The Digital Markets Act and incentives to innovate

Behavioural experiment

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Executive summary

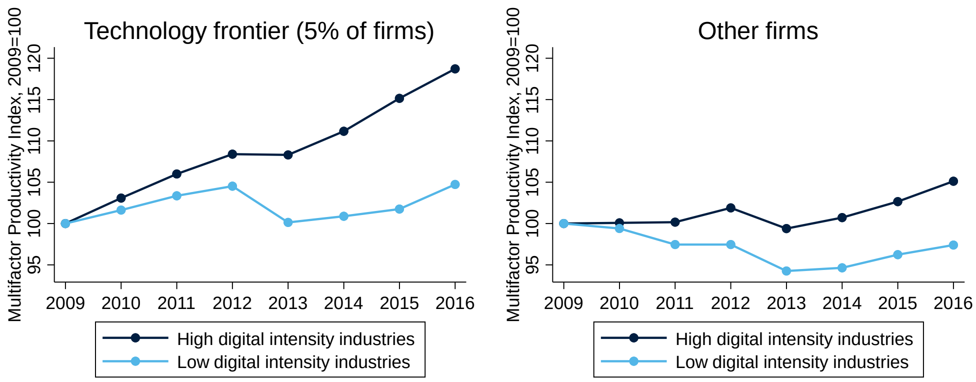
Amazon commissioned Oxera to conduct a behavioural economics experiment to test the impact of regulatory interventions, such as the proposal for the EU Digital Markets Act ('DMA'), on innovation in the EU. This experiment brings new evidence of the likely effect of these regulatory proposals.

The results showed that these interventions are likely to reduce the total amount of innovation in high digital intensity industries, which are among the main contributors to European growth.

Why does innovation in digital markets matter?

Innovation matters to society because it is *the* long-term driver of economic growth. In OECD countries the annual growth in GDP per hour worked since 2005 has been roughly half that of the five years between 2000 and 2005.[1] However, evidence from the OECD shows that industries with a high digital intensity (the left-hand side of Figure 1) exhibit a faster rate of productivity growth than their peers in low digital intensity sectors (the right-hand side). This is true of both the leading firms and the 'other' firms in each industry group. The digital sector, as defined in the DMA proposal,[2] is one of the sectors that makes the most intensive use of digital technologies.

Figure 1 Multifactor productivity in industries with high digital intensity and low digital intensity (top 5% vs all other)



Note: following the methodology in Calvino, F. et al. (2018), ('A taxonomy of digital intensive sectors', OECD Science, Technology and Industry Working Papers, No. 2018/14, OECD Publishing), industries are classified as having 'high' or 'low' digital intensities based on their share of information and communication technology ('ICT'); tangible and intangible (i.e. software) investment; share of purchases of intermediate ICT goods and services; stock of robots per hundreds of employees; share of ICT specialists in total employment; and the share of turnover from online sales.

Source: adapted from OECD (2019), 'Digitalisation and productivity: a story of complementarities', *OECD Economic Outlook*, **2019**:1.[3]

Digital industries are key to maintaining and promoting Europe's economic and social growth. If innovation in Europe decreases then output per worker will not

[1] OECD (2019), 'OECD Compendium of Productivity Indicators 2019', 29 April, http://www.oecd.org/sdd/productivity-stats/oecd-compendium-of-productivity-indicators-22252126.htm.
[2] The DMA defines the digital sector as 'the sector of products and services provided by means of or through information society services' (Article 2a), where information society services are defined as 'any service normally provided for remuneration, at a distance, by electronic means and at the individual request of a recipient of services' (point (b) of Article 1(1) of Directive (EU) 2015/1535).
[3] See: http://www.oecd.org/economy/growth/digitalisation-productivity-and-inclusiveness/.

increase and Europe will fall behind. Hence it is crucial that policymakers have a robust understanding of what drives innovation and how it affects society as they debate interventions in digital markets.

How could poorly designed policy reduce innovation?

The DMA includes various measures that might reduce digital platforms' incentive or ability to innovate. The following are examples.

- Article 5c will allow business users to promote offers to end-users and conclude contracts off the platform. This means a price comparison website remunerated through commissions may not have the incentive to invest in improved matching algorithms. This is because it may not reap the benefits of this investment if business users can use the platform to match to consumers and then direct those consumers to lower prices elsewhere, avoiding the platform's commission;
- Article 6f will allow third party providers of software to have access to the same OS and hardware that are used for the gatekeepers' own ancillary services. This may reduce the incentives for platforms to invest in innovative new features as it decreases the appropriability of their investments and reduces control over quality.

Our first report for Amazon, 'The impact of the Digital Markets Act on innovation', highlighted three reasons why we might expect the measures proposed in the DMA to be harmful for innovation and growth in the EU:

- innovators may have reduced incentives to be the next big thing if regulation reduces the size of their prize;
- European-only regulation could reduce the size of the market accessible to global innovators, reducing their overall incentives to innovate, or reducing their incentive to roll out innovations in the EU;
- if larger (global) firms are restricted in their ability to innovate, smaller (local) rivals are unlikely to fill the gap.

Empirical analysis of the link between poor regulation design and innovation in an economy is challenging because both concepts are difficult to quantify. However, a recent academic study has given support to the theoretical finding that regulation based on firms' turnover (such as the DMA) can decrease investment in innovation.[4] In this second report, we contribute to this growing body of empirical evidence, showing that poorly designed regulation can affect the degree of innovation in an economy.

Measuring innovation outputs or the extent of competitive pressure is not straightforward. Hence experimental evidence is useful in generating data from a 'game' where respondents face real incentives based on their choices. This method allows us to observe the effects of changing the rules of the game (i.e. introducing regulation).

[4] Specifically, the authors explore the stringent labour regulations in France which apply only to firms with more than 50 employees. They show that such regulation disincentivises innovation and growth for firms just below the cut-off (i.e. firms with 45–49 employees). At a macro level this decreases aggregate innovation by 5% in the French economy. See Aghion, P., Bergeaud, A. and Van Reenen, J. (2021), 'The impact of regulation on innovation', National Bureau of Economic Research (No. w28381).

The experiment

The online experiment was conducted on 298 business students at Universität Wien (the University of Vienna) in December 2020. Each round randomly matched the participants in the session into pairs with one student in the role of a 'global' firm and the other playing a 'local' firm, which differ in their cost of R&D effort. This captures the idea that global firms have an advantage in investment in R&D, through economies of scale or funding advantages.

Each participant was randomly assigned to one of three groups—a control group, representing the status quo, or one of two treatment groups:

- treatment 1 introduced a **regulatory risk** that a successful innovator may have to share the returns of their innovation;
- treatment 2 split the market between a local area and the rest of the world, and **favoured the local firm** in the local market such that the global firm might not roll out a successful innovation there.

Results

Innovation requires not only an idea but also a degree of risk taking to invest in the idea and bring that idea to market. Examining participants who were willing to invest in innovating, both the global players and the local players invested less (8.6% and 3.9% respectively) when faced with the additional risk of having to share the benefits of innovating.

In the treatment in which local players were favoured, we find a smaller treatment effect, with the local innovators decreasing their innovation efforts by 2% (the difference is statistically significant), while the global players did not change their behaviour. This result is important because it suggests that if regulation such as the DMA holds back global competitors in order to give local competitors space to innovate, it could in fact reduce the competitive pressure on the local players and lead to less innovation by them.

Implications for policymakers

The results from the first treatment indicate that an ex ante regulation which reduces the size of the prize is likely to lead to substantially less innovation output by firms that want to innovate, be they local or global players. The results from the second treatment indicate that policies aiming to favour local firms may fail.

The implications of these results could be significant for the levels of investment in R&D in the European economy. In the ICT sector alone, a rough proxy for the parts of the economy most directly affected by the DMA, business enterprise R&D amounted to more than €40.1bn in 2019 in the EU.[5]

If the effects seen in this experiment were to occur in the wider EU economy, R&D expenditure for the ICT sector would reduce by up to €3.4bn per year.[6] This reduction would lead to a material worsening in economic and social progress for European citizens. Taking account of the social returns to R&D expenditure highlighted in the literature, this could lead to a social loss of up to €6.8bn per year.

[5] See European Commission (2020), 'EU R&D SCOREBOARD: The 2020 EU Industrial R&D Investment Scoreboard', https://iri.jrc.ec.europa.eu/sites/default/files/2021-01/SB2020_final_16Dec2020_online.pdf.
[6] €3.4bn is equal to €40.1bn × 8.6%. 8.6% is our estimate of the treatment effect for the global player in the regulatory risk treatment.

1 Introduction

Amazon has commissioned Oxera to conduct a behavioural economics experiment. The purpose of the experiment is to test the effect of regulatory intervention on the level of innovation by firms.

This research builds on a previous Oxera research report, in which we carried out a review of the relevant economic literature on innovation. In the earlier report we concluded that ex ante regulation of large digital platforms risks reducing innovation, which could in turn lead to lower economic growth and harm European consumers.[7]

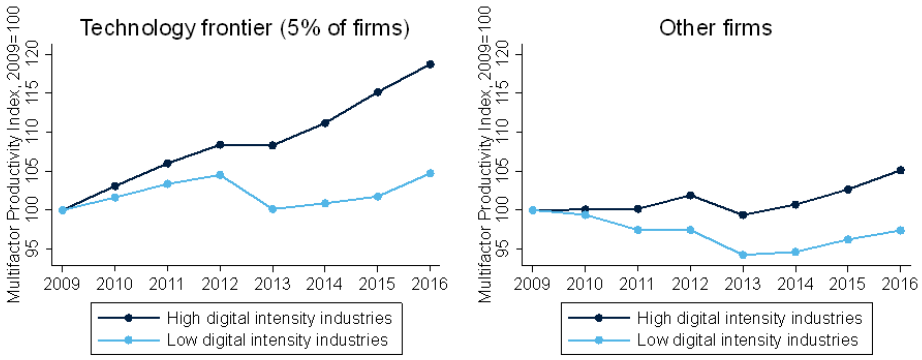
Since the publication of our report in November 2020, the European Commission has published its DMA proposals.[8] These include a number of provisions that would limit the ability of gatekeeper digital platforms to use data generated on their platforms;[9] oblige gatekeepers to share data with their competitors;[10] allow third-party business users to conclude contracts independently (not through the gatekeeper's platform);[11] and prevent gatekeepers from 'self-preferencing' their own products or services in search rankings.[12]

The potential effects of the DMA are important because we know that digital industries are key drivers of innovation, and that it is innovation that drives economic growth over the long run. Figure 1.1 shows the growth in productivity for high digital intensity firms and low digital intensity firms. The data is split between firms at the technology frontier and other firms. Among both groups high digital intensity firms have enjoyed far higher productivity growth than their low digital intensity counterparts over the 2009–16 period.

This evidence suggests that high digital intensity firms are responsible for more innovation and productivity growth than their low digital intensity counterparts. So digital industries are key to maintaining and promoting Europe's economic and social growth. If innovation in Europe is reduced then output per worker will not increase and Europe will fall behind its global rivals. Hence it is crucial that policymakers have a robust understanding of what drives innovation in the industries likely to be affected by the DMA, and how it affects society, as they debate interventions in such industries. Otherwise they could pursue policies that have the unintended consequences of hindering innovation and so holding back economic growth in Europe.

[7] Oxera (2020), 'The impact of the Digital Markets Act on innovation'.
[8] European Commission (2020), 'Proposal for a regulation of the European Parliament and of the Council on contestable and fair markets in the digital sector (Digital Markets Act)', COM/2020/842 final.
[9] DMA proposal, Articles 5(a), 6.1(a).
[10] DMA proposal, Articles 5(g), 6.1(h)–6.1(j).
[11] DMA proposal, Article 5(c).
[12] DMA proposal, Article 6.1(d).

Figure 1.1 Multifactor productivity in industries with high digital intensity and low digital intensity (top 5% vs all other)



Note: following the methodology in Calvino, F. et al. (2018), ('A taxonomy of digital intensive sectors', OECD Science, Technology and Industry Working Papers, No. 2018/14, OECD Publishing), industries are classified as having 'high' or 'low' digital intensities based on their share of information and communication technology ('ICT'); tangible and intangible (i.e. software) investment; share of purchases of intermediate ICT goods and services; stock of robots per hundreds of employees; share of ICT specialists in total employment; and the share of turnover from online sales.

Source: adapted from OECD (2019), 'Digitalisation and productivity: a story of complementarities', *OECD Economic Outlook*, **2019**:1.[13]

In this report, we take our research beyond the existing economic literature to assess the potential consequences of the DMA for innovation using a behavioural experiment ('the experiment').

The online experiment was conducted on an international group made up of mainly postgraduate MBA students at the University of Vienna in December 2020.[14] The experiment was designed by Oxera with Professor Raymond Duch, Director of the Centre for Experimental Social Science (CESS), Nuffield College, University of Oxford. We also received support from Maciej Filipek, a graduate student at the University of Vienna.

This report is structured as follows:

- section 2 describes how experiments can be used to test economic hypotheses and the potential impact of economic policy;
- section 3 sets out the design of the experimental environment;
- section 4 describes the design of our 'treatment', aimed at testing our hypotheses;
- section 5 provides the results from the experiment and explains how they can inform the debate around the DMA.

The appendices to this report are structured as follows:

- Appendix A1 provides technical details on the experimental design;
- Appendix A2 describes the demographics of the experiment participants;
- Appendix A3 shows the results of sensitivity analyses on our main results;
- Appendix A4 provides the economic theory details to solve the game;
- Appendix A5 provides some screenshots of the experiment in action.

[13] See: http://www.oecd.org/economy/growth/digitalisation-productivity-and-inclusiveness/.
[14] The participants in our experiment came from 30 countries, mostly from the EU.

2 The use of experiments to test economic hypotheses

In this section, we explain how experiments can be used to test economic hypotheses, and in particular the impact of the proposed DMA. We begin by discussing how experiments can inform policymaking, and to what extent their findings can be generalised outside the laboratory environment. We then summarise the insights from the academic literature on innovation and, based on this review, we outline the two hypotheses that we tested in the experiment.

2.1 How can experiments inform policymaking?

When new public policies are designed, businesses and policymakers do not always have readily available datasets to inform their decision making—the policymakers may, for example, be proposing policies that have never been tried before. Laboratory experiments offer a unique tool to build robust datasets tailored to answer economic questions. Even when non-experimental datasets are available, they are not necessarily designed to answer policy questions and often face limitations—for instance, because it is impossible to build counterfactual scenarios in which the proposed policy is absent.

At a high level, economic experiments can be thought of as stylised 'games'. Often participants are motivated with a financial reward which depends on their performance in the game. Experiments have an advantage relative to traditional revealed-preference[15] or stated-preference[16] tests in that they allow the researcher to generate data on a very specific issue while allowing comparison to a counterfactual. This helps test policies for their effectiveness and unintended consequences before they are implemented, and allows the effectiveness of multiple alternative policies to be compared.

To estimate the effect of alternative policies, the researcher first builds a baseline scenario representing the status quo, i.e. the situation if no policy changes occur. This is called a 'control' group. The control group is compared to one (or more) treatment groups, who face an experimental environment where the rules are changed to reflect the proposed policies. This allows the researcher to investigate the effect of different scenarios without any conflating factors (see section 4 for details on the control and treatment groups used in our experiment).

When considering the empirical analysis of the relationship between innovation and competition, the use of experiments is particularly helpful. This is mostly because of two key challenges related to using non-experimental data (see Box 5.1 of our first report).

- First, measuring innovation can be difficult using real-world data. In contrast, we can directly measure the levels of innovation in our experiment by observing the participants' chosen level of R&D investment.
- Second, there may be 'endogeneity' issues in non-experimental settings:[17] the level of competition may influence the level of innovation, *and* the level

[15] In revealed-preference tests, the researcher assumes that the preferences of consumers can be revealed by their purchasing decisions. In the context of firms' strategies, the corresponding assumption would be that firms' strategies can be inferred from their decisions.
[16] In stated-preference tests, participants are asked hypothetical questions about their preferences between different alternatives.
[17] An endogeneity problem arises when two variables affect each other. This makes estimation of the effect of one variable on the other difficult and requires the use of more advanced econometric methods (often with inconclusive outcomes).

of innovation may influence the level of competition. This makes causal analysis of different policies very challenging. In an experimental setting, the researcher has full control over the key ingredients in the economic framework.

2.2 External validity of economic experiments

When conducting an experiment, it is important to ensure its external validity to guarantee that any findings are relevant to a policymaker. External validity refers to the extent to which findings from an economic analysis can apply to real-world situations.

Economic experiments require simplification of the real world, because participants will have limited time and knowledge of all the relevant issues. As such, any experiment that is too complex will result in participants getting bored, being confused, or leaving the game.

Therefore there is a trade-off between the external validity and the simplicity of the experiment. The common view is that experiments should seek to uncover general rules of human behaviour that are not dependent on the laboratory context. Experimental results published in top academic journals have been shown to replicate well in the field.[18] It is commonly accepted that real-world details should be included in experiments to improve external validity.[19] We sought to strike this balance in our experiment. For instance, we told the participants that they were the CEO of a firm investing resources to innovate, helping them to understand the context.

Innovation requires not only a good idea but also a degree of risk taking to invest in R&D. The participants in the game therefore have to be the type of people who would, in reality, take some risk investing in innovation. To enable this, we hired students with a business background who are likely to be familiar with R&D investment decisions. We also chose to analyse only those participants who invested to some degree and behaved as innovators. In this experiment, there were a small number of participants who behaved as 'non-innovators' by repeatedly investing zero in the game (see Figure 5.2).[20]

Experimenters often observe different characters (or types) of participants, especially in contest experiments.[21] The behaviour of those different types may vary and it is common to focus the analysis on the most relevant group.[22] For

[18] Camerer, C. F. (2015), 'The Promise and Success of Lab-Field Generalizability in Experimental Economics: A Reply to Levitt and List', *Handbook of Experimental Economic Methodology*.
[19] Nieboer, J. (2020), 'Using online experiments for behaviourally informed consumer policy', *FCA Occasional Paper*, 51.
[20] Which means that it was impossible for them to innovate.
[21] For instance, Fallucchi et al. (2020) identify that one-third of participants in a contest experiment behave in a way that cannot be explained by a traditional economic model. Potters et al. (1998) show that participants in their contest experiment can be classified in different categories based on their social preferences. For details see Fallucchi, F., Mercatanti, A. and Niederreiter, J. (2020), 'Identifying types in contest experiments', *International Journal of Game Theory*, pp. 1–23; Potters, J., De Vries, C.G. and Van Winden, F. (1998), 'An experimental examination of rational rent-seeking', *European Journal of Political Economics*, **14**:4, pp. 783–800; and Herrmann, B. and Orzen, H. (2008), 'The appearance of homo rivalis: Social preferences and the nature of rent seeking', CeDEx discussion paper series.
[22] For instance, in an assessment of deception in social interactions, Belot, M. and Van de Ven, J. (2017) exclude cases in which a sender of information acts contrary to their own economic incentives. Similarly, Heinrich, T. and Mayrhofer, T. (2018) assess the impact of risk preferences in social interactions and disregard individuals exhibiting inconsistent risk preferences. Finally, in an analysis of the impact of risk taking in a cooperative setting, Strobl, R. and Wunsch, C. (2021) only focus on participants that are strictly better off than their partners, thereby disregarding potential donations by a subset of the population. For details see Belot, M. and Van de Ven, J. (2017), 'How private is private information? The ability to spot deception in an economic game', *Experimental Economics*, **20**, 19–43; Heinrich, T. and Mayrhofer, T. (2018), 'Higher-order risk preferences in social settings', *Experimental Economics,* **21**, 434–456; and Strobl, R. and Wunsch, C. (2021), 'Risky choices and solidarity: disentangling different behavioural channels', *Experimental Economics*, **24,** 31–58.

the purposes of the analysis we define ‘non-innovators’ as participants who chose not to invest for more than half of the game. We therefore drop these participants from our main analysis.[23]

2.3 Summary of the relevant literature

This sub-section briefly summarises the key findings from our previous report and presents the hypotheses to be tested in our experiment.

Our first report highlighted that both appropriability and contestability tend to increase innovation in markets. ‘Appropriability’ refers to the ability of an innovator to capture a sufficient proportion of the value of their innovation to justify their initial investment. ‘Contestability’ refers to the market in which the innovation takes place and whether it is possible for an innovator to compete for future sales in the market.[24] The positive influence of both appropriability and contestability on innovation incentives creates a policy trade-off as measures to increase the contestability of sales in the future are also likely to reduce the perceived appropriability of the value of future innovations by potential innovators.[25]

We also explained in our first report that larger markets promote innovation, as the fixed cost of innovation can then be spread over a larger number of units. The economic literature confirms this intuition.[26] This observation offers more reason to question the Commission’s expectation that innovation by global platforms can be replaced by innovation by smaller rivals.[27] While the EU is a large market, the rest of the world is far larger. The EU market alone may not provide local digital platforms with sufficient incentive to innovate. The result could be that European consumers and businesses are denied the benefits of some innovations, whereby the innovation either does not happen at all, or happens outside the EU and cannot be rolled out in the EU due to ex ante regulation.

The Commission might expect ex ante regulation of global platforms to give EU firms space to develop the next big innovation that will go on to achieve global success. However, such regulation may well reduce the likelihood of this outcome by creating uncertainty about the appropriability of such an innovation and reduce incentives for EU firms to innovate.[28]

Based on these insights from the academic literature, and the wider context of the regulatory debate, we tested two hypotheses in the experiment.

- **Hypothesis 1**: that an increased likelihood of regulation of successful innovators, forcing them to share more of the benefits of their innovation with a rival, reduces overall R&D effort. This hypothesis forms the basis for treatment 1 in the experiment (see section 4.3.1).
- **Hypothesis 2**: that barriers to global firms rolling out innovations in the EEA will see local firms increasing their R&D efforts, more than replacing the lost innovation from global firms. This hypothesis forms the basis for treatment 2 in the experiment (see section 4.3.2).

[23] Specifically, we drop 11 players who invest ECU 0 in six or more rounds of the experiment.
[24] See section 5.1 of our first report.
[25] See section 5.3 of our first report.
[26] See section 6.1 of our first report.
[27] See, for example, ‘Digital Services Act Package: *Ex ante* regulatory instrument for large online platforms with significant network effects acting as gate-keepers in the European Union’s internal market’, 2 June 2020, p. 4: ‘Consumers and business users would continue to benefit from a large choice of products and services in a digital environment, while increased competition brought by alternative online platforms would lead to better innovation outcomes’.
[28] See section 6.2 of our first report.

3 Design of the experimental environment

This section introduces the key considerations for the design of the experimental environment. In section 3.1, we describe the online environment for our experiment. In section 3.2, we discuss how participants were recruited and how we ensured they were relevant to our experiment. Finally, in section 3.3 we present the structure of the experiment and how we provided instructions to the participants to ensure they had a good understanding of the game.

3.1 The (online) laboratory environment

The main ways in which behavioural experiments can be undertaken are:

- laboratory experiments: these typically take place in a computer room in universities, and participants are monitored by an experimenter ensuring that everyone understands the instructions; or
- online experiments: these occur online and the experimenter has a low level of control, for instance in terms of ensuring the attention of participants.[29]

We opted for a hybrid approach that combined aspects of online and laboratory experiments. This was primarily due to the COVID-19 restrictions, which ruled out the use of a traditional laboratory setting. As a consequence of these restrictions, many universities have adapted quickly and turned their physical laboratories into online laboratories where they can keep a sufficient level of control over the various factors that can influence decision making. For example, video conferencing allows the experimenter to answer questions and improve participants' understanding.[30] See Appendix A1 for a detailed description of the practical considerations of this laboratory environment.

3.2 Participants

We conducted our experiment on students at the University of Vienna, most of whom were studying for an MBA. The rationale for this was that MBA students would be more representative of business managers who would make R&D investment decisions, and some might have had prior industry experience. Due to scheduling and participation issues, a small minority (just over 10%) of those who participated in the experiment were undergraduate students in business courses. These undergraduates were spread randomly across all treatments.

Using students as participants is common, including in experiments in behavioural industrial organisation.[31,32] One alternative to MBA students would have been to use industry professionals or R&D experts. However, this would have raised practical issues in achieving a large enough sample size to obtain statistically significant results.

[29] A third approach is field experiments. This involves observing the real-world behaviour of participants who are subject to different control/treatment policies. In our context, a field experiment would imply randomly modifying the regulatory environment faced by all the firms in Europe. This is impossible for obvious practical reasons.
[30] An added benefit of this approach is that it is quicker and cheaper than a traditional laboratory, as it takes less time to welcome participants and pay them at the end. This means that, given a fixed time limit (e.g. one hour), more can be included in the experiment.
[31] For a review, see Brandts, J. and Potters, J. (2018), 'Experimental industrial organisation', in L.C. Corchón and M.A. Marini (eds), *Handbook of Game Theory and Industrial Organisation,* Volume II, Edward Elgar Publishing.
[32] An alternative approach to a behavioural experiment would have been to use agent-based modelling (ABM), which is essentially a computer simulation of the innovation contest. In this context, a behavioural experiment is more useful as it draws on the behaviour of actual human subjects rather than a modeller's assumptions about how people should behave.

In total, there were 70 participants in the formal pilot and 298 participants in the final experiment.

Box 3.1 Does behaviour in economic experiments reflect real-world behaviour?

A critique often addressed on the external validity of experiments is that they use university students as participants and that the behaviour in the laboratory is unlikely to be a good guide to what would happen in real-life business situations. In behavioural industrial organisation experiments, students are often asked to play the role of firms, and researchers analyse how business strategies can be affected by different rules of the experiment.

In fact, the founding father of experimental economics, Nobel Prize-winner Vernon Smith, is famous for having shown that under very limited constraints, it is possible for students representing firms and buyers to reach a competitive market equilibrium.[33] The predictions from this simple classroom study have been shown to extend beyond the laboratory and correctly forecast market equilibrium in 'future' financial contracts markets.

More recently, experimental studies on students have, for instance, analysed how firms in oligopoly can increase the complexity of information available to buyers in order to extract more profit out of them.[34] Experiments on students have also been published in top economics journals to analyse auction mechanisms,[35] and have informed policymaking for spectrum or airport slots auctions.[36]

The European Commission has also commissioned experimental studies investigating consumer decision making in retail investment services,[37] online gambling[38] and the effect of energy efficiency information on household product purchasing decisions.[39]

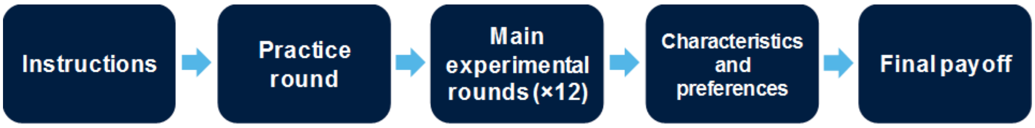
3.3 Experiment structure

An experiment is composed of multiple steps, allowing participants to understand the instructions, play the game repeatedly, and, finally, answer questions about their personal preferences and characteristics.

The structure of the experiment followed academic best practice, with clear instructions followed by a practice round and then 12 repeated rounds. The experiment structure is shown in Figure 3.1, and explained in more detail below.

[33] Smith, V.L. (2011), 'Constructivist and ecological rationality in economics', Nobel prize acceptance speech, NobelPrize.org. Nobel Media AB 2020, 23 June 2020.
[34] Kalaycı, K. and Potters, J. (2011), 'Buyer confusion and market prices', *International Journal of Industrial Organization*, **29**:1, pp. 14–22; and Kalaycı, K. (2016), 'Confusopoly: competition and obfuscation in markets', *Experimental Economics*, **19**:2, pp. 299–316.
[35] Goeree, K. and Offerman, T. (2002), 'Efficiency in auctions with private and common values: An experimental study', *American Economic Review*, **92**:3, pp. 625–643.
[36] Banks, J., Olson, M., Porter, D., Rassenti, S. and Smith, V. (2003), 'Theory, experiment and the federal communications commission spectrum auctions', *Journal of Economic Behavior & Organization*, **51**:3, pp. 303–350.
[37] Chater, N., Huck, S. and Inderst, R. (2010), 'Consumer decision-making in retail investment services: A behavioural economics perspective', report to the European Commission/SANCO.
[38] Codagnone, C., Bogliacino, F., Ivchenko, A., Veltri, G. and Gaskell, G. (2014), 'Study on online gambling and adequate measures for the protection of consumers of gambling services', report to the European Commission.
[39] Leenheer, J., Elsen, M., Mikola, N., van der Wagt, M. and Lloyd, L. (2014), 'Study on the effects on consumer behaviour of online sustainability information displays', report to the European Commission.

Figure 3.1 Experiment structure



Source: Oxera.

3.3.1 Instructions

When participants entered the Zoom meeting, instructions were presented on their screens. The instructions included information about the possible roles they might be assigned, how the experiment was structured and what financial reward they could achieve.

To ensure that participants fully understood the experiment structure, we used simple language and avoided industry jargon (e.g. we explained that ‘R&D’ means research and development). For brevity, only necessary information was included in the instructions. Moreover, all the text on the instruction screens was read out by the experimenter at the start of each session.

3.3.2 Practice round and repeated rounds

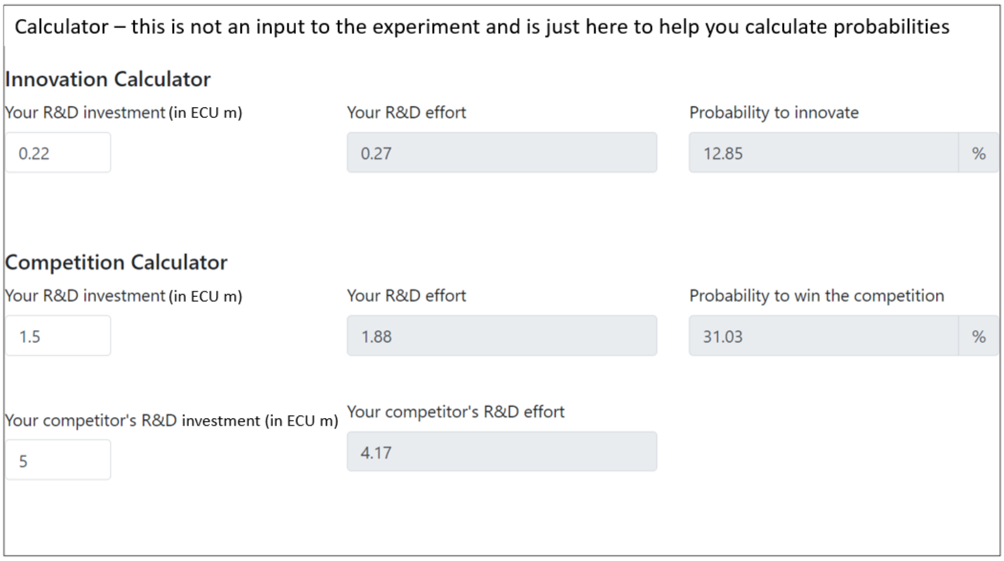
Immediately following the instructions, participants took part in a ‘practice round’ to familiarise themselves with the experiment. This practice round did not affect participant payoffs, and the participants were therefore free to try different strategies without the pressure of needing to optimise their decisions.[40]

The practice round (and all subsequent rounds) had the following screens.

- **Innovation Stage.** Participants enter their R&D expenditure. This screen also had a probability calculator, where participants could experiment with different levels of R&D expenditure for themselves and their competitor, to see how this affected their chances of innovating and winning the contest.
- **Innovation Stage—Results.** Participants were told whether they had successfully innovated.
- **Competition Stage—Results.** Participants were told the outcome of the contest.

[40] Data from the practice round has not been used in the data analysis.

Figure 3.2 Probability calculator



Note: all fields were empty when shown to the participants. This prevents the experimenter from priming participants.

Source: Oxera.

Following the practice round, there were 12 repeated rounds. We included multiple rounds so participants could learn from their decisions and potentially adopt different strategies. The rounds were identical and the decisions taken in one round did not affect the other rounds.

Each participant remained in the same role throughout the rounds. This ensured that participants had the opportunity to learn how to optimise decisions. Each round randomly matched the participants in the session into pairs (one global firm and one local firm). The participants were told this. The participants did not know the identity of the individual that they were matched with in each round, and were not given information about that participant’s actions in prior rounds. This ensured that participants viewed each round as a separate ‘game’, rather than as a ‘repeated game’.

3.3.3 Demographics and preferences

Towards the end of the experiment, participants were presented with a series of questions about their demographic characteristics and risk preferences. This information has been used in the data analysis to test whether these factors drive the results (see section 5 below). The full list of questions put to the participants is available in Appendix A5.

Given that the experiment involved uncertain payoffs, we were particularly interested in the participants’ levels of risk aversion. We also asked them questions that measured their levels of attention, loss aversion, and preferences over fairness.

3.3.4 Final payoff

Finally, participants saw a single screen that outlined their total payoff. Participants were informed of their earnings from the participation payment and performance payment.

4 Design of the control and treatments

In this section, we outline the control and two treatments in the experiment.

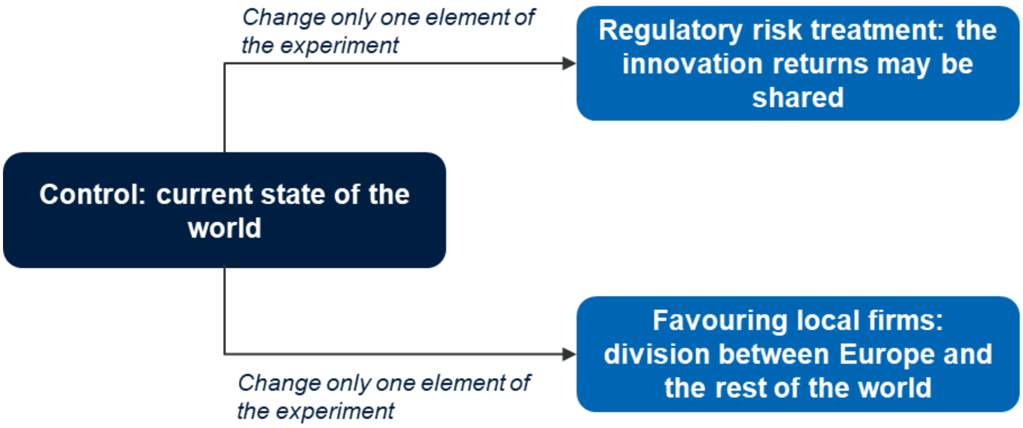
4.1 The control and treatments

To estimate the effect of alternative policies, such as a regulation like the DMA, economists first build a baseline scenario representing the status quo, i.e. if no policy changes occur. This is called a 'control' group. The control group is compared to one (or more) treatment groups, who face an experimental environment where the rules are changed to reflect the proposed policies. In each treatment, only one feature of the game is changed compared to the baseline scenario.

We used a 'between' participants design, meaning that participants in the experiment are randomly allocated to different treatments or to the control group.[41] This reduces the chance of the conflation of the participants' traits with the effect of the treatment,[42] and allows the researcher to investigate the effect of different scenarios without any conflating factors.[43]

In the experiment, we tested one control and two treatments, as shown in Figure 4.1.

Figure 4.1 The control and two treatments



Source: Oxera.

As discussed in section 2.2, all behavioural experiments are a simplification of reality. In designing the behavioural experiment we included the core elements that matter in assessing the effects of the DMA.

[41] An alternative to 'between' subjects experimental designs are 'within' subjects designs, where the behaviour of a given participant in different treatments is analysed. A downside of using a within subjects design in our case is that it may slow down the participants' ability to learn how to play the game (they have to learn two sets of rules).
[42] There remains a possibility that, by chance, a large number of participants with a particular trait, not measured by the demographic questions, are assigned to one particular group and skew the results. Large enough sample sizes reduce the chances of, but do not eliminate, this possibility.
[43] This is because only one element of the game has changed relative to the control group, and the participants' traits should not systematically differ across treatments.

4.2 The control

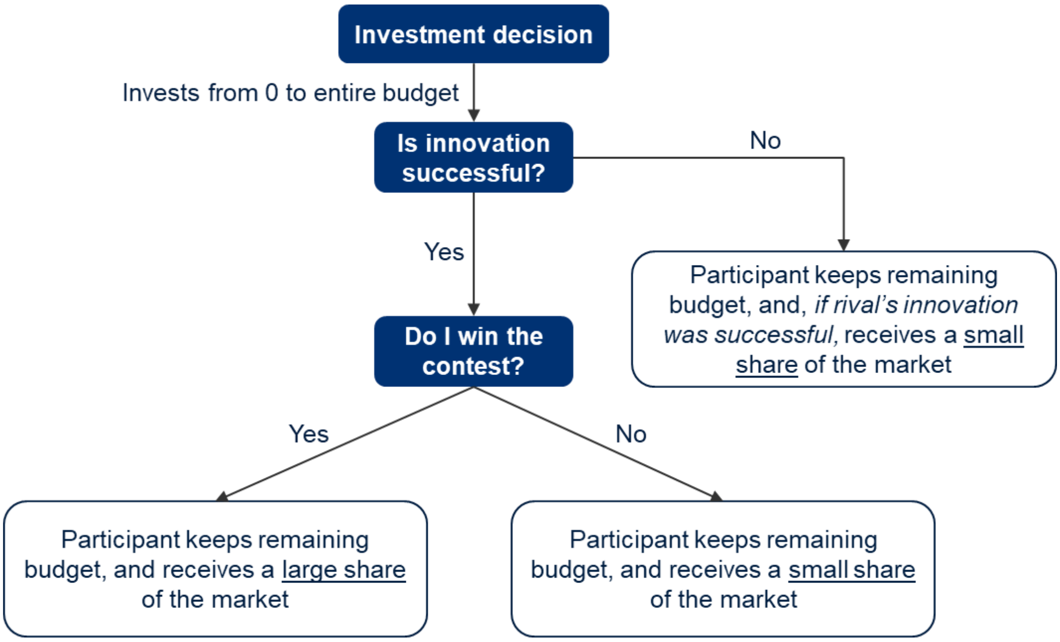
4.2.1 The innovation contest

Each round contained an innovation contest in two stages, to reflect two key elements of the reality of innovation.

- First, investment in achieving the innovation (the investment stage). This captures the uncertainty that firms face when deciding to invest in R&D, where they will not necessarily be successful in discovering an innovation.
- Second, competition over which firm's innovation wins the market (the competition stage). This stage reflects the competition between firms in the market to set their products as market leaders.

The participants only made one investment decision in each round (at the start of the investment stage). The participants were informed whether they were successful in achieving the innovation. If they were successful, they were entered into the competition stage. The likelihood of success in the competition stage depended on the level of investment made by both firms. This is shown in Figure 4.2.

Figure 4.2 The innovation contest



Source: Oxera.

The innovation success function

Whether an investment is successful in achieving the innovation is determined by the innovation success function (ISF). We chose a function designed to ensure both diminishing returns to R&D effort and that all positive levels of effort led to an innovation probability between zero and one.

For instance, if a participant decides to invest three units of R&D effort, this translates into a 65% chance of innovating. Since the participants had different costs of R&D effort, the maximum R&D effort they could exert differed (see section 4.2.2). See Appendix A1.8 for a detailed mathematical description of the ISF.

As the ISF is based on a relatively complex mathematical function, we introduced a 'probability calculator', helping the participants to calculate the probability of their innovation being successful.

The Tullock contest

The winner of the competition was determined by the Tullock contest.[44] It is one of the most widely used contest success functions (CSFs) in the economic literature on contest theory.[45] In a Tullock contest, participants can never guarantee a success in the competition.[46] However, the more R&D effort one invests into innovation, the more likely one is to win the contest. Details are provided in Appendix A1.9.

Similarly to the ISF, we introduced a probability calculator for the CSF to help the participants calculate the probability of their innovation being successful.

The rewards from winning the contest

The participants' willingness to invest resources in innovation and competition is driven by the potential returns on innovation. We framed the experiment such that the winner of the contest becomes the market leader and earns the largest share of the market.

We chose a total market size worth ECU 20m (experimental currency units), which equated to €20. The winner of the contest earned the larger part of the market, which corresponded to ECU 18m (or €18), while the other participant captured ECU 2m (or €2) of the market. These parameters were selected to ensure that the final payments to the participants were aligned with the guidelines of the laboratory at the University of Vienna, in particular to ensure that the participants would not earn too little or too much money.

4.2.2 The asymmetric two-player game

The two-player game

The experiment paired participants in each round: one global player and one local player. In other words, the game was always played between two participants. This is a common approach in the behavioural economics literature on innovation, because it strikes the right balance between the complexity of the game and testing the relevant hypotheses.[47]

Asymmetry between the global and local players

As explained in section 2.3, the hypotheses in question relate to the impact of policy on asymmetric firms (e.g. global and local). We therefore designed the experiment to reflect this asymmetry.

The asymmetry was reflected through the marginal cost of R&D effort. Apart from the marginal cost of R&D effort, the players were identical (e.g. they had the same budget). Varying the marginal cost of R&D effort reflected the way that global firms have an advantage in investment in R&D, through economies of scale, funding advantages, and learning from past successful innovation.

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[44] Tullock, G. (1980), 'Efficient rent seeking' in J.M. Buchanan, R.D. Tollison and G. Tullock (eds), *Toward a Theory of the Rent-seeking Society*, Texas A&M University Press, pp. 97–112.
[45] Dechenaux, E., Kovenock, D. and Sheremeta, R.M. (2015), 'A survey of experimental research on contests, all-pay auctions and tournaments', *Experimental Economics*, **18**:4, pp. 609–669.
[46] Success is only guaranteed if their rival exerts zero effort, but a rival's effort is not within a player's control.
[47] For example, Aghion, P., Bechtold, S., Cassar, L. and Herz, H. (2018), 'The Causal Effects of Competition on Innovation: Experimental Evidence', *Journal of Law Economics and Organization*, **34**:2, pp. 162–195.

The marginal cost of R&D effort for both players was common knowledge. The marginal cost of R&D effort for the global player was:

$$ECU\ 1.5m \text{ per unit of effort}$$

The marginal cost of R&D effort for the local player was:

$$ECU\ 2m \text{ per unit of effort}$$

Both players were given the same budget of ECU 10m.[48]

4.3 Treatments

4.3.1 Treatment 1: regulatory risk

The first treatment we introduced aimed to test hypothesis 1, as set out above. As a reminder, hypothesis 1 states that an increased likelihood of regulation of successful innovators, forcing them to share more of the benefits of their innovation with a rival, reduces overall R&D effort. This treatment was exactly the same as the control, apart from this one change. We called this treatment the ‘regulatory risk’ treatment.

The aim of the regulatory risk treatment was to assess how the uncertainty created by the introduction of new regulations might affect investment decisions by businesses.

In practice, the regulatory risk took the form of a potential decrease in the returns on innovation received by the successful innovator, if the regulation were to be implemented. We supposed that the regulatory intervention would take place with a 50% chance. If the regulatory intervention were to take place, then the innovator winning the competition stage would be able to keep only ECU 14m worth of the total market. If the regulatory intervention did not take place, the winner of the competition would keep the full returns on innovation (ECU 18m), as in the control treatment.

From an economic theory perspective, the effect of the introduction of this treatment is unambiguous. Given that it decreases the potential returns on innovation, the incentive to invest resources in R&D is therefore reduced.

4.3.2 Treatment 2: favouring the local firm

The aim of the second treatment was to assess the second hypothesis set out above. Hypothesis 2 states that putting up barriers to global firms rolling out their innovations locally might affect the balance of R&D efforts between local and global firms. We therefore call this treatment ‘favouring the local firm’.

‘Favouring the local firm’ took the form of splitting the total market size between two regions and assessing the effect of a regulation in one of the two regions. We called the two regions ‘Mountania’ and ‘Rest of world’. The selection of the name Mountania was driven by the fact that it is common in experiments not to

[48] The asymmetric marginal cost of R&D effort meant that it was less costly for the global player to invest in R&D effort. However, holding everything else the same for both players meant that both players could make the same levels of R&D investment (as both players had the same budget), although this would not result in the same levels of R&D effort. It also meant that for any given level of R&D effort both players had the same probability of innovating successfully (as both players faced the same ISF); and the Tullock contest gave both players the same chance of winning the competition (as the Tullock contest was determined by the R&D effort).

refer to names with meaning outside the laboratory environment. This prevents participants from taking decisions based on their personal preferences.[49]

We framed the introduction of the regulation as follows. The regulation is imposed in Mountania, where the local firm is from, and prevents the global firm from ever being market leader in this region. This means that if both firms innovate, the local firm is always market leader and earns a revenue stream of ECU 4.5m while the global firm earns ECU 0.5m. If the local Mountania firm fails to innovate, the global firm does not achieve regulatory approval and neither firm generates revenue streams in this market. In the rest of the world, the rule of the competition as set out in section 4.2.1 remains, but the market size in this part of the world is smaller (ECU 15m in total), and the market leader earns ECU 13.5m while the other player earns ECU 1.5m.

From an economic theory perspective, this change has an unambiguous impact on the innovation incentives of global firms and an ambiguous impact on the incentives of local firms. First, global firms face a reduced marginal benefit of their R&D effort, because the size of the market in which they can roll out innovations has reduced.

Local firms now enjoy a 'reserved area' where they need only innovate in order to become the market leader. They still compete with the global firm to roll out innovations in the rest of the world. This has two effects which point in different directions.

- Innovation wins the local market with certainty for the local firm, increasing the expected payoff from innovation and so increasing the incentive to expend R&D effort.
- Firms normally have an incentive to expend effort on R&D because it increases their chances of winning when rival successful innovations compete in the market for customers, but this incentive is now absent in Mountania so the local firm optimally expends less R&D effort.

The latter effect has parallels with the economic critique of protectionist trade measures to protect an infant industry. The industry has an incentive to continue to trade under old production methods under the protection of tariffs rather than invest in new production methods.[50] Neither effect will necessarily dominate the other, it will depend on the parameters of the interaction.

4.4 Incentivisation

In accordance with best practice, we incentivised the participants with a cash payment at the end of the experiment. This ensures that participants are motivated to try to maximise their firm's payoffs.[51] (See Appendix A1.10 for an explanation of why participants are paid in economic experiments.)

The payoff consisted of three elements (which was explained during the experiment):

- a participation fee (€7);

[49] For instance, if we had chosen 'France' or 'Germany' as names for the two regions, participants originally from these countries might have selected strategies reflecting their political views rather than what they would do in a business environment.
[50] See, for example, Baldwin, R. E. (1969), 'The Case against Infant-Industry Tariff Protection', *The Journal of Political Economy*, **77**:3, pp. 295–305, Section II.
[51] For example, see Gneezy, U. and Rustichini, A. (2000), 'Pay enough or don't pay at all', *The Quarterly Journal of Economics*, **115**:3, pp. 791–810.

- a payoff from the innovation contest (participants were told that this would be up to €20);
- a payoff from the first risk aversion question at the end of the experiment, of up to €3.85 (which varied according to participant decisions).

Following common academic practice, the payoffs to the participants were described in terms of ECUs (experimental currency units). Typically, ECUs are designed to have a lower value than euros, to mimic real-world decisions. In our experiment, we selected the exchange rate of €1 = ECU 1m.

Participants were told that they could never earn a negative payoff (i.e. they would never owe the experimenter money). Indeed, the lowest possible payoff from the whole experiment was €7.10.[52]

The payoff from the innovation contest was determined based on one of the identical rounds that participants completed. The round was randomly selected, and this was explained to participants at the beginning of the experiment.[53] While some experiments on innovation have rewarded participants on the basis of all the rounds, e.g. Aghion et al. (2018),[54] this is often because their rounds constituted one game. In our experiment, however, the rounds were independent, repeated games.

4.5 Predictions from economic theory

Given the description of the game above, it is possible to find the participants' expected R&D effort.[55] These predictions are based on the assumption that participants in the game are perfectly rational optimising machines of economic theory. Finding the reactions of the human beings who will one day be making these R&D investment decisions is the point of conducting an experiment.

The details of the calculation for the experiment have been confined to Appendix A4, but the procedure can be described as follows. The predicted outcomes for the control and treatment groups are reported in Table 4.1.

Table 4.1 Equilibrium outcomes predicted by economic theory

	R&D effort		R&D expenditure (ECUm)	
	Global firm	Local firm	Global firm	Local firm
Control	4.15	2.37	6.22	4.73
Regulatory risk treatment	3.62	1.10	5.43	4.37
Favouring local firms treatment	2.92	3.07	4.37	6.14

Source: Oxera.

52 Even if the payoff from the innovation contest was zero, all participants earned €7.00 from the participation fee plus a minimum of €0.10 from the risk aversion question.
53 Paying participants on the basis of one randomly selected round is common practice in experimental economics, and the use of this incentivisation scheme does not distort behaviour in most situations. Indeed, the advantage of paying based on one randomly selected round is that it avoids 'wealth effects', which can arise when participants adjust their effort in later rounds, due to the outcome of previous rounds (e.g. hitting their personal payoff target). For example, see Baltussen, G., Post, G.T., Van Den Assem, M.J. and Wakker, P.P. (2012), 'Random incentive systems in a dynamic choice experiment', *Experimental Economics*, **15**:3, pp. 418–443.
54 Aghion, P., Bechtold, S., Cassar, L. and Herz, H. (2018), 'The Causal Effects of Competition on Innovation: Experimental Evidence', *Journal of Law Economics and Organization*, **34**:2, pp. 162–195.
55 This can be done separately for each variant of the game across the control and treatment groups.

The reduction in R&D effort and expenditure by both local and global firms between the control and regulatory risk groups comes about because the value from winning the innovation race falls under the regulatory risk treatment.

The reduction in R&D effort by the global firm between the control and favouring local firms treatments happens for a similar reason. Since they cannot roll out their innovations in one geography, the value of winning the innovation race has fallen for global firms.

For local firms, as discussed above, winning some of the market without needing to fight a contest improves the expected payoff from innovation and encourages R&D effort. On the other hand, not needing to fend off a rival tends to discourage R&D effort as winning the contest for the lion's share of the market was part of the incentive to innovate. For the parameters we have chosen it turns out that the former effect dominates the latter.[56]

While the figures above suggest that the second treatment might be successful in promoting innovation by the local firm, it should be noted that this success comes at a cost. There is a reduction in the overall equilibrium probability of innovation being rolled out in Europe from the control scenario to the favouring local firms scenario from 90% to 66%. The increase in R&D effort by the local firm is not sufficient to replace the lost R&D effort by the global firm.[57]

[56] In addition there is a strategic effect. Because this is a game of strategic substitutes the reduction in R&D effort by the global firm leads the local firm to increase their own R&D effort as well. See Appendix A4 for further details5.4A4.
[57] For a more technical explanation and proof, see Appendix A4.

5 Results

In this section, we describe the results of the experiment. We first provide a brief summary of the results and their implications (section 5.1). We next provide a brief, simple summary of the data (section 5.2), before describing the results of our various statistical hypothesis tests (section 5.3). Finally, we look for any evidence of learning by the players in the data (section 5.4).

5.1 Summary of results

Our findings can be summarised as follows.

- In our main analysis, considering only innovators (presented in section 5.3.1) the regulatory risk treatment leads to an 8.6% decrease in effort for the global player and a 3.9% decrease in effort for the local player. The favouring the local firm treatment has a smaller impact and we find no significant effect on the global player and a 1.9% decrease in effort levels for the local player.

Similar results hold in the sensitivities where we focus on instances where players invested their whole budget, as such instances demonstrate a high willingness to invest, which is likely to lead to innovation but which might be discouraged by regulation (see section 5.3.2).

These results indicate that the introduction of these ex ante measures is likely to lead to less innovation output by those firms that want to innovate, be they local or global players.

5.1.1 Implications of results

The implications of these results could be significant for the levels of investment in R&D in the European economy. For example, if we assume that R&D expenditure in markets affected by the DMA is €100bn, then there could be a decrease of up to €8.6bn in R&D expenditures as a result of the increased regulatory risk treatment.[58] For the favouring local firms treatment, there could be a decrease in R&D spending of up to €1.9bn.[59]

In fact, and for illustration, in the ICT sector alone, business R&D amounted to more than €40.1bn in 2019 in the EU.[60] If we treat all of this as R&D expenditure that might be affected by the DMA, then as a result of the increased regulatory risk it might fall by up to €3.4bn per year.[61] Similarly, there

[58] €8.6bn is equal to €100bn × 8.6%. 8.6% is our estimate of the treatment effect for the global player.
[59] €1.9bn is equal to €100bn x 1.9%. 1.9% is our estimate of the treatment effect for the global player.
[60] See 'The 2020 EU industrial R&D investment scorecard', published by the European Commission, https://iri.jrc.ec.europa.eu/sites/default/files/2021-01/SB2020_final_16Dec2020_online.pdf. Table 1.3b reports that business R&D by EU companies in the ICT producer sector was €26.9bn and in the ICT services sector was €13.2bn. The scorecard gathers data from the annual reports of the largest companies covering 2,500 companies investing the largest sums in R&D worldwide, accounting for almost 90% of total business R&D expenditure worldwide. The numbers reported for the EU exclude the UK. The division of companies into sectors is based on Industrial Classification Benchmark (ICB) numbers which the companies identify themselves in their annual reports. 'ICT producers' in this report includes sector classification ICB4 digits that cover Computer Hardware; Electrical Components & Equipment; Electronic Equipment; Electronic Office Equipment; Semiconductors; Telecommunications Equipment. 'ICT services' includes sector classification ICB4 digits that cover Computer Services; Internet; Software; Mobile Telecommunications. Note that these totals for R&D investment are likely to be underestimates as: 1) not all EU companies are included in the data; and 2) the figures only include R&D data from companies headquartered in the EU and Figure 1.4b suggests that taking account of R&D flows (as companies headquartered in one region commission research in another) would increase the EU share of global ICT R&D expenditures.
[61] €3.4bn is equal to €40.1bn × 8.6%. 8.6% is our estimate of the treatment effect for the global player.

could be a fall in R&D expenditure of up to €0.8bn per year as a result of favouring local platforms.[62]

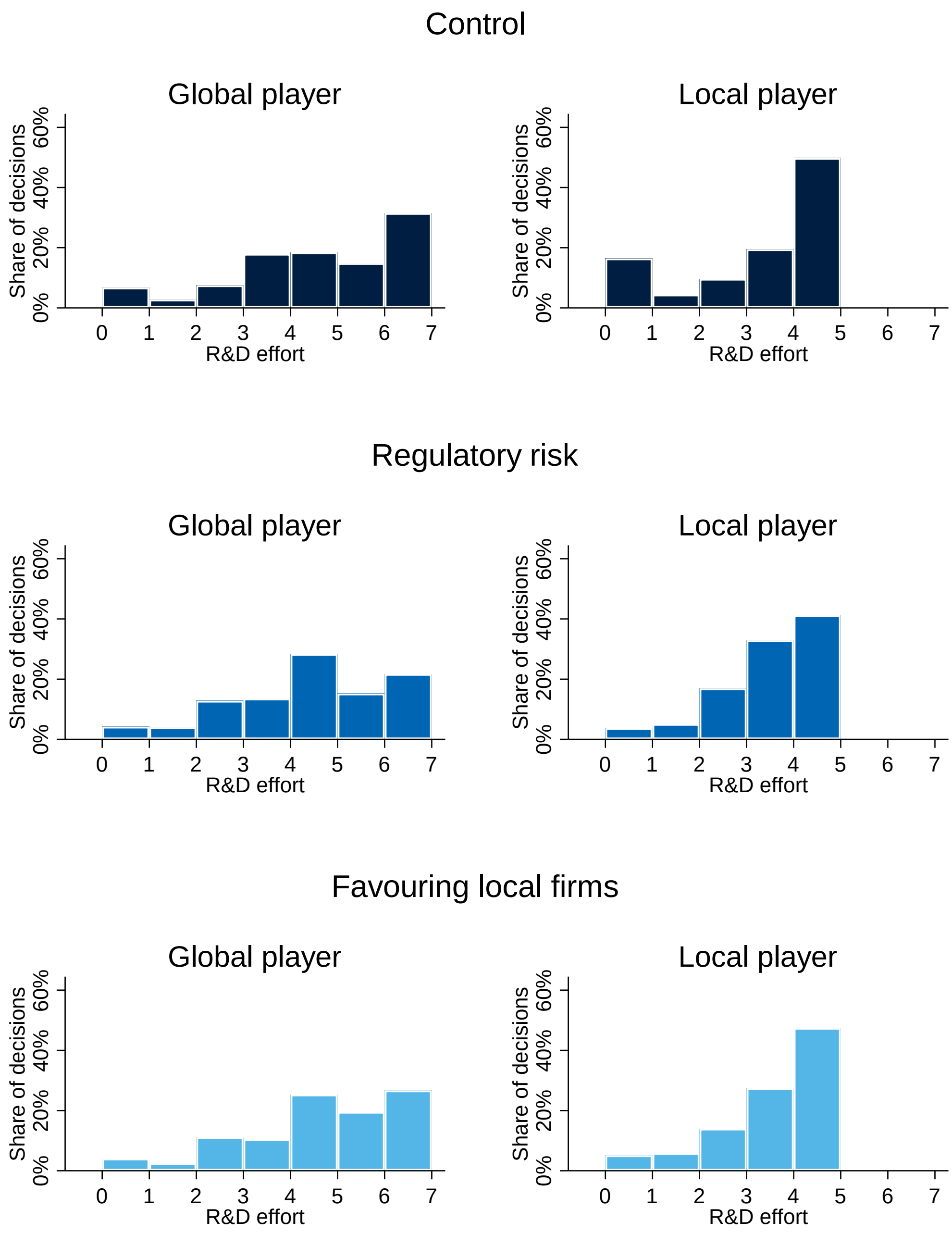
However, this is simply the reduction in R&D investment. Estimates of the social rate of return on R&D investment vary between 27% and 100% depending on the breadth of spillover effects considered.[63] Applying these estimates of the social returns to R&D spending to the €3.4bn estimate for the impact on R&D expenditure from the DMA, gives a potential social loss of the DMA up to €6.8bn per year.[64]

5.2 Simple data summary

In this sub-section, we present a simple summary of the behaviour of participants in our sample. We do not draw any conclusions on treatment effects here, but rather try to sharpen our intuition regarding the data we are analysing. Below, we describe our results by analysing R&D effort levels rather than R&D expenditure. This is because R&D effort is what feeds into the ISF (innovation success function) and CSF (contest success function). Figure 5.1 below shows the distribution of effort choices by player type and treatment.

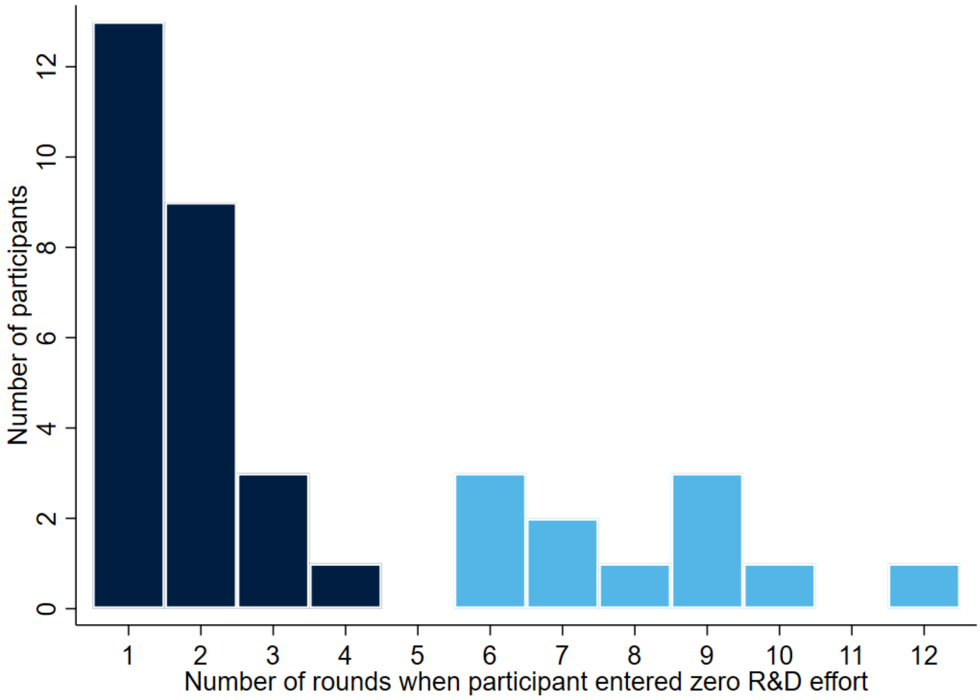
[62] €0.8bn is equal to €40.1bn x 1.9%. 1.9% is our estimate of the treatment effect for the global player.
[63] See Jones, C.I. and Williams, J.C. (1998), ‘Measuring the social return to R&D’, *The Quarterly Journal of Economics*, **113**:4, pp.1119–1135.
[64] €6.8bn is equal to €3.4bn x 2, where 2 is the social rate of return of R&D.

Figure 5.1 Distribution of effort levels for the local and global firms in each treatment



Source: Oxera analysis.

Figure 5.2 Frequency of participants who entered zero R&D effort one or more times



Note: This does not include the investment decisions made in the practice round. Neither does it include the number of players who never chose an investment level of zero.

Source: Oxera analysis.

As discussed in section 2.2, we show in Figure 5.2 that there were a small number of participants who repeatedly invested zero in the game, which means that it is impossible for them to innovate. Innovation is an inherently risky enterprise which could result in losses. People who invest nothing in R&D as frequently or more frequently than they invest some positive amount are not the people who are likely to be responsible for any future innovations.

Experimenters often observe different characters (or types) of participants. The behaviour between those different types may vary and it is common to focus the analysis on the most relevant group. For the purposes of our analysis we consider players who invest zero in six or more of the 12 rounds to be non-innovators, and thus not relevant for our report. We therefore drop these participants from our main analysis. Looking at the distribution of the number of times participants played zero, this cut-off drops those who played zero as part of a non-investing strategy, but appropriately includes those who may have played zero a few times as a means of experimentation or out of frustration. The existence of innovators and systematic non-innovators can be seen from Figure 5.2 where two distinct groups can be visually identified.[65]

Table 5.1 below shows the mean and median R&D effort levels for each treatment and player type compared to our theoretical predictions, excluding

[65] They appear to prefer to retain their initial endowment of ECU 10m (or €10) and take this as a guaranteed payoff, rather than invest some or all of it and earn returns of up to ECU 18m (€18). We considered how these people answered our demographics questions to see if those questions had recorded something indicating this aversion to R&D investment, but there were no systemic differences. It might be that these individuals were loss averse and preferred to keep the endowment, and while we did have a question to measure loss aversion among those demographic questions, it was not incentivised in the same way as the questions measuring risk aversion.

players who entered zero R&D effort six or more times. We make two observations.

Table 5.1 Simple summary statistics on effort levels in our sample (excluding players who entered zero R&D effort six or more times)

Treatment	Global players			Local players		
	Theoretical prediction	Mean effort level	Median effort level	Theoretical prediction	Mean effort level	Median effort level
Control	4.15	4.67	4.67	2.37	3.62	4.00
Regulatory risk	3.62	4.27	4.39	1.10	3.48	3.50
Favouring the local firm	2.92	4.65	4.67	3.07	3.55	4.00

Source: Oxera.

First, participants systematically over-exerted R&D effort relative to the theoretical prediction. This is not surprising and is a common observation in the experimental literature on contest theory. [66] One possible explanation is that participants enjoy 'winning' competitions beyond monetary payoffs, so over-invest.

Second, looking at these simple summary statistics we observe a decrease in R&D effort in the regulatory risk treatment and a small decrease in R&D effort in the favouring the local firm treatment. However, the best practice in the analysis of experimental data is to consider the entire distribution of decisions, rather than focusing on simple means or medians.[67] In the next sub-section, we estimate the causal effect of our two treatments by following this approach.

5.3 Hypotheses testing

In this section we test the hypotheses set out in section 2.3.

5.3.1 Analysis focusing on innovators

We compare the decisions in each treatment to the decisions in the control group. To do so, we use standard statistical procedures in experimental economics and compare the distribution of R&D effort treatments relative to the control group.

We estimate whether there is a systematic difference between the distribution of effort in the two treatments against the control group using a statistical test called the 'Mann–Whitney' test.[68] We report so-called p-values for two-sided hypothesis tests, which indicate the probability of incorrectly rejecting the

[66] Dechenaux, E., Kovenock, D. and Sheremeta, R.M. (2015), 'A survey of experimental research on contests, all-pay auctions and tournaments', *Experimental Economics*, **18**:4, pp. 609–669.
[67] See Moffatt, P.G. (2015), *Experimetrics: Econometrics for experimental economics*, Macmillan International Higher Education, section 3.5.
[68] The Mann–Whitney test is a non-parametric test commonly used in experiments. It does not rely on any assumption on the distribution of the data of interest. It is commonly used in analysis of experimental data where the assumptions of parametric tests, such as the t-test, are likely to be invalidated. As a result, while we present confidence intervals as a visual illustration of the degree of variability around the results, our assessment of statistical significance will ultimately be based on the Mann–Whitney test. Therefore, unless stated otherwise, all statistical tests in this analysis will be Mann–Whitney tests. For a full exposition, see Moffatt, P.G. (2015), *Experimetrics: Econometrics for experimental economics*, Macmillan International Higher Education, section 3.5.

hypothesis that the decisions in a given treatment were generated by the same type of behaviour as in the control group.[69]

We find that the regulation leads to a substantial decrease in R&D effort in the regulatory risk treatment. In the favouring local firm treatment, the effect is statistically significant for the local player (with a lower magnitude than in the regulatory risk treatment), but not for the global player. This analysis does not include systematic non-innovators, as they are unlikely to innovate in either scenario.[70] This corresponds to 11 participants out of a total of 298 who were classed as non-innovators.

As illustrated in Figure 5.3 below, the regulatory risk treatment leads to an 8.6% decrease in effort for the global player and a 3.9% decrease in effort for the local player. The favouring the local firm treatment has no significant effect on the global player, but leads to a 1.9% decrease in effort levels for the local player. In Table 5.2, we present detailed results of our statistical analysis.

The most interesting feature of these results is the significant and negative impact of the favouring local firms treatment on R&D efforts of local firms. Recall that the incentives of local firms are subject to two countervailing effects:

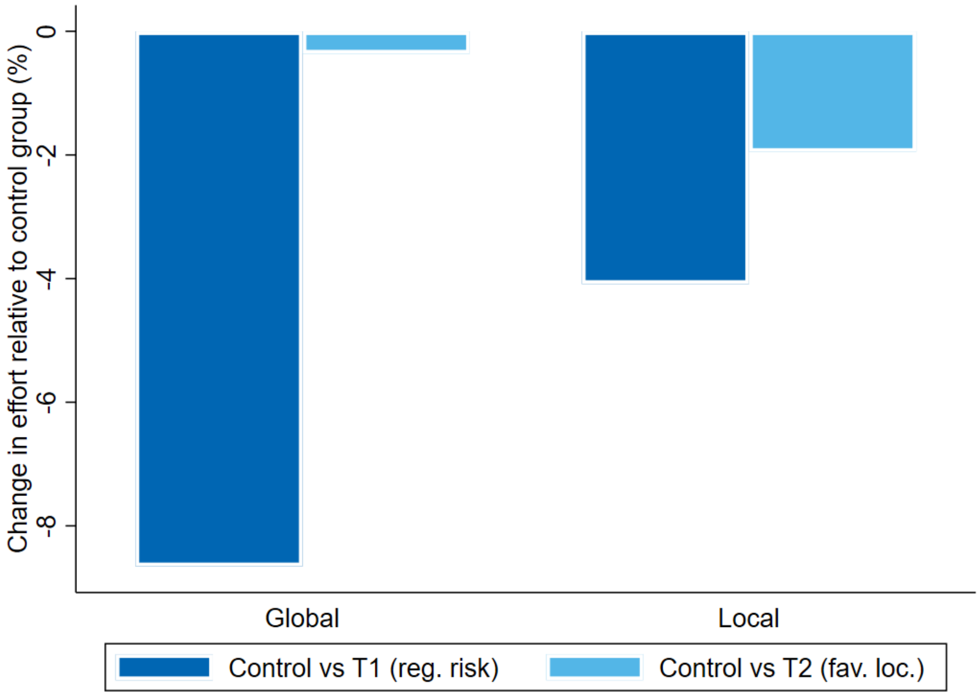
- in one sense, the expected benefit of R&D effort has increased because innovation is now sufficient to win the prize that is available in the local market; but
- in another sense, the benefit of R&D effort that came from increasing one's chances of winning the lion's share of the local market against a rival (in the event that both firms produced an innovation) has vanished (because the local firm is no longer required to play the competition game to win this market).

The theoretical result suggested that the former effect dominated the latter, but the experimental result suggests that, for real human beings, the latter effect dominates the former. Put into the context of the DMA, it would suggest that holding back global firms to create space for local firms to innovate may in fact lead the local firms to take advantage of the reduced competitive pressure and choose to innovate less.

[69] Given that the Commission's view seems to be that the proposed measures should actually increase innovation, there may be an argument for looking at one-sided hypothesis tests. However, one-sided p-values are smaller than two-sided p-values, so we have held our findings of significance to the higher standard of a two-sided hypothesis test.

[70] In Appendix A3, we present some sensitivities around this choice of cut-off. The significance of the result for the regulatory risk treatment is robust to increases in the cut-off for the number of times a participant must choose zero investment in order to be considered a non-investor and dropped from the data (up to a cut-off which only considers those choosing zero investment nine times or more out of 12 to be non-investors). The result for the 'favouring local firms' treatment becomes insignificant once the cut-off increases to 7 occasions of playing zero investment.

Figure 5.3 Treatment effect for each player type expressed as a percentage



Source: Oxera analysis.

Table 5.2 Testing for the statistical significance of the treatment effects, excluding players who invested zero effort for more than half of the experiment

	Global player				Local player			
	Mean effort (control)	Mean effort (treatment)	Treatment effect (treatment effort less control effort)	Is the difference significant?	Mean effort (control)	Mean effort (treatment)	Treatment effect (treatment effort less control effort)	Is the difference significant?
Regulatory risk	4.67 (564)	4.27 (612)	**-0.40**	Yes [p <0.01]	3.62 (516)	3.48 (600)	**-0.14**	Yes [p <0.01]
Favouring the local firm	4.67 (564)	4.65 (564)	**-0.02**	No [p = 0.63]	3.62 (516)	3.55 (588)	**-0.07**	Yes [p <0.05]

Note: figures in parentheses indicate the sample size of each group. The figures in square brackets are p-values for pairwise comparison between each treatment and the baseline treatment using a Mann–Whitney test.

Source: Oxera analysis.

5.3.2 Going 'all in'

As well as investing zero, some participants had a tendency to go 'all in' and invest their entire budget. This is the sort of behaviour that is most likely to lead to innovation. So one approach to measuring the treatment effect is to look at the impact of the proposed treatments on the tendency of the participants to invest their whole endowment.

This also acts as a sensitivity and sense check on the results from the previous sub-section because we are looking at the behaviour of people who have a willingness to invest in the uncertain process of R&D, but we are not excluding any observations—i.e. the systematic non-innovators discussed in detail above are included in this sensitivity.

The results from the previous sub-section broadly hold under this sensitivity. We find that in all treatments, the regulation leads to a decrease in the proportion of players who invest all their budget in R&D. This decrease is statistically significant for both treatment groups and holds for both the local and global players, as illustrated by Table 5.3 below.

As in the previous sub-section, we find that the introduction of regulation that favours local firms decreases the proportion of local players who invest all their endowment. This is counter to what theory would predict. Again, this appears to be because, for real human beings, the increased benefits of R&D effort in the global market outweigh the fact that you are guaranteed to have the lion's share of any innovation in the local market.

Table 5.3 Proportion of players going ‘all in’

	Global player				Local player			
	Control group	Treatment group	Difference (percentage points)	Is the difference significant?	Control group	Treatment group	Difference (percentage points)	Is the difference significant?
Regulatory risk	23% (600)	11% (612)	**-12**	Yes [p <0.01]	22% (600)	15% (600)	**-8**	Yes [p <0.01]
Favouring the local firm	23% (600)	15% (564)	**-8**	Yes [p <0.01]	22% (600)	18% (588)	**-4**	Yes [p <0.01]

Note: systematic non-innovators (players who invested zero effort for more than half of the experiment) are not dropped in this sensitivity. Similar results hold if they are included. Figures in parentheses indicate the sample size of each group. The figures in square brackets are p-values for pairwise comparison between each treatment and the baseline treatment using Pearson's chi-squared test.

Source: Oxera analysis.

5.3.3 Including systematic non-innovators in the analysis

As mentioned above, our analysis focuses on the analysis of players that can be identified as 'innovators'. As a sensitivity, we included the individuals identified as systematic non-innovators in Table 5.4 below. Here, the regulatory risk treatment has a negative and statistically significant effect on the global firm's effort, but the effect on the local firm's effort is not statistically significant (although it is negative). In the favouring the local firm treatment, we find a negative but not statistically significant treatment effect for either player type.

Table 5.4 Testing for the statistical significance of the treatment effects

Comparison	Global players Is the difference significant?	Local players Is the difference significant?
Control group vs regulatory risk treatment	Yes, negative [p <0.01]	— [p=0.37]
Control group vs favouring the local firm treatment	— [p=0.51]	— [p=0.37]

Note: the figures between square brackets are p-values for pairwise comparison between each treatment and the baseline treatment using a Mann–Whitney test.

Source: Oxera analysis.

Combined with the previous finding, this result suggests that only innovators are affected by the regulation favouring local firms. This confirms that the treatment effect we observe in this treatment is not as strong as the regulatory risk treatment and that it is innovators specifically, rather than non-innovators, who are disincentivised by the introduction of regulation.

5.4 Learning

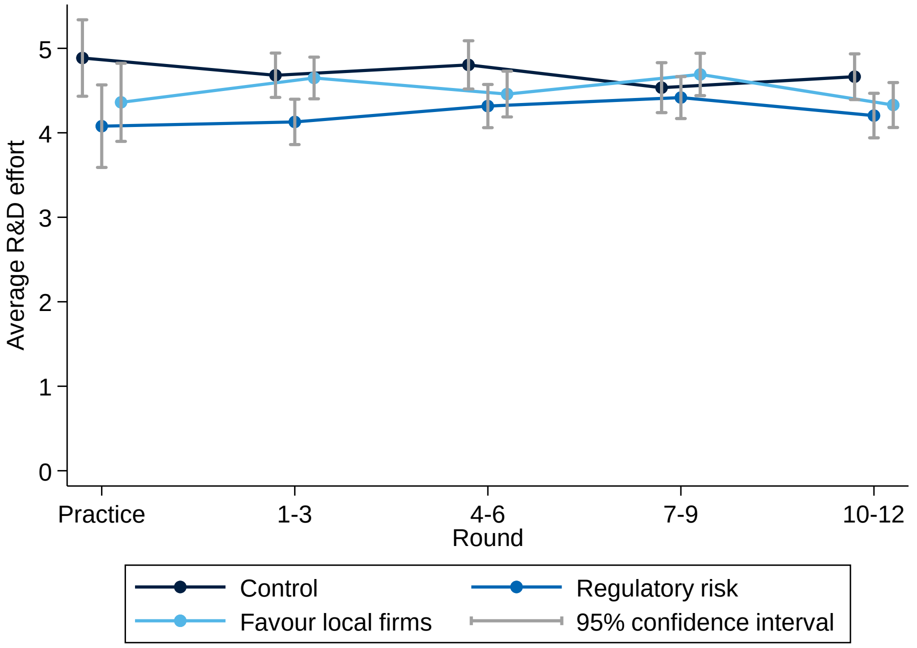
Experimenters often observe that players change their behaviour over multiple rounds of the same game. It is possible that participants may learn how to play the game throughout the experiment and converge towards the Nash equilibrium (i.e. what economic theory would predict).

We observe no statistically significant change in behaviour for either player in the control group or any treatment group for the global player. This is demonstrated by the relatively flat trend lines in Figure 5.4 below. We see in Figure 5.5 a small increase in the R&D effort level selected by the local players in all treatments and the control group.[71]

This finding suggests that the instructions were clear to the participants and that they were rapidly able to find their preferred strategy.

[71] This finding is statistically significant.

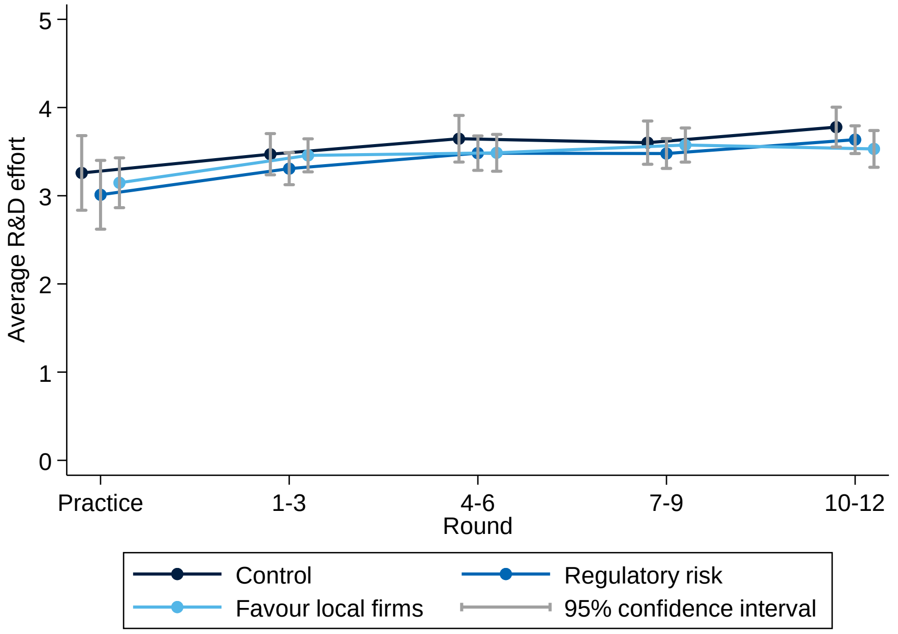
Figure 5.4 R&D effort by round for global player



Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%. This figure excludes players who entered zero R&D effort six or more times.

Source: Oxera.

Figure 5.5 R&D effort by round for local player



Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%. This figure excludes players who entered zero R&D effort six or more times.

Source: Oxera.

A1 Practical experimental design considerations

In this section we present the practical considerations we dealt with while designing the experiment.

A1.1 Language

The experiment was conducted in partnership with the University of Vienna in December 2020 and was run using their own students.

The experiment was conducted in English. We had considered conducting the experiment in German, but we chose English because many of the students on the MBA programme are not native German-speaking. Further, the MBA course is taught in English and experiments at the University of Vienna are typically conducted in English. The experimenter was fluent in English and German, and so was able to assist participants in the unlikely event that language became a problem.

A1.2 Software

The experiment was programmed in the oTree software.[72] oTree is an open-source and online software for implementing interactive experiments for economics and related fields.[73] It was created by researchers from the Toulouse School of Economics, Harvard University and ETH Zürich.

The experiment was monitored by the experimenter through video conferencing[74] due to the COVID-19 pandemic restrictions. The participants were given onscreen instructions and the experimenter read the instructions to them on the Zoom video conference to ensure complete understanding of the rules.

A1.3 Ethical approval

The experiment was conducted according to the highest ethical standards, and ethical approval from the University of Vienna was granted.

A1.4 Pilots

Before running the experiment, we ran formal and informal 'pilots' for the experiment.[75] This is common practice in any experimental field and enabled us to check:

- that the programming of the experiment functioned;
- the time taken to run the experiment;
- that participants understood the instructions.

Informal pilots (i.e. participants were not paid for their time) took place in November and December 2020, using Oxera staff and university research assistants.

The formal pilots (i.e. incentivised) took place in December 2020, using a sample of 70 students from the University of Vienna. The students in the pilot

[72] See https://www.otree.org/.
[73] Chen, D.L., Schonger, M. and Wickens, C. (2016), 'oTree—An open-source platform for laboratory, online, and field experiments', *Journal of Behavioral and Experimental Finance*, **9**, pp. 88–97.
[74] See https://zoom.us/.
[75] A pilot is a pre-test of the experiment where certain features of the experiment are calibrated.

were a mix of MBA students, Supply Chain Management MSc students, and undergraduate students.

Following the formal pilot, the only change we made was to increase the number of rounds in the experiment where participants could win money from nine to 12. This was because the experiment duration in the pilot was relatively short, and increasing the number of rounds increased the data collected. Data from the pilots has therefore not been used in the data analysis or in forming conclusions.

A1.5 Duration

The experiment was designed to take up to one hour. This provided enough time (and rounds) to ensure that participants could learn how to play the game and that enough data would be generated, but not so long that participants would lose focus.

A1.6 Sessions

The experiment was conducted in a series of 26 sessions over the course of five days. The mean number of participants per session was 11.

Each participant could take part in the experiment only once (i.e. they could not come back and take part in a different treatment) and participants in the pilot were not used again in the experiment. This ensured that all participants had the same opportunity to learn how to play the game, and that the design of one treatment (or outcome of one session) did not affect the behaviour of a participant in another treatment (or session).

A1.7 Anonymity

In accordance with best practice, participant decisions in the experiment were anonymous (i.e. the names of participants were not recorded in the data). In each session, the participants did not know which other firms were being played by which participants. Furthermore, participants' payoffs were anonymous, which meant that they were able to make their decisions without regard to their future interactions with other participants.

The invitation system used by the University of Vienna for experimental subjects will only allow each experimental subject (who must be associated with a University email address) to book onto one experimental session. Furthermore, the invitations to participate can only be sent to an individual who has been registered with the laboratory in Vienna.

The experiment was compliant with GDPR.

A1.8 ISF function

In mathematical terms the ISF is defined as:

$$i(w_i) = 1 - e^{-\lambda \times effort}$$

Where $effort$ is the R&D effort by a given firm. The parameter λ allowed for some calibration and was selected so that it was low enough that Nash equilibrium investment levels led to probabilities of innovation success that were intermediate (i.e. nearer to 50% than either 0% or 100%). This was to ensure that there would be sufficient variance in innovation outcomes. However, when this parameter was set too low, that could eliminate the existence of a pure strategy Nash equilibrium. So a balancing act was required.

A1.9 The Tullock contest success function

The Tullock contest takes the form of the following two equations for two participants, A and B:

$$Probability\ of\ winning_A = \frac{Effort_A}{Effort_A + Effort_B}$$

$$Probability\ of\ winning_B = \frac{Effort_B}{Effort_A + Effort_B}$$

In our experiment, the Tullock contest is part of a larger set of interactions determining the winner of the contest:

- if only one participant successfully innovates, then that participant wins the contest;
- if both participants successfully innovate, they enter the Tullock contest, where:
  - the chance of a participant winning the contest increases as that participant's R&D effort increases;
  - the participant that exerts the highest level of R&D effort has the greater chance of winning the contest;
  - if both participants exert the same R&D effort, then each participant has a 50% chance of winning the contest.

A1.10 Incentivised experiments

From a methodological perspective, economic experiments have two key differences relative to those in other disciplines, as follows.

1. Economists do not deceive participants about the rules of the game. Indeed, in other disciplines it is common that participants take part in an experiment and are misled by certain instructions while the real nature of the game is different. For instance, in a famous psychology experiment, participants were told that they were taking part in an experiment on the effect of food on memory, while the researchers were in fact analysing their ability to stop themselves from engaging in socially inappropriate behaviour.[76] This methodological difference arises because economic experiments are used to test predictions from economic theory in which the transparency of incentives is the most important parameter.
2. Economic experiments are incentivised and each participant's payment depends on their performance in the game they are playing. This is because economic experiments rest on the assumption that participants' decisions, as per economic theory, are directed to maximising their financial rewards in economic situations. For this assumption to hold, it is necessary that their actions in the game have consequences for their final payoff, as they would outside the laboratory.

[76] von Hippel, W. and Gonsalkorale, K. (2005), '"That is bloody revolting!" Inhibitory control of thoughts better left unsaid', *Psychological Science*, **16**:7, pp. 497–500.

Because this experiment was run online, participants were paid via PayPal.

A1.11 Data filtering

Experimental data is not immune to the requirement of some cleaning before it can be analysed. Our raw data contained the following observations which we dropped.

- **Practice rounds.** After the instructions were explained and before the main experiment began, each player was required to participate in one practice round. Their performance in this round did not count towards their final payoff and was only included so that the participants would better understand the experiment. We exclude practice rounds from our analysis.
- **'Robot players'.** There were a small number of cases where a robot player was required to stand in the place of an actual participant. This occurred if there were an odd number of participants in the session or if a participant dropped off part-way through the session. The actions of robot players are excluded from our analysis.
- **Systematic non-innovators**. There were a small number of participants who repeatedly invested zero in the game, which means that it is impossible for them to innovate (see Figure 5.2). It is common in experiments to observe different characters (or types) of participants, especially in contest experiments.[77] For the purposes of the analysis we define repeatedly playing zero as playing zero in six or more of the 12 rounds. Innovation is driven by people who are willing to invest in the inherently uncertain process of research and development of new ideas, products and production processes. We therefore drop these participants from our main analysis.

[77] See, for instance, Fallucchi, F., Mercatanti, A. and Niederreiter, J. (2020), 'Identifying types in contest experiments', *International Journal of Game Theory*, pp. 1–23; Potters, J., De Vries, C.G. and Van Winden, F. (1998), 'An experimental examination of rational rent-seeking', *European Journal of Political Economics*, **14**:4, pp. 783–800; and Herrmann, B. and Orzen, H. (2008), 'The appearance of homo rivalis: Social preferences and the nature of rent seeking', CeDEx discussion paper series.

A2 The sample

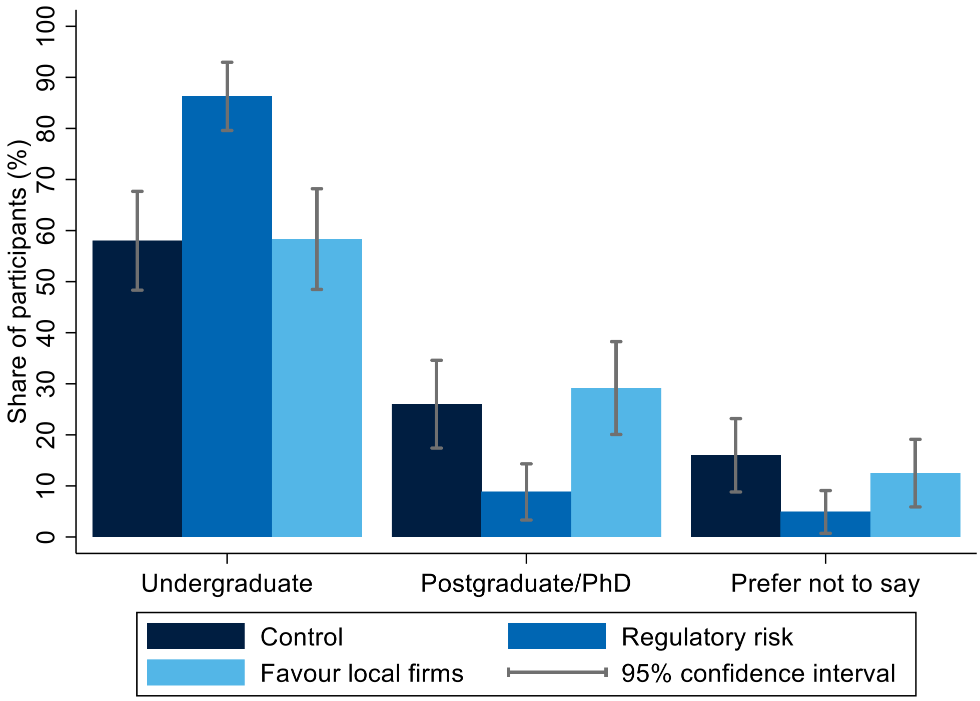
A2.1 Sample characteristics

In order for an experiment to be robust, differences between treatments should be the result of the treatments themselves only, and not due to intrinsic differences between participants. In our experiment, we randomly allocated participants to treatments such that the participant mix should be similar across treatments.

This is confirmed by an analysis of the demographic questions asked at the end of the experiment, the results of which are shown below.

A broadly similar level of education is observed within all treatment groups. However, there were significantly more participants whose highest level of education was an undergraduate degree in the regulatory risk treatment group, compared to the control group and the favouring the local firm treatment group.

Figure A2.1 Participants' highest level of education (not including the course they were enrolled on at the time of the experiment)

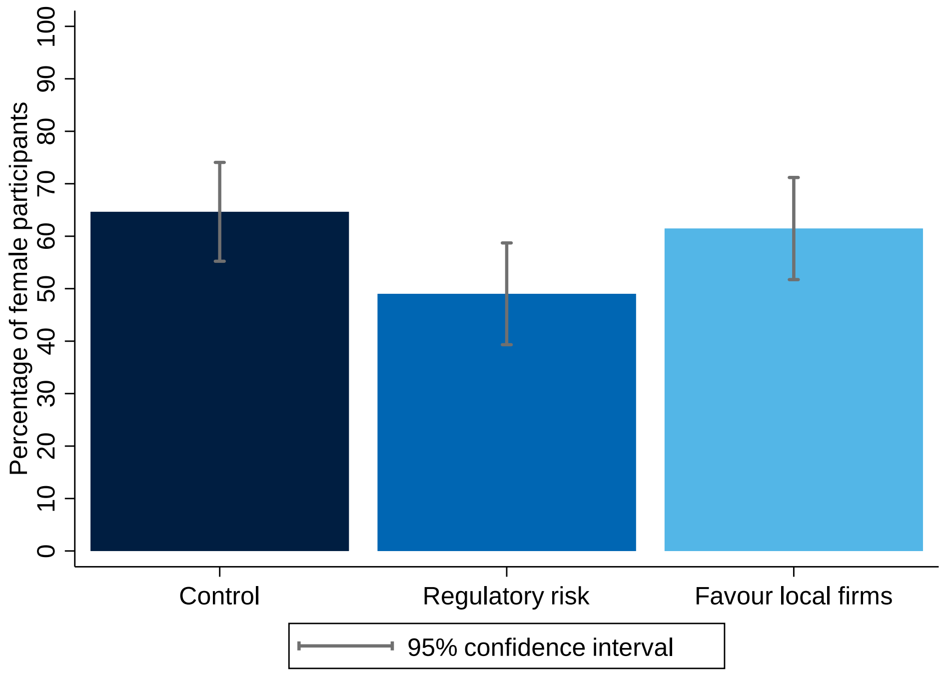


Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%.

Source: Oxera.

We observe a similar gender balance between each of the treatment groups. Overall, 58% of participants were female. There were no treatment groups that had a significantly different gender split.

Figure A2.2 Gender balance of different treatment groups

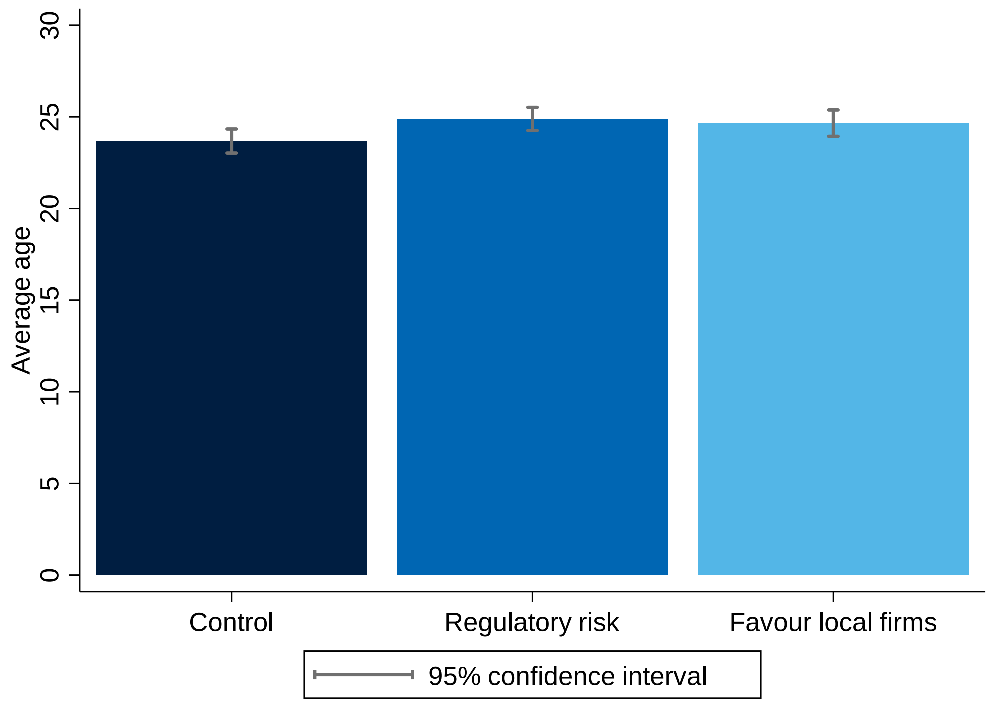


Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%.

Source: Oxera.

Similarly, each treatment group had a similar age distribution. The mean age of the participants was 24. No treatment group significantly differed from this.

Figure A2.3 Age range of different treatment groups



Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%.

Source: Oxera.

The sample size also needs to be sufficiently large such that any differences between the treatments can be accurately detected. We conducted the experiment in multiple sessions for each treatment group with different participants in each group.[78] Across the experiment, there were a total of 298 participants, across 26 sessions. This is shown in Table A2.1.

Table A2.1 Sample size

Treatment	Number of sessions	Number of participants
Control	5	100
Regulatory risk	10	102
Favouring the local firm	11	96
Total	26	298

Source: Oxera.

In order to incentivise participants, they were offered a monetary reward based on their performance. Overall, participants earned between €9 and €36.90 from the experiment. The mean earnings were €22.40, which was similar for all treatment groups. This is shown in Table A2.2.

Table A2.2 Mean payoffs

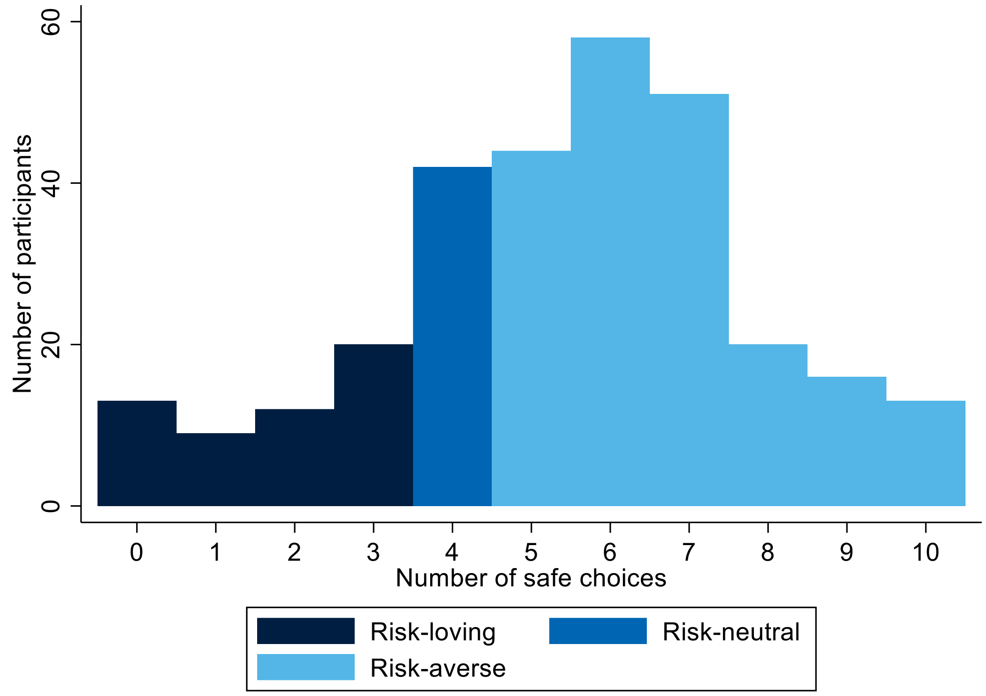
Treatment	Mean payoff (€)
Control	22.80
Regulatory risk	22.40
Favouring the local firm	21.80
Overall	22.40

Source: Oxera.

Overall, the majority of participants were risk-averse according to their answers from the Holt and Laury questions.[79] A minority of participants were risk-loving or risk-neutral (see figure below). This was consistent throughout all treatment groups.

[78] For clarity, one experimental session is where a group of participants and the experimenter met over Zoom to conduct the experiment.
[79] See description in section 3.4.3 and Holt, C.A. and Laury, S.K. (2002), 'Risk Aversion and Incentive Effects', *The American Economic Review*, **92**:5, December, pp. 1644–1655.

Figure A2.4 Risk preferences according to Holt and Laury question



Note: 0 is most risk-loving (a participant who never picks the safe option); 10 is most risk-averse (a participant who always picks the safe option) and 4 is risk-neutral. See Holt and Laury (2002) for details on these definitions.

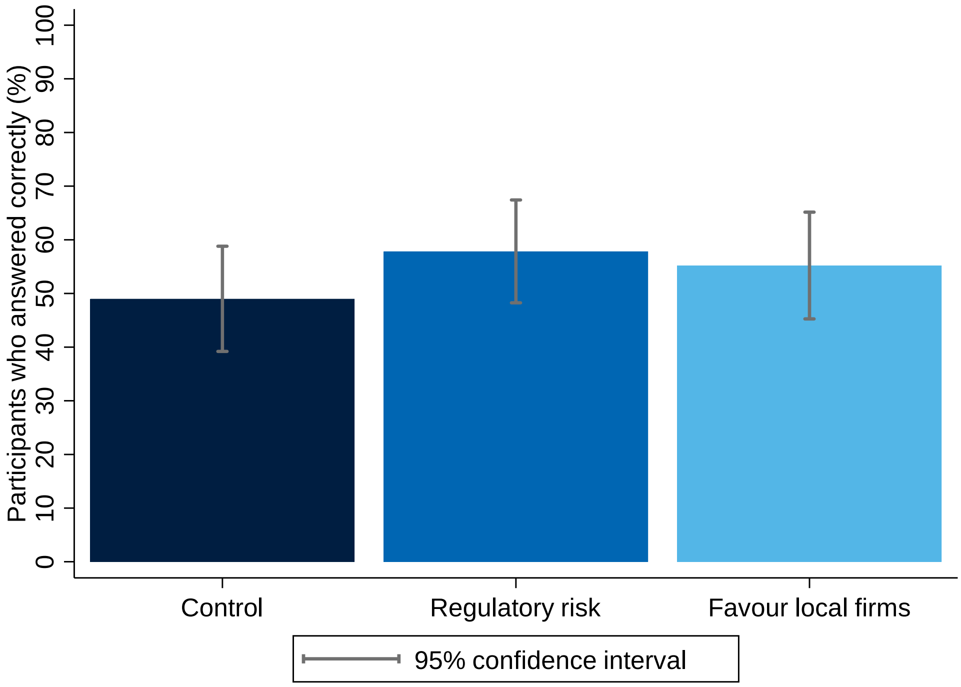
Source: Oxera.

Overall, despite some minor differences, it seems that the participants were similar across treatments.

A2.2 Participant demographics and characteristics

Figure A2.5 summarises the percentage of participants who answered the following question correctly: 'You buy a bat and ball for €1.10. The bat costs €1 more than the ball. How much does the ball cost?' The correct answer is 5 cents.

Figure A2.5 Percentage of participants who answered attention question correctly



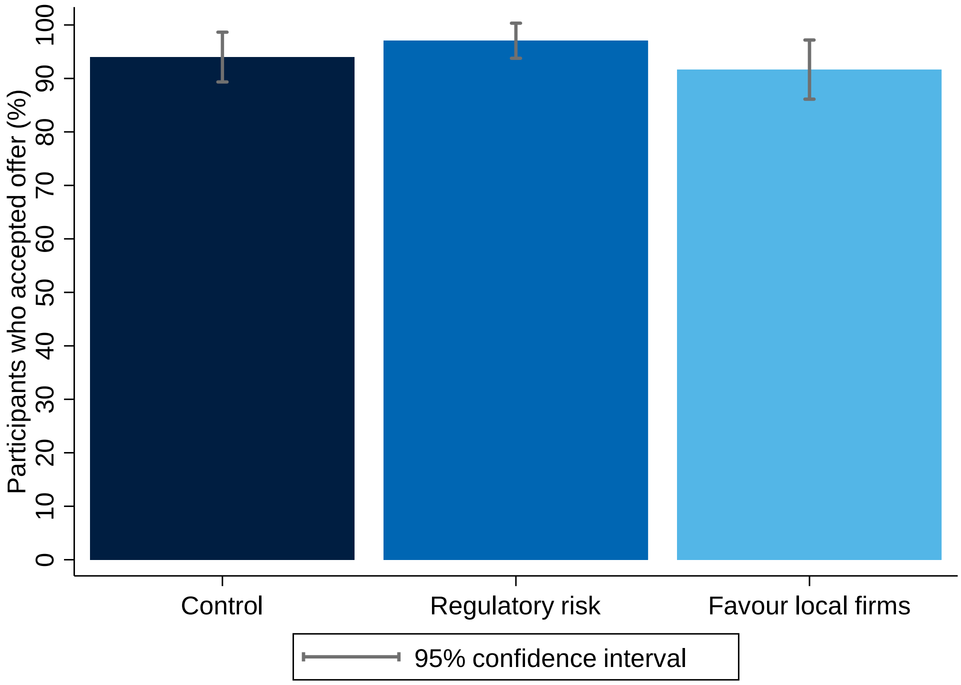
Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%.

Source: Oxera.

Overall 55% of participants answered this correctly. This was similar across all treatment groups. This shows that all samples had a similar level of participant attention.

Figure A2.6 below summarises the percentage of participants who accepted the following offer: 'Imagine you and someone else were in an experiment. The other person was given €10 and told to split it between you both. You are given the opportunity to accept or reject the offer. If you reject it, you both get €0. The other person decided to give you €4, and keep €6 for them. What would you do: accept or reject?'

Figure A2.6 Percentage of participants who accepted the offer in the fairness preferences question



Note: a confidence interval is a way to measure the precision of an estimate. It is a range of values that contains the true statistical value (i.e. across all samples) with a probability of 95%.

Source: Oxera.

Overall 95% of participants accepted this offer. This was similar across all treatment groups. This shows that all samples had a similar level of fairness preferences.

A3 Sensitivity analysis for the cut-off for non-innovating participants

As discussed in section 5.2, we consider participants who repeatedly enter zero R&D effort in multiple rounds to be systematic non-innovators. This behaviour is not consistent with the behaviour of entrepreneurs whose actions are relevant for this study, and thus these participants are removed from the baseline analysis. Specifically, we drop participants who enter zero R&D effort in six or more rounds. This cut-off is chosen based on visual inspection of the distribution presented in Figure 5.2, which indicates that there is a cluster of systematic non-innovators who enter zero R&D effort six to 12 times. The baseline analysis where these participants are dropped is presented in section 5.3.

In the table below we conduct a sensitivity to test whether our results are robust to different cut-off rules. The first two rows present the treatment effects under the full sample; this is followed by the treatment effects if we drop participants who entered zero effort in all 12 rounds; followed by the treatment effects if we drop participants who entered zero effort in 11 or more rounds, etc. The bottom two rows present the treatment effects if we drop participants who entered zero effort in one or more rounds.

Our main analysis concludes that all treatments cause a significant decrease in R&D effort, with the exception of the global player under the favouring local firms treatment (for whom there is no significant effect). These results hold for all the sensitivities where we adopt a broader definition of systematic non-innovators (i.e. where we drop players who enter zero investment in x or more rounds, where x is below six).

Not all of these results hold in some sensitivities where we drop fewer systematic non-innovators (likely due to the bias caused by the systematic non-innovators). In particular the significance of the finding that the local firm reduces R&D effort under the favouring local firms treatment becomes insignificant. However, the finding that the regulatory risk treatment leads to a reduction in R&D effort for local and global firms remains broadly significant until the definition of a systematic non-innovator requires a participant to have made no investment for 11 or more rounds.

Table A3.1 Treatment effects using different definitions for non-innovators

Exclusion rule (drop participant if they invested zero in x or more rounds)		Global player		Local player	
		Treatment effect	Significance	Treatment effect	Significance
Full sample	Regulatory risk	-0.21	Yes [p<0.01]	0.20	No
Full sample	Favouring local firms	0.18	No	0.30	No
12	Regulatory risk	-0.21	Yes [p<0.01]	0.14	No
12	Favouring local firms	0.18	No	0.24	No
11	Regulatory risk	-0.21	Yes [p<0.01]	0.14	No
11	Favouring local firms	0.18	No	0.24	No
10	Regulatory risk	-0.21	Yes [p<0.01]	0.08	Yes [p<0.05]
10	Favouring local firms	0.18	No	0.17	No
9	Regulatory risk	-0.27	Yes [p<0.01]	-0.03	Yes [p<0.01]
9	Favouring local firms	0.12	No	0.07	No
8	Regulatory risk	-0.32	Yes [p<0.01]	-0.03	Yes [p<0.01]
8	Favouring local firms	0.07	No	0.07	No
7	Regulatory risk	-0.40	Yes [p<0.01]	-0.08	Yes [p<0.01]
7	Favouring local firms	-0.02	No	0.02	No
6	Regulatory risk	-0.40	Yes [p<0.01]	-0.15	Yes [p<0.01]
6	Favouring local firms	-0.02	No	-0.07	Yes [p<0.05]
5	Regulatory risk	-0.40	Yes [p<0.01]	-0.15	Yes [p<0.01]
5	Favouring local firms	-0.02	No	-0.07	Yes [p<0.05]
4	Regulatory risk	-0.40	Yes [p<0.01]	-0.18	Yes [p<0.01]
4	Favouring local firms	-0.02	No	-0.10	Yes [p<0.05]
3	Regulatory risk	-0.40	Yes [p<0.01]	-0.20	Yes [p<0.01]
3	Favouring local firms	-0.02	No	-0.13	Yes [p<0.05]
2	Regulatory risk	-0.39	Yes [p<0.01]	-0.28	Yes [p<0.01]
2	Favouring local firms	0.00	No	-0.15	Yes [p<0.05]
1	Regulatory risk	-0.33	Yes [p<0.01]	-0.35	Yes [p<0.01]
1	Favouring local firms	0.02	No	-0.20	Yes [p<0.01]

Note: the treatment effect is calculated as the difference in average effort between the control group and the treatment group for any given sample. The figures between brackets are p-values for pairwise comparison between each treatment and the baseline treatment using a Mann–Whitney test.

Source: Oxera.

A4 Solving the game

The experimental analysis set out in our report above is based on a two-player innovation game. In this appendix, we set out and solve this innovation game, finding the Nash equilibrium in the control and two treatments. The game's theoretic solution and the empirical evidence from our experiments are qualitatively similar in terms of the predicted and actual effects of the DMA proposals on the chances of an innovation being rolled out in Europe.

The Nash equilibrium is a solution concept for strategic interactions from game theory, which is commonly used in economics. It is not necessarily how real people will behave in an interaction, hence the value added by experiments. A Nash equilibrium in this interaction is where each player chooses the investment level that is optimal for them, given the investment level chosen by their rival. Another phrase sometimes used to describe this situation is mutual best response. It is a profile of investment choices from which neither player would unilaterally want to deviate.

A4.1 The innovation contest

In this section, we set out the basic model which captures the game played by the control group, and then set out the modifications to that basic model which capture the interaction between the players in the treatment groups. The different behaviours between the control group and the groups playing in the treatment groups give some idea as to the impact of the proposed changes in the DMA.

A4.1.1 Basic setting

Here we set out the model of the control treatment. We then briefly describe the equilibrium concept (Nash equilibrium); set out the expected payoffs that each player in the game can achieve as a function of their own action choices and the action choices of their opponent; use these expected payoffs to describe best response functions; and finally describe the parameters used in the model and the equilibrium found.

The model

There are two players in the innovation game—player 1 represents a global firm and player 2 represents a local firm. Each player chooses an investment effort w_i to innovate and the cost of effort is denoted as $C(w_i)$. We assume a constant marginal cost function: $C(w_i) = \gamma_i w_i$. In this model, player 1 is assumed to have a lower marginal cost of effort compared to player 2, i.e. $\gamma_1 < \gamma_2$.

This model assumes that both players are endowed with W as their R&D investment budget. Both players invest such that $C(w_i) \leq W$. We confine attention to interior solutions where the investment resource constraint does not bind.

Both players are assumed to have a risk neutral utility function simply equal to their profit $U(\pi_i) = \pi_i$, a typical assumption of profit-maximising firms. Each player makes only one choice, their investment in R&D. That investment then determines the probabilities of particular outcomes in the two stages that follow.

Stage 1: Innovation success or failure

Players choose investment effort levels w_i and innovate with probability $i(w_i)$, which is the innovation success function (ISF). The potential outcomes of the investment stage are presented in the table below.

Table A4.1 Possible innovation stage outcomes

	Player 2 innovates (probability $\boldsymbol{i(w_2)}$)	**Player 2 does not innovate** (probability $\boldsymbol{(1-i(w_2))}$)
Player 1 innovates (probability $i(w_1)$)	Scenario 1: both players innovate Prob: $i(w_1)i(w_2)$	Scenario 2: only player 1 innovates Prob: $i(w_1)(1-i(w_2))$
Player 1 does not innovate (probability $(1-i(w_1))$)	Scenario 3: only player 2 innovates Prob: $(1-i(w_1))i(w_2)$	Scenario 4: neither player innovates Prob: $(1-i(w_1))(1-i(w_2))$

Source: Oxera.

Stage 2: Competition

The value firms can extract from the innovation is denoted by V. However, even assuming only one player is successful at innovating, no player will extract the entire value themselves. The winner of the innovation contest extracts only a portion, α of this value, while a portion, $1-\alpha$ leaks out to their rival in the form of external spillovers. The winner of the innovation contest is determined as follows.

- If neither player successfully innovates, there is no new product and no contest – i.e. both players get 0 value, and the value, V, is not generated.
- If only one player innovates, the innovating player automatically wins the contest and receives αV. The non-innovating player is still able to benefit from the positive spillovers and receives $(1-\alpha)V$.
- If both players innovated, they play a Tullock contest based on their R&D effort levels. Player i's probability of winning the Tullock contest is therefore $w_i/(w_i+w_j)$.[80] The winner of the Tullock contest is then the winner of the innovation contest and gets αV, while the loser gets $(1-\alpha)V$.[81]

The potential payoffs based on the scenarios are reflected in the table below.

Table A4.2 Competition payoffs

Scenario	Global player	Local player
1	$\left(\frac{w_1}{w_1+w_2}\right)\alpha V+\left(\frac{w_2}{w_1+w_2}\right)(1-\alpha)V$	$\left(\frac{w_2}{w_1+w_2}\right)\alpha V+\left(\frac{w_1}{w_1+w_2}\right)(1-\alpha)V$
2	αV	$(1-\alpha)V$
3	$(1-\alpha)V$	αV
4	0	0

Source: Oxera.

To calculate the expected payoff for each player it is now only necessary to multiply the payoff from each scenario in Table A4.1 by the probability of that

[80] More generally, in an N player game, player i's probability of winning the Tullock contest is $w_i/\sum_{j=1}^{N}w_j$. This comes from Tullock, G. (1980), 'Efficient rent seeking' in J.M. Buchanan, R.D. Tollison and G. Tullock (eds), pp. 97–112, *Toward a Theory of the Rent-seeking Society*, Texas A&M University Press.
[81] Note that this is the *same* effort that was the input into the innovation success function.

scenario from Table A4.2; and then add any retained R&D investment budget, $W - \gamma_i w_i$.

A4.1.2 Equilibrium concept

The Nash equilibrium is calculated by first deriving the 'best response functions' for each player. Player 1's best response function records the best R&D effort level for player 1 to choose for any given R&D effort choice of player 2. Similarly, player 2's best response function records the best R&D effort level for player 2 to choose for any given R&D effort choice by player 1. 'Best' here means the choice which maximises one's own payoff. The Nash equilibrium is where player 1's choice is their best response to player 2's choice, which is itself player 2's best response to player 1—a situation of 'mutual best response'.

We next write down the expressions for the expected profit of each player, and then derive the best response functions by finding the first and second order conditions for each player to maximise their own profit for any given investment choice of their rival. From here, it is sometimes the case that an algebraic solution can be found, but—based on the functional forms used here—that is not possible. We have therefore used numerical methods to find the effort choices that lead to mutual best response.

A4.1.3 Expected payoff function

Each player's expected payoff is the expected value of winning the competition plus the remaining endowment unused.

This translates to the expected payoff within each scenario (as set out in Table A4.1 above) multiplied by the chance of each scenario occurring (as set out in Table A4.2 above).

The expected payoff for player 1 is

$$E\pi_1(w_1, w_2) = i(w_1)i(w_2)\left[\left(\frac{w_1}{w_1 + w_2}\right)\alpha V + \left(\frac{w_2}{w_1 + w_2}\right)(1-\alpha)V\right] + i(w_1)\big(1 - i(w_2)\big)\alpha V + \big(1 - i(w_1)\big)i(w_2)(1-\alpha)V + W_1 - \gamma_1 w_1$$

Similarly, the expected payoff for player 2 is

$$E\pi_2(w_1, w_2) = i(w_1)i(w_2)\left[\left(\frac{w_2}{w_1 + w_2}\right)\alpha V + \left(\frac{w_1}{w_1 + w_2}\right)(1-\alpha)V\right] + i(w_2)\big(1 - i(w_1)\big)\alpha V + \big(1 - i(w_2)\big)i(w_1)(1-\alpha)V + W_2 - \gamma_2 w_2$$

Where $i(w_i)$ represents the innovation success function, the functional form for which is set out in Box A4.1.

Box A4.1 Innovation

We have adopted the following innovation function which sees diminishing marginal returns to additional innovation effort:

$$i(w_i) = 1 - e^{-\lambda w_i}$$

$$i'(w_i) = \lambda e^{-\lambda w_i}$$

$$i''(w_i) = -\lambda^2 e^{-\lambda w_i}$$

Source: Oxera.

A4.1.4 Players' best response functions

Each player's expected profit is maximised where the first derivative of their expected profit function is equal to zero and the second derivative of their expected profit function is less than zero.[82]

For player 1, this requires

$$\frac{\partial E\pi_1}{\partial w_1} = \frac{i(w_1)i(w_2)w_2(2\alpha-1)V}{(w_1+w_2)^2} + \frac{i'(w_1)i(w_2)w_1(2\alpha-1)V}{w_1+w_2} + i'(w_1)\big(1-i(w_2)\big)\alpha V - \gamma_1 = 0$$

Where $i'(w_i)$ represents the derivative of the ISF with respect to the player's R&D effort.

$$\frac{\partial^2 E\pi_1}{\partial w_1^2} = -\frac{2i(w_1)i(w_2)w_2(2\alpha-1)V}{(w_1+w_2)^3} + \frac{2i'(w_1)i(w_2)w_2(2\alpha-1)V}{(w_1+w_2)^2} + \frac{i''(w_1)i(w_2)w_1(2\alpha-1)V}{w_1+w_2} + i''(w_1)\big(1-i(w_2)\big)\alpha V < 0$$

Where $i''(w_i)$ represents the second derivative of the ISF with respect to the player's R&D effort.

For player 2, the equivalent conditions are:

$$\frac{\partial E\pi_2}{\partial w_2} = \frac{i(w_1)i(w_2)w_1(2\alpha-1)V}{(w_1+w_2)^2} + \frac{i(w_1)i'(w_2)w_2(2\alpha-1)V}{w_1+w_2} + i'(w_2)\big(1-i(w_1)\big)\alpha V - \gamma_2 = 0$$

$$\frac{\partial^2 E\pi_2}{\partial w_2^2} = -\frac{2i(w_1)i(w_2)w_1(2\alpha-1)V}{(w_1+w_2)^3} + \frac{2i'(w_2)i(w_1)w_1(2\alpha-1)V}{(w_1+w_2)^2} + \frac{i''(w_2)i(w_1)w_2(2\alpha-1)V}{w_1+w_2} + i''(w_2)\big(1-i(w_1)\big)\alpha V < 0$$

A4.1.5 Parameters and equilibrium

The table below shows the parameters and the equilibrium effort levels that constitute a Nash equilibrium.

Table A4.3 Parameters and equilibrium effort levels

Parameter	Player 1	Player 2
α	0.9	
V	20	
λ	0.35	0.35
W	10	10
γ_i	1.5	2
Equilibrium effort (w_i^*)	**4.15**	**2.37**

Source: Oxera.

The calibration of these parameters was designed to achieve the following:

- an equilibrium in which the probability of successful innovation for each player was bounded away from extremes; with this parameter configuration,

[82] These are the first and second order conditions referred to above.

the probabilities of successful innovation by the global and local firm respectively are 77% and 56%;

- parameters that would be relatively easy for participants to work with, understand and use;
- monetary parameters that could relatively easily be converted into intuitive units of millions of ECUs; and that could then be converted back to euros for the payments to the participants at an exchange rate of ECU 1m = €1;
- differences between local and global firms large enough to ensure players behaved differently in these two positions.

A4.1.6 Comparative statics

A point of interest is whether the interaction is one of strategic substitutes or strategic complements.[83] In this context:

- a game of strategic substitutes is one where players reduce their own R&D effort in response to an increase in their rival's R&D effort; and
- a game of strategic complements is one where players increase their own R&D effort in response to an increase in their rival's R&D effort.

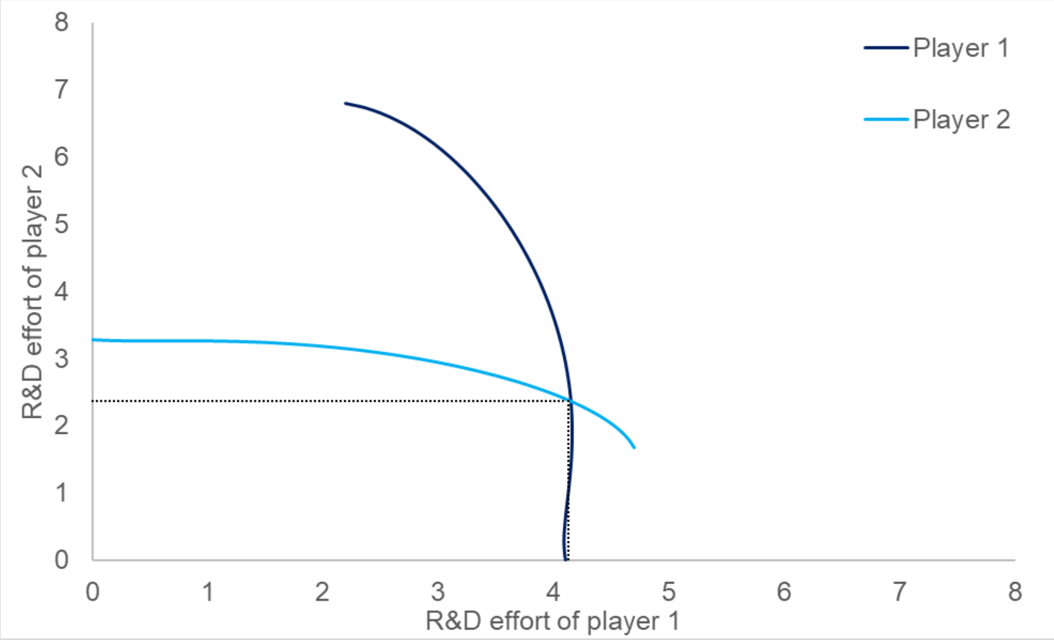
If the game is one of strategic complements, the cross-partial derivative of the expected profit function with respect to both players' R&D effort choice would be positive. Strategic substitutes would be suggested by a negative cross-partial derivative. Analysis of the cross-partial derivative is inconclusive as the answer will depend on the parameters in this game.

$$\frac{\partial^2 \pi_2}{\partial w_1 \partial w_2} = \frac{i(w_1)i(w_2)(w_2 - w_1)(2\alpha - 1)V}{(w_1 + w_2)^3} + \frac{[i'(w_1)i(w_2)w_1 - i(w_1)i'(w_2)w_2](2\alpha - 1)V}{(w_1 + w_2)^2} - \frac{i'(w_1)i'(w_2)[w_1\alpha + w_2(1 - \alpha)]V}{(w_1 + w_2)} \gtrless 0$$

Note that if $w_1 \approx w_2$, then the first two terms of this expression will be approximately zero and the cross-partial derivative would be negative, so we would have a game of strategic substitutes. By inspection of the best response functions, which are shown to be mostly downwards sloping below, we can see that the relevant paradigm is one of strategic substitutes.

[83] Bulow, J., Geanakopolos, J. and Klemperer, P. (1985), 'Multimarket Oligopoly: Strategic Substitutes and Complements', *Journal of Political Economy*, **93**:3, pp. 488–511.

Figure A4.1 Graphing best response functions



Source: Oxera.

A4.2 Treatment 1—regulatory risk

As discussed in our first report, the DMA effectively seeks to make markets more contestable, but this can come at the expense of making innovations less appropriable. In what follows, we recap briefly how we incorporate this risk into our treatment 1 of our model and how this affects the Nash equilibrium outcomes.

A4.2.1 The model

We model the regulatory uncertainty as uncertainty over the proportion of the value of an innovation, V, that the successful innovator will be able to keep and the proportion that will be shared with a rival. Recall that in the control group, this proportion was denoted as α. We suppose that the regulatory intervention takes place with probability p, and that if the regulatory intervention takes place, then an innovator will only be able to keep $\beta < \alpha$ of the value of their innovation (with the remaining $1 - \beta$ going to their rival).

So the expected prize from either being the only innovator or winning the innovation contest can be denoted as follows:

$$E(V_{win}) = (1 - p)\alpha V + p\beta V = \big(\alpha - p(\alpha - \beta)\big)V$$

Similarly, the expected prize from either innovating but losing the Tullock contest, or failing to innovate when one's rival innovates can be denoted as follows:

$$E(V_{lose}) = (1 - p)(1 - \alpha)V + p(1 - \beta)V = \big[1 - \big(\alpha - p(\alpha - \beta)\big)\big]V$$

For simplicity of expression, define $\delta \equiv \alpha - p(\alpha - \beta) < \alpha$ then,

$$E(V_{win}) = \delta V$$

$$E(V_{lose}) = (1 - \delta)V$$

The expected profit and best response functions now take the same form as in the control group, just substituting α for δ.

A4.2.2 Equilibrium and solution

In keeping with good experimental practice, we only change one element of the model between the treatment and the control group, so all of the experimental parameters remain as in Table A4.3 above. The table below records the value of the new parameters, the implications for δ, and the equilibrium outcomes.

Table A4.4 New parameter values and equilibrium—treatment 1

Parameters	Player 1	Player 2
p	0.5	
β	0.7	
δ	0.8	
Equilibrium effort (w_i^*)	**3.62**	**1.10**

Source: Oxera.

A4.2.3 Comparative statics

Note that the equilibrium effort of both the global and the local player has reduced in this treatment. This can be explained through some comparative statics. Since $\delta < \alpha$, Treatment 1 is equivalent to a reduction in α (in the terminology of the control treatment). For both players, the original best response function shifts as a result of a change in the parameter α, such that when α decreases, each player will exert less effort for any given effort level by their rival.

To see this for player 1, express the first order condition that defines their best response function as follows:

$$f(\alpha, w_1) = \frac{i(w_1)i(w_2)w_2(2\alpha - 1)V}{(w_1 + w_2)^2} + \frac{i'(w_1)i(w_2)w_1(2\alpha - 1)V}{w_1 + w_2} + i'(w_1)\big(1 - i(w_2)\big)\alpha V - \gamma_1 = 0$$

Now consider small changes in α and w_1 ($d\alpha$ and dw_1 respectively), such that the overall value of $f(\alpha, w_1)$ remains constant at 0. This implies:

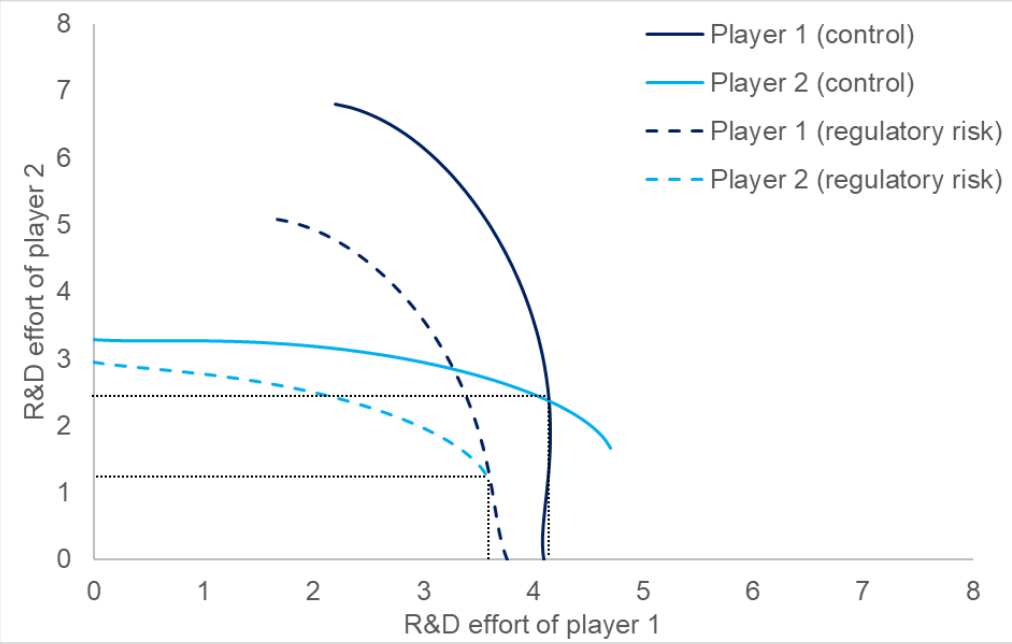
$$\frac{\partial f}{\partial \alpha} d\alpha + \frac{\partial f}{\partial w_1} dw_1 = 0 \Rightarrow \frac{dw_1}{d\alpha} = \frac{\partial f/\partial \alpha}{-\partial f/\partial w_1}$$

Note that $\partial f/\partial w_1$ is simply the second derivative of the objective function, so if we are indeed on the reaction function, it must be the case that $\partial f/\partial w_1 < 0$, which means that $sign\{dw_1/d\alpha\} = sign\{\partial f/\partial \alpha\}$.

$$\frac{\partial f}{\partial \alpha} = \frac{2i(w_1)i(w_2)w_2V}{(w_1 + w_2)^2} + \frac{2i'(w_1)i(w_2)w_1V}{w_1 + w_2} + i'(w_1)\big(1 - i(w_2)\big)V > 0$$

This means players' reaction functions shift inwards as a result of the treatment. This inward shift and the resulting change in equilibrium R&D effort levels is shown below.

Figure A4.2 The impact of treatment 1 on equilibrium R&D effort



Source: Oxera.

A4.3 Treatment 2—favouring the local firm

Our second treatment, as explained in greater detail in the main report, considers the impact of the DMA in terms of the potential restrictions on market entry by large global platforms. Such restrictions would only apply in 'Mountania' and global platforms would remain free to innovate and roll out those innovations in the rest of the world.

A4.3.1 Expected payoff function

The expected payoff functions in this treatment can be divided into two parts. The first part is the same as the expected payoff function in the control treatment, except that the parameter V is replaced by the parameter V_{ROW}. The second part is an augmentation to account for what happens in Mountania. In the equations below, we highlight the second part for clarity, labelling it 'Mountania'.

The expected payoff for player 1 is:

$$E\pi_1(w_1, w_2) = i(w_1)i(w_2)\left[\left(\frac{w_1}{w_1+w_2}\right)\alpha V_{ROW} + \left(\frac{w_2}{w_1+w_2}\right)(1-\alpha)V_{ROW}\right] + i(w_1)\big(1-i(w_2)\big)\alpha V_{ROW} + \big(1-i(w_1)\big)i(w_2)(1-\alpha)V_{ROW} + W_1 - \gamma_1 w_1 \underbrace{+i(w_2)(1-\alpha)V_M}_{\text{Mountania}}$$

The expected payoff for player 2 is:

$$E\pi_2(w_1, w_2) = i(w_1)i(w_2)\left[\left(\frac{w_2}{w_1+w_2}\right)\alpha V_{ROW} + \left(\frac{w_1}{w_1+w_2}\right)(1-\alpha)V_{ROW}\right] + i(w_2)\big(1-i(w_1)\big)\alpha V_{ROW} + \big(1-i(w_2)\big)i(w_1)(1-\alpha)V_{ROW} + W_2 - \gamma_2 w_2 \underbrace{+i(w_2)\alpha V_M}_{\text{Mountania}}$$

A4.3.2 Best response functions

The best response function of player 1 is very similar to that in the control group since the local rival's innovation success is beyond player 1's control.

$$\frac{\partial \pi_1}{\partial w_1} = \frac{i(w_1)i(w_2)w_2(2\alpha-1)V_{ROW}}{(w_1+w_2)^2} + \frac{i'(w_1)i(w_2)w_1(2\alpha-1)V_{ROW}}{w_1+w_2} + i'(w_1)\big(1-i(w_2)\big)\alpha V_{ROW} - \gamma_1 = 0$$

Note that this has the same form as the best response function of player 1 in the control group version of the game. So the second order conditions will too, and will be as above in section A4.1, except with V_{ROW} substituting for V.

$$\frac{\partial^2 E\pi_1}{\partial w_1^2} = -\frac{2i(w_1)i(w_2)w_2(2\alpha-1)V_{ROW}}{(w_1+w_2)^3} + \frac{2i'(w_1)i(w_2)w_2(2\alpha-1)V_{ROW}}{(w_1+w_2)^2} + \frac{i''(w_1)i(w_2)w_1(2\alpha-1)V_{ROW}}{w_1+w_2} + i''(w_1)\big(1-i(w_2)\big)\alpha V_{ROW} < 0$$

Since innovation rollout in Mountania is within the control of player 2, there are more substantial changes to their best response function.

$$\frac{\partial \pi_2}{\partial w_2} = \frac{i(w_1)i(w_2)w_1(2\alpha-1)V_{ROW}}{(w_1+w_2)^2} + \frac{i(w_1)i'(w_2)w_2(2\alpha-1)V_{ROW}}{w_1+w_2} + i'(w_2)\big(1-i(w_1)\big)\alpha V_{ROW} - \gamma_2 \underbrace{+ i'(w_2)\alpha V_M}_{\text{Mountania}} = 0$$

The second order condition for player 2 under treatment 2 is therefore:

$$\frac{\partial^2 E\pi_2}{\partial w_2^2} = -\frac{2i(w_1)i(w_2)w_1(2\alpha-1)V_{ROW}}{(w_1+w_2)^3} + \frac{2i(w_1)i'(w_2)w_1(2\alpha-1)V_{ROW}}{(w_1+w_2)^2} + \frac{i(w_1)i''(w_2)w_2(2\alpha-1)V_{ROW}}{w_1+w_2} + i''(w_2)\big(1-i(w_1)\big)\alpha V_{ROW} \underbrace{+ i''(w_2)\alpha V_M}_{\text{Mountania}} < 0$$

A4.3.3 Equilibrium and solution

In keeping with good experimental practice, we only change one element of the model between the treatment and the control group, so all of the experimental parameters remain as in Table A4.3above. The table below records the value of the new parameters V_M and V_{ROW}

Table A4.5 Parameter values and equilibrium—treatment 2

Parameter	Player 1	Player 2
V_{ROW}	15	
V_M	5	
$V = V_{ROW} + V_M$	20	
Equilibrium (w_i^*)	**2.92**	**3.07**

Source: Oxera.

Note that player 1's R&D effort has decreased while player 2's R&D effort has increased. Player 1's R&D effort decreases because there is effectively, for player 1, a reduction in the prize from successful innovation because they will not be able to roll out their innovation in one particular region. Player 2 sees no such reduction in the potential prize they could win from successful innovation, but there is a reduction in the size of the prize for which they are *competing* and an additional prize for which they no longer need to compete. So whether Player 2's best response function shifts in or out is ambiguous.

Although, in this example, the policy succeeds in prompting more R&D effort from the local firm, that comes at a cost. The probability of innovation being successfully rolled out in Europe falls as a result of the treatment. This is because the only way for innovation to roll out in Europe under the treatment is for player 2 to successfully innovate. In the control treatment, innovation would be rolled out in Europe if either the global firm or the local firm (or both) successfully innovated.

A4.3.4 Comparative statics

To understand why player 2 increases their R&D effort while player 1 reduces theirs, consider the first order conditions that determine the reaction functions. First recall that the only difference between the best response function for player 1 in treatment 2 compared to the control group is that V is replaced by V_{ROW} in the treatment. Since $V_{ROW} < V$, this means that the incentive to invest in R&D effort has strictly reduced. This corresponds to an inwards shift in the best response function for player 1 so that they choose lower levels of R&D effort for every level of R&D effort chosen by player 2.

Now consider the changes to the best response function for player 2. This can be given a marginal benefit of effort equal to marginal cost of effort interpretation. When expressed like this, the reaction function for the game played by the control group can be written as:

$$MB_{Control} = \frac{i(w_1)i(w_2)w_1(2\alpha - 1)V}{(w_1 + w_2)^2} + \frac{i(w_1)i'(w_2)w_2(2\alpha - 1)V}{w_1 + w_2} + i'(w_2)\big(1 - i(w_1)\big)\alpha V = \gamma_2$$

The reaction function for the game played by players in treatment 2 can be written as:

$$MB_{T2} = \frac{i(w_1)i(w_2)w_1(2\alpha - 1)V_{ROW}}{(w_1 + w_2)^2} + \frac{i(w_1)i'(w_2)w_2(2\alpha - 1)V_{ROW}}{w_1 + w_2} + i'(w_2)\big(1 - i(w_1)\big)\alpha V_{ROW} + i'(w_2)\alpha V_M = \gamma_2$$

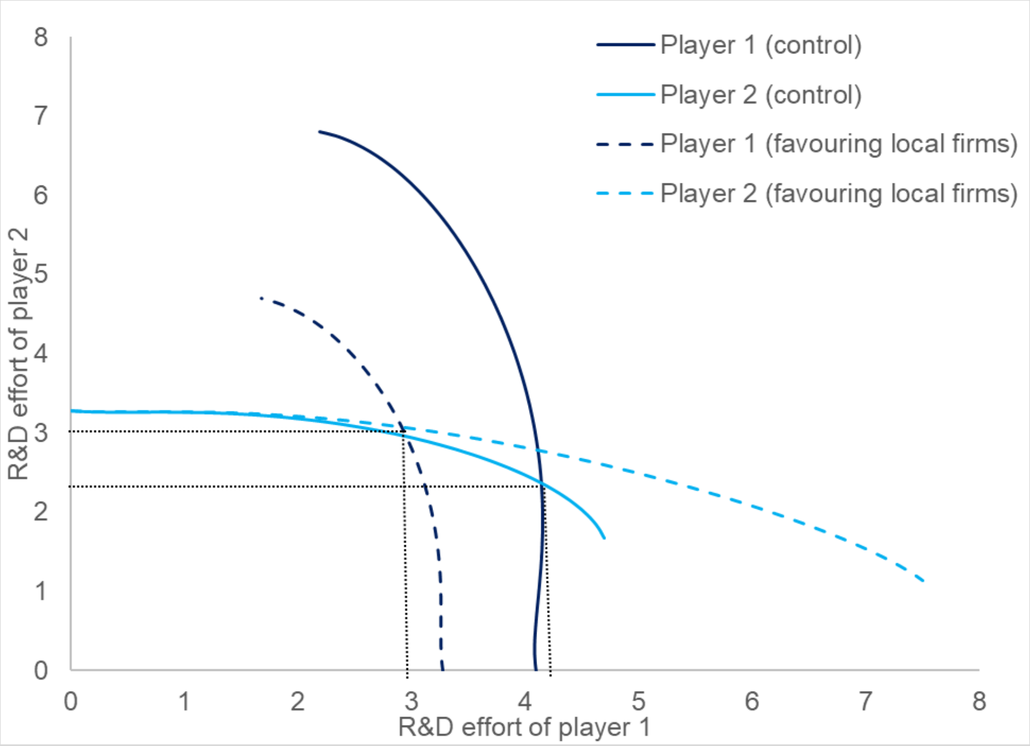
In each case, the left-hand side is the marginal benefit of effort while the right-hand side is the marginal cost of effort. Comparing the marginal benefit of effort between the control and treatment groups and using the fact that $V = V_{ROW} + V_{EU}$, we can show that

$$MB_{T2} - MB_{Control} = \frac{i'(w_2)i(w_1)\big(w_1\alpha + w_2(1 - \alpha)\big)V_M}{w_1 + w_2} - \frac{i(w_1)i(w_2)w_1(2\alpha - 1)V_M}{(w_1 + w_2)^2}$$

The first term in this expression represents the increase in the marginal benefit of R&D effort for player 2 given that the expected value of a successful innovation has increased, given that innovation is now sufficient for winning the EU market. The second term represents a reduction in the marginal benefit of R&D effort given that the effort no longer increases the probability of winning a contest with a rival that has also innovated. So the overall effect is ambiguous and depends on the parameterisation of the game.

For the parameters we have chosen, the overall effect is to increase the effort choice of player 2. This can be seen from the way in which the best response function for player 2 shifts outwards as a result of the treatment.

Figure A4.3 The impact of treatment 2 on equilibrium R&D effort



Source: Oxera.

Note that in addition to the shifting of the best response functions, there is another effect at work, called the strategic effect. The strategic effect is best illustrated by thinking about the local player’s change in R&D effort between the control and treatment 2 scenarios. As well as the outward shift of their best response function, player 2’s choice is also influenced by the reduction in R&D effort from player 1. Because this is a game of strategic substitutes, this has a further impact, leading player 2 to increase their R&D effort.

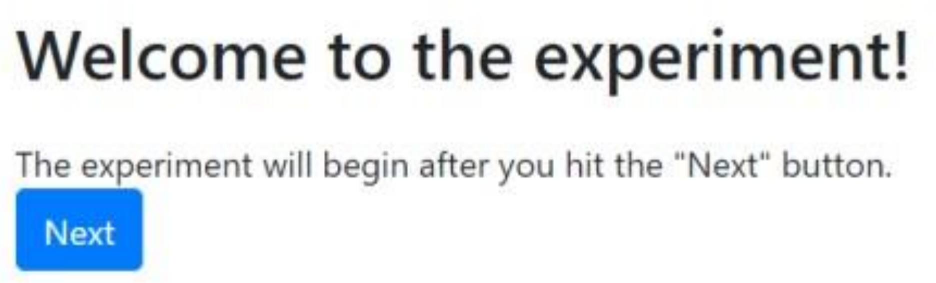
A5 Experiment screenshots

In this appendix we show the screens of the participants in the experiment.

A5.1 Control group

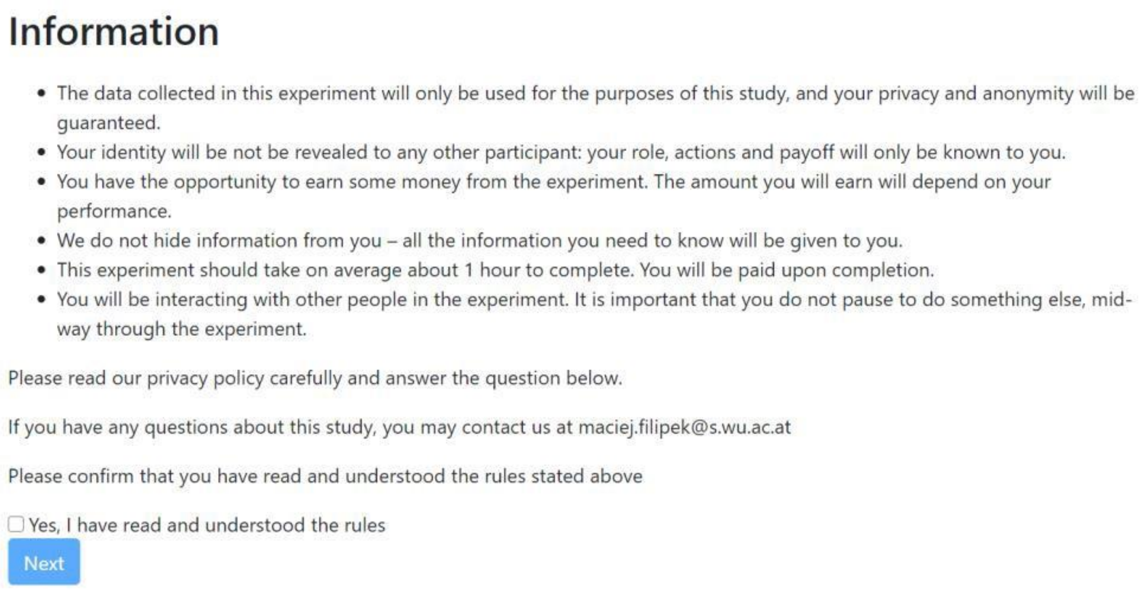
We show below the screens faced by the participants in the control group.

Figure A5.1 Welcome screen of the experiment



Source: Oxera.

Figure A5.2 Information screen



Source: Oxera.

Figure A5.3 Experiment instructions screen 1 of 5

Instructions (1/5): Your earnings

- The money you earn in this experiment will be composed of two parts:
  - A completion award for finishing the experiment. This is worth €7.00
  - A performance award related to the success of your company in the tasks, which we will refer to as 'payoff'. This is worth on average €10.00 on top of the completion award.
- The 'in game' currency is Experimental Currency Units (ECU). Your aim is to earn as much ECU as possible. The conversion rate is ECU 1m to €1.00.
- You cannot earn a negative total payoff (you will never owe the experimenter any money).
- Your payoff will be transferred to you at the end of the experiment via PayPal. Your payoff is anonymous – it will not be revealed to any other participant.

Next

Source: Oxera.

Figure A5.4 Experiment instructions screen 2 of 5

Instructions (2/5): Overview

- In this experiment you are the CEO of a firm. You will have the opportunity to invest in Research & Development (R&D) to secure an innovation and gain an edge over your competitors.
- Innovation is a two stage process:
  1. **Investment stage:** You invest in R&D which may allow you to discover an innovation. If both you and your competitor discover this innovation then you enter the next stage...
  2. **Competition stage:** You and your competitor launch your innovations and compete to become market leader (and therefore earn more profits).

There will be one practice round followed by 12 real rounds which will have an impact on your real-world payoff.

One of the real rounds will be randomly chosen at the end of your experiment to determine your payoff.

Next

Source: Oxera.

Figure A5.5 Experiment instructions screen 3 of 5

Instructions (3/5): Roles

- At the start of the experiment you will be assigned a role. Your role will be either the CEO of a global firm or the CEO of a local firm.
- Your role will remain the same throughout all rounds.
- The difference between the local firm and the global firm is that the global firm is more efficient at R&D.
  - Each unit of research effort costs the global firm ECU 1.50m.
  - Each unit of research effort costs the local firm ECU 2.00m.
  - You will be asked to choose your expenditure on research effort.

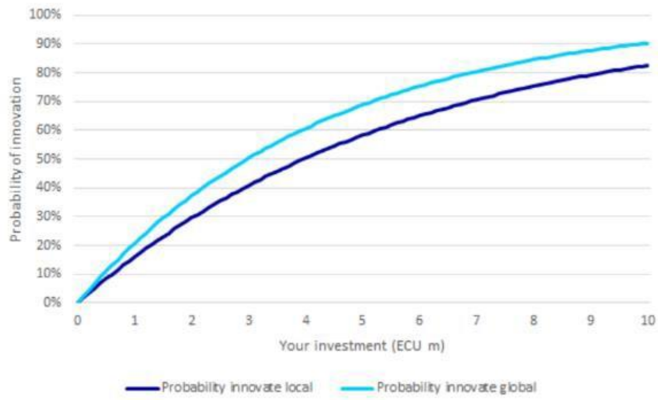
Next

Source: Oxera.

Figure A5.6 Experiment instructions screen 4 of 5

Instructions (4/5): Innovation Stage

- At the start of each round you will always have a budget of ECU 10m to invest in innovation (this does not depend on your past performance).
- What you don't invest, you keep as part of your performance payoff. However the more resources you invest in the innovation stage, the more likely you are to discover an innovation
- The probability of successfully innovating is determined as follows:



Next

Source: Oxera.

Figure A5.7 Experiment instructions screen 5 of 5

Instructions (5/5): Competition Stage

- If both you and your competitor successfully discover an innovation then we enter the competition stage.
- Your probability of winning the competition stage and becoming market leader is determined by both your own R&D effort and your competitor's R&D effort:

$$\text{Your probability of winning} = \frac{\text{Your R\&D effort}}{\text{Competitor's R\&D effort} + \text{Your R\&D effort}}$$

- The more you invest, the more likely you are to win the competition stage. The more your competitor invests, the less likely you are to win the competition stage.
- You will have a calculator to show your chances of winning the competition stage.

The overall payoff for each round

- The figure below summarises how the payoff of each round is determined:

Payoff = Revenue Stream + R&D budget − Cost of spending on R&D

- The revenue streams that your firm earns depends on whether you innovated and whether you won the competition stage:

The Scenario	The Revenue Streams
If **you fail to innovate**, and your competitor also fails	No new product market is discovered. You generate no revenue streams in this scenario.
If **you fail to innovate**, but your competitor succeeds	You buy a patent from your competitor and capture a small part of the market. You earn **ECU 2.0m** in this market.
If **you succeed in innovating**, but lose the competition stage	
If **you succeed in innovating**, but your competitor fails	You become market leader and earn **ECU 18.0m**.
If **you succeed in innovating**, and you win the competition stage	

- At the end of the experiment, one of the rounds will be randomly selected and your payment will be based on your performance in that round.

Next

Source: Oxera.

Figure A5.8 Experiment waiting room screen

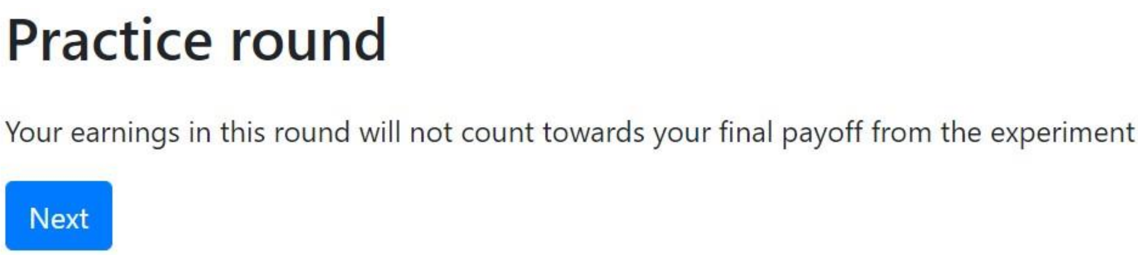
Waiting Room

You are about to enter the waiting room of the experiment. When all participants are ready, the next round will begin. Press "Next" when you have read this page.

Next

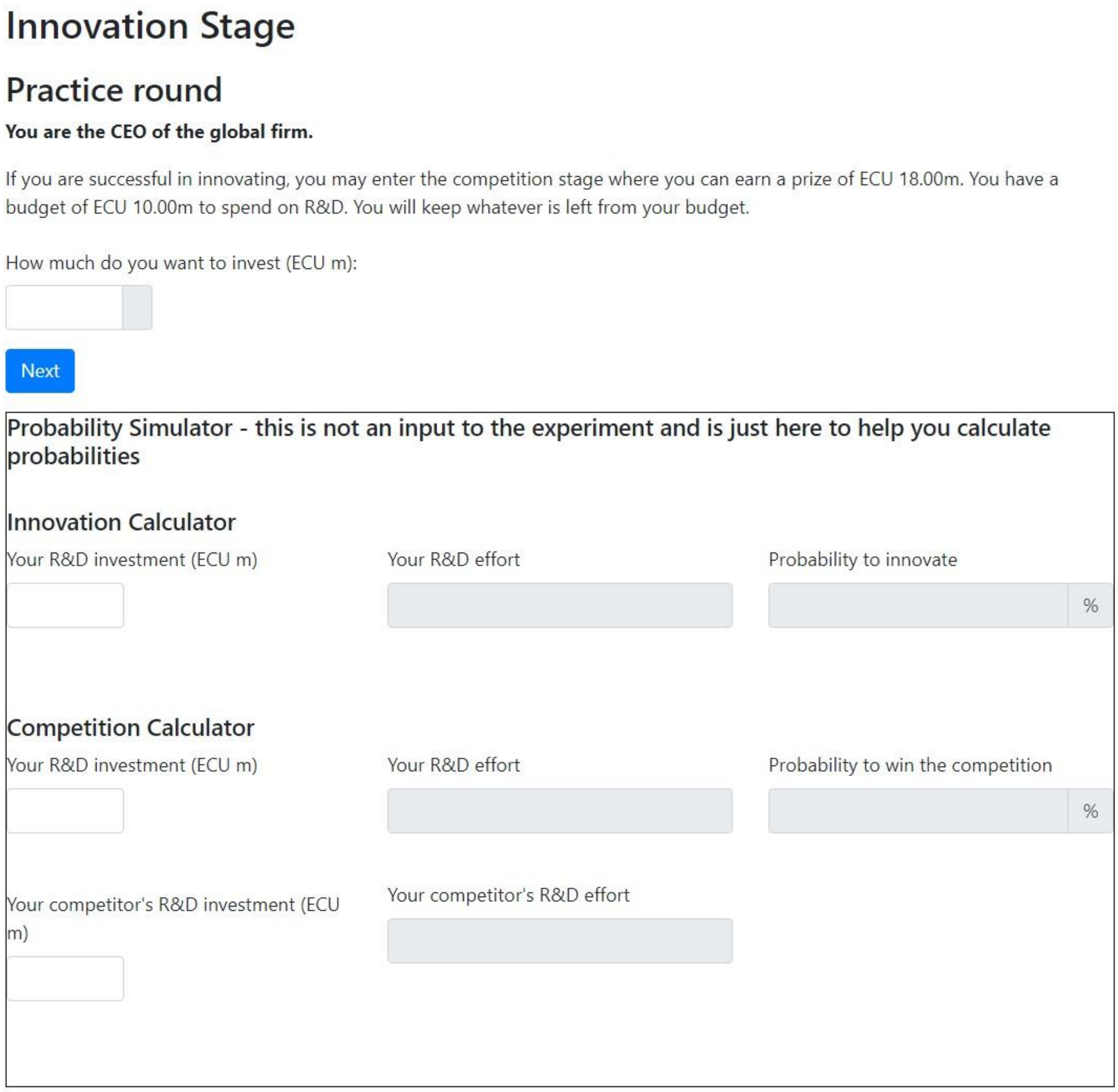
Source: Oxera.

Figure A5.9 Experiment practice round screen



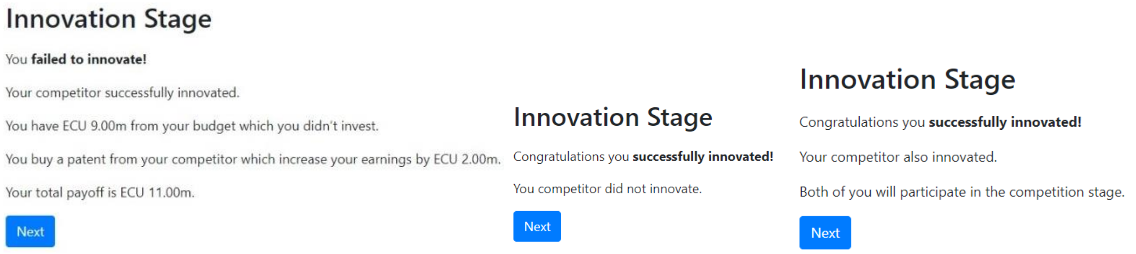
Source: Oxera.

Figure A5.10 Experiment practice round—innovation stage screen



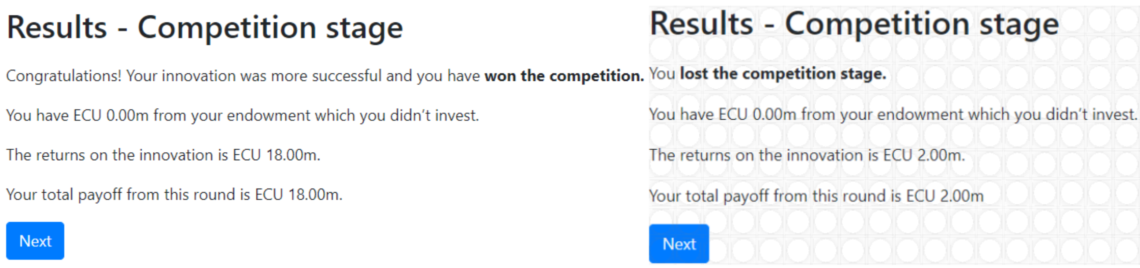
Source: Oxera.

Figure A5.11 Experiment innovation stage results screens, for all possible scenarios



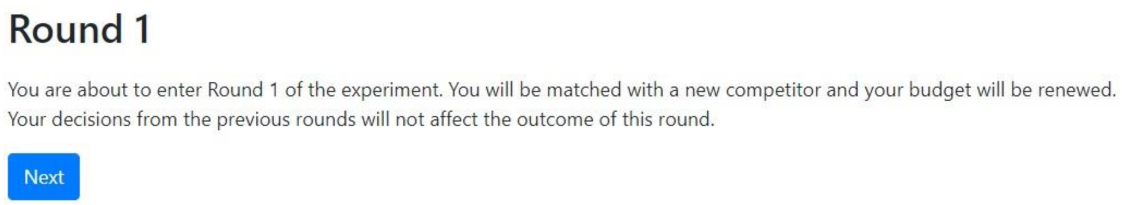
Source: Oxera.

Figure A5.12 Experiment competition stage results screen



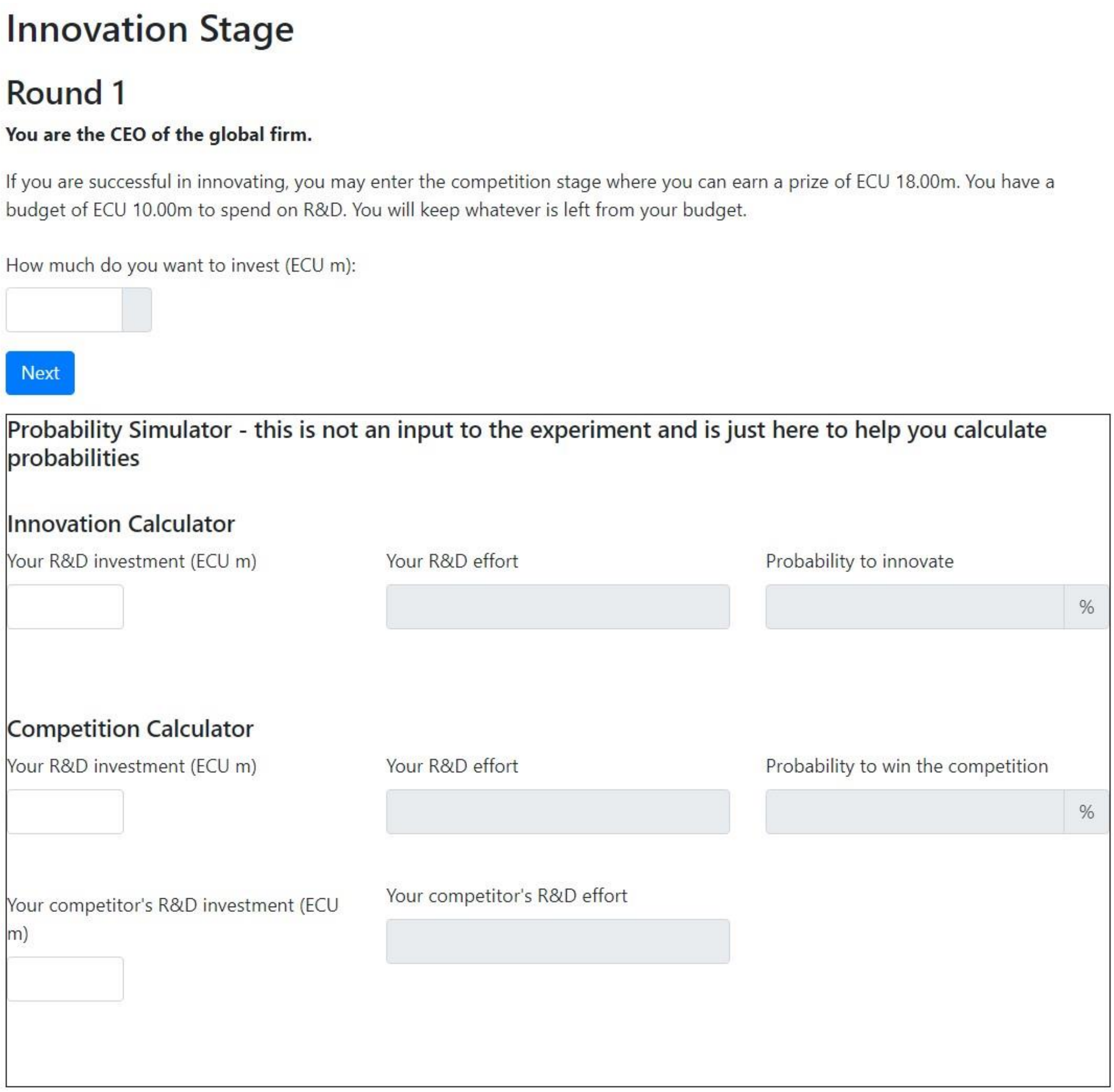
Source: Oxera.

Figure A5.13 Introduction to round 1 screen



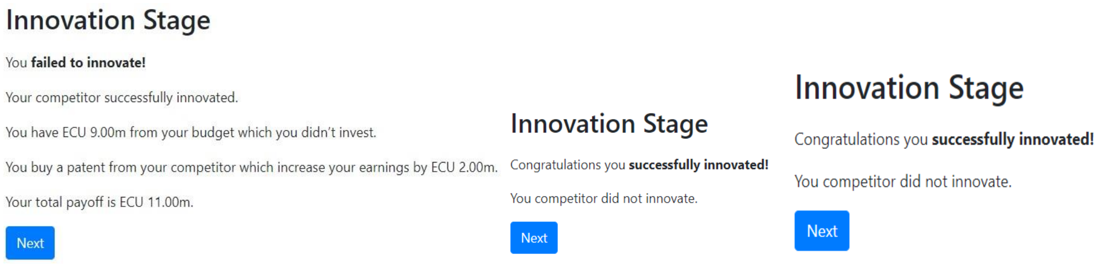
Source: Oxera.

Figure A5.14 Round 1 innovation stage screen



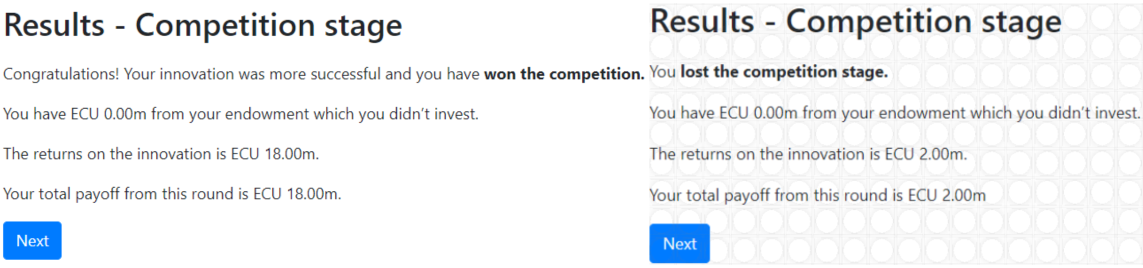
Source: Oxera.

Figure A5.15 Innovation stage results screen, for all potential scenarios



Source: Oxera.

Figure A5.16 Competition stage results screen



Source: Oxera.

A5.2 Regulatory risk treatment

We show below the screens in the regulatory risk treatment that differ relative to the control group.

Figure A5.17 Experiment instructions (5 of 5) competition stage screen

Instructions (5/5): Competition Stage

- If both you and your competitor successfully discover an innovation then we enter the competition stage.
- Your probability of winning the competition stage and becoming market leader is determined by both your own R&D effort and your competitor's R&D effort:

$$\text{Your probability of winning} = \frac{\text{Your R\&D effort}}{\text{Competitor's R\&D effort} + \text{Your R\&D effort}}$$

- The more you invest, the more likely you are to win the competition stage. The more your competitor invests, the less likely you are to win the competition stage.
- You will have a calculator to show your chances of winning the competition stage.

The overall payoff for each round

- The figure below summarises how the payoff of each round is determined:

Payoff = Revenue Stream + R&D budget − Cost of spending on R&D

- The revenue streams that your firm earns depends on whether you innovated and whether you won the competition stage. It also depends on whether there is a regulation imposed:

<table>
<tr><th>The Scenario</th><th>The Revenue Streams</th></tr>
<tr><td>If you fail to innovate, and your competitor also fails</td><td>No new product market is discovered. You generate no revenue streams in this scenario.</td></tr>
<tr><td>If you fail to innovate, but your competitor succeeds</td><td rowspan="2">You buy a patent from your competitor and capture a small part of the market.
There is some uncertainty over your revenues due to the regulation.

There is a 50% chance that you generate revenue streams of ECU 2m.
However, there is a 50% chance that the regulation will be imposed.
This regulation will be favourable to you and you will generate revenue streams of ECU 6m.</td></tr>
<tr><td>If you succeed in innovating, but lose the competition stage</td></tr>
<tr><td>If you succeed in innovating, but your competitor fails</td><td rowspan="2">You become market leader, however there is some uncertainty over your revenues due to the regulation.

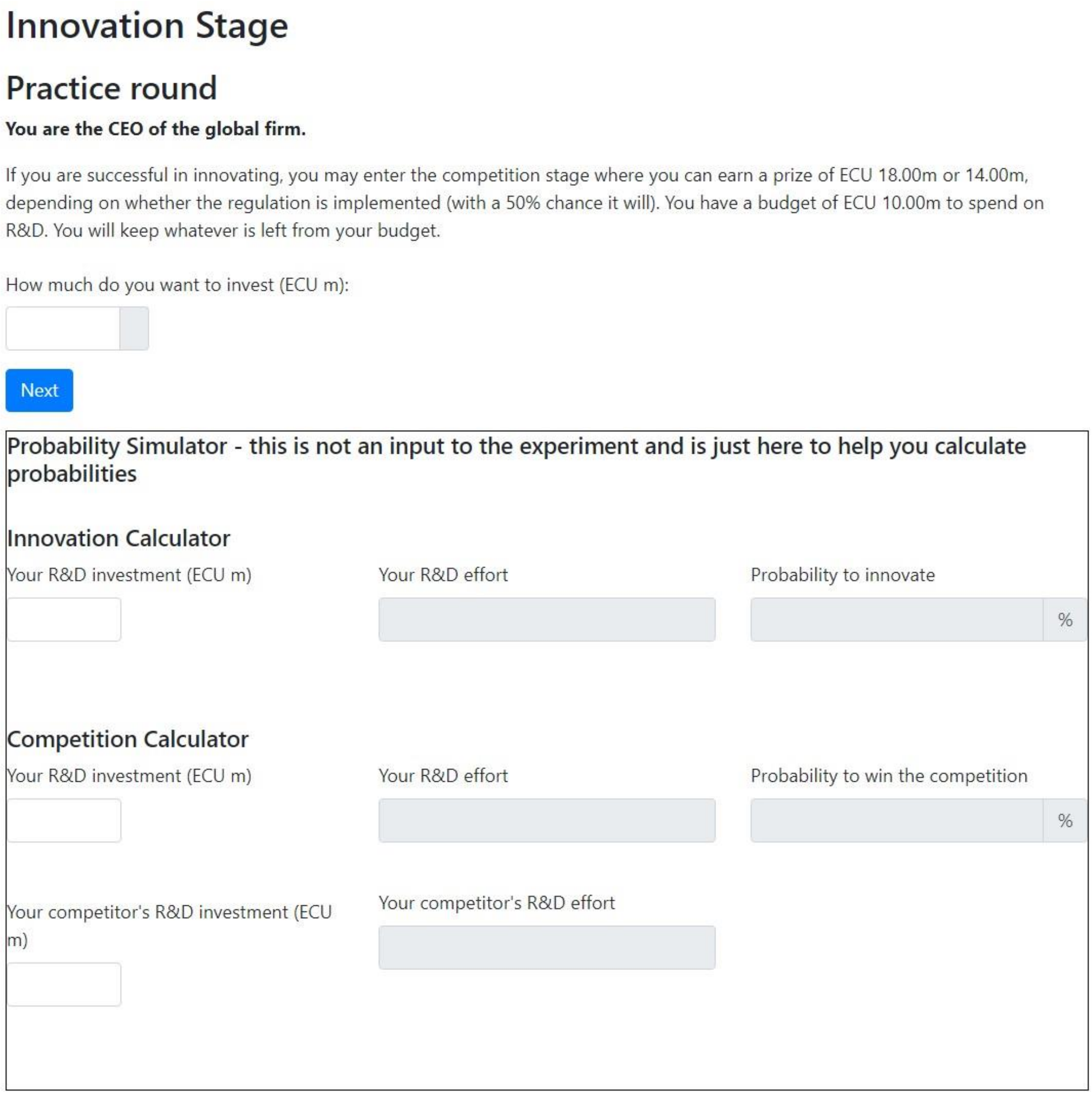
There is a 50% chance that you generate revenue streams of ECU 18m.
However there is a 50% chance that the regulation will be imposed.
This regulation will be unfavourable for you and you will generate revenue streams of ECU 14m.</td></tr>
<tr><td>If you succeed in innovating, and you win the competition stage</td></tr>
</table>

- At the end of the experiment, one of the rounds will be randomly selected and your payment will be based on your performance in that round.

Next

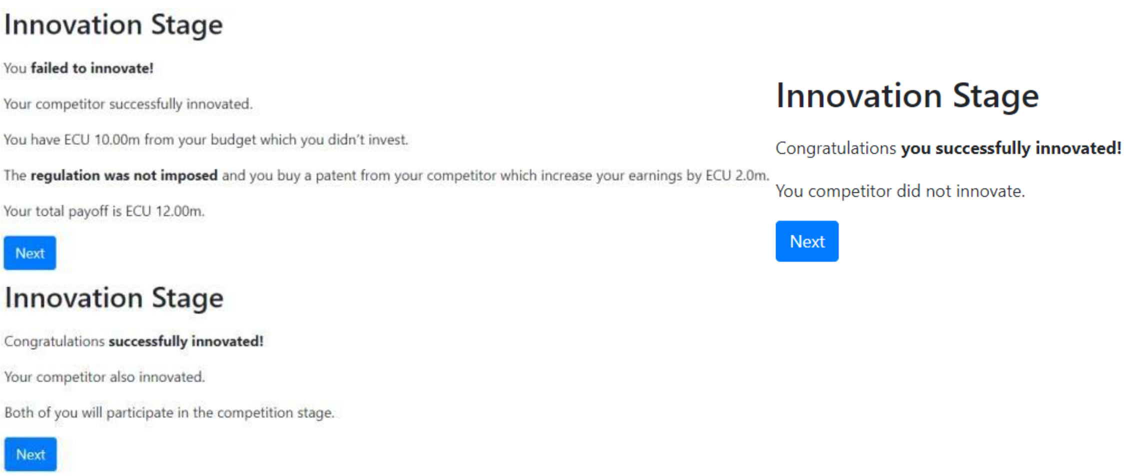
Source: Oxera.

Figure A5.18 Innovation stage practice round screen



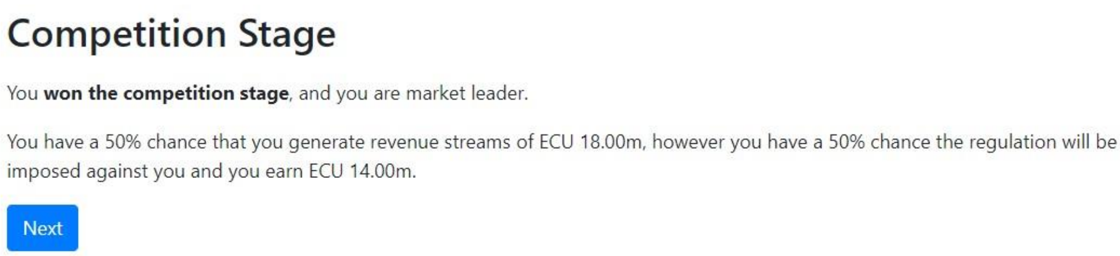
Source: Oxera.

Figure A5.19 Innovation stage results screen, for all possible scenarios



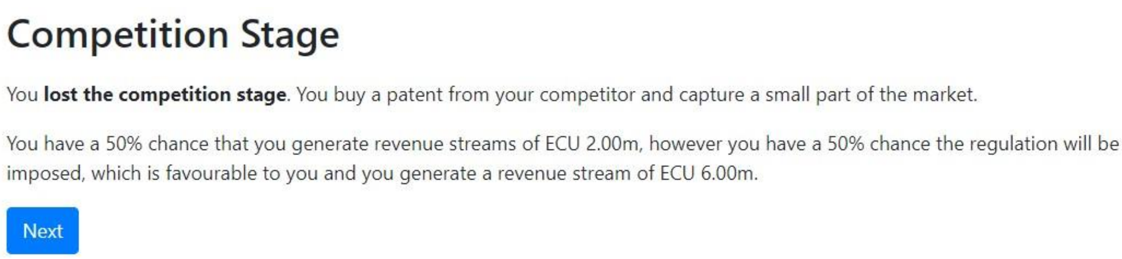
Source: Oxera.

Figure A5.20 Competition stage results screen—won



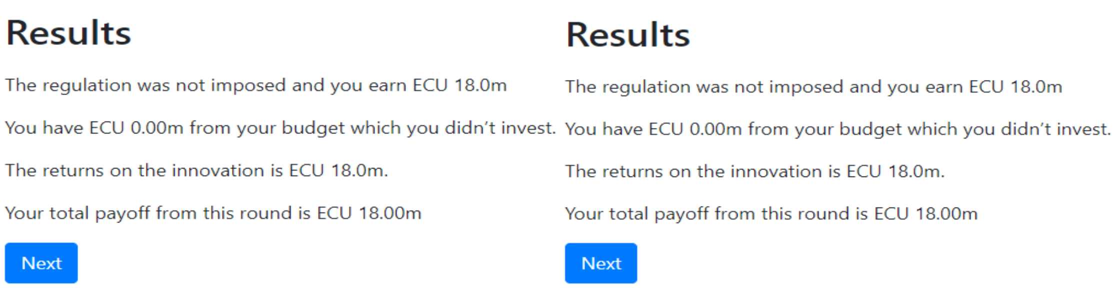
Source: Oxera.

Figure A5.21 Competition stage results screen—lost



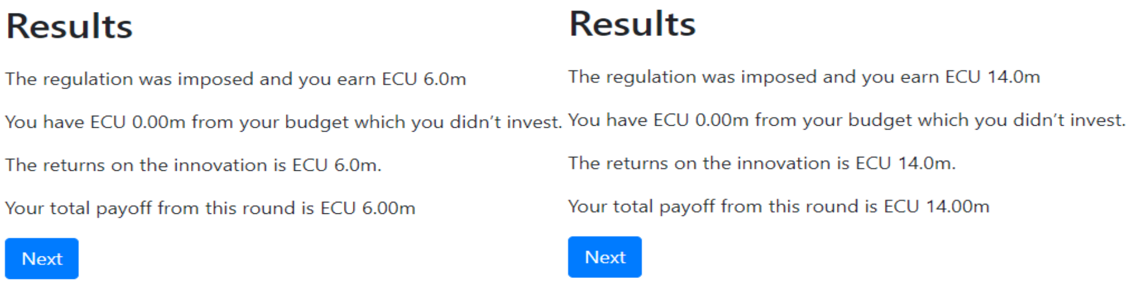
Source: Oxera.

Figure A5.22 Results screen, for all possible scenarios



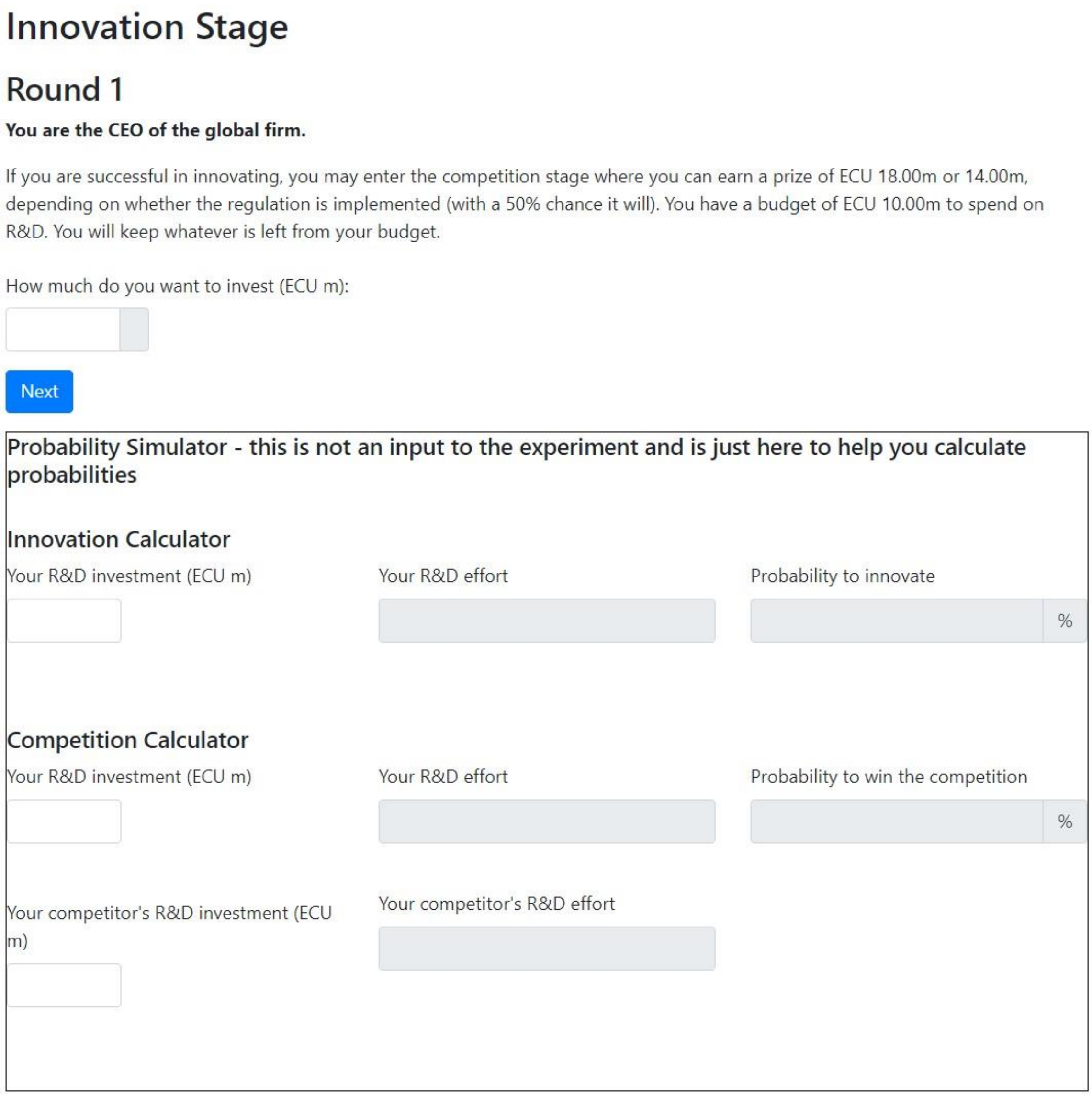
Source: Oxera.

Figure A5.23 Results screen



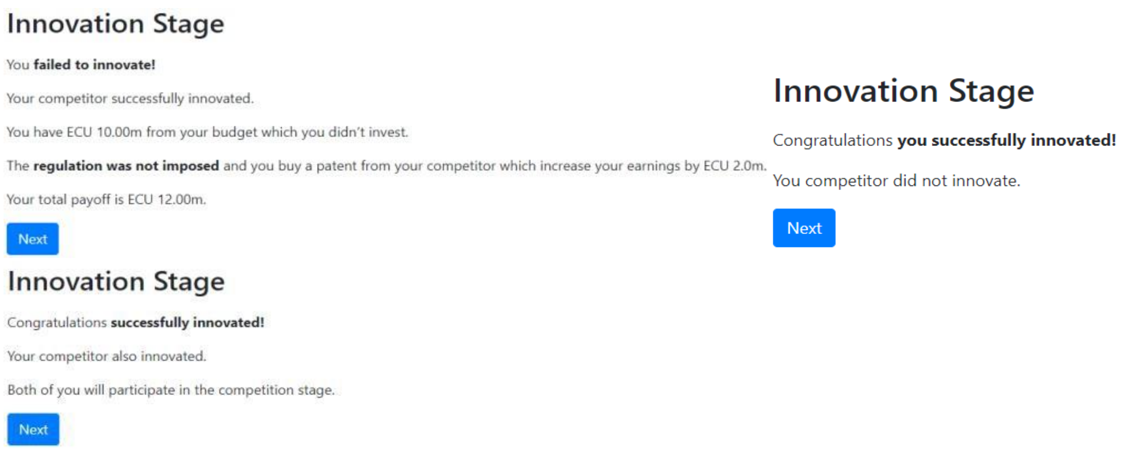
Source: Oxera.

Figure A5.24 Experiment round 1 innovation stage screen



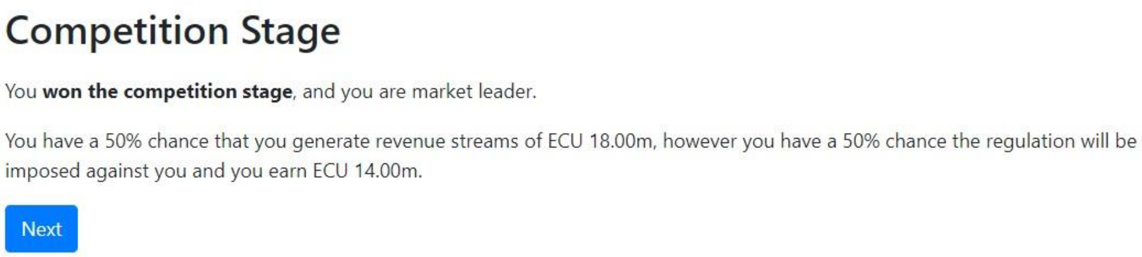
Source: Oxera.

Figure A5.25 Innovation stage results screen, for all possible scenarios



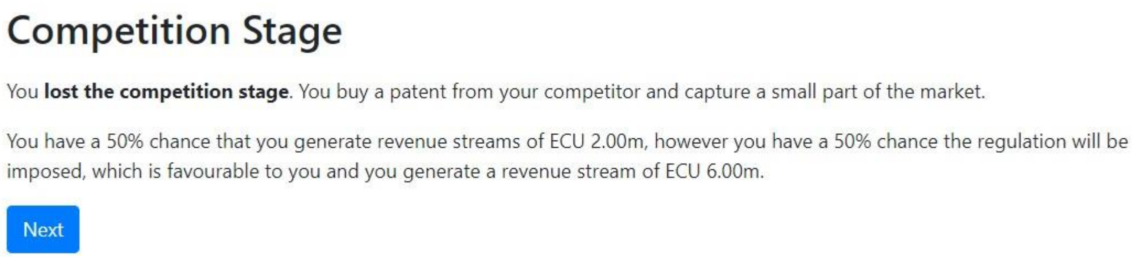
Source: Oxera.

Figure A5.26 Competition stage results screen—won



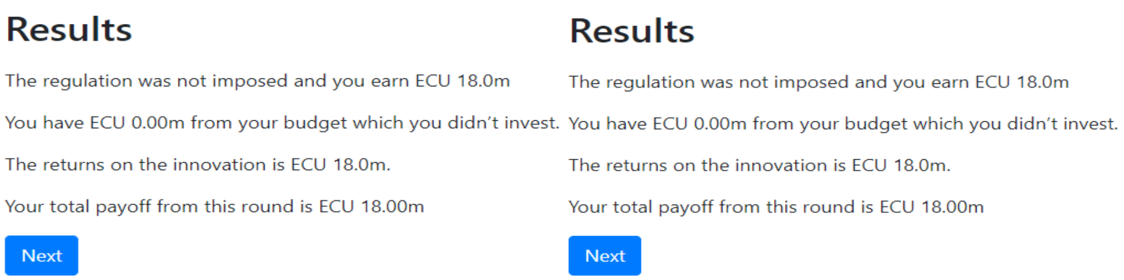
Source: Oxera.

Figure A5.27 Competition stage results screen—lost



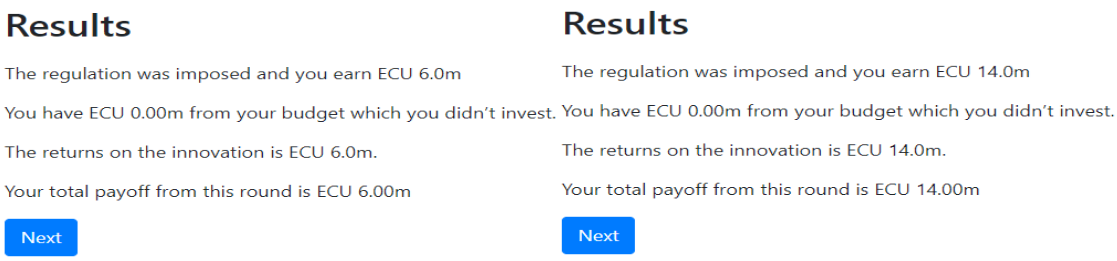
Source: Oxera.

Figure A5.28 Results screen, for all possible scenarios



Source: Oxera.

Figure A5.29 Results screen



Source: Oxera.

A5.3 Favouring the local firm

We show below the screens in the favouring the local firm treatment that differ relative to the control group.

Figure A5.30 Experiment instructions (5 of 5) competition stage

Instructions (5/5): Competition Stage

- If both you and your competitor successfully discover an innovation then you enter the competition stage.
- There are two regions: Mountania and the rest of world.
- Mountania is the region where the local firm is from.
- You will make one investment decision which will impact your revenues in both regions.
- If the local firm innovates, the local firm will always be market leader in Mountania.
- The global firm will never be market leader in Mountania.
- If both firms innovate then the market leader of the rest of world is determined by both your own R&D effort and your competitor's R&D effort:

$$\text{Your probability of winning rest of world} = \frac{\text{Your R\&D effort}}{\text{Competitor's R\&D effort} + \text{Your R\&D effort}}$$

- The more you invest, the more likely you are to win the competition for the rest of world. The more your competitor invests, the less likely you are to win the competition for the rest of world.
- You will have a calculator to show your chances of winning the competition stage.

The overall payoff for each round

- The figure below summarises how the payoff of each round is determined:

$$\text{Payoff} = \text{Revenue stream in Mountania} + \text{Revenue stream Rest of world} + \text{R\&D budget} - \text{Cost of spending on R\&D}$$

- The revenue streams that your firm earns in Mountania depends on your role and whether you successfully innovated.
- The revenue streams that your firm earns in the rest of world does not depend on your role. It only depends on whether you successfully innovated and whether you won the competition.

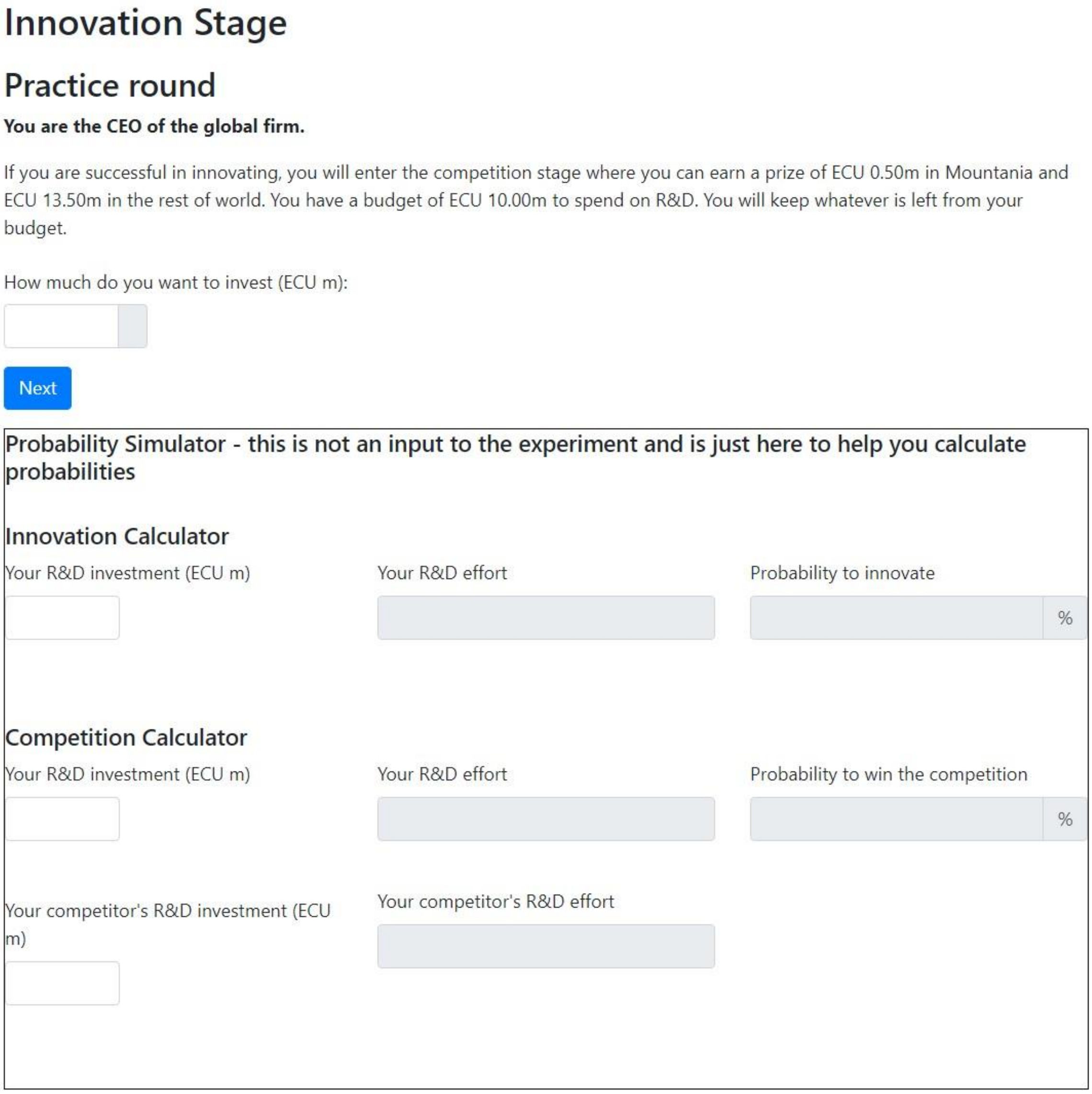
<table>
<tr><th>The Scenario</th><th>The Revenue Streams in <u>Mountania</u></th></tr>
<tr><td>If both firms fail to innovate</td><td>No new product market is discovered. You generate no revenue streams in this scenario.</td></tr>
<tr><td>If the local Mountania firm fails to innovate, but the global firm successfully innovates</td><td>Mountania does not grant regulatory approval to the innovation.
Both firms generate no revenue streams in this market.</td></tr>
<tr><td>If the local Mountania successfully innovates, but the global firm does not innovate</td><td rowspan="2">The local Mountania firm becomes leader in this market and earns revenue streams of ECU 4.5m.
The global firm captures a small part of the market earns revenue streams of ECU 0.5m.</td></tr>
<tr><td>If both firms successfully innovate</td></tr>
<tr><th>The Scenario</th><th>The Revenue Streams in <u>Rest of world</u></th></tr>
<tr><td>If you fail to innovate, and your competitor also fails</td><td>No new product market is discovered. You generate no revenue streams in this scenario.</td></tr>
<tr><td>If you fail to innovate, but your competitor succeeds</td><td rowspan="2">You buy a patent from your competitor and capture a small part of the market. You earn ECU 1.5m in this market.</td></tr>
<tr><td>If you succeed in innovating, but lose the competition stage</td></tr>
<tr><td>If you succeed in innovating, but your competitor fails</td><td rowspan="2">You become market leader and earn ECU 13.5m.</td></tr>
<tr><td>If you succeed in innovating, and you win the competition stage</td></tr>
</table>

- At the end of the experiment, one of the rounds will be randomly selected and your payment will be based on your performance in that round.

Next

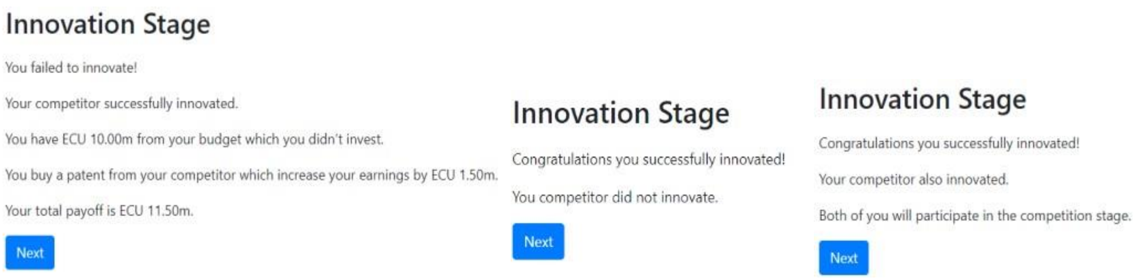
Source: Oxera.

Figure A5.31 Experiment practice round innovation stage



Source: Oxera.

Figure A5.32 Innovation stage results screen, for all possible scenarios



Source: Oxera.

Figure A5.33 Competition stage results screen for the different scenarios

Results - Competition stage

You are the global firm, so you will never be market leader in Mountania. You earn revenues of ECU 0.0m in Mountania

You **won the competition stage**, and you are market leader in the rest of the world. You earn revenues of ECU 13.50m in the rest of the world.

You have ECU 0.00m from your budget which you didn't invest.

Your total payoff from this round is ECU 13.50m.

Next

Results - Competition stage

You are the local firm, so you will always be market leader in Mountania. You earn revenues of ECU 4.5m in Mountania

You **won the competition stage**, and you are market leader in the rest of the world. You earn revenues of ECU 13.50m in the rest of the world.

You have ECU 0.00m from your budget which you didn't invest.

Your total payoff from this round is ECU 18.00m.

Next

Results - Competition stage

You are the local firm, so you will always be market leader in Mountania. You earn revenues of ECU 4.5m in Mountania

You **lost the competition stage**, so you have a small market share in the rest of the world. You earn revenues of 1.50m in the rest of the world.

You have ECU 0.00m from your budget which you didn't invest.

Your total payoff from this round is ECU 6.00

Next

Results - Competition stage

You are the global firm, so you will never be market leader in Mountania. You earn revenues of ECU 0.5m in Mountania

You **won the competition stage**, and you are market leader in the rest of the world. You earn revenues of ECU 13.50m in the rest of the world.

You have ECU 0.00m from your budget which you didn't invest.

Your total payoff from this round is ECU 14.00m.

Next

Figure A5.34 Innovation stage round 1 screen

Innovation Stage

Round 1

You are the CEO of the global firm.

If you are successful in innovating, you will enter the competition stage where you can earn a prize of ECU 0.50m in Mountania and ECU 13.50m in the rest of world. You have a budget of ECU 10.00m to spend on R&D. You will keep whatever is left from your budget.

How much do you want to invest (ECU m):

Next

Probability Simulator - this is not an input to the experiment and is just here to help you calculate probabilities

Innovation Calculator

Your R&D investment (ECU m) | Your R&D effort | Probability to innovate %

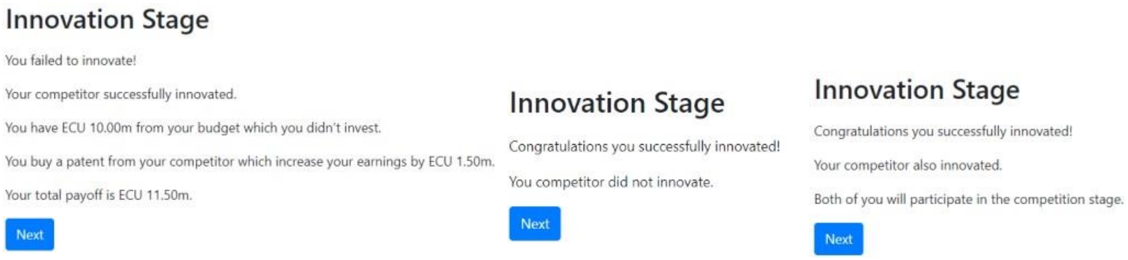
Competition Calculator

Your R&D investment (ECU m) | Your R&D effort | Probability to win the competition %

Your competitor's R&D investment (ECU m) | Your competitor's R&D effort

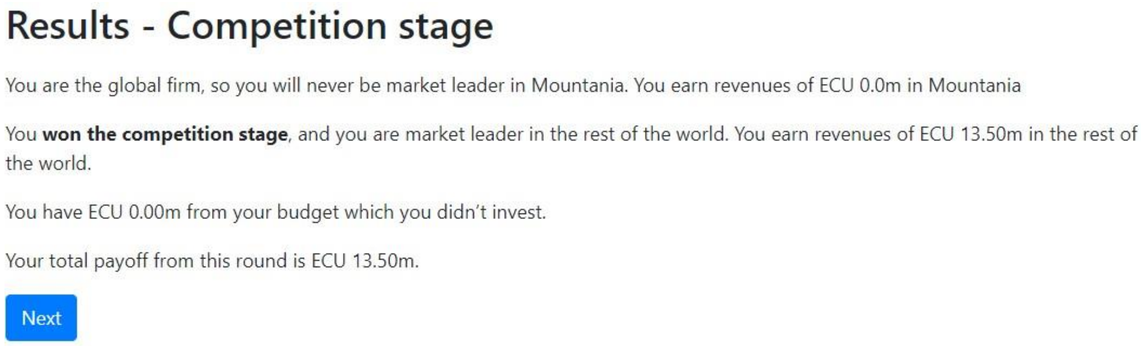
Source: Oxera.

Figure A5.35 Innovation stage results screen, for all possible scenarios



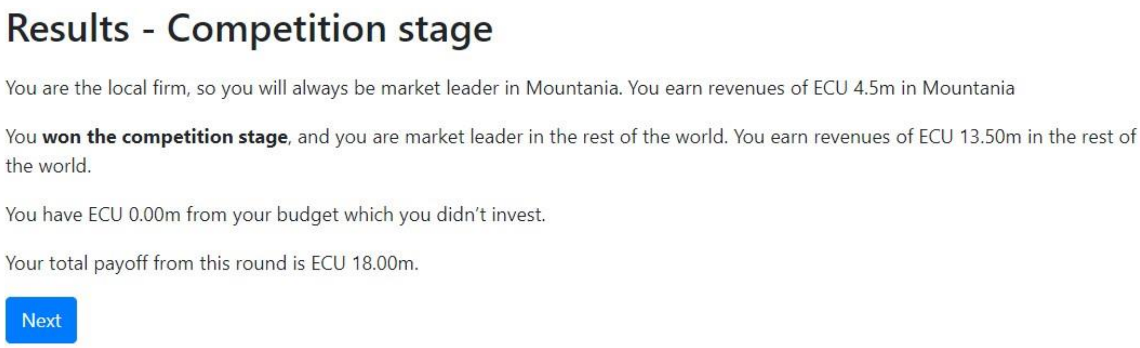
Source: Oxera.

Figure A5.36 Competition stage results screen



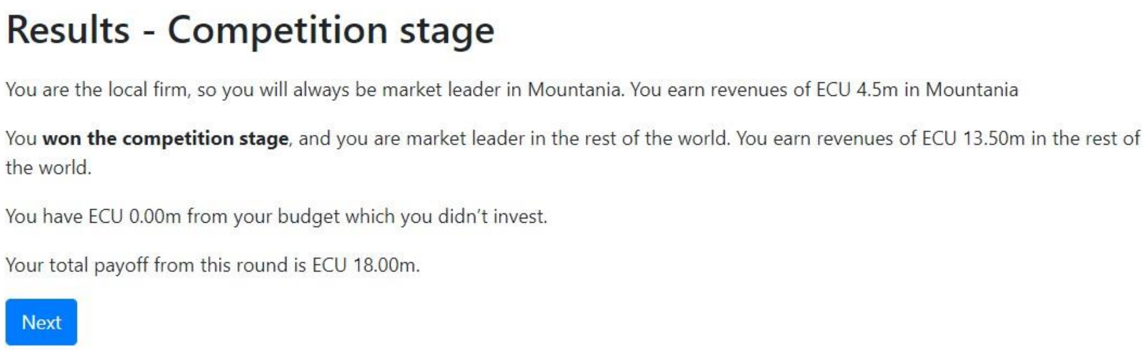
Source: Oxera.

Figure A5.37 Competition stage results screen



Source: Oxera.

Figure A5.38 Competition stage results screen



Source: Oxera.

Figure A5.39 Competition stage results screen

Results - Competition stage

You are the local firm, so you will always be market leader in Mountania. You earn revenues of ECU 4.5m in Mountania

You **lost the competition stage**, so you have a small market share in the rest of the world. You earn revenues of 1.50m in the rest of the world.

You have ECU 0.00m from your budget which you didn't invest.

Your total payoff from this round is ECU 6.00

Next

Source: Oxera.

Figure A5.40 Competition stage results screen

Results - Competition stage

You are the global firm, so you will never be market leader in Mountania. You earn revenues of ECU 0.5m in Mountania

You **won the competition stage**, and you are market leader in the rest of the world. You earn revenues of ECU 13.50m in the rest of the world.

You have ECU 0.00m from your budget which you didn't invest.

Your total payoff from this round is ECU 14.00m.

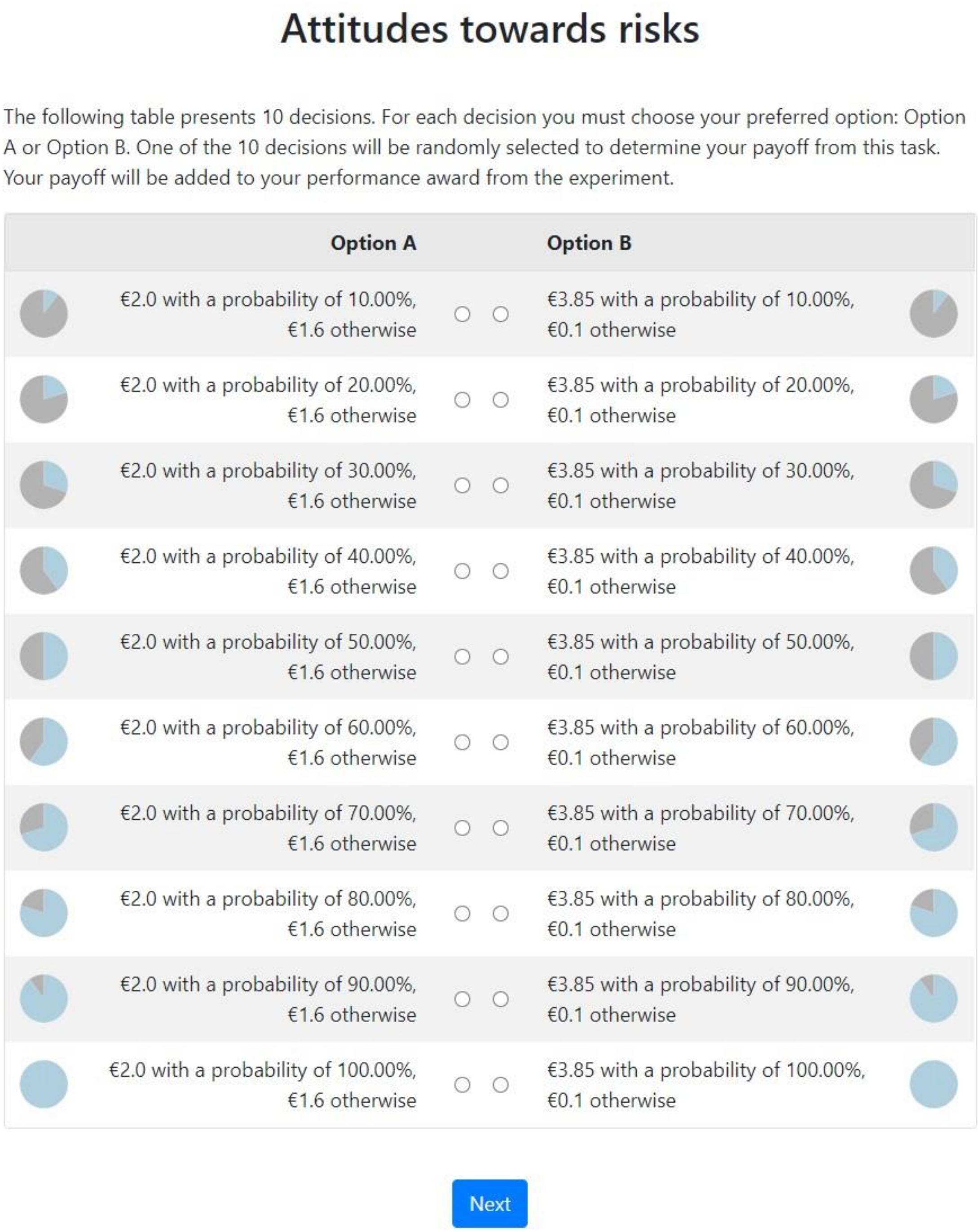
Next

Source: Oxera.

A5.4 Demographics and results

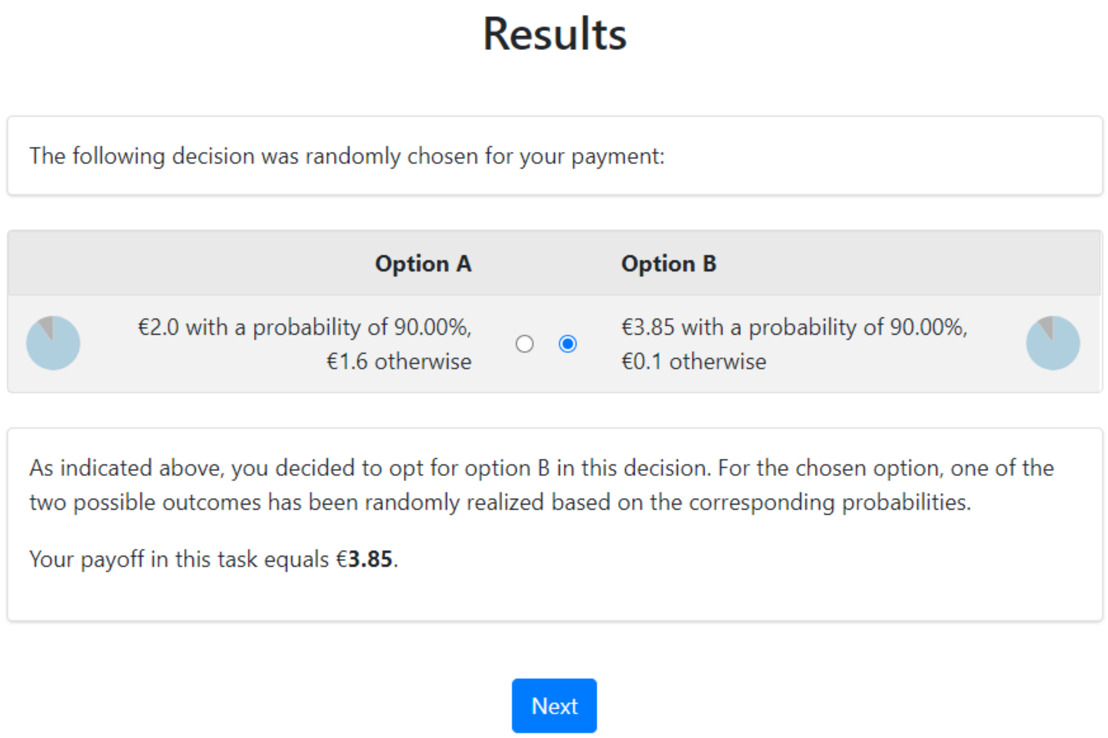
In this section, we show the demographic questions that the participants were asked at the end of the control group and all treatments, and the results screens.

Figure A5.41 Attitudes towards risks screen



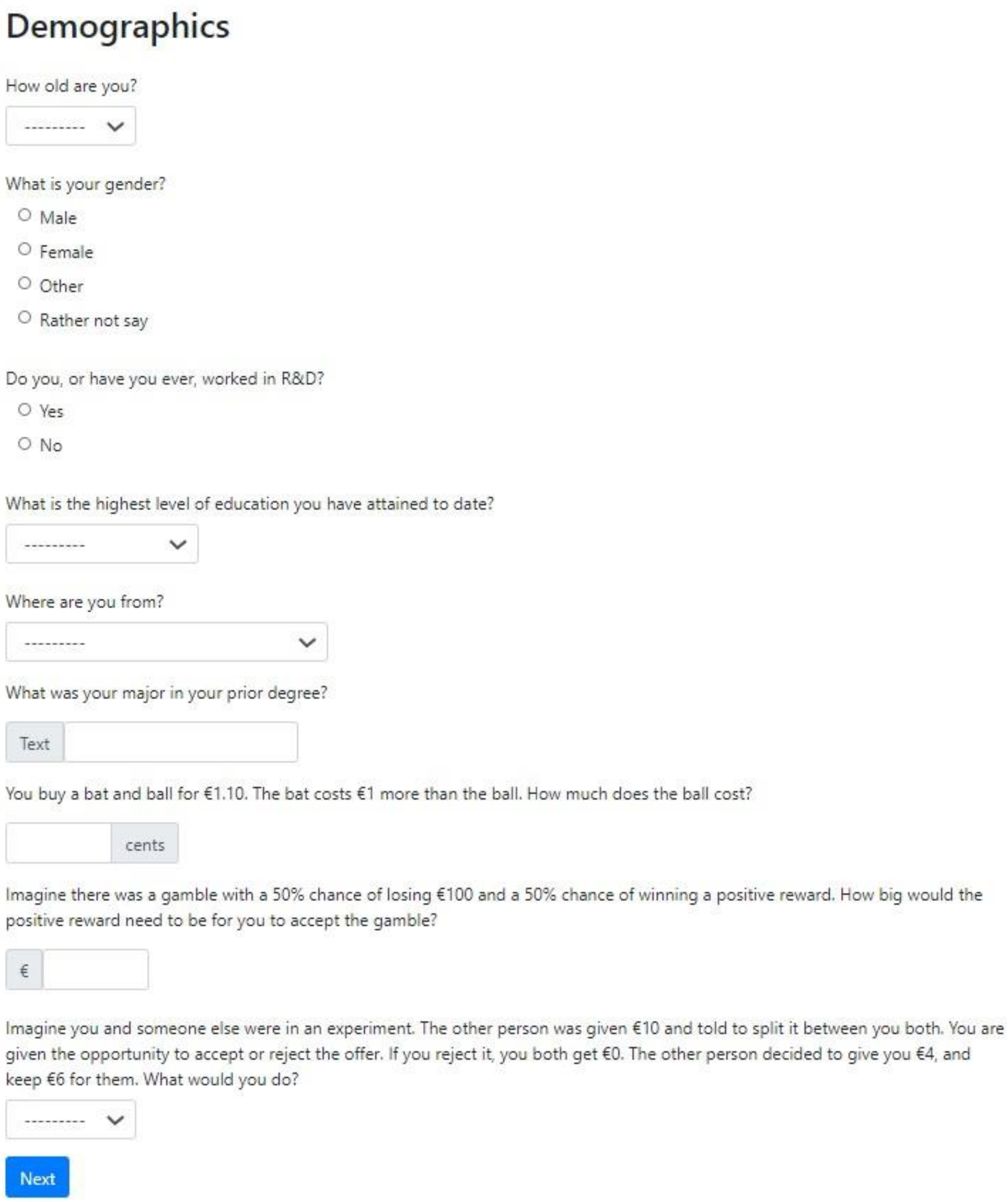
Source: Oxera.

Figure A5.42 Experiment results screen



Source: Oxera.

Figure A5.43 Demographics screen



Demographics

How old are you?

What is your gender?

- Male
- Female
- Other
- Rather not say

Do you, or have you ever, worked in R&D?

- Yes
- No

What is the highest level of education you have attained to date?

Where are you from?

What was your major in your prior degree?

Text

You buy a bat and ball for €1.10. The bat costs €1 more than the ball. How much does the ball cost?

cents

Imagine there was a gamble with a 50% chance of losing €100 and a 50% chance of winning a positive reward. How big would the positive reward need to be for you to accept the gamble?

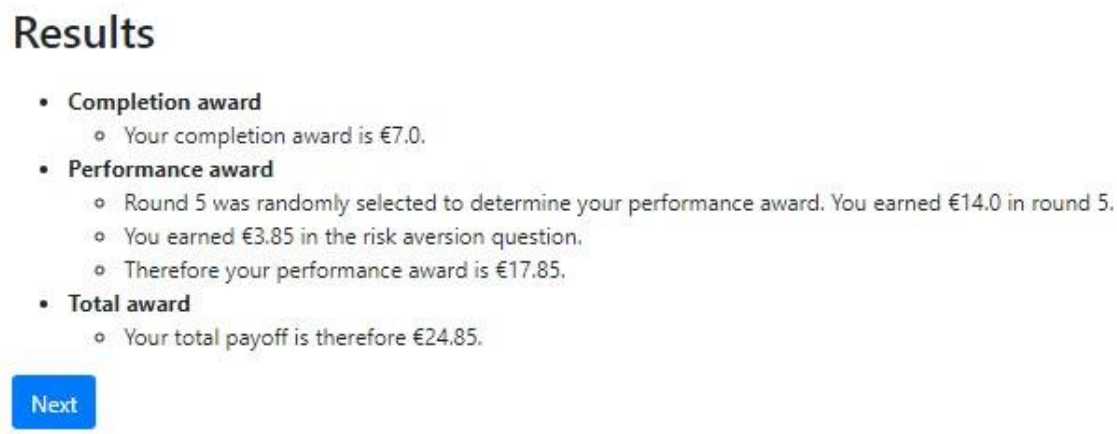
€

Imagine you and someone else were in an experiment. The other person was given €10 and told to split it between you both. You are given the opportunity to accept or reject the offer. If you reject it, you both get €0. The other person decided to give you €4, and keep €6 for them. What would you do?

Next

Source: Oxera.

Figure A5.44 Experiment results screen



Source: Oxera.

www.oxera.com

compelling economics