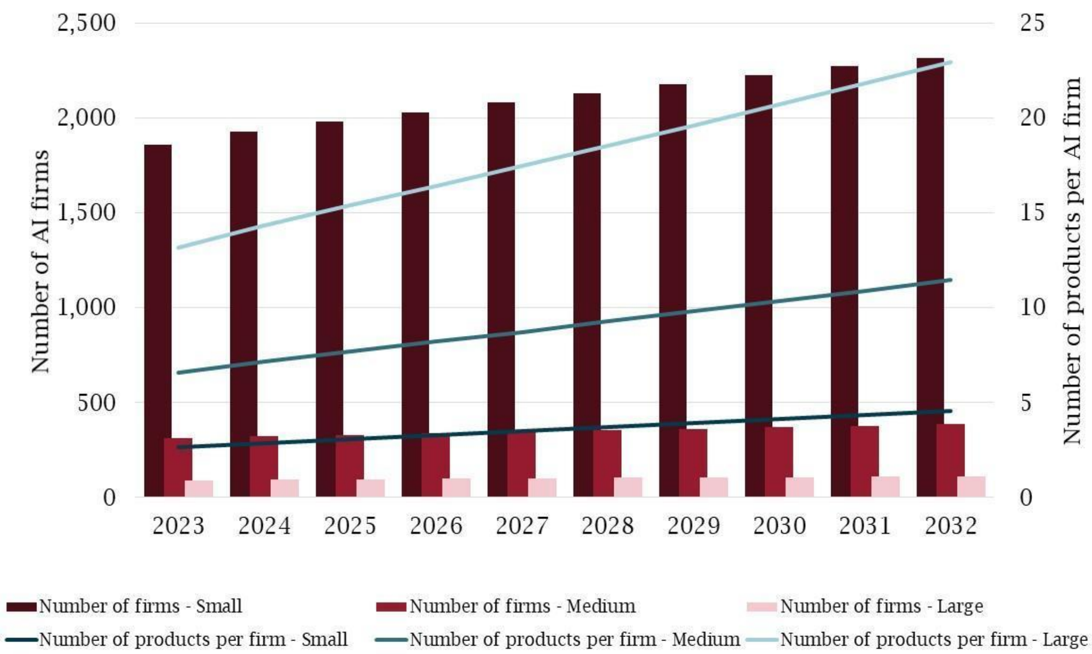
[52] Study to Support an Impact Assessment of Regulatory Requirements for Artificial Intelligence in Europe. Available at: https://op.europa.eu/en/publication-detail/-/publication/55538b70-a638-11eb-9585-01aa75ed71a1

[53] The assumptions are detailed in annex A.3.3 and were agreed on with the DCMS team to be reasonable.

[54] We assume that 28% of the total AI revenues growth is attributed to growth in the number of firms, and the rest, 72%, is attributed to the growth in the number of products per firm.

estimates of the number of AI firms and AI products per AI firm, broken down by size and projected across our 10-year analysis horizon. These results are presented in Figure 8 below.

Figure 8 Number of firms and number of products per AI firm, by size



Source: Frontier Economics

(c) The amount of Venture Capital (VC) investment in UK AI firms:

In section 6.1.5, we explain how regulation and market uncertainty affect investment in SME AI firms. To model how market uncertainty leads to changes in the value of the AI market, we need to understand the level of VC investment in AI and how that responds to uncertainty.[55] Therefore, the baseline levels of VC investment in AI need to be captured in our model. Using the average growth rate in VC investments between the years 2019 and 2021, which are available in the data, we project the expected baseline VC investment up to 2032. [56]

(d) The SME Return on Investment (ROI) in the market:

To model the impacts of uncertainty on investment levels and AI revenues, we also require an estimate of the baseline annual ROI for AI SMEs in the market.[57] This metric

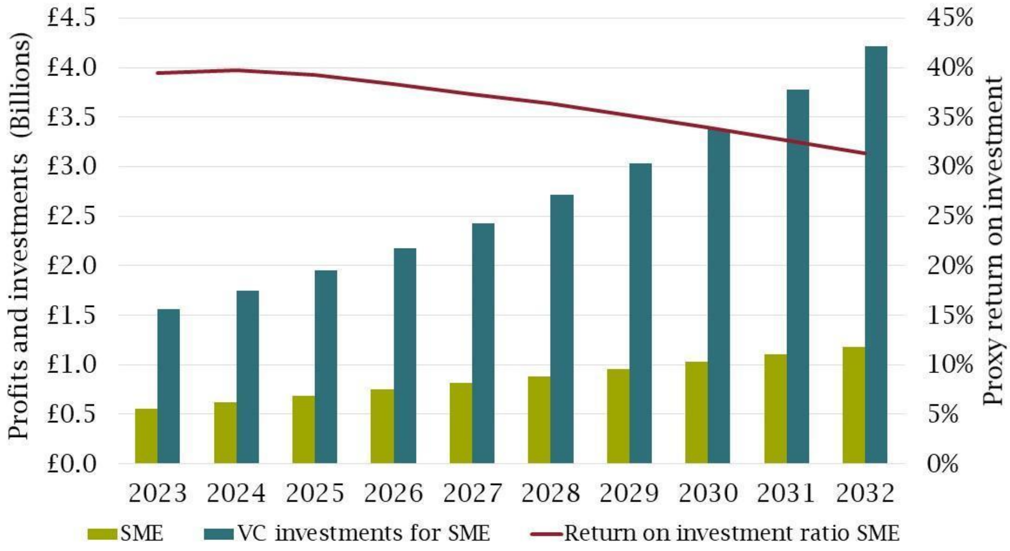
[55] https://pitchbook.com/blog/what-is-venture-capital

[56] Based on CrunchBase data. For further details, please see annex A.3.4.

[57] We only look at the impact on SMEs as VC investment is more likely to be invested into SMEs and start-ups. Further evidence collaborate the assumption that uncertainty in the market would not materially impact large firms but would affect

is also used later in section 6.1.3 to understand how changes in private investment under each scenario change revenues in the AI market. To arrive at the SME ROI in the baseline, we use the VC estimate from the step above as a proxy for SME AI investments. We estimate SME AI firms' revenues by allocating the total AI revenues we calculated in step 1 according to SMEs' assumed contribution to that revenue. By applying a profit margin to the estimated SMEs' revenues, we arrive at estimated SME profits.[58] Figure 9 below presents projections for SME profits, VC investment, and proxy ROI.

Figure 9 Baseline projection of SME profits, VC investment and proxy ROI



Source: Frontier Economics

Note: The ROI calculations are based on two separate estimations. The decrease seen in the ROI over the year is reasonable given that returns on technology are expected to be higher in their infancy and lower as they become more widely used (this reflects the high risk that new technologies might have at the start).

As noted above, these baseline projections are our point of reference for understanding the impact of alternative regulatory regimes on the value of the AI market and regulatory costs. The sections below explain our methodology for translating each regulatory scenario into estimates of impact using the mechanisms described above. We also set out the main assumptions we have made and, where applicable, methodological differences between the two scenarios.

SMEs. Please see Dejuan-Bitria, D. Ghirelli, C. Economic policy uncertainty and investment in Spain. SERIEs 12, 351–388 (2021). Available at: https://link.springer.com/article/10.1007/s13209-021-00237-5

[58] We apply an assumed profit margin of 10% across all AI firms. For further details about this assumption and further methodology explanations, please see annex A.3.4.

6.1.2 Prohibition of certain AI products and services

Under both scenarios, we anticipate that regulation will prohibit some AI products and services that are considered to have an unacceptable level of risk. As a result, revenues from prohibited products will no longer be part of overall AI revenues in the UK. Modelling this requires three steps - detailed below.

For each scenario, we estimate the percentage of businesses that would be prohibited.[59] Although the prohibition is based on products and not firms, for simplicity, we assume that AI firms would be prohibited in full.[60] The modelling of the proportion of businesses that fall under prohibition under each scenario is done as follows:

- Scenario 1 establishes a central AI regulator. A lack of international precedent and limited evidence means that we model the proportion of firms that would be prohibited by assessing the AI risk on a sector basis and using the number of AI firms in each sector to reach total firm estimates. We first use the assumed level of AI risk (low, medium and high) likely to be associated with each sector and make a judgement about what each risk level suggests about the proportion of AI firms that would be prohibited.[61] For example, a sector with a medium level of AI risk would indicate that 5% of AI firms in the sector would be prohibited and, therefore, would not enter or exit the market.[62] We then take the number of AI firms in each sector and arrive at the total number of AI firms across all sectors that would fall under prohibition, which allows us to calculate the total percentage of AI firms that would be prohibited.[63] We estimate that about 3.2% of AI firms would be prohibited by the regulation defined in scenario 1.
- Scenario 2 assumes a sectoral AI regulation with outcome-based, rather than technology-based, risk considerations, which we believe would provide more accurate identification of prohibited AI products. This is because sector regulators are likely to have more industry-specific knowledge to identify AI systems that pose unacceptable risks without the need for a blanket regulation, as suggested by scenario 1.64 This view has been collaborated by several stakeholders[65] who indicated that sectoral regulation was preferred, for this reason, specifically

[59] We note that businesses may change their products to adjust to the regulation and avoid prohibition. For the purposes of the model, we assume the prohibited element is central to those prohibited, which means that such adjustment is not possible.

[60] Mathematically reducing the proportion of businesses in full or removing the proportion of the products across all businesses would yield the same result, assuming that the distribution of prohibited and HRS products would be uniformly distributed across AI firms. Please see annex A.4 for further details.

[61] The DCMS team provided the assumed risk levels per sector and the relevant percentage of prohibited firms. For further details, please see annex A.4

[62] For further details, please see annex A.4

[63] For further details, please see annex A.4

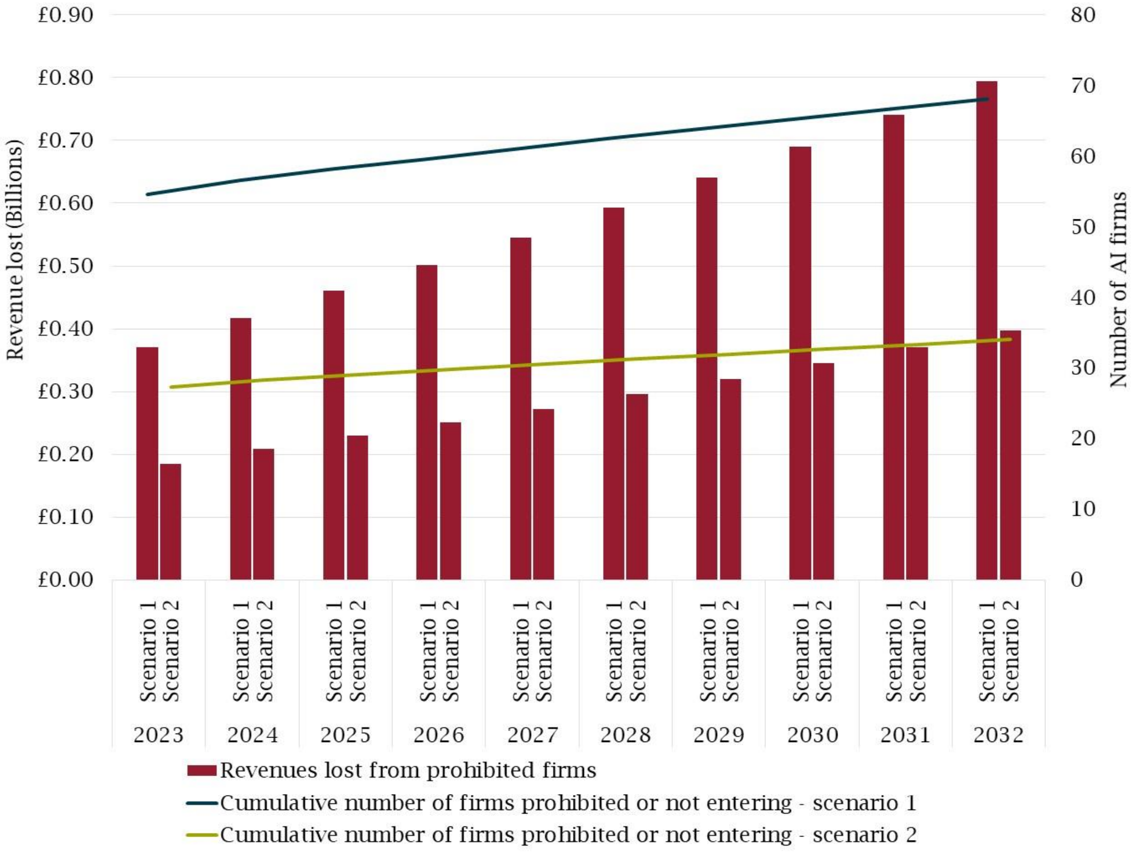
[64] Based on conversations with an AI expert.

[65] Refers to businesses interviewed as part of the focused stakeholder engagement.

mentioning their ability to be more precise in identifying prohibited and high-risk AI systems. In light of these findings, the percentage of firms prohibited in scenario 2 is 1.6%, half of the scenario 1 estimate.[66]

These percentages are applied equally to all businesses in the market, regardless of size. The average revenues from the firms, which would be prohibited under each scenario, are subtracted from the AI revenues estimated in the baseline scenario. Figure 10 below presents the net change in AI revenues due to prohibition.

Figure 10 Number of firms leaving the market and AI revenues lost due to prohibition – relative to baseline



Source: Frontier Economics

Note: Net of baseline scenario revenues. Applying average revenues for small, medium, and large firms separately for prohibited AI firms. For further details, please see annex A.5

Unsurprisingly, the model estimates that double the revenue is lost in scenario 1 compared to scenario 2. This result is assumption-driven, and further investigation into what percentage of AI firms would leave the market due to prohibition may provide more accurate results and the ability to compare this impact under each regulatory scenario more robustly.

66 For further details, please see annex A.4

6.1.3 Business costs from compliance with the regulation

Both regulatory scenarios require firms to comply with a range of requirements. Among these are conformity assessments and fulfilling transparency obligations. The mechanism by which costs ultimately translate into impacts is common across scenarios, but the magnitude of costs associated with compliance and which firms are affected by those requirements vary. In light of information received from conversations with stakeholders, our modelling of compliance costs comprises three steps. These steps reflect the range of decisions businesses may need to take when faced with these costs:

1. Modelling the costs of compliance per business (i.e., modelling outcomes)
2. Modelling businesses' decisions about compliance costs (i.e., modelling mechanisms)
3. Modelling business decisions' impacts (i.e., modelling impacts)

The section below sets out these steps and the final impact that compliance costs have on the AI market under each regulatory scenario.

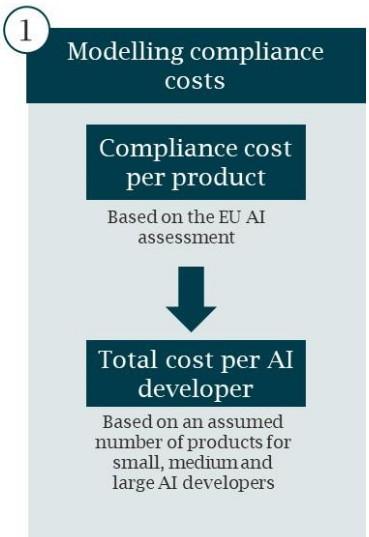
(a) Modelling the costs of compliance per business (i.e., modelling outcomes):

The calculation of compliance costs is done in two main stages, as shown in Figure 11. We first calculate the compliance cost per AI product (which we define as a unique product requiring compliance assessment) and then estimate the sum of those costs for each business.

The cost calculation per AI product is based on the Study to Support the EU AI Act Impact Assessment and utilises the estimates of minutes spent by employees, Full-Time Equivalent (FTE)[67] of additional service and employees, and other expenses that would be required by firms to ensure compliance with each section of the regulation.[68] For each scenario, we model:

- In scenario 1, we model the cost of compliance with the HRS requirements and the costs of compliance with transparency requirements for non-HRS interacting with a natural person.

Figure 11 Compliance costs schematic model



Source: Frontier Economics

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[67] Full-Time-Equivalent (FTE) refers to the unit of measurement equivalent to an individual. In our model, that refers to the number of hours needed for a given task required for compliance with the regulation.

[68] We use the UK 75th percentile hourly rates for science research, engineering and technology professionals in 2021. For additional costs, which are reported in EUR, we convert to GBP using the average Bank of England exchange rate in 2020. Please see annex A.6 for further details.

- For scenario 2, we estimate the cost for HRS compliance and compliance with the minimum requirements that all AI firms must adhere to. We assume that these minimum requirements would not be required in addition to HRS requirements, and as such, this cost is applicable only for the non-HRS proportion of the market

Several other aspects of each regulatory scenario may create additional costs to businesses, but these are not included in the model, as evidence suggests these would be negligible. The first costs not included are costs from one-off "familiarisation" with regulation, which might be incurred under both scenarios, from an investment in understating the new regulation and assessing whether their products are part of the prohibition list or considered HRS. Our estimations revealed that these one-off costs are negligible compared to other costs and, as such, not modelled in this part of the analysis.[69] [70] The second type of costs not modelled are those associated with the voluntary code of conduct for non-HRS firms indicated for scenario 1, which theoretically creates costs for businesses implementing the relevant processes. Stakeholders have indicated that since this is a voluntary option, only businesses that already have those processes in place would comply with the code of conduct, meaning that there should not be any substantive new costs, compared to the baseline scenario, in the market. Given the low and insignificant costs associated with these aspects of regulation, we assume both to have zero costs to businesses and exclude them from the model.

To arrive at a typical cost per business of different sizes, we multiply the per-unique-product unit cost (which is assumed to be the same per unit for any organisation size) by the number of unique products typical for businesses of each size. We assume that the number of unique products per business in 2020 is 2, 5 and 10 for small, medium, and large AI firms, respectively.[71] This exercise is done for each of the years and provides the anticipated total compliance costs for typical large, medium and small AI firms.

Lastly, we estimate the total compliance costs across all AI firms by applying the costs per business to the percentage of AI firms subject to each compliance requirement. Mirroring our assumption about the percentage of firms that would be caught by the prohibition, we assume that AI firms would fall fully under the various regulatory categories (e.g., HRS, non-HRS etc.) rather than only specific products they sell.

[69] The cost per unit was estimated at £160. Even for large firms in the model, this cost was £1,600, which is only incurred once. For further details, please see annex A.6.3

[70] Using DCMS's analysis of the expected impact of GDPR, this cost per business is about £30 (This can be higher or lower, depending on the scenario). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1016471/Data_Reform_Impact_Analysis_Paper.pdf. Paragraph 57.

[71] The assumption is based on a general impression from stakeholder interviews, which was agreed upon as reasonable with the DCMS team. For further details, please see annex A.3.4.

Instead of using the Study to Support the EU AI Act assumption[72], we apply the methodology described above for assessing the level of prohibited firms to assess the proportion of AI firms that would fall under the HRS definition. We first assume the level of AI risk (low, medium and high) associated with each sector and what each risk level suggests about the proportion of AI firms that would be considered HRS. For example, a sector with a medium level of AI risk would indicate that 20% of AI firms in the sector would be considered HRS.[73] We then take the number of AI firms in each sector and arrive at the total number of AI firms across all sectors that would fall under the HRS definition, which allows us to calculate the total percentage of AI firms that would be considered HRS. Similarly, to assess the percentage that would have to adhere to the light transparency requirement, we estimate the proportion of products in each sector that would interact with a natural person.[74] [75] Since we assume that sectoral regulators would better understand the products under their jurisdiction, the regulatory regime under scenario 2 is assumed to provide a more precise HRS list. As such, the assumed percentage of HRS businesses is half of that in scenario 1. Table 1 below presents the annual compliance costs estimates, which we assume to be constant over the model's ten-year horizon.

Table 1 Compliance cost per business – by business size and % of impacted businesses

Cost items for each scenario	Small	Medium	Large
Assumed number of products per business	2	5	10
Scenario 1			
Compliance cost per product			
Total HRS compliance	£33,906	£33,906	£28,252
Transparency and disclaimers for AI interacting with a natural person (non-HRS systems)	£2,751	£2,751	£2,751
Compliance cost per firm			
Total HRS compliance	£67,812	£169,531	£282,517
Transparency and disclaimers for AI interacting with a natural person (non-HRS systems)	£5,503	£13,757	£27,513
Scenario 2			
Compliance cost per product			
Total HRS compliance	£29,759	£29,759	£25,236
Minimum requirements (non-HRS)	£2,884	£2,884	£2,884
Compliance cost per firm			

[72] The Study to Support the EU AI Act Impact Assessment estimates that the percentage of firms falling under the HRS definition would be 10% but does not provide any reasoning to explain this estimate. This lack of clarity was also criticised by Axel Voss, a member of the European parliament, who has recently published a "Request to review the Impact Assessment of the AI Act", where he also raised questions with regards to this assumption. Available at: https://www.kaizenner.eu/post/juri-draft-aia2

[73] For further details, please see annex A.4.

[74] The EU AI Act asks firms that interact with a natural person (and which do not fall under the HRS list) to adhere to lighter transparency requirements.

[75] For further details, please see annex A.4.

Total HRS compliance	£59,519	£148,797	£252,359
Minimum requirements (non-HRS)	£5,767	£14,418	£28,836

Source: *Frontier Economics*

Note: *In our model, we assume that regulation starts only in 2023. This table shows the cost per product and per firm had regulation started in 2020. As such, the costs for the first year of regulation would be higher, given the increase in the projected number of AI products from 2020 to 2023.*

Combining the information from Table 1 with the estimates of the number of AI firms in each size category from our baseline, we calculate the total compliance costs for AI firms under both scenarios, which are presented in Figure 12 below. Although the per product and per business HRS compliance costs are slightly lower for scenario 2, the fact that minimum requirements are applied across all AI firms, while HRS and transparency requirements are applied only to part of the firms, leads to higher total compliance costs in scenario 2 compared to scenario 1.

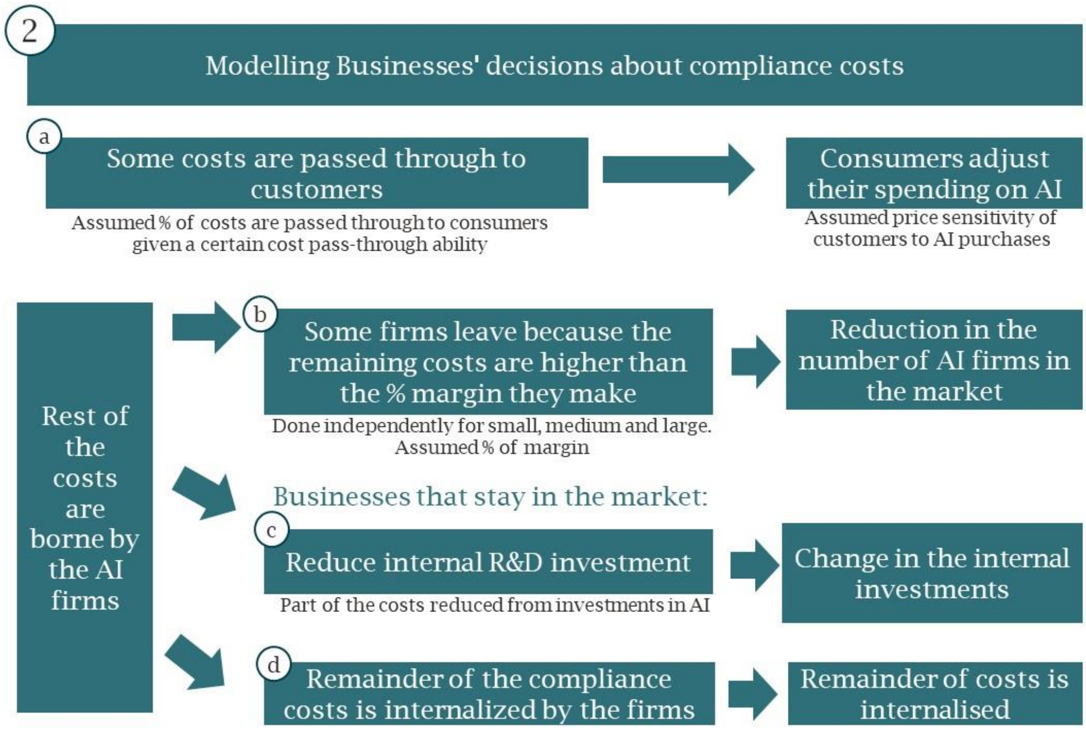
Figure 12 Total compliance costs

Source: *Frontier Economics*

(b) Modelling the impact of compliance costs on businesses' decisions (i.e., modelling mechanisms)

Compliance costs lead to several sequential decisions that firms need to make. Based on stakeholder insight, AI firms in the model make several consecutive decisions in response to an increase in compliance costs. Figure 13 shows a schematic representation of those choices. We explain each below.

Figure 13 Schematic representation of business decisions given the compliance costs they face



Source: Frontier Economics

a. Pass-through a portion of the total compliance costs to consumers:

New compliance costs are common across a sector and can potentially be passed through to consumers. Cost pass-through describes: "when a business changes the prices of the products or services it supplies following a change in the costs it incurs in producing them."[76] Factors such as market concentration, demand for the product, and whether the cost increase is sector-wide or firm-specific can impact businesses' ability to pass-through costs.[77] To assess how much businesses would be able to pass on to consumers requires understanding the sector-wide cost pass-through ability.

Currently, we could not identify a study that has looked at estimating the cost pass-through ability for AI (or even high-tech) products. In addition, it was not possible to identify a credible source for the current cost levels for AI firms, which is required

[76] Cost pass-through: theory, measurement, and potential policy implications (RBB ,2014) . Available at: https://www.gov.uk/government/publications/cost-pass-through-theory-measurement-and-policy-implications#:~:text=Cost%20pass%2Dthrough%20describes%20what,it%20incurs%20in%20producing%20them.

[77] Ibid.

for the usage of the pass-through elasticity modelling.[78] Given these limitations, and since it is out of scope for this project to undertake an economic study to estimate this ability[79], we use a simplified assumption that businesses would be able to pass through half of the compliance costs that they incur.[80]

This cost pass-through increases the price of AI products and impacts consumers' purchasing levels. Consumers' sensitivity to AI prices will determine how the price increase affects final AI revenues in the market. As with cost pass-through, we were not able to identify any credible source that would provide a price sensitivity estimation for AI products, and we do not model the quantity of AI products sold in the market, which means it was not possible to incorporate a price elasticity to understand market changes.[81] Therefore, the model assumes that a £1 price increase would lead to a total revenue loss of £0.5 in the AI market. This assumption implies a somewhat inelastic consumer demand for AI products, which means that price increases would reduce consumption but at a lower rate than the rate of the price increase.[82]

b. **Decide whether to leave the market:**

The remaining compliance costs (after costs that will be passed to consumers are subtracted) impact businesses' ability to stay in the market. We assume that only businesses whose remaining compliance costs are lower than their absolute profit would stay in the market (i.e., those that will not see losses due to regulation). Although we assume the same profit margin across firm sizes, the decision is different for small, medium and large firms. Small AI firms would have fewer unique AI products and hence lower total compliance costs; they would also have lower revenues, making it harder for them to survive the cost increase.[83] In line with this

[78] Since the pass-through elasticity is defined as the % change in price from a % change in cost, one needs to have the initial cost level for AI to utilise the costs pass-through elasticity.

[79] Such a study requires a complex economic experiment which is outside the scope of this project.

[80] The RBB report "Cost pass-through: theory, measurement, and potential policy implications" (RBB, 2014) includes a literature review, available at the time, about the ability to pass through costs. The estimates are volatile and the assumption of 50% is in the reported range. We were not able to locate any more current indications of what would be a relevant cost pass-through. As such, we agreed on this assumption with the DCMS team.

[81] Price elasticity of demand is defined as the % change in the quantity of consumption given a % increase in price. As such, to utilise the price elasticity of demand, one needs to know the initial price and the initial consumption level.

[82] Depending on the actual prices and quantity of AI products in the market, the way we model the impact of compliance cost pass-through to consumers and the final impacts on AI revenues implies an elasticity of ca. -0.7 where 0 would be perfect inelasticity (no consumption change give price increase) and -1 unitary elasticity (1% price increase leads to 1% consumption decrease). For further information please see annex A.7.3.

[83] Although the compliance cost per unit is the same for every firm size, we assume that each business size would have a different number of unique AI products making the overall compliance costs higher for larger firms in nominal terms. Although both the number of products and revenues are lower for SMEs the ratio of SMEs' revenues to that of large firms is much smaller than the ratio of the number of unique AI products between SMEs and large firms. The result is that a higher proportion of SME firms would be unable to withstand the compliance costs.

insight, the model produces a higher compliance cost-to-revenue ratio for SMEs compared to of large firms.

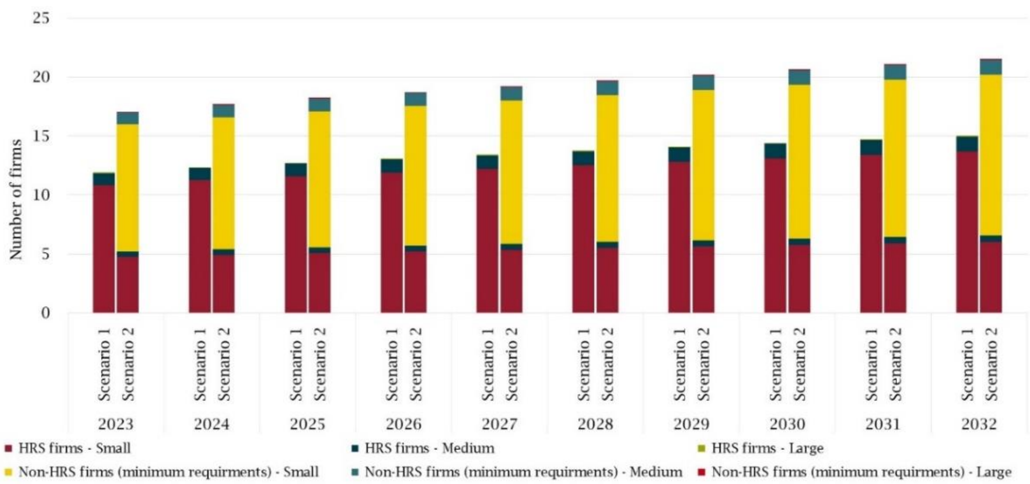
Assuming a uniform distribution of AI firms by revenue within each size category and a profit margin of 10% across all AI firms, we identify the number of firms in each size category that are not able to withstand the compliance cost increase and leave the AI market. Revenues for these companies are then lost.[84]

Figure 14 presents the number of firms in each size category that exit or will not enter the market, in the future, due to compliance costs under each scenario. Small firms are impacted most under both scenarios for two main reasons:

- First, the ratio of compliance costs to revenues is higher for small firms compared to medium and large firms.[85]
- Second, there are many more small firms in the market compared to medium and large ones, which increases the chances that a firm would not be able to survive the regulatory compliance costs.

It is also clear that more companies exit or do not enter the market under scenario 2. This result is driven by firms leaving the market due to minimum requirements compliance. Although Table 1 above showed that costs associated with minimum requirements are smaller compared to HRS-related costs, minimum requirements are applied to all firms in the market (while HRS is applied to only a small proportion of firms), increasing the number of firms not able to withstand these costs. As a result, the total number of firms exiting or not entering the market due to compliance costs is higher in scenario 2.

Figure 14 Number of firms that exit or do not enter the market due to compliance costs



[84] For further details, please see annex A.7.2

[85] For further details, please see annex A.7.2

Source: Frontier Economics

c. Decide to reduce internal R&D investment (for those businesses that remain):

Businesses that are able to remain in the market still need to deal with the compliance costs that they are not able to pass through to customers. Stakeholder interviews highlighted that some (or all) of these remaining compliance costs would be taken from internal firm investments in R&D. A reduction in investments of this kind (across the whole market) is expected to result in a lagged reduction in AI revenues.

We do not have a source for internal levels of R&D investment in the market, so we use a proxy for this in our modelling. We estimate an annual return on investment (ROI) figure by using the baseline information on VC investments and an approximation of business profits.[86] This ROI is then used as a proxy for the relationship between investment and revenues for all firms. We recognise that this is a simplified assumption, but given the scope of this work, the approximation provides a reasonable representation of AI ROI, which allows us to model how a reduction in R&D investment impacts AI revenues.[87]

In practice, from the baseline calculations, we use profits of a given year and VC investment from the year before to arrive at a baseline ROI.[88] Assuming that the ROI would not change between the baseline scenario and the two regulatory options, we can interact the anticipated reduction in R&D investments with the ROI to see how revenues change. Since the costs are different for each firm size, we calculate these changes separately for each size category.

d. Residual compliance costs are incurred fully by businesses (i.e., a non-governmental cost of regulation)

After businesses pass-through costs to consumers and decide how much of the remaining costs they want to take from R&D, they internalise the residual compliance costs. This residual does not have a further real impact on the economy but rather acts similarly to a tax on business profits and effectively as a transfer between consumers and producers or shareholders. Therefore, we do not consider this effect further in our model. This is different to the estimated reduction of AI revenues which is taken to proxy the real impact of; a) the productivity loss associated with losing AI developers from the market; and b) the consumer and

[86] Profits are calculated by applying the profit margin to AI revenues. We assume that VC investments only fund SME AI firms. Large AI firms would have internal investment abilities and, as such, consider only SME revenues for the ROI calculation.

[87] This assumption might be oversimplified since it assumes that ROI from VC investments is similar to the ROI from internal investment in R&D, and it assumes large firms' ROI is similar to that of SMEs.

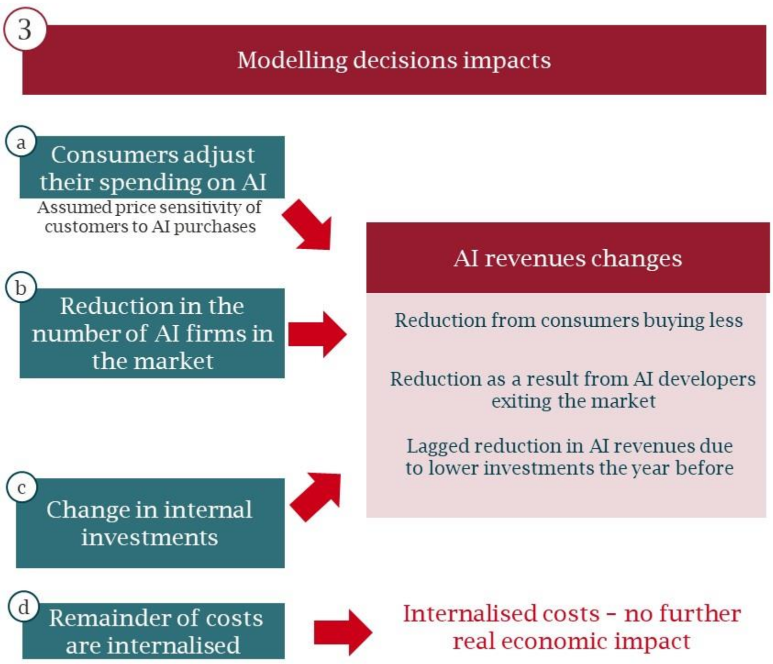
[88] Profits are estimated by applying the assumed profit margin on AI revenues. For further details, please see annex A.7.4.

downstream business productivity loss associated with an increase in the price or loss of AI inputs.

(c) Modelling the implication of businesses' decisions

Figure 15 presents a schematic graph of the implications of these decisions. The magnitude of these results (and consequently their impact on AI revenues) depends primarily on the level of compliance costs estimated for each scenario and the proportion of businesses that incur those costs (e.g., number of HRS).

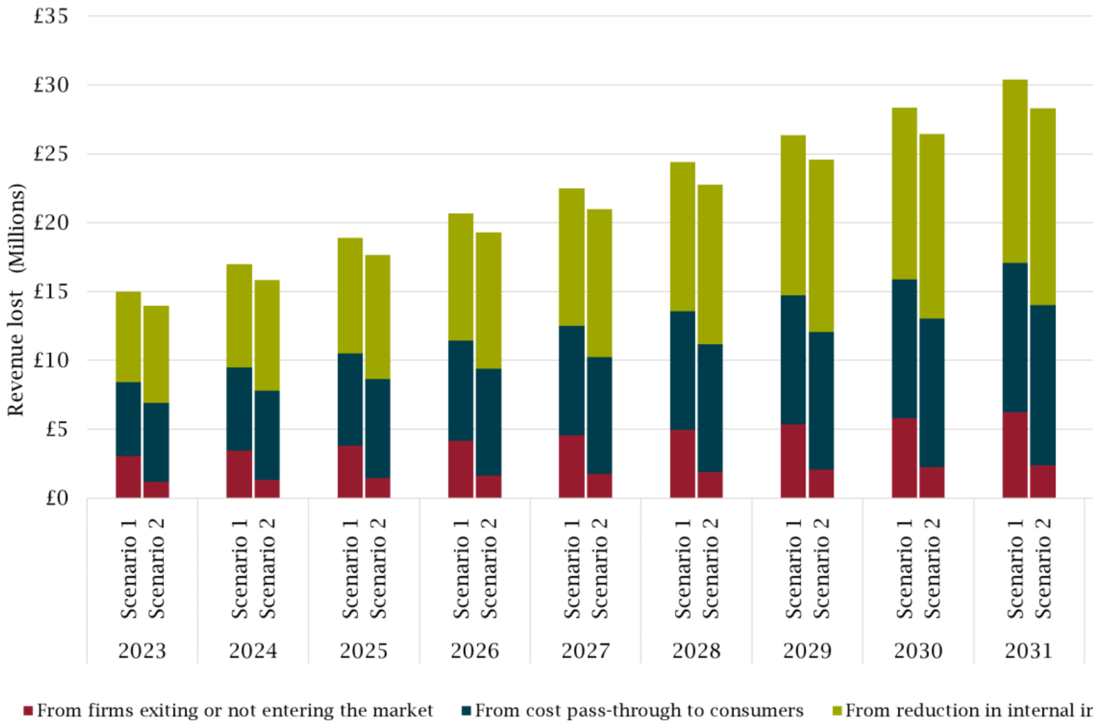
Figure 15 Schematic representation of the impacts given businesses' decisions



Source: Frontier Economics

Figure 16 below presents the revenue reduction due to compliance-costs split by the origin of the change. Although Table 1 above shows that the total compliance costs under scenario 1 are lower than under scenario 2, the overall AI revenue reduction due to compliance costs in scenario 1 is still higher compared to that in scenario 2. The main driver of this flipped result is the number and nature of the firms that exit (or do not enter) the market due to compliance costs. First, the proportion of HRS firms is smaller under scenario 2, leading to a lower number of HRS firms leaving the market. Second, although minimal requirements are applied to all AI firms, their average revenue lost is much lower compared to the average revenue of the HRS firms, which exit under scenario 1. Even though there are more overall AI firms leaving the market due to compliance costs under scenario 2, there are fewer HRS firms leaving leading to a lower impact on AI revenues lost.

Figure 16 Reduction in AI revenues due to compliance costs split by mechanism for each year



Source: Frontier Economics

6.1.4 Customer trust and its impact on AI expenditure and data sharing

Trust in AI is critical for the sector's success because it increases purchases of AI products and services, and it increases consumers' willingness to share data with AI systems. For non-AI products, variation in trust (or perception of risk) mainly affects the level of product purchases.[89] If consumers do not trust a microwave to be safe, for example, they will not buy it, and sales will drop. For AI, the amount of trust in the products may also change the level of data individuals are willing to share.[90] Given the self-learning nature of AI, changes to data sharing directly impact the ability of AI products to learn and improve, eventually improving productivity in the market. When evaluating AI regulation, we must address both aspects of consumer trust. With these two aspects in mind, our consumer trust modelling includes three high-level steps:

1. Modelling change in consumer trust (i.e., modelling outcomes)

[89] Suleman, D. Sabil, S. Rusiyati, S. Sari, I. Rachmawati, S. Nurhayaty, E & Parancika, R. (2021). Exploring the relationship between trust, ease of use after purchase and switching re-purchase intention. International Journal of Data and Network Science, 5(3), 465-470. Available at: http://growingscience.com/beta/ijds/4959-exploring-the-relationship-between-trust-ease-of-use-after-purchase-and-switching-re-purchase-intention.html

[90] http://theodi.org/wp-content/uploads/2021/03/RPT_Trust-in-data-ecosystems-23.02.21-STC-final-report.pdf

2. Modelling consumer trust impacts on data sharing and purchasing intentions (i.e., modelling mechanisms)
3. Modelling changes in AI revenues (i.e., modelling impacts)

Below we explore each modelling stage in turn.

(a) Modelling the costs of compliance per business (i.e., modelling outcomes):

The starting point of this part of the model is understanding how each aspect of AI regulation may affect consumers' trust in AI. Public trust can refer to different things, including willingness to interact with a service or the perceived level of risk that a service presents to individuals. The level of trust also depends on several drivers, including the technical, legal and cultural considerations the public associate with AI. Work by the Centre for Data Ethics and Innovation (CDEI) "Assessing trust in the public sector" (July 2020) discusses at length the various benefits and limitations of public trust in data sharing and identifies that legal clarity can help increase public trust, although this may be limited given other aspects affecting public trust.[91] The same paper also noted that "there has been a relatively limited effort by the government and wider public sector to address public trust explicitly".[92] Our attempt to identify independent evidence on which to base the assessment of how consumers' trust may change with the introduction of AI regulation showed that no substantial further advances had been made in this field since the publication of the CDEI report.

Since the impact of AI regulation on trust, and subsequently on data sharing and AI purchases, is important for future consideration of AI regulation, we proceed with an indicative model of trust change that is based on insights from stakeholders and AI experts we interviewed as part of this project. Overall, these conversations indicated that the most important aspect of regulation for enhancing consumers' trust was the inclusion of transparency requirements. However, to be effective drivers of trust, these requirements need to be meaningful and not become a 'tick-box' transparency exercise with which consumers disengage. The remaining aspects of AI regulation were thought to be much less impactful on trust since the typical member of the population would not be aware of them. We also discussed our findings with the CDEI, who indicated that their work in this area suggests regulation may increase trust by a relatively small amount, and the impact on purchasing behaviour was complex and difficult to determine. Table 2 below provides our modelling assumptions about how trust changes for each aspect of the AI regulation. Trust is measured on the Likert scale, between 1 and 5, where 5 indicates the highest trust level and 1 the lowest. To be

[91] https://www.gov.uk/government/publications/cdei-publishes-its-first-report-on-public-sector-data-sharing/addressing-trust-in-public-sector-data-use

[92] Ibid.

conservative, we assume the highest level of trust change to be 0.5 points on the Likert scale.

Table 2 Assumed trust changes for each aspect of regulation

Aspects of regulation	# points trust change	Scenario applies to	Comments (out of Likert scale)
HRS Conformity assessment (ex-ante)	0.00	Scenario 1	Based on conversations with an AI expert and the views of stakeholders. Having conformity assessments for HRS might have an even more limited impact (compared to the impact of prohibition) on consumers' trust. Mainly, as the majority of the population would not be aware of the regulation. We assume no impact.
Transparency requirements for non-HRS that interact with a natural person	0.50	Scenario 1	Both experts agree that transparency requirements would have the most impact on consumers' trust. For scenario 1, this might be slightly limited as the perception was that businesses would deal with these requirements as a 'tick-box' exercise.
Voluntary codes of conduct	0.00	Scenario 1	Based on stakeholders' views and corroboration by an expert, only businesses that already do internal processes to identify risk would engage with this. As such, this causes no further impact on trust.
HRS Conformity assessment (ex-post)	0.00	Scenario 2	Based on conversations with an AI expert and the views of stakeholders. Having conformity assessments for HRS might have an even more limited impact (compared to the impact of prohibition) on consumers' trust, mainly as the majority of the population would not be aware of the regulation. We assume no impact.
Transparency requirements for all (minimum)	0.50	Scenario 2	Both experts agree that transparency requirements would have the most impact on consumers' trust. For scenario 1, this might be slightly limited, as the perception was that businesses would deal with these requirements as a 'tick-box' exercise. For scenario 2, if the outline of the transparency is more about explaining the processes and having accountability for the results, then this should be higher than 1. We assume a simpler transparency requirement.
Self-conformity assessment for all (minimum)	0.25	Scenario 2	Based on conversations with an AI expert, having a self-assessment that is results-based should result in high trust for consumers, as accountability and transparency would be visible to them. We assume only a quarter-point chance, to be conservative, as we also heard that conformity requirements usually do not impact trust as much as transparency.
Prohibition	0.25	Both scenarios 1 and 2	Based on conversations with an AI expert and the views of stakeholders. Prohibition is expected to have a limited impact on consumers' trust, mainly as the majority of the population would not be aware of the regulation and the prohibition list.
HRS Identification and public list	0.00	Both scenarios 1 and 2	Based on conversations with an AI expert and the views of stakeholders. HRS identification is expected to have an even more limited impact (compared to the impact of prohibition) on consumers' trust, mainly as the majority of the population would not be aware of the regulation and the HRS list. We assume no impact.

HRS Transparency requirements	0.50	Both scenarios 1 and 2	Both experts agree that transparency requirements would have the most tangible impact on consumers' trust. For scenario 1, this might be slightly limited as the perception was that businesses would deal with those requirements as a 'tick-box' exercise.

Source: Frontier Economics

Note: Based on several conversations with stakeholders and AI experts

We interact the change in the level of trust associated with each aspect of regulation with the proportion of the market that this aspect is expected to affect. For example, HRS transparency requirements are anticipated to only impact the trust levels of those customers who interact with HRS. We assume, in most cases, that the percentage of consumers impacted is the same as the percentage of AI firms impacted by that specific regulatory aspect.[93] Repeating this across all aspects of regulation generates a weighted trust change for each scenario. Table 3 below presents the estimated weighted average trust point change for each scenario. This is then used to inform the level of data sharing and AI purchases, as explained below.

Table 3 Weighted average change in trust levels by scenario

Aspect of regulation	# points trust change	% of the AI market impacted
Scenario 1		
Prohibition	0.25	100%
HRS Identification and public list	0.00	8%
HRS Transparency requirements	0.50	8%
HRS Conformity assessment (ex-ante)	0.00	8%
Transparency requirements for non-HRS that interact with a natural person	0.50	39%
Voluntary codes of conduct	0.00	100%
The average change in trust level	0.08	
Scenario 2		
Prohibition	0.25	100%
HRS Identification and public list	0.00	4%
HRS Transparency requirements	0.50	4%
HRS Conformity assessment (ex-post)	0.00	4%
Transparency requirements for all (minimum)	0.50	100%
The average change in trust level	0.13	

Source: Frontier Economics

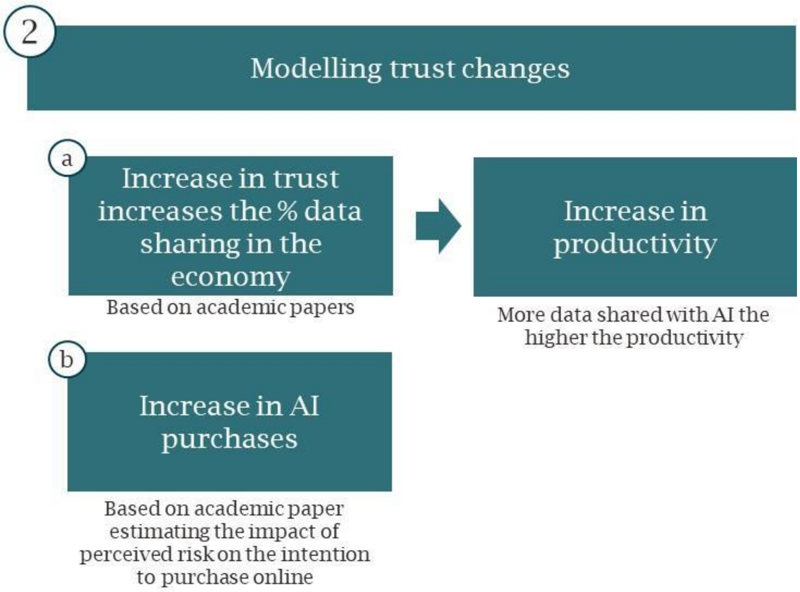
Note: Point change on a Likert scale. The only aspect of regulation assumed to affect the full market, although it applies to only part of the market, is prohibition. The assumption is that knowing most harmful products would be excluded from the market would increase consumers' trust across the market.

(b) Modelling consumer trust impacts on data sharing and purchasing intentions (i.e., modelling mechanisms)

[93] Weighing the trust changes for each aspect by the proportion of the market that is impacted implicitly assumes that products and consumers are distributed similarly in the market. We acknowledge that some AI products might be sold at a higher/lower rate than what is assumed for their production, but due to lack of information on this, we believe this is a reasonable assumption

A change in trust operates through two mechanisms that eventually change the level of AI revenues in the market: i) via an impact on data sharing, which affects the productivity of AI firms, and ii) via a change in the level of AI purchases. These mechanisms are presented in Figure 17 and explained in the sections below.

Figure 17 Schematic representation of the mechanisms interacting with consumer trust



Source: Frontier Economics

(i) Increase in data sharing that leads to improved productivity of AI firms

In a previous Frontier Economics report for the Open Data Institute (ODI), we found that a one-point change on a Likert scale of trust level is associated with a 0.27 point change on the Likert scale in data sharing (see Figure 18).[94] Assuming a baseline data sharing level of 4 points would mean a 6.75% change in data sharing for a 1 point change in the trust levels.[95] [96]Multiplying this percentage with the average change in trust we found for each scenario produces the overall percentage change in the data sharing level in the market. For scenario 1 it is 1.09% and for scenario 2 it is 2.30%.[97]

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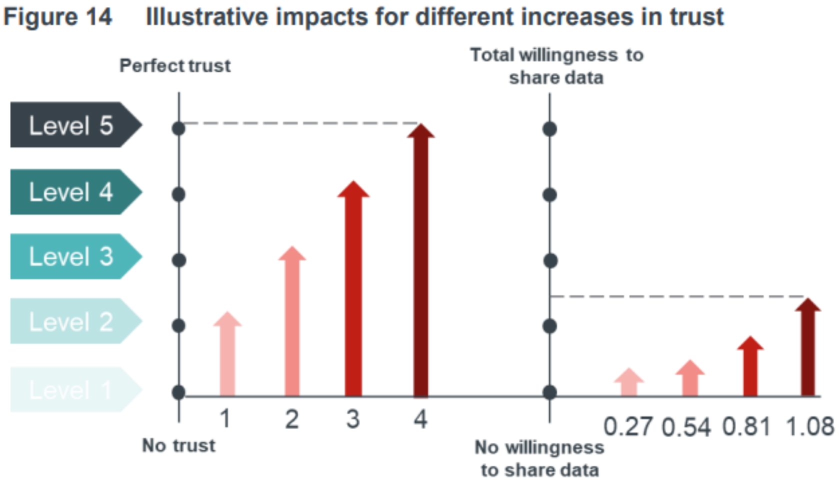
[94] http://theodi.org/wp-content/uploads/2021/03/RPT_Trust-in-data-ecosystems-23.02.21-STC-final-report.pdf

[95] 0.27 out of 4 is equal to 0.0675.

[97] For further explanation of these calculations, please see annex A.8.

Figure 18 Levels of trust and impact on data sharing



Source: *Frontier Economics. Economic Impact of Trust in Data Ecosystems. February 2021. Available at http://theodi.org/wp-content/uploads/2021/03/RPT_Trust-in-data-ecosystems-23.02.21-STC-final-report.pdf*

A Nesta paper (2014) has estimated how much firms' productivity increases with an internal increase in data capabilities. Overall, it was estimated that a 1 standard deviation change in data usage would increase firms' productivity by 8%.[98] The Nesta paper looked at how various aspects of data capabilities within a firm impacted their productivity, not only data collection. With that in mind, we apply the change in the trust level to the capabilities relevant to the AI regulation (e.g., data collection) and arrive at a weighted change in data capabilities. That change then interacts with the 8% productivity increase, leading to a 0.012% increase in productivity in scenario 1 and a 0.026% increase in scenario 2. These productivity improvements are applied to AI revenues.[99]

(ii) Increase in purchases of AI products:

To model how a change in trust impacts purchases of AI, we use a paper that looks at how perceived risk impacts consumers' intentions to purchase products online.[100] The paper provides an estimate of how consumer perceptions of various aspects of risk associated with online shopping impact their willingness to purchase products online. The paper includes five aspects of risk; financial risk, product risk, security risk, time risk, and social risk. We believe that only social and security risks are relevant to how the trust in AI affects purchase decisions due to regulation changes - since the regulation aims to reduce social harms (such as discrimination) and increase security in AI usage. We assume a baseline risk

[98] https://media.nesta.org.uk/documents/1405_the_analytical_firm_-_final.pdf

[99] For further details, please see annex A.8.

[100] https://www.tandfonline.com/doi/pdf/10.1080/23311975.2020.1869363?needAccess=true

perception associated with purchases of AI products of 3 on the Likert scale[101]. We then adjust this risk perception according to how AI regulation is expected to change social and security risks (based on this paper) from the trust changes estimated in step a). We arrive at the new perceived risk associated with AI purchases by weighing the perceived change in social and security risks (alongside the other risks), which we assume stay constant.[102] The change in perceived risk then interacts with the estimated impact on purchase intention found in the paper. For scenario 1, this leads to an estimate of a 0.38% change in the intention to purchase AI systems, while for scenario 2, the equivalent increase is 0.81%.

We note that this methodology has various limitations (explored below), but our view is that the model yields a good sense of the order of magnitude of likely changes in purchasing intentions and, subsequently, changes in AI revenues driven by a change in consumer trust. One assumption we rely on is that perceived risk, and trust levels are similar. Although the two are not the same, one can argue that trust and risk perception are the inverse of each other. If one perceives less risk from something, one will trust it more, and vice versa. Second, we assume that the intention to shop online has the same risk sensitivity as purchases of AI products – an assumption that can be debated. Since the model aims to indicate (rather than estimate) how different trust levels would impact AI purchases, we believe these assumptions give a reliable answer. Further research might be appropriate to accurately estimate how consumers' trust may impact AI purchases, although limited data currently exists in this area.

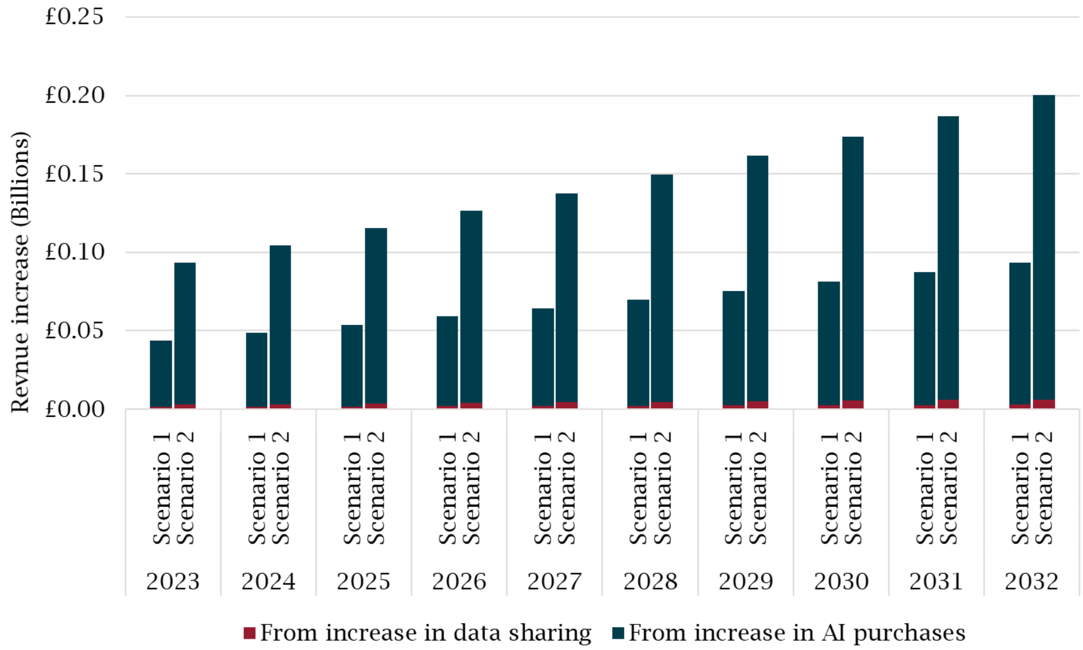
(c) Modelling changes in AI revenues (i.e., modelling impacts)

Both of the mechanisms described above affect AI revenues. An increase in trust leads to an increase in data sharing with AI systems, increased productivity and an increase in AI revenue. The fact that customers have more trust in AI products increases their purchasing levels, also leading to higher AI revenues. Figure 19 presents the combined impact of these mechanisms on AI revenues in each scenario.

[101] For risk perception, the higher the score the lower the risk perception.

[102] For further details about this calculation, please see annex A.8.

Figure 19 Net increase in AI revenues due to increases in trust – split by mechanism



Source: Frontier Economics
Note: Net increase in revenues

The higher trust increase, under scenario 2, leads to overall higher positive impacts on AI revenues compared to scenario 1. It is important to note that purchasing impact drives the main positive impact from consumers' trust increase, rather than the increase in AI revenues from productivity. Given that this mechanism modelling is based on a paper that deals with a similar, but not the same, question and has several limitations to it and its application, it may result in an overestimation of this aspect. Further research into how consumer trust changes with the introduction of different AI regulations and how that impacts AI purchases might provide a more robust estimation of this impact.

6.1.5 Market uncertainty and impacts on AI investments

By creating uncertainty, new regulations can change the confidence of investors in certain markets, making them change how much they invest, resulting in impacts on AI revenues. For example, it has been reported that the Brexit referendum, which was an unexpected change in UK policy, has led to a gradual reduction of 11% in investments.[103] The introduction of the General Data Protection Regulation (GDPR) also created uncertainty, particularly regulatory uncertainty, which impacted investment levels in the UK. A study by Jia et el. (2019) found

[103] https://blogs.lse.ac.uk/brexit/2019/09/11/the-impact-of-brexit-on-uk-firms-reduced-investments-and-decreased-productivity/

that the short-term impact of GDPR on EU technology firms has led to a double-digit percentage decline in VC funding compared to their US counterparts.[104] The same paper also highlights that this impact of market uncertainty appears more profound for young technology companies (which would most likely fall under the SME category).[105] In the section below, we explain how we modelled the impact of regulation on market uncertainty, the level of VC investments in AI SME firms, and AI revenues.

Our modelling of market uncertainty includes three high-level steps:

1. Modelling the change in market uncertainty due to AI regulation (i.e., modelling outcomes).
2. Modelling changes in VC investment levels, which result from a change in uncertainty (i.e., modelling mechanisms).
3. Modelling how the change in VC investment levels affects AI revenues (i.e., modelling impacts).

Below, we explore each modelling stage in turn.

(a) Modelling the change in market uncertainty due to AI regulation (i.e., modelling outcomes)

The first step is to identify a relevant measure of market uncertainty and estimate how it would change under each regulatory scenario. Various measures of market uncertainty are available and include, for example, stock-market volatility[106] and the index of Economic Policy Uncertainty (EPU)[107]. We use the EPU for our modelling as it is the measure used in the study by Dejuan-Bitri (2021), which studies the impact a change in uncertainty can have on levels of private investment.[108]

UK historic monthly EPU index data is publicly available and used in our model to assess the uncertainty changes that AI regulation could create. Table 4 shows EPU monthly changes between months when particularly interesting and relevant events (for the purposes of this study) happened in the UK. The EPU drastically changed in the month of the Brexit referendum, increasing by 2.57 EPU index points in June 2016. The onset of the COVID-19 pandemic had a more moderate impact, increasing the index by 1.42 points in March 2020. The most relevant impact for our study is likely to be the change in the EPU index following the introduction of GDPR, which

[104] https://voxeu.org/article/short-run-effects-gdpr-technology-venture-investment

[105] Ibid.

[106] Measures the level of the overall value of fluctuations in the stock market. See: https://www.fidelity.com.hk/en/start-investing/learn-about-investing/your-guide-to-stock-investing/understanding-stock-market-volatility-and-how-it-could-help-you#:~:text=What%20is%20volatility%3F,may%20happen%20in%20the%20future.

[107] Measures the policy-related uncertainty in a given country based on news articles referring to policy changes and uncertainty in a given month https://www.policyuncertainty.com/uk_monthly.html

[108] https://link.springer.com/article/10.1007/s13209-021-00237-5

led to a mild reaction of 0.19 points in May 2018.[109] Out of these three policy events, we believe that AI regulation in scenario 1 would have a similar EPU change effect as seen after the introduction of GDPR. We also assume that for scenario 2, AI regulation would have a milder impact and set the change in EPU to half of that in scenario 1 (or half of what was recorded after the introduction of GDPR). Since scenario 2 is sectoral and delivered by existing regulators, the regulation is expected to cause less uncertainty and is likely to be explained and communicated more clearly to firms in each sector compared to central regulation (i.e., scenario 1). This view was collaborated by the stakeholders we interviewed, saying they believe sectoral regulators would be able to communicate the regulatory requirements more clearly, as they better understand the specific needs of firms in their jurisdiction. Our final assumptions are that the EPU index increases 0.19 points in scenario 1 and 0.10 in scenario 2.[110]

Table 4 Changes in the EPU index for selected policy events in the UK

Policy event	Monthly EPU change
Brexit referendum	2.57
Covid-19 pandemic outbreak	1.42
Introduction of GDPR	0.19
Model assumptions:	
Scenario 1	0.19
Scenario 2	0.10

Source: *Frontier Economics*

Note: *EPU changes are calculated as the difference in the EPU index between two months: Brexit – between May and June 2016, GDPR - between April and May 2018, and COVID-19 – between February and March 2020*

(b) Mechanisms: Modelling changes in VC investments due to market uncertainty

To evaluate the impact that changes in the EPU index can have on investments, we assume this effect is applied to SME firms only. There are two reasons we focus on SMEs. First, the Dejuan-Bitri (2021) study, which we use in our model to measure this impact, did not find any statistically significant relationship between changes in the EPU index and the investment rate of large firms.[111] Second, the level of VC investments in our model is mainly used to fund SMEs.[112] As such, we focus our analysis on how the estimated change in the EPU index would impact the level of VC investment for SMEs in the AI market.

[109] No other major events occurred over that June 2018, which might have increased the EPU index. We acknowledge that the change in the EPU may be driven partially by the introduction of GDPR.

[110] For further details, please see annex A.9.

[111] https://link.springer.com/article/10.1007/s13209-021-00237-5

[112] https://pitchbook.com/blog/what-is-venture-capital

The impact of EPU changes on VC levels is based on Dejuan-Bitri (2021). It estimates that, for SMEs, a one-point increase in the EPU index decreases the private investment rate by 4.7 percentage points.[113] To use this finding in our model, we need to estimate the investment rate, which the paper defines as, “the sum of gross fixed tangible and intangible capital formation divided by the total capital stock.” In this project's scope, we were not able to identify a source that would provide either of those two statistics. To address this issue, we utilise available information to arrive at a proxy for the investment rate. For gross fixed tangible and intangible capital formation, we use the VC investment level found in the baseline and make several adjustments to arrive at a relevant proxy. Mainly, we adjust to include governmental investment and debt to create a total capital investment in SMEs.[114] We acknowledge that these adjustments do not yield the exact statistic used in the paper, but we believe this is a reasonable approximation. For the total capital stock, we adjust total AI revenues to arrive at a proxy. Mainly, we inflate annual AI revenues by the IT sector price-to-cost ratio. We again acknowledge that this simplification may yield an inaccurate estimation, but given that most SME AI firms are not public companies, there is no information about their stock capital value. We arrive at a 13%-16% baseline investment rate across the modelling years - using those approximations. To verify that those estimations are reasonable, we cross-check our findings of investments rates with the average investment rate reported in Dejuan-Bitri (2021). The paper reports 13%, which is the lower bound of our estimates.[115] We believe it is reasonable to assume a slightly higher investment rate in our model since we focus on AI SME firms that would be more likely to rely on private investment.

Using the EPU change found in step 1, the paper's estimate of the impact on investment rates, and our annual investment rate estimate, we calculate the new annual investment rate for our scenarios. We assume regulatory uncertainty is temporary and will impact the market for two years, from 2023 to 2024, for both scenarios. This assumption is based on evidence that regulatory changes have an impact on uncertainty in the market, but it is limited to a couple of years (depending on the importance of the regulation to the economy).[116] Deducting the percentage change in investment from the investment rates for these years provides the new investment rate for the impacted two years and, subsequently, the new level of investments.

(c) Impacts: Modelling changes to AI revenues given changes to VC investments

The changes in SME VC investment levels for the years 2023-2024 impact AI revenues and profits. The modelling is based on the assumption that the baseline ROI would not change under each scenario. With that in mind, we can interact the new levels of

[113] https://link.springer.com/article/10.1007/s13209-021-00237-5

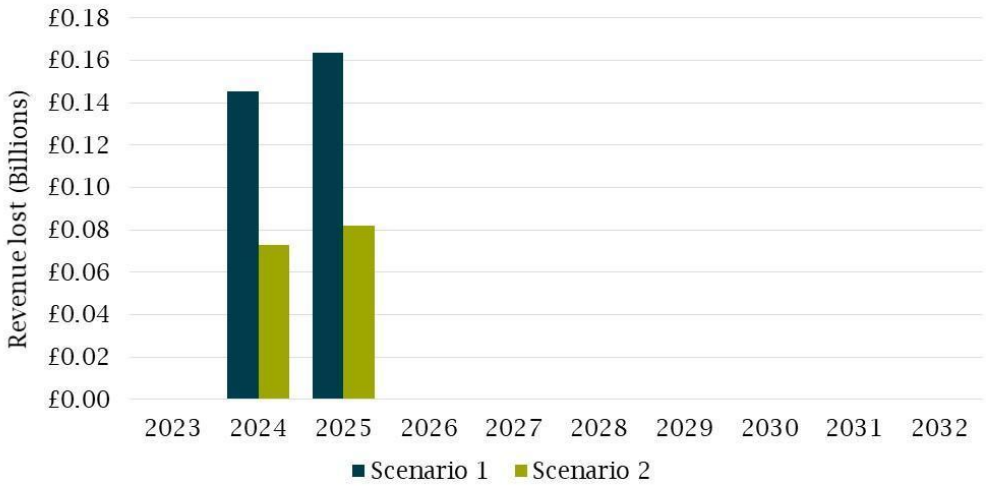
[114] For further details, please see annex A.9.

[115] https://link.springer.com/article/10.1007/s13209-021-00237-5/tables/1.

[116] For further details, please see annex A.9.

investment with the stable baseline ROI to estimate the change in AI profits from the lower level of VC investment. We can then derive new AI revenues, given this change in profits. Figure 20 below shows the AI revenue changes due to changes in uncertainty. Note that the change in AI revenues starts in the year 2024 and not 2023 since investment is expected to have a lagged impact on profits and revenues.[117]

Figure 20 Reduction in AI revenues due to changes in the level of VC investments



Source: *Frontier Economics*

Note: *Uncertainty changes start the same year the regulation starts, 2023. Given that investments affect revenues only the year after, the revenue loss is seen in 2024 and 2025 as the uncertainty is assumed to persist for three years.*

6.1.6 Total market size projection over the next decade

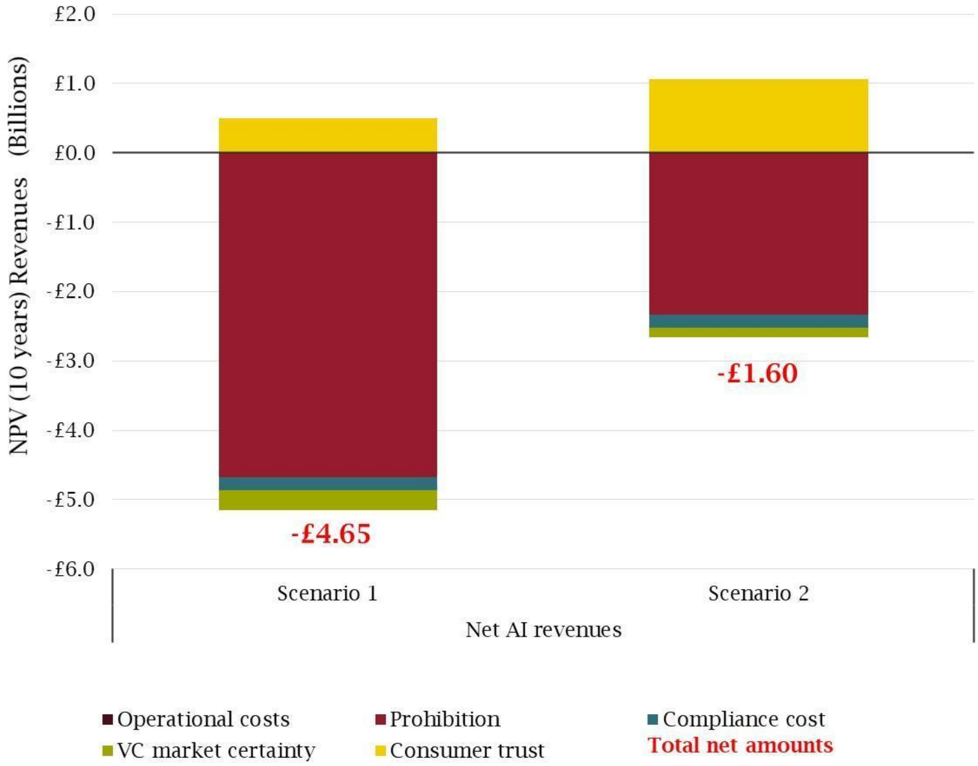
Figure 21 below presents the total impacts on AI revenues from AI regulation under each scenario. The three main takeaways are:

1. Prohibition of AI systems is the main driver of a reduction in AI revenues.
2. The indicative positive impact of consumer trust shows its power to mitigate some of the negative impacts of regulation.
3. Overall, scenario 2 provides a smaller estimated AI revenue loss than scenario 1.

We discuss each below.

[117] For further details, please see annex A.9.

Figure 21 Top ten-year NPV (2023-2032) AI revenue changes due to the AI regulation under each scenario



Source: *Frontier Economics*

Amongst the first striking results is that the most substantial negative impact on AI revenues is due to revenues from firms that exit (or do not enter in the future) due to prohibition. This result might be surprising at first, given the percentage of AI firms that fall under prohibition is smaller than those that would fall under the HRS category in both scenarios. However, there are two main drivers of this result. First, prohibition is applied to firms across the market and the revenues of the prohibited firms are assumed to be the average revenue of the firms in each size category. In contrast, revenues lost as a result of firms exiting (or not entering) due to compliance costs are taken from the bottom of the revenue distribution (i.e. the least profitable), making this impact much smaller.

Second, when faced with compliance costs, firms have ways to mitigate the burden put on them by passing-through part of the costs to consumers and reducing R&D investment. The cost pass-through to consumers is further mitigated by consumers reducing their purchases to adjust to the price increase, which leads to an overall decrease in AI revenues. This decrease is equal to half of the costs that were initially passed through to consumers. It is important to note that the reduction in AI revenues reflects part, but not all, of the consumer loss associated with the price change. It captures the loss to consumers who are no longer able to purchase the products following the price rise (assuming that there are no alternatives to which they can easily substitute). But it does not capture the loss of consumer surplus for those consumers who still purchase but are now paying more than they previously were for the same products.

Any future AI regulation should strive to understand the percentage of firms that would fall under prohibition. Although based on this result alone, one might think the best AI regulation would aim to reduce the list of prohibited AI products, as we discuss further in section 6.2.2, a key aim of AI regulation and prohibition of AI systems is to remove potential harmful outcomes from the market. Therefore, there is a careful balance to be struck between reducing the prohibited list of AI applications — and reducing the negative impact on revenues shown above — and maximising the removal of AI harm discussed below. Well-balanced AI regulation would aim to be as precise as possible in its approach to prohibition in order to remove most AI harms whilst making sure that firms that do not pose harm are not forced to exit the market. In other words, the regulatory framework should seek to maximise the removal of firms and products that are harmful whilst minimising the removal of the firms and products that are not harmful and valued by consumers.

Consumer trust is the only quantified positive impact of the regulation on AI revenues and has the potential to somewhat balance the negative impacts of the regulation. As mentioned in section 6.1.4, we are aware that consumer trust modelling is extremely challenging, and currently, there is no comprehensive study to show how a hypothetical regulation may change consumers' trust in AI. For that reason, the positive impact of consumer trust presented above should be treated as an indication of the importance of increasing consumer trust in the AI market, directly through further purchases or indirectly through sharing more data. The actual change and the magnitude of the positive impact of AI regulation will be highly dependent on how transparency requirements are defined under the AI regulation. Experts told us that the main driver of changes in consumer trust would be proper transparency and explainability of the AI systems. If the increase in AI trust has the potential to lead to the positive impact (and the magnitude) indicated above, it is worth understanding what (if any) are the regulatory conditions that would maximise it. As suggested by the CDEI, further research into what impacts consumers' trust should be conducted to inform policymakers about which regulatory regimes might create the highest trust levels to maximise the positive impact shown to be possible in this model.[118]

The third result apparent in the figure is that the net negative impact on AI revenues is lower under scenario 2. The positive impact on AI revenues via the trust is larger in scenario 2 compared to scenario 1 and the negative impacts (from compliance costs, uncertainty and firms leaving the market due to prohibition) are smaller in scenario 2. These results are based on various assumptions made throughout our model. In some areas, those assumptions are based on information found in the literature, but where evidence was limited, we based our assumptions on insights from the stakeholder

[118] Trust can also increase for consumers of the downstream market, creating further positive benefits.

engagement conducted for this analysis.[119] The better performance of scenario 2 is driven by the fact that it outlines sectoral. Outcome-based regulation that was perceived to increase consumer trust more (due to the minimum requirements) but has less impact on prohibition and HRS requirements (which are based on the view that sectoral regulation would be more targeted). It is essential to consider these assumptions when devising a regulatory regime and make sure that these aspects are well-thought-out and evidenced (as much as possible given the forward-looking nature of an appraisal exercise) to yield a better-informed policy design.

6.1.7 Regulatory costs

Regulatory costs in this report refer to the financial burden that the government would incur to implement and sustain the regulation. For governments, the costs may include labour required to operate a regulator, which would undertake tasks addressing complaints and checking business compliance. Other costs can include the capital needed for any building and the technology needed to run the regulatory operation. Given that the requirements of the regulatory body or bodies are different for each scenario, we explain how these were calculated for each scenario, separately.

i. Governmental regulatory costs under scenario 1

Scenario 1 includes creating a new central regulator that would oversee AI regulation and provide AI-specific governance. To model the costs associated with such a governance structure, we estimate the costs needed to set up the central regulator and the annual operational costs to sustain it.

The estimates for the initial investment costs were provided by DCMS based on conversations with other regulatory bodies in the UK. They are set at a one-off cost of £38 million in the model.

We estimate the annual operating costs by modelling the labour costs needed to undertake the regulatory work defined in scenario 1 (i.e. updating the prohibition and HRS lists, addressing complaints, undertaking ex-ante conformity checks, etc.). For this modelling, we need to estimate the number of employees that the central regulator would employ and their annual wage.

For estimating the annual workforce needed for operating the central regulator, we first looked at the number of employees employed by several other regulators in the

[119] We interviewed seven UK based AI businesses (developers) of various sizes and from a variety of sectors. In addition, we conducted a workshop with seven AI firms to gather further views. Lastly, we talked to one regulator and two AI experts. The conversations were kept anonymous and confidential to receive honest and helpful information, as such, we do not include the summary of each conversation in the report. Annex B presents the takeaways gathered from the main discussion topics across interviews. We note assumptions or decisions that are based on information received from stakeholders.

UK.[120] Using these as a guide, we assume that a new central AI regulator would require 500 employees, an assumption confirmed by the DCMS team. For the following years, we assume that the number of employees would increase in line with the growth rate in AI revenues estimated for scenario 1.

We then estimate the average wage of the employees in the central regulator. We use information about the number of employees and the total annual costs of several regulatory bodies to assess the most plausible annual cost per employee, ~£100k per employee. Please note that these are not wages, as we assume that the total expenditure reported induces operational costs, such as electricity and other non-wage costs.[121] The assumed cost per employee is then multiplied by the number of modelled employees.

ii. Governmental regulatory costs under scenario 2

Scenario 2 assumes that responsibility for regulating AI would sit with existing regulators, including a new coordinating AI function that would ensure consistency. As such, there is no initial investment needed to set up a new regulator as in scenario 1. To model the regulatory costs under this scenario, we estimate the additional labour resources needed across relevant existing regulators required to address AI regulatory responsibilities, and, as in scenario 1, we multiply that by the cost per employee.

We first identify the number of regulators that would be required to add the AI regulation to their responsibilities, increasing their number of employees. We identified 61 regulators that fit this description in the UK.[122] We then estimate the average number of employees across these regulatory bodies. We were not able to find a comprehensive data set with the number of employees for each regulator. Instead, we looked at nine regulators and their reported workforce, which allowed us to estimate an average of 500 employees per regulator.[123] We then increased the number of employees needed to fulfil the additional AI regulation by 1.5%.[124] This assumption provides a total increase of 458 employees across the 61 regulatory bodies, which is nearly the same number of additional employees as in scenario 1. For the following years, we assume that the number of employees will increase at the growth rate in the AI revenues estimated for scenario 2.

Lastly, we estimate the average cost per employee of the additional employees. We use information about the number of employees and the total annual costs of several

[120] For further details, please see annex A.10.

[121] For further details, please see annex A.10.

[122] See annex A.10 for the full list.

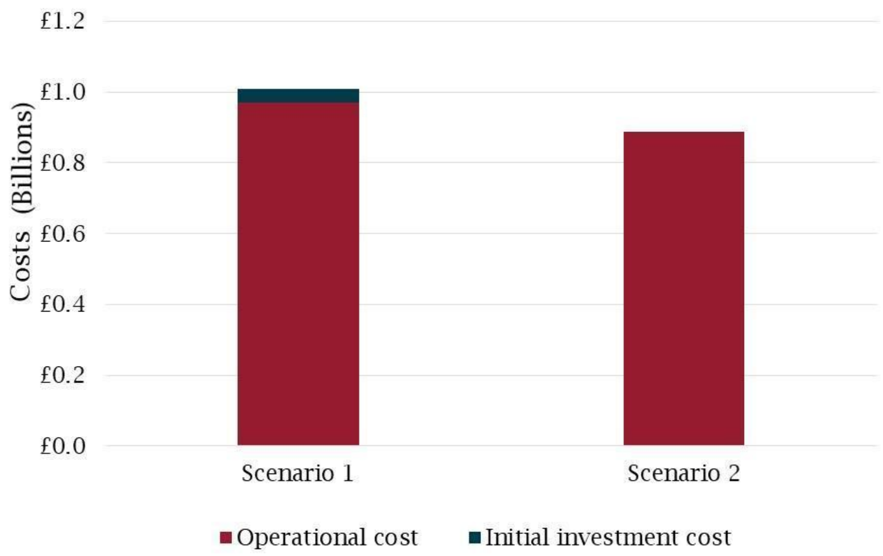
[123] For further details, please see annex A.10.

[124] Assumption agreed upon with the DCMS team.

regulatory bodies to assess the most plausible annual cost per employee. Please note that those are not wages as we assume that the total expenditure reported induces operational costs such as electricity and other non-wage costs.[125] The assumed cost per employee is then multiplied by the number of modelled employees.

Figure 22 presents the total governmental regulatory costs. It shows that costs are similar under both scenarios but slightly higher for scenario 1. It is important to note that governmental regulatory costs over the assessment horizon are highly related to AI market size under each scenario and would increase the bigger the value of the AI market. Governmental costs should always be considered alongside the benefits they create.

Figure 22 Total governmental regulatory costs



Source: Frontier Economics
Note: NPV of governmental regulatory costs from 2023 to 2032

6.1.8 Compliance costs for non-AI firms that develop in-house AI systems (not for sale)

Our model and report so far have focused on the impact of AI regulation on AI firms, those who develop and sell AI products and services, but other firms (non-AI firms from now on) might also be affected by AI regulation. Some non-AI firms might develop in-house AI which is then embedded in their non-AI products, others may use AI to increase efficiencies in their internal processes. Regardless, those companies might need to comply with the regulations and incur compliance costs.

[125] For further details, please see annex A.10.

The AI Activity in UK Businesses report estimates that 40% of all firms adopting AI are primarily developing in-house[126]. These non-AI firms would need to comply with AI regulations and incur the associated costs. Non-AI firms operate in the downstream market and sell their non-AI products to downstream consumers. Estimating the impacts that regulatory costs would create requires a separate model that includes estimates of those firms' downstream market statistics, such as revenues and investments and how much relates to AI. Given the project's scope, we are unable to account for these second-order impacts and instead discuss below how decisions by non-AI firms would compare to those done by AI firms. We also calculate a potential range of compliance costs for non-AI firms and highlight the importance of further understanding these costs.

Non-AI firms would likely have a similar decision process for dealing with compliance costs to that of AI firms (described in section 6.1.3) but potentially not with the same degree of impact. We anticipate that in-house developers are more likely than AI firms to stay in the market, despite additional regulatory costs, as they may be able to use other technologies to provide their downstream products or source cheaper AI solutions. Like AI firms, they would also be able to pass through some of the cost increases to their consumers, but we believe that cost pass-through would be lower for two main reasons. First, we assume that the proportion of AI-related costs in their total production costs would be smaller than for AI firms. Second, given that non-AI firms are more likely to operate in non-AI markets, the cost increase due to compliance with AI regulation would be firm-specific and not sector-wide, reducing their ability to pass through a high proportion of the cost increase.[127] Non-AI firms might also reduce some internal AI investments to account for the increase in costs. Consumer trust may also be impacted in a similar way to AI firms, given that customers would still interact with AI products and be aware of new transparency requirements. We believe that the only impact that would not materially accrue to these businesses would be a change in VC investments due to uncertainty, as these are not AI-specific firms. It is reasonable to believe that regulatory uncertainty in AI would not substantially impact the investment levels they see.[128] Since these non-AI firms are scattered across different sectors, modeling these impacts would independently require data for each sector. Given this data limitation and the high complexity of this type of modelling, we proceed with estimating a potential range of compliance costs that may be incurred by those businesses - using two different methodologies:

1. Scale the compliance costs that are calculated for AI firms by a factor of about two-thirds, reflecting the proportion of the market that is assumed to develop in-house products.
2. Build bottom-up estimates of the compliance costs for non-AI firms. We do this by utilising the estimated amount of in-house AI products developed by non-AI firms in the AI Activity

[126] AI Activity in UK Businesses, DCMS (2022)

[127] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/320912/Cost_Pass-Through_Report.pdf

[128] This may not be true for all non-AI firms in the market. For some, AI would be an important aspect of their non-AI product since AI regulation may change the level of VC investment.

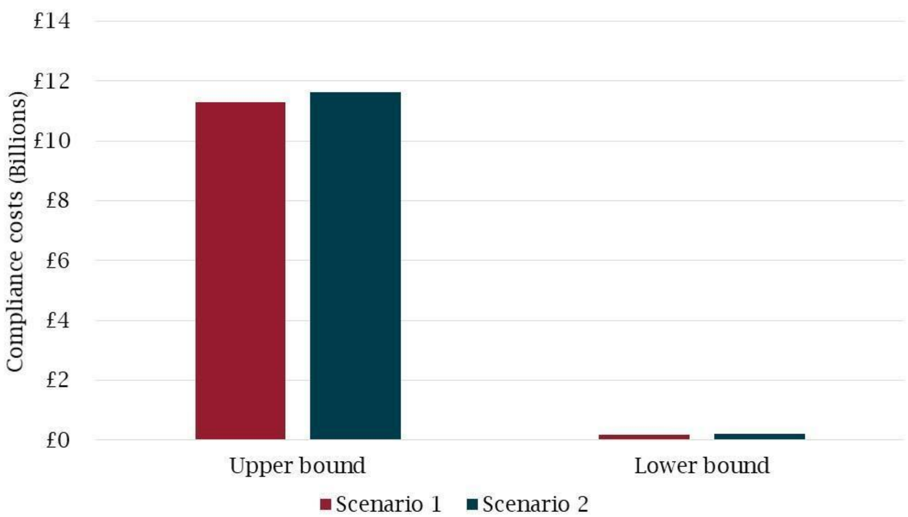
in UK Businesses report and the estimates of compliance costs-per-product used for AI firms.

We explain each methodology and its result below.

The first methodology applies the assumed proportion of the AI market developed in-house by non-AI firms. In the AI Activity in UK Businesses report, it is estimated that 40% of firms that have adopted AI products have done so primarily from in-house development. This was the reason we removed 40% of AI expenditure when creating the AI revenues proxy for AI firms in section 6.1.1. Therefore, we assume that our estimate of compliance costs for AI firms represents 60% of the total compliance costs incurred by AI firms, and the remaining 40% reflects the compliance costs of those non-AI firms developing AI in-house.[129]

The second methodology is more complex and utilises the estimated number of in-house AI development firms presented in the AI Activity in UK Businesses report. We start by estimating the number of non-AI firms that are assumed to be developing in-house AI products. We then split them by size category into small, medium, and large businesses.[130] We take the estimated compliance costs per unique AI product for AI firms (assuming that compliance costs per unit are the same for in-house development) and assume that the same proportion of non-AI firms would fall under each regulatory aspect (e.g. prohibition, HRS, etc.). We then arrive at an estimate of total compliance costs from in-house development by non-AI firms.

Figure 23 NPV for ten years (2023-2032): Total compliance costs for non-AI firms that develop in-house AI products using two methodologies



Source: Frontier Economics

[129] Applying a percentage calculation assuming that AI-firms' compliance costs represent 60% of total compliance costs.

[130] Since we do not have the distribution of small, medium and large businesses that develop in-house AI products, we use the same distribution as for AI-firms.

More importantly, the second methodology is based on an extrapolation of the number of businesses that, in a survey, said they had developed AI in-house. Some businesses may have replied yes to this question, while their AI development would not be considered AI under each regulatory scenario. Regardless, these results show that regulatory clarity is crucial in this market. If all in-house AI developers were to believe that they need to comply with the regulation, it might lead to very high compliance costs. As explained above, those may create various inadvertent impacts, such as a decrease in AI R&D and cost pass-through to consumers in a wide variety of sectors.

The calculations of compliance costs above do not include any one-off familiarisation costs, which were excluded from the calculation of AI firms' compliance costs, as those were too small. Given that the number of non-AI firms is estimated at more than 100,000, familiarisation costs across these firms can be substantial. As mentioned above, we estimate familiarisation costs to be about £160 per unique AI product. Using the number of firms and estimated unique AI products, we estimate these costs to be more than £37 million in one-off costs that would be incurred in the first year of introducing the AI regulation by these businesses. Given that all firms would have to familiarise themselves with the regulation under both scenarios (for scenario 1 all firms need to understand if they fall under HRS, while in scenario 2 all firms need to familiarise themselves with the minimum requirements), all firms in the market in both scenarios would incur the same familiarisation costs. Although those costs are small compared to the total NPV for compliance costs shown above, this is an additional cost the government should consider when thinking about AI regulation.

6.2 Qualitative analysis

As mentioned in the previous section, in addition to the quantitative model, we have undertaken a qualitative analysis to assess two potential outputs and their associated impacts. At this stage, due to data and time limitations, we are not in a position to assess these effects in a quantitative way. We examine the potential effects of regulation on:

- trade costs; and
- the harm and the benefits that AI systems could generate for consumers.

6.2.1 Trade costs

Regulation (i.e. any rules that dictate how a product can be manufactured, handled, or advertised) is one example of a non-tariff trade measure (i.e. a measure other than a customs tariff that affects international trade). While tariffs always introduce a net cost on international trade, the same is not true of non-tariff measures. In fact, some measures might even be trade-enhancing if they reduce transaction costs (e.g. associated with asymmetric information) by allowing businesses to signal product quality.[131]

[131] See for example UNCTAD (2017), Non-Tariff Measures: Economic Assessment and Policy Options for Development.

Regulation of the sort considered in this report could introduce regulatory fragmentation across countries and this, in turn, imposes costs on trade. These costs could be either direct or indirect compliance costs that reflect, for example, lost opportunities to achieve economies of scale because products or services have to be modified or lost product variety because some products in certain markets become unviable.

Whilst the focus of this report is on the UK domestic impact of different regulatory frameworks for AI, this last section summarises the impact that AI regulation could have on trade.

In this context, there are two mechanisms that are relevant:

- AI systems have the potential to reduce trade costs through a variety of channels. They can reduce the fixed costs of supplying markets (e.g. through better analytics) or by improving the efficiency of infrastructure that supports trade (e.g. trade finance, logistics and transport). These efficiencies can, in turn, increase the magnitude of trade flows in goods and services across borders. To the extent that AI regulation will have an impact on the number of AI systems available on the market (including the systems that are used to reduce trade costs), it could also have an indirect impact on trade through the efficiencies foregone.
- Regulatory asymmetry and fragmentation between the UK and other jurisdictions could have an impact on UK firms developing, purchasing and using AI systems, as it could make it more costly and/or complex to export AI systems developed domestically or import AI technologies from abroad. The cost increase would also apply to products with which AI is embedded or bundled. Although AI systems are mostly software products characterised by low marginal costs, significant economies of scale and low physical costs associated with import and export activities, complying with different regulations in different jurisdictions could still impose additional material costs with the potential to affect firms' decisions in relation to trade.

AI (together with other digital technologies) is perceived to have the potential to profoundly transform the way we trade, who trades and what is traded.[132] For example, AI can be used to improve predictions of future trends, such as changes in consumer demand, and to better manage risk along the supply chain. By allowing businesses to better manage complex and dispersed production units, such tools reduce trade costs by improving the overall efficiency of global value chains.

Similarly, smart manufacturing emphasises connectivity and could open up global value chains to more specific participation by specialised service suppliers in areas such as R&D, design, robotics, and data analytics tailored to discrete tasks in the supply chain.[133]

Furthermore, many customs administrations are trying to leverage AI-driven technologies in order to support smarter operations and efficiency (which has a direct impact on trade costs).

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[132] https://www.wto.org/english/res_e/publications_e/world_trade_report18_e.pdf

[133] https://www.brookings.edu/research/the-impact-of-artificial-intelligence-on-international-trade/

For example, machine learning can be used for AI-based risk management, automated container image processing and object recognition, cargo tracking geodata analytics and other activities. Similarly, natural language processing (NLP) can support the automated classification of products, optical character recognition (OCR) and data storage, and e-customs platforms with embedded chatbots that provide 24/7 customer service.[134]

To the extent that some of these technologies are more expensive as a result of AI regulation and others might not be developed/launched because the regulatory burden is expected to make the technology unprofitable, AI regulation could have an indirect impact on trade costs.

In relation to the second mechanism, the literature and the data available are more limited and less developed. Generally, the expectation is that regulatory heterogeneity increases trade costs by:[135]

1. increasing the costs of gathering information on regulatory requirements in different markets/jurisdictions;
2. adjusting the specifications of AI systems to comply with different regulatory requirements abroad, with possible losses in economies of scale or possibilities for product differentiation; and
3. undertaking various conformity assessment procedures to demonstrate compliance.

The materiality of these costs differs by activity and sector. For example, it is likely that in manufacturing sectors and services that use AI intensively, specification costs will be the primary source of costs. The costs and the frictions caused by regulatory asymmetry will also be impacted by other factors, such as:

1. **De-facto standards:** in certain circumstances, some regulatory frameworks become de-facto standards on an international level, meaning that firms decide to comply with a specific regulation even if they are not directly subject to it. This phenomenon can occur because a specific regulation is, or is perceived to be, particularly effective and clear or because it affects a particularly large market, inducing firms to adopt these standards for commercial reasons. De-facto standards can also emerge because compliance represents a quality signal to the market. If the UK becomes a de-facto international standard, the costs of regulatory asymmetry for UK firms will be reduced.[136]

2. **"Nested" regulation:** similarly, if divergence mainly occurs in terms of stringency (i.e. the overall framework is similar and the rules across different jurisdictions can be seen as "nested"), the costs and the frictions associated with it will be lower compared to an environment where there is divergence with the overall approach to regulation (e.g. if one

134 https://worldcustomsjournal.org/Archives/Volume%2014%2C%20Number%202%20(Oct%202020)/1902%2001%20WCJ%20v14n2%20Kafondo.pdf?_t=1603239884

135 https://read.oecd-ilibrary.org/governance/international-regulatory-co-operation-and-trade_9789264275942-en#page7

136 For an overview of de-facto industry standards, a good summary of the literature is included in https://repub.eur.nl/pub/77382/

jurisdiction designs a regulation based on ex-ante assessments and another based on ex-post interventions). Against this backdrop, it is important to note that many of the stakeholders involved in our interviews believe that, should the UK and other major jurisdictions adopt different regulatory frameworks (characterised by different degrees of stringency), they expect to comply with the most stringent regulation across all jurisdictions. This is to avoid the costs and complexity of designing different systems in different jurisdictions. This is clearly more complex when there is uncertainty associated with the future direction of regulation.

3. **Adequacy conditions:** the agreement of adequacy conditions with other jurisdictions (similar to those agreed with the EU in the context of data protection and GDPR)[137] has the potential to reduce the costs and frictions caused by regulatory asymmetry. This will be particularly important with the EU, given that it is one of the "first movers" in AI regulation on an international basis. But it will also be important in relation to countries like Singapore, Japan, Canada, Israel and the US as they develop their own regulatory frameworks for AI (see the introductory section for more details).

4. **Dynamic asymmetry:** regulatory divergence is a dynamic concept. While scenario 1 could be free of trade frictions with other jurisdictions adopting similar approaches in the short-term, regulation in jurisdictions might change over time and gradually generate trade costs in the medium-term. This is particularly relevant in the context of the EU AI Act, which empowers[138] the Commission to adopt delegated acts in accordance with Article 73 TFEU to update the definition and scope of high-risk AI systems under certain conditions.

In the context of our analysis, the first mechanism (described above) is relevant in both scenarios, as regulation will change the amount of AI systems on the market. This could affect the potential AI has to reduce trade costs because lowering supply increases the price and/or reduces the quality of AI as an input into functions that might reduce trade costs (e.g. consumer analytics is more expensive for a firm to access or is less tailored to its needs).

Conversely, regulatory asymmetry, the second mechanism described above, is expected to be more relevant in scenario 2 since the regulatory divergence between that model and the EU's proposals are more noticeable. In this context, regulatory asymmetry could increase export costs for AI-intensive firms based in the UK exporting to the EU. Whilst the difference between the scenario 2 model and the EU's AI Act proposals are known, asymmetry and trade frictions could also occur in scenario 1 depending on the extent to which other jurisdictions diverge from a centralised, horizontal model and the categorisation of risks.

At this stage, due to data and time limitations, we cannot quantify the magnitude of the two mechanisms described above. The paragraph below provides some high-level indications in

137 https://ico.org.uk/for-organisations/dp-at-the-end-of-the-transition-period/data-protection-and-the-eu-in-detail/adequacy

138 This provision is present in Article 7 of the Commission's proposal. It is important to note that the final text - negotiated with the Parliament and the Council - might be different.

relation to the data, information and methodological requirements to conduct a quantification exercise in this space:

- In relation to mechanism 1, it is possible to collect evidence on how AI reduces measures of trade costs (e.g. by making trade finance more accessible or by increasing the efficiency of logistics and trade facilitation measures). There is substantial literature on trade costs and how specific trade-supporting activities (e.g. finance, facilitation, logistics) affect trade costs and trade. The key challenge would be to assess how these costs may change in response to the change in the price or quality of AI as a result of regulation. The most complex approach would be to use a stylised partial-equilibrium model (e.g. based on Cournot competition between AI suppliers). This would draw on findings of projected exit by businesses to derive price impacts of AI, which could be used as a basis for understanding changes to trade costs. A simpler approach would seek to triangulate findings from literature reviews and interviews to understand the likely range of effects of changes to AI viability on expected costs of particular trade-supporting activities and, through that, to come to a view on the likely changes to trade costs. These findings could be used as inputs in a gravity model of trade of AI-intensive products (see below).

- In relation to mechanism 2, the costs of regulatory fragmentation could, in principle, be captured through two approaches. More specifically:

  - A top-down methodology could use measures of regulatory fragmentation and then input these into a gravity model of trade to measure the impacts. This approach has been applied to services trade using the OECD's services trade restrictiveness index (STRI).[139] The main difficulties in the context of AI are related to the lack of data; there are no bilateral data on AI flows, meaning these would need to be inferred by developing a classification of AI-intensive goods and services.[140] A more challenging constraint is the need to develop an index of regulatory divergence relating to AI. The OECD STRI (and variants thereof like the Digital Services Trade Restrictiveness Index[141]) commonly used for these exercises do not capture AI-specific regulation. One way to address this challenge could be to assess whether fragmentation in AI regulation is strongly correlated with fragmentation in other policy areas that are captured by the STRI (e.g. data governance or other aspects of digital policy). That could be done through interviews with experts. If correlation is strong then these elements could be used to proxy for fragmentation in AI-specific regulation.

- It is important to note that the OECD has already used this approach in other aspects of trade analysis: for example, there is no data on restrictions affecting specific types of environmental services. However, since these services, and the restrictions on them, are

[139] See Hildegrun Nordas (2016), Services Trade Restrictiveness Index: The Trade Effects of Regulatory Divergence, OECD, available at https://www.wto.org/english/res_e/reser_e/gtdw_e/wkshop16_e/nordas_e.pdf

[140] This could be done by triangulating between interviews, and drawing on existing product classifications, for example, the product list underpinning the WTO Information Technology Agreement.

[141] https://qdd.oecd.org/subject.aspx?Subject=STRI_DIGITAL

strongly correlated with restrictions that apply to sectors for which data are available, it has been possible to conduct a quantitative trade analysis on trade in environmental services.[142]

- Alternatively (or to complement the top-down analysis described above), a bottom-up methodology could be adopted. Specifically, it could be possible to build on the impacts estimated in the compliance costs section of the report and to use those in a gravity model of trade. It will be important to distinguish the costs that are specific to fragmentation from compliance costs generally (i.e. for a UK company operating in both jurisdictions, what would be the incremental cost associated with export over and above domestic sales). This could be done through a combination of literature review and in-depth interviews with businesses. Once these costs are identified, the next step would be to estimate the proportion of the overall cost base for AI-traded products represented by these compliance costs. This will allow us to calculate ad valorem[143] tariff equivalents for the compliance costs, which can then be used as inputs into a gravity model of trade.

6.2.2 Consumer harm and benefits

One of the main objectives of AI regulation is to minimise the harm caused by AI systems to users and citizens, whilst maximising the benefits that consumers and society can extract from it. This is highlighted in the third pillar of the National AI Strategy, which aims to establish a "clear, proportionate and effective framework for regulating AI that supports innovation while addressing actual risks and harms".[144]

The literature we reviewed has identified various categories of harm that are directly or indirectly related to AI. The following paragraphs outline them in more detail and propose a conceptual framework that can be used to appraise the impact different regulatory frameworks might have in preventing harm to the benefit to the economy and society.

(a) Discrimination in relation to protected characteristics

The most frequently mentioned area of concern with AI is discrimination against protected characteristics. Numerous studies have highlighted the risks that AI and automated decision-making systems pose to the principles of equality and non-

[142] Sauvage, J. and C. Timiliotis (2017), "Trade in services related to the environment", OECD Trade and Environment Working Papers, No. 2017/02, OECD Publishing, Paris, https://doi.org/10.1787/dc99bf2b-en

[143] i.e. a fixed percentage charge levied on imports

[144] https://www.gov.uk/government/publications/national-ai-strategy/national-ai-strategy-html-version

discrimination[145] (e.g. in hiring decisions,[146] access to bank loans,[147] healthcare,[148], housing,[149] and other areas).

From a technical perspective, the main drivers of these concerns are:

- unrepresentative training samples (e.g. an AI system trained on a dataset that contains a disproportionate number of observations from male individuals and will therefore be more accurate[150] in predicting health outcomes of male patients);[151]
- discriminatory human input in the data (e.g. an AI system assessing employees' performances trained on years of performance reviews written by individuals with a bias towards certain protected characteristics);
- biased programmers (e.g. the designers of AI systems might have conscious or unconscious biases towards certain protected characteristics); and
- feedback loops (the data generated by biased/discriminatory AI systems can be used to train new AI systems creating a vicious cycle of discrimination and bias).[152]

As it emerges from this list, these concerns relate to both conscious and unconscious discrimination, highlighting the risk that some AI systems may perpetuate discrimination without its users or developers being aware of any prejudice and without explicitly including information on protected characteristics (the so-called reconstruction problem, where the AI system is able to deduce information on ethnicity, gender, and disability even if data points on these characteristics are not included in the training dataset).[153]

The debate on how regulation can address these issues is still open in the economics and policymaking communities. However, there seems to be a growing consensus[154] on the importance of focusing on outcomes rather than on the AI process that leads to the

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145 A recent study by Prof. Frederik Zuiderveen Borgesius, commissioned by the Council of Europe, provides a comprehensive literature review on the topic: https://rm.coe.int/discrimination-artificial-intelligence-and-algorithmic-decision-making/1680925d73

146 https://hbr.org/2019/05/all-the-ways-hiring-algorithms-can-introduce-bias

147 https://www.forbes.com/sites/korihale/2021/09/02/ai-bias-caused-80-of-black-mortgage-applicants-to-be-denied/

149 http://hrlr.law.columbia.edu/files/2020/11/251_Schneider.pdf

150 This issue is not only related to the accuracy, but also to the rates of false positives, which have a different impact depending on the context. For example, a false positive for a re-offending algorithm means that an individual stays in prison unjustly; a false negative for a cancer screening algorithm means that an individual potentially misses life-saving treatment. See Chouldecheva 2017 for more details.

151 It is important to note that even when databases are roughly representative in terms of the number of observations of the relevant groups, algorithms can still make predictive errors when the groups differ significantly in terms of their characteristics, e.g. propensity to have a particular illness in the case of a healthcare algorithm.

152 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3361280

153 https://www.cs.cornell.edu/home/kleinber/aer18-fairness.pdf

154 https://hbr.org/2021/09/ai-regulation-is-coming

outcome.[155] For example, if a university is interested in a more equal and diverse community of students, it appears more effective to establish an admission quota rather than force an AI algorithm to ignore the parameters that might lead to discriminating against certain protected categories. On the basis of this literature, it appears that a regulatory framework focused on outcomes rather than on processes (keeping everything else constant) might be more likely to tackle and prevent discriminatory outcomes generated by AI systems. Whilst this recommendation appears evidence-based from a theoretical perspective, in practice, there isn't a single measure of unbiased outcomes, and it is often particularly challenging, if not impossible, to achieve equality on all measures.

Generally, based on our experience in regulatory economics in different sectors and jurisdictions, we believe that designing a goal-oriented regulatory regime, which is focused on outcomes rather than processes, is the best starting point when regulating fast-paced and novel sectors like AI.

(b) Social manipulation and behaviour distortion

Another frequently mentioned concern in relation to AI is the possibility of using these technologies to mislead individuals or to convince them to behave in a particular way - motivated by commercial, economic or political interests.[156]

Manipulative marketing and electoral strategies have existed for a long time. However, these strategies, combined with the collection of enormous amounts of data for AI algorithmic systems, have far expanded the capabilities of what can be done to drive users to specific choices and behaviour. The use of AI and harvesting of user data have already changed the social discourse, and existing evidence shows they have contributed to polarisation and diminished the shared understanding of facts and priorities, which are critical for democratic politics,[157] through "filter bubbles" and "echo chambers".[158]

The main concerns in this area relate to:

- the use of "deep-fakes" (i.e. manipulated or synthetic audio or visual media that seem authentic, and which feature people that appear to say or do something they have never said or done);[159] and

[155] The papers presented at a recent conference organised by the American Economic Society provide a good overview of the academic debate on the issue: https://www.aeaweb.org/conference/2022/preliminary/1450?q=eNqrVipOLS7OzM8LqSxIVbKqhnGVrAxrawGICArI

[156] https://voxeu.org/article/dangers-unregulated-artificial-intelligence

[157] https://www.straitstimes.com/opinion/ai-data-bonanza-will-intensify-geo-strategic-competition

[158] https://www.aeaweb.org/articles?id=10.1257/aer.20191777

[159] A comprehensive review of the literature on deepfakes and on the best regulatory frameworks in this context is a recent report published by the European Parliament: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/690039/EPRS_STU(2021)690039_EN.pdf

- hyper-targeting techniques (i.e. tools used to tailor content and communication to the preferences and orientations of individual consumers and voters).

The literature on how to regulate and mitigate these concerns is relatively well-developed.[160] In this context, there seems to be consensus on the idea that regulating the technological dimension of deepfakes will not suffice and that citizens need additional support to protect their rights in this complex environment. In order to be effective in both scenario 1 and scenario 2, AI regulation will need to be complemented by other interventions such as educational campaigns to inform consumers about the risks and opportunities associated with certain technologies.

(c) Online harm

Online harm can take various different forms, including terrorist content, activities related to child abuse and exploitation, hate crime, and digital fraud.[161] The relationship between AI and online harm is complex and not unidirectional, and it is important to note that a significant proportion of online harm is outside the scope of AI technologies.

On the one hand, AI can be used to prevent, identify or remove harmful content from the internet AI-powered facial recognition technologies can be used to estimate the age of specific users and to refuse access to age-restricted content. Also, AI-powered digital nudges can regulate online behaviour. Online bots can ask users to reconsider the offending part of their post, suggest more acceptable revisions, or introduce a slight time delay to give the user a cooling-off period before posting.

On the other hand, AI can be used to promote harmful content (e.g. terrorist videos) and to make this type of content less detectable by other AI systems aimed at removing them from the internet. This is related to the so-called cat-and-mouse paradox: a mechanism through which improvement in image forensic techniques and harmful content detection capabilities help AI systems become better at avoiding these technologies, becoming less detectable and, therefore, harmful.[162]

On balance, there seems to be a general consensus on the idea that AI is a crucial instrument to tackle online harm, and this aspect needs to be taken into account when

[160] A selection of particularly relevant articles include: https://www.media.mit.edu/projects/detect-fakes/overview/; https://www.rathenau.nl/en/digital-society/digital-threats-democracy; https://www.asisonline.org/security-management-magazine/latest-news/today-in-security/2021/january/U-S-Laws-Address-Deepfakes/; https://www.congress.gov/bill/116th-congress/house-bill/3230/text; https://www.wilmerhale.com/en/insights/client-alerts/20201217-new-yorks-right-to-publicity-and-deepfakes-law-breaks-new-ground; https://openaccess.thecvf.com/content_CVPRW_2019/papers/Media%20Forensics/Agarwal_Protecting_World_Leaders_Against_Deep_Fakes_CVPRW_2019_paper.pdf ; https://www.digimarc.com/docs/default-source/default-document-library/deepfakepaperreviseddmrcweb.pdf; https://technode.com/2019/12/03/china-targets-deepfake-content-with-new-regulation/; http://www.warse.org/IJATCSE/static/pdf/file/ijatcse58932020.pdf; https://publications.jrc.ec.europa.eu/repository/handle/JRC122023

[161] https://www.gov.uk/government/consultations/online-harms-white-paper/online-harms-white-paper

[162] https://arxiv.org/abs/1901.08971

designing a regulatory framework for AI. For example, the UK Online Harms White Paper[163] cites numerous cases in which AI is already being used to combat online harm.

In this context, a recent study commissioned by Ofcom has identified four priorities for effective regulation of AI in this space:

- encourage the development of content moderation services by third-party providers;
- encourage data sharing across these providers;
- build public confidence in these systems; and
- ensure the performance of these systems is transparent and understandable.[164]

These objectives could be achieved in both scenarios 1 and 2. On the one hand, in scenario 1, a central regulator will be able to leverage its experience across sectors and apply learnings from one sector (e.g. the role of human oversight in age verification systems to access online content) to other industries and sectors (e.g. age verification systems in e-commerce). On the other hand, in scenario 2, sector-specific regulators might be better placed in understanding how these priorities can be pursued in each specific context (e.g. data sharing in healthcare has completely different risks and implications compared to data sharing in the finance sector). On balance, based on the literature we reviewed, the outcome of our stakeholder interviews and our experience in regulatory economics, it is not clear ex-ante which scenario is better designed to minimise AI-driven online harm.

(d) Price discrimination, collusion and market volatility

The fourth category of concerns emerges when AI technologies are used to determine the prices of goods, services or assets.

- With regard to price discrimination, the concern comes from the idea that AI systems could enable firms to charge different prices from different consumers for the same or similar products, thanks to the massive volumes of personal data disclosed by consumers online. It is, therefore, often posited that the use of AI-enabled pricing algorithms and access to rich datasets of consumer behaviour will enable finer-grained price discrimination, which will transfer welfare and utility from consumers to firms.[165] In fact, several models proposed in the scientific literature have shown the ability to price discriminate at a higher degree of granularity.[166]As for collusion, there

[163] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973939/Online_Harms_White_Paper_V2.pdf

[164] https://www.ofcom.org.uk/__data/assets/pdf_file/0028/157249/cambridge-consultants-ai-content-moderation.pdf

[165] Although an extensive discussion on price discrimination is outside of the scope of this report, it is important to note that price discrimination does not automatically lead to a welfare loss. First- and second-degree price discrimination are often associated with increases in total welfare, and there are instances in which even third-degree price discrimination does not lead to a loss of total welfare.

[166] https://orbi.uliege.be/bitstream/2268/250255/1/Gautier2020_Article_AIAlgorithmsPriceDiscriminatio.pdf

is a concern that AI systems could become experts at tacit collusion due to two key factors differentiating them from conventional price-setting methods:

- Speed - since computers can pull in pricing data quickly, particularly in digital markets.
- Predictability - this is important for achieving and sustaining collusion.[167]

However, the literature in this field has not reached a consensus on the extent to which AI-powered systems are more likely to collude compared to humans.

Focusing on financial markets, on the one hand, AI could increase market volatility through large sales or purchases executed simultaneously, thereby creating new sources of vulnerabilities. Furthermore, the convergence of trading strategies creates the risk of self-reinforcing feedback loops that can trigger sharp price moves and flash crashes.[168] On the other hand, some highlight the possibility that extensive use of AI will result in more efficient markets with lower volatility since the impact of subjective evaluation of information by humans will be minimised, and with that, the associated noise.[169] Once again, there is no consensus on the net effect of these two factors.

Whilst these concerns should be taken into account when designing a regulatory framework for AI, we believe that sectoral regulation (e.g. financial, consumer protection, and competition authorities) seems better suited to tackle these issues compared to AI-specific regulation.

This assessment is based on our experience in advising on regulatory matters in different sectors and countries. We have found that clear, targeted and goal-oriented regulatory frameworks are more effective and introduce fewer distortions in the market compared to unclear, wide-ranging regulations. For example, if there are concerns in relation to the anticompetitive effects that certain AI-powered pricing systems could introduce in some markets, these are likely to be better addressed by specific rules and interventions made by competition authorities rather than by more general AI regulations implemented by a central AI regulator.

(e) Privacy

AI magnifies the ability to use personal information in ways that can violate privacy interests by raising the analysis of personal information to new levels of power and speed. Facial recognition is a good example of this increased risk, where the rich databases of digital photographs available via social media, websites, driver's licence

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167 https://www.competitionlawinsight.com/competition-issues/algorithms-and-price-collusion--1.htm

168 https://oecdonthelevel.com/2021/07/12/artificial-intelligence-in-finance-is-machine-learning-going-to-dominate-the-markets/

169 https://towardsdatascience.com/impact-of-artificial-intelligence-and-machine-learning-on-trading-and-investing-7175ef2ad64e

registries, surveillance cameras, and many other sources enable rapid machine recognition of the faces of individual humans.[170]

AI and privacy regulations are clearly interlinked, and any regulatory framework in the field of AI should take these implications into account. However, for the same reasons presented above concerning price discrimination, collusion and market volatility, we believe these concerns appear to be better addressed by targeted and goal-oriented data regulation rather than AI regulation. It is important to note that AI technologies are often developed and implemented as part of a wider data and digital ecosystem, highlighting the importance of aligning and coordinating regulatory intervention in these sectors with AI regulation.

(f) Other

Other use-cases of AI harms, frequently referred to in literature, are; social scoring (i.e. a combination of government and business surveillance that gives citizens a "score" that can restrict the ability of individuals to take actions) and automated weapons (i.e. a type of autonomous military system that can independently search for and engage targets based on programmed constraints and descriptions).[171] These are potentially harmful technologies powered by AI and would be considered when thinking about an effective regulatory regime for AI. However, due to their high level of sensitivity, they are outside the scope of this research.

(g) A conceptual framework to analyse consumer harm in the context of AI regulation

From the previous paragraphs, it is evident that a high level of complexity and granularity is required for a thorough analysis of AI-centric consumer harm. For this report, we propose adopting a conceptual three-step framework.

First, we propose identifying the areas directly impacted by AI regulation. As mentioned above, concerns about; privacy, collusion, price discrimination and market volatility are crucial aspects to be considered when designing and implementing AI regulation. They appear to be more effectively regulated through dedicated sectoral frameworks (e.g. data privacy rules, competition law, and financial regulation) rather than AI-specific regulation. As a result, we suggest restricting the focus to three main categories of harm:

- Discrimination in relation to protected characteristics.
- Social manipulation and behaviour distortion.
- Online harm.

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[170] https://www.brookings.edu/research/protecting-privacy-in-an-ai-driven-world/

[171] https://www.weforum.org/agenda/2021/06/the-accelerating-development-of-weapons-powered-by-artificial-risk-is-a-risk-to-humanity/

Second, we suggest focusing on the differences between regulatory scenarios in minimising harmful outcomes. Table 5 below provides a preliminary high-level conceptual starting point to conduct this exercise.

Table 5 Impact of differences between scenarios 1 and 2 in relation to consumer harm

Difference	**Discrimination**	**Social manipulation/behaviour distortion**	**Online harm**
Central vs decentralised	No intuitive difference / comparative advantage of one scenario.	Perhaps a centralised regulator has a wider overview of the multiple channels through which this category of harm can materialise compared to sector-specific regulators. However, this is a preliminary thought as this aspect was not explored in detail in the interviews or the literature review.	No intuitive difference / comparative advantage of one scenario (see dedicated section above for more details).
Process-based vs outcome-based	Outcome-based is expected to be more effective in preventing discriminatory outcomes, as regulating the process does not guarantee a specific outcome.	Outcome-based is expected to be more effective in preventing this category of harm.	Outcome-based is expected to be more effective in preventing online harm, as regulating the process does not guarantee that harmful outcomes will not be generated as a result.
HRS-focused vs based on a minimum requirement	To the extent that discriminatory outcomes are expected to be generated in a subset of contexts (e.g. recruitment, health, and welfare payments), a focus on HRS seems more effective in preventing	The key question is the extent to which social manipulation occurs in a limited subset of contexts. Intuitively, it is a category of harm that could be generated across a variety of systems and sectors (media, entertainment, public services, etc.). Therefore an HRS-focused framework might be able to effectively tackle it.	To the extent that online harm is expected to be generated in a subset of contexts (e.g. social networks, video-sharing, and gaming platforms) a focus on HRS seems more effective in preventing them.

	them.		

Source: Frontier Economics

On balance, based on the literature reviewed and the inputs collected from stakeholders, we are not in a position to assess what scenario is likely to be more effective in tackling consumer harm. This is because the mechanisms through which AI can generate harm are numerous, complex and, often, opaque, which means that they cannot be decomposed to appraise how different regulatory approaches could prevent them.

Third, in light of the impossibility of measuring or estimating the number of harmful outcomes that could be prevented, it can be helpful to use existing evidence and literature on the monetary value of certain harmful outcomes as a point of reference to understand the opportunity a reduction in harmful outcomes could represent. The following subsection focuses on this third step.

(h) Assessing the order of magnitude of consumer harm

As discussed above, it is difficult to estimate the impact that regulation might have on the number of harmful outcomes generated by AI. Harmful events like discrimination, social manipulation and online harm are also intrinsically difficult to cost accurately, as their impact on the economy and society is not always immediately captured by monetary values.

In light of this intrinsic complexity, some existing literature has attempted to attach a financial value to some of the outcomes listed above. Although this is subject to limitations, we believe it is helpful to provide an order of magnitude that a reduction of harmful events could represent - from an economic perspective.

For example, regarding discrimination in relation to protected characteristics, a 2018 study by the Centre for Economics and Business Research (CEBR)[172] estimated that the economic cost of workplace discrimination to the UK Economy was £127 billion. The vast majority of the cost derives from gender discrimination (£123bn), discrimination against ethnic minorities (£2.6bn), and discrimination as a result of sexual orientation (£2bn). Using this study as a point of reference, we could hypothesise that if AI were responsible for 1% of the discrimination currently occurring in the workplace, and a regulatory framework could reduce the probability of a discriminatory outcome by 10%, it would be reasonable to expect an economic benefit of about £100m.

Similarly, a 2016 study by the OECD estimated that gradually reducing discrimination in social institutions could lead to an annual average increase in the world GDP growth rate of 0.03 to 0.6 percentage points by 2030.[173] This is an international macroeconomic study, but it could be used to contextualise the opportunity represented by a reduction

[172] https://cebr.com/reports/cebr-research-with-involve-on-the-value-of-diversity/

[173] https://www.oecd.org/dev/development-gender/SIGI_cost_final.pdf

in discrimination. Applied to UK GDP figures, these percentages translate into £7bn to £132bn.

Focusing on human rights and their economic value, the Danish Institute for Human Rights used macroeconometric techniques to find a positive long-run effect of freedoms and the right to participate in economic growth at the macroeconomic level. The study is affected by limitations that make it impossible to attach a monetary value to the positive impact. However, it is important to note as it concluded that the main drivers of this economic relationship are freedom of speech, freedom of assembly and association, and electoral self-determination.[174]

From a microeconomic perspective, the Equality and Human Rights Commission[175] has used the Vento Scale[176] to produce a range of monetary value for different degrees of discrimination: from £900 to £8,600 for minor and isolated episodes to £25,700 to £42,900 for more serious violations. These values are regularly used to award damages in litigation claims related to discrimination and could be used to put in context the effects of AI regulation in preventing episodes of harm.

In relation to online harm, a recent study produced by the Australian Institute estimated the economic costs of online harassment and cyberhate in Australia at $3.7 billion - in terms of health costs and lost income (~£2.1bn).[177] More specifically, the study estimated that the most common episodes of online harassment were abusive language (27%), being sent unwanted sexual material (18%), and threats of physical violence or death (8%). The impacts of online abuse were estimated to be substantial. For example, of those who said they had experienced harassment or cyberhate, one in four said they had seen a medical professional as a result, and one in four also said it had impacted their work.

In terms of social manipulation, estimating the economic costs of these harmful episodes is more complicated due to the interlinked and long-term nature of these effects. The only relevant analysis we are aware of is a 2019 study by the University of Baltimore, which estimated the global cost of fake news at approximately $78 billion.[178] Once again, although affected by a variety of limitations, this study could be used to put in context the economic opportunity represented by a reduction in harmful outcomes - in terms of social manipulation.

174 https://www.humanrights.dk/sites/humanrights.dk/files/media/migrated/final_human_rights_and_economic_growth_-_an_econometric_analysis.pdf

175 https://www.equalityhumanrights.com/sites/default/files/quantification-of-claims-guidance.pdf

176 It is important to note that the Vento scale is used to quantify harm above and beyond any financial or economic loss suffered by the claimant as a result of the discriminatory conduct.

177 https://australiainstitute.org.au/post/online-harassment-and-cyberhate-costs-australians-3-7b/

178 https://s3.amazonaws.com/media.mediapost.com/uploads/EconomicCostOfFakeNews.pdf

In summary, based on existing literature and due to the complexity of the sector, it appears impossible to estimate the monetary impacts that AI regulation could generate in preventing harm. However, the paragraphs above listed some useful estimates that can be used to understand the order of magnitude of these impacts.

(i) Assessing the trade-offs between prevented harm and lost benefits

As mentioned, one of the main objectives of AI regulation is to minimise the harm caused by AI systems to users and citizens while maximising the benefits consumers and society can extract from it.

Therefore, it is important to consider that whenever an AI system leaves the market (or enters the market in a different form) because of regulation, some harmful outcomes might be prevented, but some consumers will also lose the benefits generated by these systems. There is extensive literature on the benefits generated by AI, which include:[179]

1. productivity;[180]
2. cybersecurity;[181]
3. quality of work;[182] and
4. other.

The subsections above focused on the harm that could be caused by AI technologies and potentially prevented by effective AI regulation. It highlighted the difficulty in estimating the impact of different regulatory frameworks on harm and monetising the value of this impact. In this context, it is more complex to estimate the impact different regulatory approaches are expected to have on the benefits generated by AI and to quantify them.

This complexity is further enhanced by the fact that some of the sources of potential consumer harm described above are, at the same time, drivers of benefits to businesses and/or consumers. For example, whilst hyper-targeting techniques could be used to distort individual behaviours and implement social manipulation strategies, they are also valuable technologies for firms willing to advertise their products in an efficient and effective manner. Similarly, AI algorithms in areas such as recruitment could result in better skills and job matching across the economy, with benefits for both workers and firms. Analysing quantitatively the tension between these risks and benefits is outside the scope of this report. However, these are conceptual considerations that should be taken into account when designing an effective AI regulation.

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[179] Please see section 2 for more details on the benefits of AI.

[180] https://mitsloan.mit.edu/ideas-made-to-matter/how-to-prepare-ai-productivity-boom

[181] https://www.ceps.eu/artificial-intelligence-and-cybersecurity/

[182] https://www.purestorage.com/resources/type-a/rise-data-storage-as-a-service.html

On balance, based on inputs from the experts involved in our stakeholder engagement process, an approach to AI regulation that is outcome-based and goal-oriented is expected to be more effective in achieving a balance between harm prevention and benefit maximisation.

This is because the benefits and the harms generated by AI technologies are highly dependent on the context in which the system is used. As a result, sector regulators might be better positioned than central regulators to understand and appraise these benefits and to compare them with the potential harm that could be caused by AI systems. Furthermore, a framework that is outcome-oriented rather than process-oriented is more effective in finding the right balance between prevented harm and lost benefits.

Based on our experience in regulatory economics in different sectors and countries, it is difficult to establish ex-ante which scenario is better designed to achieve the best possible outcome in this complex trade-off. However, our stakeholder engagement exercise has shown that regulation will need to be extremely clear and particularly goal-focused to be effective. This finding is in line with our experience in other sectors and countries.

7 Conclusions

The analysis above aims to uncover the impacts that AI regulation may have. The quantitative and qualitative analyses indicate the following:

1. **Prohibition of AI systems and removal of harmful outcomes should be considered together since they are the main drivers of impact from AI regulation:**

   The quantitative analysis showed that the largest impact on AI revenues would be from prohibited firms' revenues being lost from the AI market. Although we estimate the impact on AI revenues, this is an approximation of the economic impact that the regulation would have on the market. The reduction in AI revenues due to regulation ultimately reflects the value that downstream businesses and consumers have placed on those products which would no longer be available.[183] By contrast, the purpose of prohibiting certain products from the market is to remove harmful outcomes – the harms that the downstream businesses or consumers do not fully internalise. That means that although prohibition would remove a substantial amount of value from the market, it would also reduce the non-internalised negative impacts – mitigating the reduction in value modelled from prohibition. As explained in section 6, it is not possible at the moment to quantify the level of harm reduction associated with AI regulation or prohibition to indicate if the value of the removal of harm would be higher than the potential reduction in the AI revenues. The results of the model indicate that a balancing act between maximising the removal of harmful outcomes and minimising the negative impact of this removal should be of high importance when considering AI regulation. In particular, it is important to understand what regulatory regime would be best able to prohibit harmful outcomes (where the harms of an outcome are higher than the benefit) while making sure that AI systems with low-risk outcomes are kept on the market. AI experts and stakeholders we spoke to suggested that scenario 2, where prohibition is context-based rather than technology-based and determined by sector-specific regulators, would best strike this balance.

2. **Consumer trust has the potential to generate additional benefits and negate, to an extent, the costs AI regulation would have on the market**

   The quantitative model results show that trust could significantly mitigate the costs created by AI regulation. This positive impact should only be perceived as an indication, given the limited research we could find on this topic, but it reveals that this is an area of interest for future considerations.[184] If consumers' trust can create the benefits shown, it can drive a

[183] As noted above, this assumes that there are no immediate substitute products for consumers who are no longer able to purchase and no immediately substitutable inputs for downstream firms who are no longer able to use the AI inputs. Given the unique advantages associated with AI, this appears to be a reasonable assumption. Since we do not capture the consumer surplus loss for those customers who continue to purchase at a higher price, together this implies that these revenue losses represent a lower bound for the real impact of these changes.

[184] Given the limited available data and information about this topic, these results are mainly reliant on the assumptions and estimates guided by the focused stakeholder engagement exercise conducted for this project.

substantially positive impact, somewhat negating the costs. Further research into this area is needed to reveal if the assumptions and mechanisms used in this report are realistic, and if so, what would be the best AI regulatory regime to maximise consumers' trust.

3. **The potentially high costs incurred by non-AI firms developing AI products in-house show the need for AI regulation to effectively target the firms affected by the regulation**

   The last section of our quantitative analysis revealed that non-AI firms that develop AI products in-house could incur substantial compliance costs. AI can be integrated and used by non-AI firms to increase efficiencies or as part of their non-AI offerings. Given this broad use of AI across many sectors, it is estimated that more than 100,000 non-AI firms might need to undergo minimum compliance costs and HRS compliance (in scenario 2), which would create a substantial burden on the economy. AI regulation should be assessed carefully while making sure that a) it is clear about which firms should be within the scope of different parts of the regulation (i.e. firms will avoid complying with regulations they do not need) and b) balances any requirements that are compulsory to all firms and the burden it would create across the economy with how effective it would be in removing harmful outcomes.

4. **The overall impact might be higher than presented in this report**

The analysis in this report looked at the impacts that regulation would have on AI firms and non-AI firms that develop AI. We have estimated the change in AI revenues, which we use as a proxy for the value of lost sales to consumers of AI products. But AI is thought to be associated with highly productive firms, so any loss of revenue from AI firms is likely to be associated with a productivity loss in the economy (as AI jobs and inputs will be redeployed in less productive areas of the economy). This productivity loss is not currently captured by our estimates. Moreover, our estimates do not fully capture the lost consumer surplus associated with consumers who continue to purchase AI products and services at a higher price than previously.

In addition, AI serves as an input to production for many other sectors of the economy. Our estimates are a proxy for this wider loss of value in the downstream market, as they reflect the value placed on AI inputs by these firms, making an implicit assumption about the lack of credible substitutes for AI inputs. However, the productivity and wider value loss associated with this change may be larger and could be a field for further study.

Lastly, our model did not consider the impact of AI regulation on the R&D of AI in the UK, which may have additional impacts on the UK economy. For example, stakeholders indicated that one of the reasons they are placed in the UK is the talent pool available in the country. If AI regulations would reduce the level of AI research and decrease the attractiveness of the UK for AI firms (directly or indirectly) through the reduction of the AI market and investments in AI R&D, it would have further economic impacts not covered in this report. The potential impacts on R&D were outside of the project's scope but given their potential effect on the UK's positioning as a global AI leader, they should be considered further.

5. **Regulatory asymmetry may have a further impact on the economy**

There are two main ways in which AI regulation may impact trade. As previously mentioned, AI is an important input to various industries. The transport and logistics sector (including customs agencies) uses AI to increase efficiency in global trade. The impacts described above may reduce the level of AI used in transport and logistics and create a further negative impact on the economy by reducing overall global trade volume and value.

In addition, if the regulation in different jurisdictions is different, it may create additional costs for firms that operate and trade AI systems across jurisdictions. There are three aspects that are particularly relevant in relation to regulatory asymmetry.

First, due to their effectiveness and clarity and/or the size of the market they regulate, the rules passed by some jurisdictions may end up becoming de-facto international standards, with firms complying with a specific regulation even if it is not directly subject to it, as compliance represents an effective signal to the market. If the UK approach becomes a de-facto international standard, the costs of regulatory asymmetry for UK firms will be reduced.

Similarly, if divergence mainly occurs in terms of stringency (i.e. the overall framework is similar and the rules across different jurisdictions can be seen as "nested"), the costs and the frictions associated with it will be lower compared to an environment where there is divergence with the overall approach to regulation (for example, if one jurisdiction designs a regulation based on ex-ante assessments and another based on ex-post interventions).

Lastly, the agreement of adequacy conditions with other jurisdictions (similar to those agreed with the EU in the context of data protection and GDPR)[185] has the potential to reduce the costs and frictions caused by regulatory asymmetry.

6. **Quantitative and qualitative results of this analysis should always be considered together**

Some impacts were not possible to evaluate quantitatively but are critical when assessing the impacts of different AI regulation. These include the impacts of a reduction in consumers' harm and trade friction impacts. It is tempting to only look at the quantitative analysis and draw the conclusion that AI regulation would create only costs and negative impacts. But, as in many cases, the interesting and more complex discussions take place in the qualitative analysis. In this case, a key benefit of regulating AI, the removal of harmful outcomes, is not captured in the quantitative analysis, but the qualitative analysis shows that the removal of those harms can deliver large benefits. Questions remain,

[185] https://ico.org.uk/for-organisations/dp-at-the-end-of-the-transition-period/data-protection-and-the-eu-in-detail/adequacy/

including to what extent this would benefit the market and whether these benefits would be higher than the costs? While these are still unclear, it does not mean they should be ignored.