H2020 MSCA-ITN-2018

ReTraCE Project

Realising the Transition to the Circular Economy

D4.5

Consumer perceptions, intended and actual behaviours: implications for the transition towards the Circular Economy

This research has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Innovative Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE project).

Project acronym: **ReTraCE**

Project title: **Realising the Transition towards the Circular Economy: Models, Methods and Applications**

Coordinator: The University of Sheffield

Reference: 814247

Program: H2020-MSCA-ITN-2018

Start: 1st November 2018

Duration: 48 months

Website: www.retrace-itn.eu

Consortium:

The University of Sheffield (USFD)

Università degli Studi di Napoli Parthenope

University of Kassel (UniKassel)

South East European Research Centre (SEERC)

Academy of Business in Society (ABIS)

Högskolan Dalarna (HDA)

University of Kent (UniKent)

Tata Steel UK Limited (Tata)

Olympia Electronics SA (OE)

Erasmus University Rotterdam (EUR)

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Deliverable

Number: **D4.5**

Title: **Consumer perception and emerging services opportunities**

Lead beneficiary: South-East European Research Centre (SEERC)

Work package: WP4

Dissemination level: *Public (PU)*

Nature: *Report*

Due date: 31.05.2022 (Extended to 31.07.2022)

Submission date: 31.07.2022

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EXECUTIVE SUMMARY

Consumer engagement in circular economy (CE) practices is a necessary condition for their success. In fact, only through consumption practices that bring us closer to more sustainable futures can the CE achieve its goal of sustainable development. This, according to findings from our recent work, calls for consumer research that focuses on the quantities consumed and the concept of sufficiency. Moreover, among the most significant problems with extant sustainable consumer behaviour (SCB) research we identify is the intentions-behaviour gap (IBG). Thereby, behavioural intentions and attitudes reported by research participants fail to realistically match observations of their real behaviour when ethical considerations are at hand. We design and conduct an experiment rooted in the common pool resource (CPR) framework, allowing us to observe participants' behaviour directly (i.e. without self-reports), and measure self-reported behavioural intentions with different framings. The data are analysed by means of factor analysis, allowing us to explore the factor structure underlying the behavioural intentions items, and three linear regression models, to explore the explanatory potential of differently framed intentions on actual behavioural outcomes. Our results suggest that it is necessary to make changes beyond conscious consumer choice if we are to achieve more sustainable consumption and production. Particularly, behavioural shifts that are necessary to achieve more sustainable futures, like consuming less, are not always clearly articulated and/or perceived as such by consumers, making it difficult for them to act on their attitudes and intentions to behave more sustainably, regardless of their intensity. Moreover, the results highlight the significance of the IBG in this context and call for further research to consider negatively framed intentions, that match the context-specificity of the behaviour of interest, as they seem to offer greater explanatory power than their positively framed counterparts. Furthermore, a previously undocumented gender effect is revealed, whereby the IBG seems to worsen for female participants. This contrasts with the increased adoption of sustainable practices observed for females when compared to males and suggest that gender differences may be unrealistically inflated when employing self-reported data.

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LIST OF ABBREVIATIONS/ACRONYMS USED

ES – Earth System

PB – Planetary Boundaries

CE – Circular economy

SCB – Sustainable consumer behaviour

IBG – Intentions-behaviour gap

DM – Decision Maker

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1 INTRODUCTION

The dominant socio-economic frameworks in affluent nations, driven by a rhetoric of incessant economic growth, have confined societies into a system that incentivises and requires the limitless creation of consumer needs, which the market then works to accommodate. The associated levels of resource extraction and other environmental impacts are unsustainable, which has led to the identification of consumption as one of the main growing environmental problems, if not the main one (Hertwich et al., 2010; ; UNEP, 2013; ; UNEP, 2019; EEA, 2020). For example, every year the Global Footprint Network calculates the "Earth overshoot day", the day on which the use of renewable natural resources exceeds the planet's ability to produce them within a year. Since 1980, Earth overshoot day has, on average, arrived earlier with each successive year exhibiting a clear global trend (GFN, 2022). Similar observations have been made regarding soil degradation and erosion, which is happening somewhere between 10 and 40 times faster than it can naturally recover (Pimentel, 2006), and with the use of non-renewable resources necessary to support current technology-intensive societies, of which 70% had already been deemed globally scarce by 2008 (Clugston, 2012). Perhaps the most significant effort to understand the impacts of human-economic activity on the planet globally and holistically in terms of (1) its ability to recover from said shocks and (2) the associated risk to human civilisations, comes from the framework of Planetary Boundaries (PB) (Rockström et al., 2009; Steffen et al., 2015). The Earth system (ES) is currently in a state of transition from the Holocene, a state of stability which is the only one known to be capable of sustaining human lives for population sizes of the present magnitude, to the Anthropocene, a state whose nature is still to be determined and whose fate will depend on the degree to which human-economic shocks will push the ES away from a Holocene-like state. Within this framework, several PB have been defined beyond which the ES enters a high uncertainty domain regarding its future and its ability to sustain human life (Rockström et al., 2009). Hence, operating within these PB defines a safe operating space for humanity by minimising the likeliness of deviating from a Holocene-like state. The last account of the state of these boundaries shows that we are currently operating outside the safe domain in at least four of the seven currently measurable PB (Steffen et al., 2015). In other words, the global unsustainability of human-economic activity in the ES, is a fact that calls for an urgent paradigm shift, and particular care should be given to the consumption patterns and lifestyles that socio-economic systems require to strive.

The Circular Economy (CE) represents the latest attempt to drive the paradigm shift necessary to accommodate human life on the planet sustainably. It relies on a complex systems perspective (EMAF, 2013; Kirchherr et al., 2017) to optimise the whole socio-economic system and not just its individual components, hence accounting for the interactions and synergies between its parts, with the goal of attaining sustainable development. Fundamentally, material flows in a CE are such that biological nutrients are fed back to the biosphere safely, while technical nutrients are re-circulated maintaining their quality to maximise their use value to society, without entering the biosphere and becoming waste (EMAF, 2013). In particular, the CE proposes a re-thinking of the business models that drive our societies from all perspectives (e.g. regulatory context, consumer behaviour and supply chains), in order to enable more sustainable modes of production and consumption revolving around the 3R (reduce, reuse, recycle) framework. The CE is being

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currently promoted by nations, international bodies, and corporations and businesses around the world (Korhonen et al., 2018a). This inter-stakeholder and international diffusion is one of the concept's strongest attributes, but has also contributed to the CE becoming an essentially contested concept (Korhonen et al., 2018b) since it has led to a lack of agreement regarding its definition and the emergence of perspectives with often competing objectives. In sum, the characterisation of the CE requires further attention, and the concept is of interest to virtually all of policy, industry, academics, and civil spheres internationally.

Making production and consumption processes more circular requires the adoption of new conceptions of ownership, waste, and end-of-life management of material products (Camacho-Otero et al., 2018). Consumer acceptance of these new conceptions, as well as their active involvement in closing material loops is critical to the success of these circular strategies. As such, consumer behaviour plays a central role in both enabling the success of the business models and processes that characterise the CE and, more generally, achieving sustainable levels of human-economic activity. Despite that, the consumption side of the CE has not been addressed nearly as much as the production side in the CE literature. There have been efforts to understand attitudinal factors and mechanisms behind consumers' preference for products differentiated through their reported circular attributes (Testa et al., 2020). However, a sound conceptualisation of the meaning of the CE for consumers, beyond the purchase of products greened through circularity, is missing from the literature (Georgantzis Garcia et al., 2021). As a result, factors linked to consumers' habitual consumption and consumption culture and means for enabling the success of a CE by focusing on its goals remain poorly understood (Camacho-Otero et al., 2018; Parajuly et al., 2020). Camacho-Otero et al. (2018) begin to address this gap by offering a synthesis of research on consumption in the CE by means of a systematic literature review. In our recent work, we extend Camacho-Otero et al.'s (2018) efforts by critically reviewing the CE literature to develop a conceptualisation of consumption in the CE that respects the priorities of the concept's defining characteristics (Georgantzis Garcia et al., 2021). Moreover, we identify extant literatures that overlap significantly with the resultant conceptualisation (e.g., sustainable or ethical consumer behaviour) and highlight several commonly overlooked shortcomings that can be imposed given a direct transfer of these concepts, methods, and knowledge to CE-focused studies. This section provides a synthesis of our review (Georgantzis Garcia et al., 2021) and concludes by building on it to introduce the conceptual framework behind the experimental methodology employed in this report.

2 BACKGROUND

2.1 Consumption in the Circular Economy

Among the biggest challenges that research on the CE has been facing is the development of a definition of sufficient specificity and rigour. As a response, Kirchherr et al. (2017) review 114 existing definitions of the CE and extract a definition, consciously put together to capture all the defining characteristics of the CE identified by their review. The definition reads as follows:

> "A Circular Economy describes an economic system that is based on business models which replace the "end-of-life" concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus

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> operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations" (pp. 224–225)

The fact that this definition was carefully constructed to incorporate all the fundamental characteristics of the CE implies that failing to address its entirety poses the risk of leading to incomplete conceptions of the CE in the literature, and in turn, confusing and incompatible research. In developing a conceptual understanding of consumption in the CE, the following two points or rules follow from this definition:

1. **The hierarchical nature of strategies for circularity:** The order of the strategies as presented in Kirchherr et al. (2017)'s definition is not random. Instead, strategies appearing first are preferred, by definition, to those that come up later in the definition (Kirchherr et al., 2017). This idea is also highlighted by Europe's waste-management hierarchy (Singh and Ordoñez, 2016; Camacho-Otero et al., 2018).
2. **The accomplishment of sustainable development is the goal of the CE:** It does not suffice to define the CE and its processes in terms of "means", it is necessary to also acknowledge its "ends" (Kirchherr et al., 2017; Korhonen et al., 2018b). Therefore, considerations of consumer behaviour in the CE cannot disregard the environmental and other externalities of said behaviours and practices.

Consumption behaviours that aim to achieve sustainable development reflect the United Nations Environmental Programme's notion of sustainable consumption (UNEP, 2001; Peattie, 2010). Therefore, according to Kirchherr et al.'s (2017) definition quoted above, sustainable consumption and associated sustainable consumer behaviour (SCB) are part of the micro-level foundations on which the CE paradigm relies. In this sense, while the CE can be considered a still maturing idea, the consumption behaviours it entails, i.e. SCB, have to a large extent been researched in the consumer behaviour literature (Peattie, 2010). Moreover, the SCB literature overlaps significantly with research using different adjectives to refer to the type of consumer behaviour of interest, such as "ethical consumer behaviour", "green consumer behaviour", "responsible consumer behaviour", "pro-environmental consumer behaviour" (Georgantzis Garcia et al., 2021). These different adjectives quite often refer to the same thing, leading to confusion and difficulty to piece knowledge together (Peattie, 2010). The main exception is that of ethical consumer behaviour, which has been defined as behaviour "that concerns a certain ethical issue" (De Pelsmacker et al., 2005, p. 512), making SCB a subset of these behaviours, sustainability being an important ethical issue (Doane, 2001). In sum, there is a lot to gain from adapting and improving knowledge from existing research that is more experienced, on SCB and the discussed overlapping concepts, into the study of consumer behaviour in a CE.

2.2 <u>Global sustainability, natural capital, and well-being: Consumption quality or quantity?</u>

In an economy, finite resources are used and affected directly (e.g. material resource extraction) or indirectly (e.g. pollution) to provide goods and services to the population, who take on the role of

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consumers. Through consumption, demand is created which results in optimally matching supply which requires resource extraction and the creation of other externalities influencing the state of the ES. Therefore, the question of environmental sustainability requires considering three main factors: the number of consumers sharing the ES, the amount of individual consumption, and the rate of exchange between end consumption and resource extraction and/or other externalities. The latter is the efficiency of consumption, i.e. how much the ES must be perturbed to provide one unit of consumed end-product. In other words, in considering the case of currently dominant economies these factors translate into population size, people's ability to consume (usually referred to as affluence and is directly related to income), and the system's resource efficiency in providing its goods/services, which is essentially determined by the technology available to the world at a given time (Thøgersen, 2014).

Research has used the concept of "biocapacity use" (measured in global hectares), essentially a measure of perturbations on the ES due to human processes, to explore the population levels that could be considered sustainable given empirical observations of global average per capita potential for biocapacity use, or income. As of 2005, given the global average per capita income of around 2.7 global biocapacity hectares/person, a population of 5 billion or less (and not 7 as it was) would have been required to be considered sustainable (Assadourian et al., 2010). Since then, population has continued to grow and is set to continue do so given the increasing fertility in developing nations and life-expectancy increases overall. The average age of the population is also set to increase as life-expectancy surpasses life-expectancy at birth which remains effectively constant (Reisch and Thøgersen, 2015). Moreover, economies are also growing, leading to increased affluence in terms of global average per capita income. Hence, the global average affluence per-consumer is also constantly increasing. In other words, the situation is only becoming worse on both the population and the affluence fronts.

It remains to consider the technological factor explicitly since the dominant view is that technology, through innovation and the right policies to enable it, will be capable of addressing the ecological issues we face (Reisch and Thøgersen, 2015). However, the technological factor is at its best uncertain both in terms of its speed of action and its actual consequences. Technological solutions alone run the risk of falling into Jevon's paradox (Alcott, 2005), which implies worsening the situation when increasing efficiency simultaneously to increasing affluence and consumption. This is one of many rebound effects that can hinder the realisation of positive outcomes from technological advancements. Another worth mentioning is the behavioural rebound (Sun and Trudel, 2015). Research has found that when given an option to recycle (the only difference being the existence of a recycling bin in the laboratory), experimental subjects utilised significantly more of the available materials/resources to complete the same tasks leading, in fact, to a worse associated impact compared to the treatment where the recycling technology (bin) was not provided. From these considerations, it follows that technology alone is highly unlikely to solve the current ecological and climate crises within an economic context which requires and promotes consumerism.

We have talked about how economies operate; we now turn to why and under which circumstances economies that operate in this manner are indeed desirable. An ecological and a classical economist would both agree that what makes the existence of a market economy desirable is its ability to provide people with a subjective non-material object we call wellbeing. However,

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their opinions would differ with regards to the potential of the consumption of man-made capital[1] to provide infinitely increasing wellbeing (Daly and Farley, 2004). The ecological economist would argue that while consumption of man-made capital can offer wellbeing, its provision requires the depletion of natural capital, which is capital naturally available in nature and ecosystems. If humans meet their most pressing needs first, which is a realistic assumption to make, for each additional unit of man-made capital consumed their well-being increases less. Similarly, since nature's capacity to provide goods is increasingly hindered the more the ES is perturbed, the cost of provision of man-made capital increases with each unit consumed. Hence, at some point, the value of producing further man-made capital is shadowed by the associated loss lost from depleting natural capital. This theoretically leads to the conclusion that some amount of man-made capital production/consumption must be enough or sufficient. Conversely, the classical economist simply does not acknowledge the existence of natural capital, hence leading to a vision where well-being can be infinitely provided through the production and depletion of man-made capital at no apparent cost.

Empirical support for the view that that a limit must exist in relation to the ability of man-made capital to offer well-being is provided by reports that beyond a certain threshold, increases in material possessions, energy use (Jackson, 2009; Abdallah et al., 2009) and income (Inglehart and Klingemann, 2003) cease to lead to increases in reported well-being. In fact, research finds that this threshold has long been exceeded in developed countries, since growth and well-being are no longer coupled (Daly and Cobb, 1989; Mulder et al., 2006; Jackson, 2009). The reasons behind this decoupling may or may not be related to the cost, in terms of natural capital, of provision of man-made capital as the ecological economist would posit. However, even if the depletion of natural capital is only part of the reason, the fact that this decoupling exists cannot be ignored in the way that striving for infinite growth, the dominant picture in current economies, does. Moreover, unsustainable consumption patterns have been linked with increases in inequity and vice versa (Wilkinson and Pickett, 2011; Vergragt, 2013), further highlighting the existence of a level of growth that should be considered sufficient when focusing on its ability to increase wellbeing.

Despite all the above observations, current economies guided by free-market and endless growth paradigms continue to dominate the picture. Since the rise of neoliberal capitalism in the 1970s, the growth in economic activity and life standards has been overwhelming (Carrington et al., 2016). Such economic systems fundamentally rely on the constant creation of new consumer needs, through for example marketing and fashion cycles, that the market then works to accommodate. In other words, consumerism is necessary for the survival of current economies since it is necessary for constant economic growth. As discussed previously, it is this constant increase in consumption facilitated by the institutionalisation of consumerist cultures and lifestyles that undermines the potential of technological advancements to overcome the dangers of rebound effects and offer sustainability improvements.

Naturally, given the foundations of the currently dominant rationale, the overwhelming majority of emerging efforts to drive consumer behaviour towards more sustainable patterns focus

[1] By capital we refer to a stock of something, that can be physical or not, capable of providing goods and services to humans. For our purposes, only capitals of a physical nature will be considered.

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on the consumption/production of less impactful/more efficient product and service alternatives, while maintaining the installed consumerist-oriented consumption culture (i.e. green consumerism) (Akenji, 2014). This means that the solutions that dominate the landscape are purely technological, becoming highly susceptible to rebound effects which lead to even worse scenarios of unsustainability. Hence, these solutions are not enough and fail to acknowledge how current growth-driven economies naturally lead to unsustainable patterns of production and consumption, even with the availability of technology and innovation (Jackson, 2009). The implications of these observations for consumption are of critical importance. Making consumption sustainable requires making changes to the economic system, the infrastructures and institutions, the power relationships and the dominant lifestyles and consumption culture (Vergragt et al., 2014).

For consumers, this means shifting from current consumerist cultures to a culture and lifestyle guided by sufficiency, i.e. asking the question of how much is enough? (Princen, 2005; Brown and Vergragt, 2016). In contrast, the consumer behaviour literature to date has mostly focused on qualitative aspects of what is consumed (green consumerism). In other words, research has become conditioned by the idea that sustainable consumption equates to the consumption of greener alternatives, disregarding completely the quantity consumed. Our analysis, however, leads to a different conclusion. That the concept of sustainability is more meaningfully linked to behavioural outcomes with respect to their coherence with sufficiency, and hence quantity (Georgantzis Garcia et al. 2021).

2.3 The intentions-behaviour gap in sustainable consumption

As we find in our previous work (Georgantzis Garcia et al., 2021), the consumer behaviour literature looking at SCB, and other overlapping concepts, is affected by the intentions-behaviour gap (IBG) phenomenon. This describes a mismatch between individuals' self-reported intentions to behave more sustainably and their actual adoption of more sustainable behaviours (Carrington et al., 2010). The research literature on the IBG distinguishes between the modeller and the methodologist perspectives, each claiming a different cause for the IBG (Frank and Brock, 2018). The first (modeller) regards the IBG as being a consequence of a lack of heterogeneity in the theoretical frameworks used to understand behaviour, with the Theory of Planned Behaviour (TPB)[2] disproportionately dominating the landscape. Among the most prominent factors that have been theorised to be missing from the TPB are implementation intentions, which refer to the degree to which a specific plan to act on one's intentions exists and would mediate the intentions-behaviour relationship (Belk, 1975; Ajzen and Madden, 1986; Gollwitzer, 1999; Carrington et al., 2010), and cognitive dissonance due to not acting in accordance to one's intentions or attitudes, which would play a positive moderating role in the intentions-behaviour relationship (Chatzidakis et al., 2007; Szmigin et al., 2009; Gregory-Smith et al., 2013; McDonald et al., 2015). Despite their appearance in exploratory efforts in the literature, these theorised causes for the IBG have not been sufficiently tested quantitatively and are far from being validated to date. These observations

[2] The Theory of Planned Behaviour posits that behavioural outcomes are determined by the strength of behavioural intentions to act in said manner, which are in turn determined by attitudes towards the behaviour, perceived behavioural control and subjective norms.

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call for theoretical innovation around the IBG for contexts of SCB, not only to test extant hypotheses, but also to develop new ones and contribute to extending theory.

On the other hand, the second (methodologist) perspective understands the IBG as emerging from the use of self-reported measures of attitudes, intentions and behaviour in survey and other methodologies, which are thought to be biased due to social desirability, hypotheticality and other similar issues. The former refers to biases in questionnaire responses due to the participants being compelled to answer in accordance with what they regard as socially desirable rather than realistically (Schwarz, 1999). The latter bias operates through respondents' often distorted perception of their most likely response given hypothetical situations, which in turn provides biased outcomes in the questionnaires (Murphy et al., 2005; Maleetipwan-Mattsson et al., 2013; Araña and León, 2013). These and other biases have been quoted as highly significant numerous times, especially in questions regarding ethical matters (Fuller et al., 2016; Auger and Devinney, 2007; Murphy et al., 2005). Conversely, there are a few studies that claim that the effect of many of these biases is often negligible (Araña and León, 2013; Fuller et al., 2016). Therefore, research is yet to reach consensus regarding their significance. In sum, methodological biases require particular care and there is a need to better understand their significance with respect to the study of SCB. To this end, moving away from self-reported measures of behaviour is desirable to avoid these biases altogether but also for contrasting against comparable studies using self-reports to explore the IBG empirically (Georgantzis Garcia et al., 2021).

Considering these research gaps, we argue that there is a need to better understand the IBG, as well as to acknowledge that without looking at behaviour quantitatively we may not obtain a complete picture of SCB and the factors enabling or hindering it. Moreover, the one-dimensionality and consequent incompleteness of the understanding of behaviour that can be obtained through a single theoretical lens, such as the TPB, must also be addressed through innovative theoretical perspectives, both on the intentions-behaviour relationship and directly on SCB. Finally, methodological innovation is necessary, beyond self-report-based approaches, to better understand the significance of each potential source of the IBG and offer additional perspectives for eventual contrasting. Furthermore, reliance on an incomplete and biased understanding of what SCB entails, to which gaps in current consumer research contribute, hinders the design of the right policies to achieve the desired goal of sustainable development. Therefore, here we aim to align with calls for further research from our recent work (Georgantzis Garcia et al., 2021) where we find that there is a need for consumer research that:

1. Focuses on the quantity of consumption rather than the quality of consumption.
2. Is designed to observe behaviour of individuals directly, i.e. not through self-reports.
3. Does not focus on behavioural intentions nor self-reported behaviour to draw conclusions about actual behaviour.

2.4 Social dilemmas and the tragedy of the commons

Taking a step back, one may ask fundamentally why more sustainable behaviours and choices are not naturally reached while being generally desirable. Indeed, if it is generally desirable why

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wouldn't consumers naturally choose to behave more sustainably? The answer begins from unpacking who these behaviours benefit, how much, and in what way.

In general (and assuming its correct classification as being sustainable), a more sustainable choice of behaviour by a consumer is better for the collective good than a less sustainable avenue. This is because a choice being more sustainable, by definition, must imply ecological, social, and economic improvements with respect to less sustainable choices, all of which in one way or another contribute to improvements that are shared by everyone in the planet, i.e. the collective good. An equally valid and simultaneously true perspective on the same issue is that the important globally incident costs that arise from unsustainable consumption patterns, are shared by everyone, whether these are physical or moral. The problem is that making the more sustainable choice often bears a direct cost for the decision maker (DM), whether it is the case that such a choice costs more money, is more time consuming, requires increased effort, is less aligned with one's habits, there is a lack of infrastructure to support it, is less aligned with social norms or any other issue that might result in an individual cost to the DM, from making the more sustainable choice. As such, the individual costs of acting sustainably, which are experienced individually, can very often surpass those from acting less so, which are shared, this in turn creates an incentive for the DM to not act sustainably. Such a situation is widely known as a social dilemma: a situation where individuals' optimal decision making is set to lead to an outcome that is less than optimal collectively (Liebrand, 1983). In other words, there is a conflict between what is "best" for the individual locally and what would be "best" for the collective.

Resource extraction through consumption essentially describes a context where the shared resources are non-excludable and highly subtractable, such resources are also known as common resources or *commons* (Ostrom et al., 1992). This just means that one person consuming does not prevent another person from doing so, which is certainly true at the resource extraction level, and that the level of consumption is not significantly constrained, which is true since the current individual affluence limit on consumption still allows for a lot more than the sustainable threshold and allows for continuously growing individual consumption levels as economies continue to grow by design.

The presence of the social dilemma that emerges from this context makes commons susceptible to what is known as the "Tragedy of the Commons" (Hardin, 1968), a situation where the system within which decision making is embedded incentivises the DM to extract effectively unlimitedly leading the finite resource to its unavoidable deterioration. Then, the question of shifting consumer behaviour towards more sustainable patterns is about understanding how the tragedy of the commons can be avoided in this context.

As argued by Hardin (1968), this cannot be achieved through appeals to individual responsibility alone since the system naturally favours non-cooperators. An institutional perspective further supports this idea: consumer behaviour (micro-level) is of paramount importance to setting up and stabilising the right institution of consumption towards sustainability, however, top-down efforts (macro-level) addressing the very foundations of the system giving rise to these incentives are simultaneously required (Georgantzis Garcia et al., 2021).

Conveniently, shared commons scenarios have been amply studied using experimental methods in economics, a framework commonly referred to as common pool resource (CPR)

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games, to understand people's behaviour under these circumstances (e.g. Gardner, Ostrom and Walker, 1990; Fischer, Irlenbusch and Sadrieh, 2004). In the experiments, real monetary incentives are designed into the game which are *compatible* with those of the situation of interest, which in this case is the social dilemma arising from commons (also commonly referred to as commons dilemma). This ensures that observed extraction or consumption behaviour is representative of participants' actual decision making under the same incentives, making the methodology particularly relevant given the limitations of self-reported accounts of behaviour. Additionally, it is particularly well suited to considerations about the quantity consumed, although it can easily be adapted to incorporate or alternatively explore qualitative aspects too. In sum, the CPR framework is well suited for our aim of acknowledging and addressing the research gaps identified in our literature review, listed at the end of the previous section, hence contributing to filling important knowledge gaps for the SCB literature, and the CE literature more widely, which are critical to the design of better policies towards more sustainable futures.

The rest of this report is structured as follows: In Section 2, a CPR experiment is proposed which allows us to observe the behaviour of participants in a situation representative of (un)sustainable consumption. In the same section (Section 2.1), the implementation of the experiment is discussed together with participant recruitment considerations. Then, in Section 2.2, operationalisation of the constructs of interest are addressed. In Section 3, the results of our analyses are presented in detail. Finally, in Section 4, implications of our results are discussed.

3 THE ARMAGEDDON GAME: AN EXPERIMENT ABOUT SUSTAINABLE CONSUMPTION

To observe behaviour, an experiment is proposed such that the incentives and framing that are representative of the situation of interest are appropriately reproduced. In this case, that is consumption leading to increased risk of a catastrophic future outcome, due to resource deterioration or more generally perturbation of the ES, when carried out at unsustainable levels. The characterising elements of this situation inspire the development of a new kind of CPR extraction game, which we call *The Armageddon Game* (AG)[3]. By assigning real monetary returns for participants based on the outcomes of the game when played under laboratory conditions, the AG serves as a basis for creating incentives representative of the situation of interest, i.e. SCB. More precisely, this creates a tool for the observation of behaviour that is representative of decision making under incentives present in real life, hence overcoming the limitations associated with self-reported measures of behaviour.

The game has features of a CPR game but is adapted to a dynamic and probabilistic setting, to reflect the features of sustainable consumption. Since all real consumption takes place within the Earth system (ES), everyone benefits from its existence. In the real world, everyone benefits equally from the ES's existence regardless of whether their decisions have contributed more to its continuation or extinction (in line with the CPR paradigm). In the game, this translates into the

[3] Please refer to Appendix A for a detailed description and mathematical formulation of the Armageddon game.

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probability of the ES's survival in the future representing the collective benefit or public good. Given the context of sustainable consumption, players interact with the common fund by consuming its tokens. The tokens collected by each player will determine their individual profit, while the size of the common fund will determine the probability of survival for the world. Hence, players have a purely individual incentive to maximise their consumption, opposed by a collectively shared incentive to maintain the probability of survival of the world at a high enough level. Therein lies the social dilemma faced by players, as required by the situation of interest. An in-depth description of the game and the parametrisation employed in the experiment are provided in Appendix A.

3.1 Experimental protocol

Data were collected in three days, comprising a total of eight sessions, during November of 2021. In each of the first two days, three sessions with 40 participants each were carried out. The final day, two sessions were run, one with 40 participants first; followed by a final one with 16 participants. In total, the experiment hosted 296 participants (74 groups of 4 participants each) from the subject pool of the Laboratori d'Economia Experimental (LEE) (Universitat Jaume I, Castellón, Spain). The experiment was programmed and implemented using z-Tree (Zurich Toolbox for Readymade Economic Experiments) software (Fischbacher, 2007). To minimise COVID-19-associated risks to participants, researchers and laboratory staff, the laboratory had a protocol in place that was always adhered to closely by all parties involved. Participants were made aware of the protocol in the recruitment email, prior to making the decision to participate. This research has obtained ethics clearance from the Research Ethics Committee of Sheffield University Management School (SUMS)[4]. All participants were 18 years old or older, and no deception was used in the experimental setup. All participants in the experiment completed written consent forms before the start of each experimental session. The data was anonymised before the analyses.

On arrival to the laboratory, participants were instructed to sit such that their order of arrival had nothing to do with room's layout during the experiment. This was done as an extra step, on top of the measures already present in the laboratory, to minimise the risk of groups of participants interacting during the experiment. Participants were then asked to complete the consent form, of which they had been informed in the recruitment email.

Before the start of the experiment, and after reading a description of a hypothetical setting mirroring that of the AG in which they would later engage, all participants completed a short questionnaire about their intentions to behave if faced with said setting. Once all participants had finished answering the pre-experiment questionnaire, the lead researcher moved on to reading the parts of the instructions that were common to both treatments[5]. Here, participants were informed

[4]Reference Number: 042752

[5] Two different treatments were carried out; however, the treatment variable is irrelevant to this report given the chosen operationalisation of behaviour. Despite that, since it did influence decisions regarding experimental protocol it is mentioned here for completeness. It is worth noting that, in all sessions, half the participants were from one treatment, and half were from the other. This is not envisaged to negatively affect any of the conclusions that can be drawn from subsequent analyses described in this report.

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that they would be randomly grouped with three other participants, forming groups of four. Also, that during the experiment, earnings and payments would be expressed in experimental tokens following an exchange rate of 10 tokens = 1€. Then, the next part of the instructions, detailing the payments, was read aloud to all participants. Participants were informed of the existence of two payments: Payment 1, defined as the extraction in tokens corresponding to one of the rounds played determined at random, and Payment 2, defined as individuals' number of tokens accumulated over all rounds; provided a randomly determined "**final round**" is reached. Finally, some general rules forbidding the use of a calculator and any form of communication between participants were read. Participants were then allowed plenty of time (10 minutes maximum) to read the part of the instructions which differs slightly between treatments.

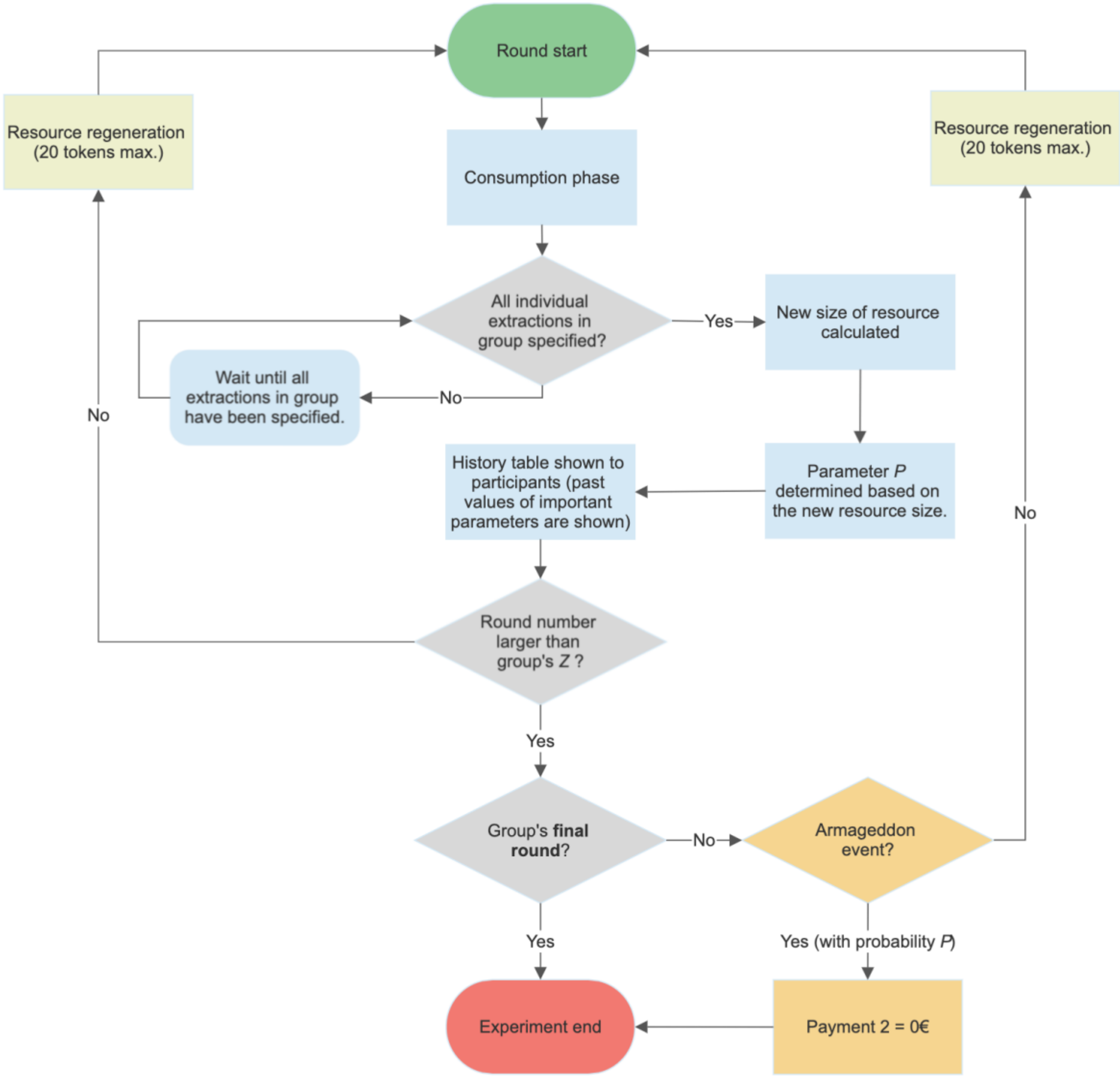

Figure 1. Flow chart of the Armageddon game experiment from the start of the first round to end of experiment.

The rest of the instructions were read individually by participants. They were informed that there would be rounds, across which initial conditions may change but the decision will remain of the same type. The AG was then introduced by describing each round as two separate phases: the

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beginning and the end of the round. Participants were informed that in the beginning phase of the round, they will be shown the number of tokens available in a common fund; shared among all members of their group and which will start off containing 1300 tokens; from which they will have to choose an integer number of tokens, between (and including) 1 and 18, to extract. Also, that all other members of the group will be making the same type of decision. Next, it was explained to participants that once all members of their group have decided, the tokens they extract individually will be added to a private fund, and the common fund will be left with the tokens remaining. To finalise the beginning phase of the round, they were informed that a parameter P, representing a percentage, will be calculated based on the size of the common fund after extraction. Namely, the larger the size of the common fund, the lower the value of P.

Now onto the end of the round phase. Here, participants were informed that they will be shown a "history" table containing the values of the following variables: common fund size, private fund size, collective extraction (i.e. the sum of all individual extractions in the same group), individual extraction, and the percentage P.[6] Next, participants were informed that beyond a randomly determined round (named *Z*), unknown to both researchers and participants, P will represent the probability of an Armageddon (or end-of-the world) event taking place before the start of the next round, for their group. Before that time, the probability of an Armageddon event taking place will be 0. Additionally, that such an event taking place will result in an abrupt ending of the game and emptying of all private funds in the affected group, making all Payment 2s for said group equal to 0€. Provided the game moves on to the next round, the common fund will regenerate 20 tokens (max.), without ever surpassing the common fund's original size of 1300 tokens. Finally, participants were informed that once the common fund has regenerated, they will move onto the next round which will be the same as the previous one except potentially for the size of the common fund, which may decrease or increase between rounds. Also, that this process will be repeated from one round to the next until one of two things happens: An Armageddon event ends the game abruptly and prematurely, or the final round (which is determined at random for each group) is reached. A flow chart of the AG experiment as explained to participants is shown in Figure 1.

Participants were given a full copy of the instructions containing a glossary at the end with succinct definitions and information for each of the concepts introduced in the instructions. These concepts are: Common fund, private fund, extraction/consumption, Armageddon event, P parameter, final round, and payment round. Everyone was allowed to refer to the full instructions, glossary, and/or raise their hands to ask for clarifications at any given time beyond this point and until the end of the experiment. This helps minimise the negative effects that lack of comprehension of the game may otherwise have on experimental outcomes, which is important to address given the complexity of the game at first glance. As a further measure to minimise this risk, participants completed an instruction comprehension test, designed to address typical misconceptions or misunderstandings about the game. The test included questions (8 in total)

[6] The percentage P, was only shown in one of the treatments. This represents the treatment variable, such that half of the groups were given full information while the other half were not told the exact value of the percentage. However, this is irrelevant to this report's analyses and results.

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about the definition and consequences of an Armageddon event, the P parameter, the common fund, the private fund, Payment 1, Payment 2, and the determination of the total profit of participants. The test was not meant as a filtering strategy, i.e. no participants were cut off based on their performance, instead its purpose was to give participants a further platform to make considerations about the experiment, and realise potential misunderstandings they may have, before engaging with it. In addition, their time of completion was recorded as a proxy for individuals' comprehension of the game, enabling us to control for this issue were we to find a need to do so. Furthermore, we argue that given the context of sustainable consumption, it may often be the case that the dynamics in which consumers engage with the global scale through their behaviour may be poorly understood. Therefore, rather than an unwanted feature, this can in fact induce a more realistic representation of the situation of interest.

Having completed the instruction comprehension test, participants moved on to play the AG, and once they reached the end of the game, they were asked to complete a short questionnaire. This contained demographic questions and questions capturing psychological features of participants. Namely, they were asked items pertaining to their sustainable-behavioural intentions. Other psychometric instruments were also included; however, they lie beyond the scope of this report.

3.1.1 Participants

Participants were recruited through LEE's established data panel and recruitment procedures. The experiments were carried out in the same laboratory, located in Castellón, Spain. While the data panel is primarily composed of students, it contains students at different stages of education and non-students. No quotas were imposed on sampling regarding age nor education. In our sample (n=296; mean age = 22.2; female = 52.03%), at the time of data collection there were, 52.7% had attained a bachelor's degree or equivalent, 34.8% had completed upper secondary education, 5.41% had completed short-cycle tertiary education, another 5.41% had attained a Master's degree or equivalent, while the remaining respondents had either completed post-secondary non-tertiary education (1.01%), less than primary education (1 respondent) or was at the Doctoral level (1 respondent). In other words, our sample is far from the typically criticised undergraduate student samples. Moreover, participants usually have some experience with participating in experiments in economics, which helps increase comprehension of both the game, and the consequences, hence boosting incentive compatibility. Comparable representation from both genders was sought at the treatment level, to allow for proper control and exploration of gender effects (T1: female = 52.7%; T0: female = 51.4%). On recruitment, all participants were given a copy of the information sheet to read in their own time and were informed that the completion of a consent form will be required to participate.

3.2 Measurement and operationalisation of constructs

3.2.1 Behavioural intentions: Internal vs. external (to the experiment)

In addition to observing behaviour through the experiment, some measurement items (questionnaire type questions) measured in 7-point Likert scales, were also put in place to measure

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respondents' behavioural intentions. Specifically, this was done at two points during participants' involvement in the study: Before being given the instructions of the game, that is without knowing about the game they will be participating in, and after the end of the game. In the former case, a general description mirroring the game they were about to participate in was provided, then they were asked questions about what their intentions would be regarding their consumption behaviour in the described hypothetical setting. The questions are listed below:

1. I would extract as much as possible from the resource.
2. I would extract as little as possible from the resource.
3. I would extract as much as possible from the resource, as long as the probability that the world ends is not too high.
4. I would intend to behave so as to leave everyone in the group as well off as possible.
5. I would extract from the resource as much as others in the group.
6. The most important thing for me would be to benefit as much as possible from the resource.
7. The most important thing for me would be for everyone in the group to benefit as much as possible from the resource, without leaving anyone worse off than anyone else.

These can be classified as intentions that are *internal* to the experimental setting. In other words, they are intentions about a specific consumption context in which behaviour can then be observed. This is not usually the case in survey studies about SCB, where intentions and behaviour can rarely be matched one-to-one in terms of the setting and context. For example, intentions are often measured in more general terms, such as "intentions to be more responsible" or "intentions to recycle more", however the behaviour of interest tends to either be more specific, like "turning off the lights when they're not necessary" or measured by many measurement items pertaining to different behaviours of interest, that can be considered pro-environmental. Conversely, in our experiment, the internal intentions are about the exact game they are about to play.

At the end of the experiment, all participants completed a questionnaire, including demographic questions and general intentions to behave more sustainable in the future, to reduce the amount of waste they produce, and to consume less in general. Below we list the questions that were employed:

1. I would like to consume products and services in a sustainable way in the future.
2. I will try to consume products and services in a sustainable way in the future.
3. I will insist on consuming products and services in a sustainable way in the future.

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4. I would like to consume less in the future.
5. I will insist on consuming less in the future.
6. I am willing to consume less in the future.
7. How likely is it that you will consume less in the future?
8. I would like to produce less waste in the future.
9. I will try to produce less waste in the future.
10. I will insist on producing less waste in the future.

These, besides being of a general focus, can be classified as *external* to the experiment. Hence, the typical misalignment of setting and context between measured intentions and behaviour are present when it comes to these items. However, since behaviour is observed rather than measured through self-reports, it enables us to explore the real misalignment between these external intentions and actual behaviour.

3.2.2 Operationalisation of intentions and behaviour

Two factor analyses are performed on internal and external intentions items, respectively. The resulting groupings into factors provide information about the degree to which these items reflect the same latent construct. That is, grouped items can be thought of as capturing part of an overarching construct, unique to each respondent, which is unobservable directly. Moreover, these factors can be predicted and their scores for each respondent can be used as input into statistical models as a single variable. Therefore, an initial exploration will uncover the factor structure behind all the items, after which, these will be used as measures for intentions and to explore the relationship between intentions and other variables, e.g. behaviour.

We operationalise behaviour by looking at respondents' average consumption behaviour over time, relative to consumption behaviour of other players within the same group. In other words, what we call the average relative consumption of respondent i is defined as follows:

$$\text{avgrelconsum}_i = mean\left(\frac{\text{consumption}}{\text{rest of the group's mean consumption}}\right)_i$$

Given the hierarchical nature of the (absolute) consumption variable (i.e. consumption happens within groups, within subjects and at each period), using this as an outcome variable would require multilevel statistical modelling techniques, which are beyond the scope of this report. Said analysis is in the works as this report is being finalised. The resulting variable, avgrelconsum, condenses information about respondents' behaviour over time and within their own "world". This removes the hierarchical structure from the data and allows for simpler modelling techniques, offering an

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alternative perspective, and not a poorer one, compared to the multilevel models that will be fitted with absolute consumption as the dependent variable.

4 RESULTS

To provide an initial picture of the evolution of behaviour that could be observed in the experiments, the average extraction over all participants is computed for each round and plotted over time. The result is presented in Figure 2 (red line). Along with the between-subjects average extraction the graph contains benchmark solutions, namely the static Nash equilibrium (pink line in Figure 2) and the collective optimal strategy (blue line in Figure 2), for a utility model characterised by a myopic (underestimating risks, leading to overestimation of immediate returns) view of the AG (see Appendix B for a detailed description of the model and benchmark solutions calculations). In the model, the decision-maker fails to acknowledge the consequences that their behaviour could have in the long run (modelled as a failure to account for the multiplicative nature of joint probabilities), hence "myopic", leading to a significant overestimation of the probability of collecting the contents in their private fund. This leads to a static collective optimal strategy that is well above the sustainable threshold of 5 tokens (shown in green in Figure 2), namely 11 tokens, and a static Nash equilibrium that nears the maximum possible extraction, namely 17 tokens. Therefore, it correctly characterises the commons dilemma faced by players. While the model may or may not actually represent participants' decision-making, its purpose here is not explanatory. Rather, it seeks to offer a point of reference or comparison for interpreting the behaviour observed in the experiment. Despite that, it does point at an important fundamental fact, that behaving cooperatively or pro-socially does not necessarily imply being sustainable, since there is an idiosyncratic decision-making process underlying behaviour which can lead to distorted interpretations of one's externalities.

If we were to look through the lens of a myopic decision-maker, the average extraction over all subjects in the experiment could be considered cooperative from the offset. Particularly, average extraction revolves around 11 tokens (blue line in Figure 2) for the first 7 to 9 rounds. In reality, these extraction levels are almost certain to lead to an Armageddon event eventually if sustained over time, i.e. they are far from sustainable. The average extraction can be seen to decrease steadily between periods 7 and 24, from around 11 tokens to 8 tokens, and beyond this point a steeper decrease can be observed, namely from 8 tokens to about 5 tokens (i.e. the sustainable threshold) in the following 4 rounds. Finally, the average extraction line can be seen to revolve around the sustainable threshold and some abrupt jumps can be observed, affecting the smoothness of the line. This happens because beyond round 25, less than half of the groups remain so the average is computed with less data points. Therefore, as the last rounds are reached, we are observing the behaviour of just a few participants in the graph in Figure 2. It is not surprising, therefore, that there is an abrupt drop towards the 5 tokens mark after round 25, since the groups that have survived have managed to do so by behaving somewhat sustainably.

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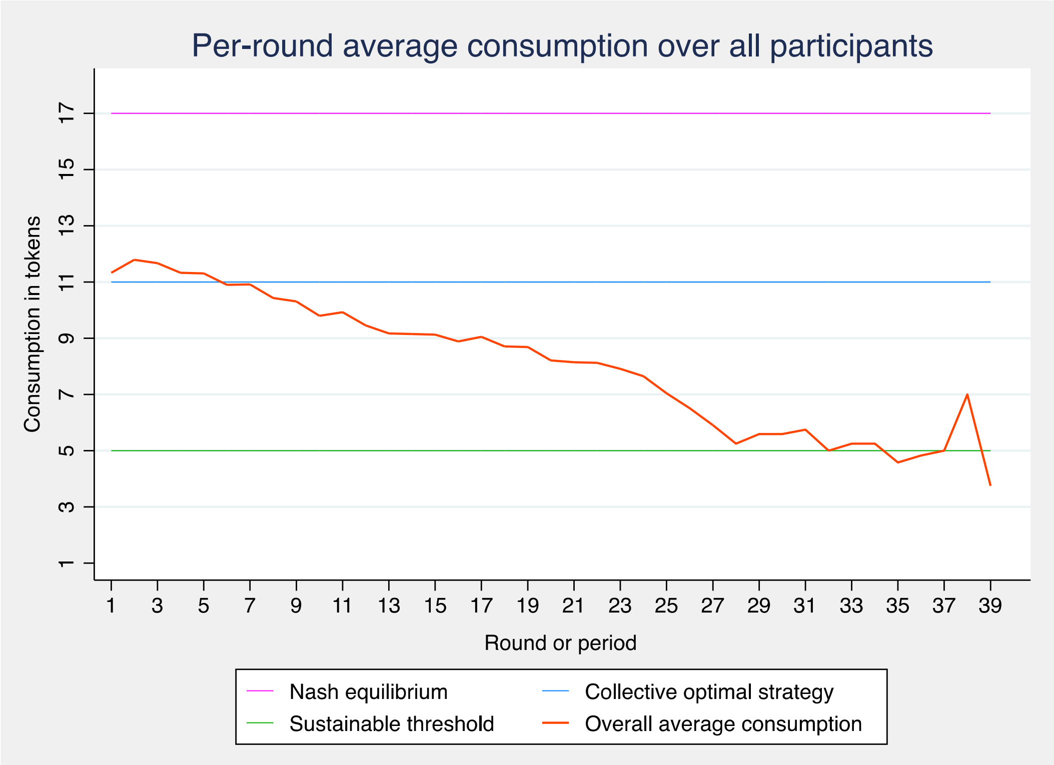

Figure 2. Average consumption over all participants is computed for each round. The above graph shows how this average evolves from one round to the next (shown in red). Also shown, are benchmark solutions, namely the static Nash equilibrium (pink line) and the collective optimal strategy (blue line), for a utility model characterised by a myopic (underestimating future consequences, leading to overestimation of immediate returns) view of the AG (see Appendix B for a detailed description of the model and benchmark solutions calculations). The sustainable threshold is also shown (green line). The between-player average extraction of a group being higher than this threshold, means the common pool will be unable to recover to its state in the previous round, and is therefore unsustainable.

In sum, by looking at the average behaviour shown in Figure 2, participants did try to reduce their consumption as the common pool was depleted and the probability of survival reduced over time. However, the reaction happens at a much slower rate than necessary to survive until the final round. This fact is also made apparent by the fact that only 3/74 groups survived until their group's randomly determined final round. This points towards a significant underestimation of the risks associated with consuming unsustainably, in terms of the average behaviour observed, potentially driven by several factors. For example, the shared consequences with participants' future and hypothetical selves, the responsibility and consequences being shared with others in the group, accompanied by a myopic (underestimating future consequences) view of the situation. All of which are characteristics of the relationship between consumption behaviour and sustainability, replicated by the AG.

4.1 Factor analyses on behavioural intentions

All factor analyses performed here take ordinal items, measured on 7-point Likert scales, as continuous by employing Pearson's correlations. This, as recent works suggest, is not a bigger assumption that the alternative method based on the use of polychoric correlations makes, i.e.

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that the underlying latent variables are bivariate normally distributed (Robitzsch, 2020). Moreover, there are reports that treating ordinal variables as continuous when they contain more than 3 scale points leads to more robust results when compared to the alternative method (Rhemtulla et al., 2012). Additionally, reported values are determined using (iterated) principal axis factoring (PAF) such that no distributional assumptions are necessary about the data. However, all analyses were also replicated using maximum likelihood (ML) estimation, providing a point of comparison and validation of the results. All results derived from the PAF estimation method were closely mirrored in the ML method, with slight deviations in some uniqueness estimations. Despite that, all likelihood-ratio tests comparing the saturated models to the derived 2 factor models were significant, supporting the same factor structures as the PAF estimation method.

Item	**f1_selfint (α=0.74)**	**f2_otherint (α=0.57)**	**Communality**
I would extract as much as possible from the resources.	0.7639		0.5762
I would extract as little as possible from the resources. (reversed)	0.7274		0.5307
I would extract as much as possible from the resources, as long as the probability of the end of the world is not too high.	0.5477		0.2935
The most important thing for me would be to benefit as much as possible from the resources.	0.5817		0.3308
I would intend to behave so as to leave everyone in the group as well off as possible.		0.3762	0.2624
I would extract as much as others from the resources.		0.4684	0.2156
The most important thing for me would be for everyone in the group to benefit as much as possible from the resource, without leaving anyone worse off than anyone else.		0.8771	0.7557

Table 1. The results of exploratory factor analysis (EFA) on internal intentions measurement items are shown. The loadings, for oblique rotated factors, on each of the underlying items are presented. The first factor, f1_selfint (α=0.74), collects items where intentions are framed negatively, i.e. intentions to behave selfishly. The second factor, f2_otherint (α=0.57), gathers intentions to behave in a manner that is other-regarding and cooperative. The communalities for each item are also presented.

4.1.1 *Behavioural intentions: Internal to the experimental setting*

We call internal behavioural intentions those concerning the very setting of the AG. These were elicited through self-reported items while participants were considering hypothetically being present in a setting mimicking the AG. Measurement items related to internal intentions were subjected to an exploratory factor analysis, the results of which are presented in Table 1. The presented factor loadings correspond to oblique rotation of the factors. A two-factor structure is revealed. The first factor, which we call f1_selfint (α=0.74), gathers items related to intentions to behave in such a way such that self-profit is maximised. These can be thought of as negatively

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framed intentions. The second factor, which we call f2_otherint (α=0.57), relates to other-regarding behavioural intentions, or positively framed intentions. This indicates that negatively and positively framed behavioural intentions elicit different types of responses.

Item	f1_sustwastebi (α=0.90)	f2_reducebi (α=0.92)	Communality
I would like to consume products and services in a sustainable way in the future.	0.8690		0.6555
I will try to consume products and services in a sustainable way in the future.	0.8620		0.7104
I will insist on consuming products and services in a sustainable way in the future.	0.8069		0.6494
I would like to produce less waste in the future.	0.6336		0.4993
I will try to produce less waste in the future.	0.6085		0.5707
I will insist on producing less waste in the future.	0.5824		0.6283
I would like to consume less in the future.		0.8643	0.6778
I will insist on consuming less in the future.		0.8774	0.7791
I am willing to consume less in the future.		0.8523	0.7177
How likely is it that you will consume less in the future?		0.5808	0.5763

Table 2. The results of exploratory factor analysis (EFA) on external intentions measurement items are shown. The loadings, for oblique rotated factors, on each of the underlying items are presented. The first factor, f1_sustwastebi (α=0.90), collects items about intentions to behave more sustainably and reduce the amount of waste produced. The second factor, f2_reducebi (α=0.92), gathers intentions to consume less. The communalities for each item are also presented.

4.1.2 Behavioural intentions: External to the experimental setting

We call external intentions those that are not specific to the experimental setting, i.e. the AG. These were elicited at the end of the experiment using self-reports on items adapted from (Si et al., 2020). An exploratory factor analysis was conducted on these items the results of which are presented in Table 2. The presented factor loadings correspond to oblique rotation of the factors. The analysis reveals a two-factor structure. The first factor, which we call f1_sustwastebi (α=0.90), relates to intentions to behave more sustainably and reduce the amount of waste produced. The second factor, which we call f2_reducebi (α=0.92), is related to intentions to consume less, or reduce consumption in general. This factor structure points at a difference in perceptio between behaving more sustainably and reducing waste, and consuming less.

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4.2 Internal and external intentions, and behaviour

Descriptive statistics for the variables employed in the statistical modelling phase are provided in Table 3. Namely, the variables shown are: AGE, i.e. participants' age; FEM, i.e. gender coded as 1=female and 0=male; avgrelconsum, i.e. the within-subjects average of extraction size relative to the rest of the group; f1_selfint, i.e. selfish internal behavioural intentions factor; f2_otherint, i.e. other-regarding internal behavioural intentions factor; f1_sustwastebi, i.e. external intentions to behave more sustainably/reduce waste; and f2_reducebi, i.e. external intentions to consume less.

Variable	Obs	Mean	Std. dev.	Min	Max
AGE	296	22.15	4.7	18	69
FEM	296	0.52	0.5	0	1
avgrelconsum	296	1.08	0.4	0.29	3.42
f1_selfint	296	0.00	0.9	-1.87	1.88
f2_otherint	296	0.00	0.9	-2.96	1.28
f1_sustwastebi	296	0.00	1.0	-5.20	1.16
f2_reducebi	296	0.00	1.0	-3.17	1.43

Table 3. Descriptive statistics for variables: AGE, i.e. participants' age; FEM, i.e. gender coded as 1=female and 0=male; avgrelconsum, i.e. the within-subjects average of extraction size relative to the rest of the group; f1_selfint, i.e. selfish internal behavioural intentions factor; f2_otherint, i.e. other-regarding internal behavioural intentions factor; f1_sustwastebi, i.e. external intentions to behave more sustainably/reduce waste; and f2_reducebi, i.e. external intentions to consume less.

Three linear regression models are fitted and presented in Table 4. The first model takes behaviour, i.e. avgrelconsum, as the dependent variable and both internal and external behavioural intentions as independent. The other two models use external intentions, to behave more sustainably and reduce waste; and external intentions to consume less, respectively, as dependent, while internal intentions are modelled as explanatory. The aim being to explore the extent to which even highly context-specific self-reported intentions are better connected to actual behaviour than to other self-reported measures of intentions. All models have a statistically significant F-statistic, indicating that the models fitted all have at least one effect which is different from zero, supporting the models' significance statistically.

4.2.1 Behaviour and intentions

In the first model (R^2=0.034), the effect of internal selfish intentions on behaviour is highly significant. Namely, it predicts higher relative extractions for participants with higher scores in selfish intentions, as one might expect. Interestingly, this is the only predictor with a statistically significant effect, and hence explanatory potential, on behaviour. The results indicate that only the negatively framed, context-specific intentions were able to explain

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subsequent behavioural outcomes in our data. This indicates that generally and positively framed intentions may be more susceptible to the IBG.

Independent variables	**Dependent: avgrelconsum**	**Dependent: f1_sustwastebi**	**Dependent: f2_reducebi**
f1_selfint	0.090**	-0.149*	-0.181**
f2_otherint	0.006	0.092	0.092
f1_sustwastebi	0.007		
f2_reducebi	-0.012		
AGE	0.005	0.000	0.013
FEM	0.025	0.441***	0.425***
_cons	0.962***	-0.219	-0.519*
R^2	0.03	0.11	0.12
N	296	296	296
F	2.26*	8.69***	10.24***

legend: * p<.05; ** p<.01; *** p<.001

Table 4. Three linear regression models, estimated with OLS, are shown. The first model uses all intentions variables as predictors and the behaviour variable, avgrelconsum, as dependent. The second model takes external intentions to behave more sustainably/reduce waste as dependent and internal intentions as independent. In the third model, external intentions to consume less are explained in terms of internal intentions. All models control for age and gender.

4.2.2 Internal and external intentions

The remaining models (R^2=0.11 and R^2=0.12) used internal, context-specific intentions to understand/explain external, general intentions. As shown in Table 4, both models exhibit very similar outcomes. Like in the first model, selfish internal intentions have a statistically significant effect on both external intention factors. In this case, of course, the effect is negative. Meaning that higher scores in the selfish intentions factor predict lower scores in, both intentions to behave more sustainably and reduce waste, and intentions to consume less.

Moreover, both models uncover a highly significant gender effect which was not present in the behavioural model. Namely, being female predicts higher scores in self-reported intentions to, both behave more sustainably and reduce waste, and intentions to consume less. The fact that this effect is not present in the behavioural model indicates that the IBG may be subject to gender effects, with the problem worsening for females with respect to males.

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5 DISCUSSION

5.1 Behaving more sustainably or consuming less?

In the real world, what makes consumption behaviour more sustainable is not so clear. Primarily due to complex mechanisms which are difficult (if not impossible) for people to account for when engaging in consumption. For example, there are rebound effects; whereby efforts to reduce impacts may have side effects in the opposite direction, potentially leading to worsened environmental or social impacts (Alcott, 2005, Sun and Trudel, 2015). Therefore, while the existence of such efforts may be considered "better" at first glance, the result may not be the desired one. The landscape is also influenced by competing messages communicated to consumers through green marketing and information campaigns (Polonsky and Rosenberger, 2001; Chen and Chang, 2013), emerging primarily due to competing interests of the market, which rarely align with solving the global climate and environmental crises, and imperfect information available to governments (Hepburn, 2010). The information overload that consumers experience as a result makes it difficult for them to develop a realistic understanding of what behaving sustainably entails (Schlaile et al., 2018). Even more so, in a setting where new understandings of and potential solutions to the problem are emerging, and the solutions that are most strongly advocated for, i.e. high entropy solutions like recycling, are almost certainly not enough. On top of that, societal scepticism surrounding science is at a surge (Rutjens et al., 2022), which only amplifies the potential for a distorted perception, particularly when the solution requires bigger changes to behaviour than just separating waste for recycling on disposal. All this complexity creates an unavoidable mismatch between what is perceived by consumers, and what really makes consumption more sustainable.

Our results offer empirical support for this idea. A factor analysis on behavioural intentions measurement items reveals that consuming more sustainably and reducing waste are related to a different factor than consuming less. Therefore, the associated items invoked different responses in participants, meaning that consuming less was perceived as different from consuming more sustainably and reducing waste. As discussed in Section 1.1.2, there is a pressing need to reduce the quantities consumed rather than consume the same or increasing amounts of greener (or marketed as greener) products. As such, consuming less is not only a means by which to be more sustainable, but also potentially a necessary step. In other words, while consumers may have a real desire to behave more sustainably and/or an understanding of the ethical need to do so, it may not be clear to them *what* this would entail. Even more so when actions required are more highly disruptive of the consumerist habits that we have developed through socio-economic systems that require the constant creation of consumer needs, and subsequent increased consumption levels, to strive.

The experimental setting was designed to create a clear definition of what can be considered sustainable behaviour. That is, group extractions that are smaller than or equal to the regeneration rate of the resource. In other words, it allowed us to observe people's behaviour when the definition of sustainable consumption is clear and so are the potential consequences of unsustainable consumption. Despite that, only three out of all 74 groups in the experiment survived until the final round and, consequently, managed to collect the contents of their private funds. This, together with the slow reaction to increasing risk or resource degradation seen in the between-subjects average behaviour, depicted in Figure 2, point towards a significant underestimation of risks associated with unsustainable consumption even in the presence of unrealistically perfect information.

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In sum, our results point to the need to shift attention away from consumer responsibility alone, and emphasise the need to look for alternative solutions. This is in line with recent research suggesting that we need to "look elsewhere for transformative opportunities" (Coffin and Egan–Wyer, 2022; p.107), where the authors argue the *gap* would be better characterised as a *cap* given that it originates primarily beyond the consumers' control.

5.2 Negatively framed, context-specific behavioural intentions and behaviour

As revealed by our factor analysis, intentions to behave without regard for how others may be affected, i.e. intentions to not behave pro-environmentally/socially or negatively framed intentions, elicited different types of response, than positively framed intentions; i.e. behavioural intentions to consume pro-environmentally/socially. Both negatively and positively framed intentions, were measured at a context-specific level; i.e. they were specifically addressing the setting of the AG. Alternatively, intentions can be general such that their context and setting are less concretely specified, like the intentions to be more sustainable, reduce waste or consume less, which we measured through self-reports at the end of the experiment, i.e. external intentions. General (i.e. non-context-specific) and context-specific intentions were examined in terms of their ability to explain behavioural outcomes in the experiment by means of a linear regression model. The model revealed a statistically significant effect only from negatively framed, context-specific behavioural intentions on behaviour. That is, general and positively framed intentions were unable to explain behavioural outcomes as measured in the experiment.

Since both external (general) intentions factors were positively framed, our results do not allow us to determine whether their inability to explain behaviour was due to their lack of contextual focus or due to being framed as positive. Most likely, both mechanisms are at work simultaneously. Closer inspection of the behavioural model reveals that the p-value for the effect of intentions to consume less on behaviour, is smaller than that for the effect of intentions to be more sustainable and reduce waste on behaviour, despite not being statistically significant. The former being better aligned with the context-specificity of the observed behaviour than the latter, suggests that context-specificity does indeed play a role. Further support for this idea is provided by the internal-external intentions models where negatively framed intentions had a stronger and more highly significant effect on intentions to consume less than it had on intentions to behave more sustainably and reduce waste. As such, what seems most likely is that the gap between intentions and behaviour is minimised when the contextual specificity of the measured intentions matches that of the measured behaviour. In other words, for purely self-reported data, intentions that are context-specificity compatible to the behaviours of interest are most likely to properly align with one another. However, said alignment is not necessarily representative of the degree of alignment between intentions and actual behaviour, which would contribute to the inability of research using self-reports to characterise consumers' real adoption of sustainable consumption practices. On the other hand, where behaviour is observed in the laboratory or the field, it most often becomes of high context-specificity, which would benefit from matching high context-specificity on measurement of intentions. Therefore, when it comes to understanding consumer behaviour that is representative of reality, better context-specificity alignment between intentions and behaviour is desirable.

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Our results point towards an improved ability to explain behaviour for negatively framed, over positively framed, intentions. Moreover, a further two linear regression models seeking to explain general intentions in terms of context-specific intentions result in similar outcomes. Namely, while positively framed intentions were unable to explain general intentions, negatively framed intentions had a statistically significant effect. Therefore, not only was a negative framing better correlated with behaviour, but also with further self-reported behavioural intentions of a different context-specificity. This further supports the superiority of negative framings of intentions when compared to positive ones.

In sum, our results suggest that using negative framings in the measurement of intentions and making them context-specific to the consumption setting of interest, can aid in closing the methodological portion of the gap between intentions and behaviour. Therefore, we propose that further research should include negative framings of intentions and make them as aligned with the context in which behaviour is observed as possible, to produce responses of higher fidelity. Moreover, our results call for care in interpreting results where self-reported measures of behaviour are used. Namely, good context-specificity alignment between intentions and behaviour measured through self-reports can result in an underestimation of the gap between reported intentions and real behaviour. In other words, while they may be able to explain self-reported behaviour, resulting in statistically significant effects, this may not be the case for actual behavioural outcomes.

5.3 Gender and the intentions-behaviour gap

The internal-external intentions models revealed a statistically significant effect of gender on external intentions which was not found in the behavioural model. Namely, both models consistently predicted higher scores of self-reported intentions for females than for males. However, this effect not being present in the behavioural model indicates that while gender has something to say about self-reports, this is not the case when it comes to actual behaviour. This can either be explained by males underreporting on their behavioural intentions to consume more responsibly with respect to reality, or by females overreporting their intentions. However, theoretically the latter seems more likely. Therefore, this result may indicate that females are more concerned with being perceived socially as more sustainable than males, without this translating into an actual behavioural outcome. An alternative perspective is that females may have a more distorted perception of what being sustainable entails, resulting in a gap between how sustainable they intend to be and their actual behaviour. The opposite could also be true, that males have an equally distorted and inverted perception of what being more sustainable entails, however, this would require their actions to be more sustainable than they intend them to be, which is highly unlikely given the context and other findings in our analysis. In sum, the IBG can be thought as being moderated by gender, with the problem becoming worse for females when compared with males. Therefore, our results call for a reconsideration of research reporting on increased adoption of SCB for females over males, particularly when relying only on self-reported data to make such claims.

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5.4 Policy implications

Policy's heavy focus on individual action and on high entropy solutions, like recycling, is not only certain to not achieve more sustainable futures, but it also contributes to distorting public perception, hence enlarging the IBG (or lowering the cap). The same goes for (unregulated) marketing campaigns that tend to reduce the problem to qualitative aspects of consumption and with the clear incentive to use these to achieve market differentiation. An institutional perspective is necessary, where structural change requires bigger shocks to the system than a single micro-level actor, like consumers, can hope to achieve.

6 CONCLUSIONS

A transition to a CE requires that certain changes are made to consumption behaviour and patterns to succeed. Our current understanding of consumer behaviour in contexts of ethical significance, like sustainability, has been shown to be strongly limited by the consumers' tendency to not act on their intentions - the intention-behaviour gap phenomenon. In turn, this hinders the possibility of developing the right policy, business models and marketing strategies for successfully transitioning to more sustainable futures. In this report, we explored the relationship between consumer perception, reported intentions and actual behaviour by means of a decision-making experiment that we designed based on the CPR framework: The Armageddon Game. The experiment allowed to observe behaviour representative of the situation of interest (i.e. SCB) directly, rather than relying on self-reports. Based on our results, we claim that future research should explore the use of negatively framed measures of behavioural intentions as they seem to better align with actual behavioural outcomes. Additionally, considering a previously undocumented gender effect on the IBG that arises from our analysis, which is enlarged for females in comparison to males, would require further attention from future research. Overall, the results point to an inability of consumers to correctly estimate the full extent of the consequences of their externalities, even in the presence of quasi-perfect information (and in a much less complex setting than the real world), when these would take place in the future and are probabilistically determined (like in the real world). Moreover, this also contributes to building a distorted understanding of what behaving sustainably actually means. As such, our results call for a policy shift away from its dominant reliance on individual responsibility, and towards creating the right environment for the desired behaviours to arise.

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APPENDICES

A. The Armageddon Game – A generalised definition and experimental parametrisation

The Armageddon game (AG) is, at its core, a common pool resource (CPR) extraction game in which, as the CPR deteriorates due to overconsumption, the probability of a catastrophic outcome for agents increases. Agents share access to a CPR from which they will have to choose how many tokens, between $\boldsymbol{x_{bot}}$ and $\boldsymbol{x_{top}}$, to extract once every round. Tokens extracted by each agent are collected in their respective private funds. At the end of every round $\boldsymbol{t}$, the common pool contains $\boldsymbol{G_t = G_0 - \sum_{i=1}^{N} x_{i,t}}$ tokens, where $\boldsymbol{x_{i,t}}$ is agent $\boldsymbol{i}$'s extraction from the CPR at round $\boldsymbol{t}$, $\boldsymbol{G_0}$ is the size of the CPR at the beginning of the game, and $\boldsymbol{N}$ is the number of agents sharing the CPR. Then, a probability $\boldsymbol{P_t = f(G_t)}$, is computed such that $\boldsymbol{f}: \mathbb{Z} \to [\boldsymbol{0}, \boldsymbol{1}]$ is a monotonically descending function. In turn, $\boldsymbol{P_t}$ is the probability that the game will end abruptly, and all private funds will be emptied, hence leaving all agents earning nothing. Provided that the game continues onto the next round, the CPR regenerates $\boldsymbol{R}$ tokens (fixed across rounds) such that $\boldsymbol{G_{t+1} = G_t + R}$, and the extraction process is repeated once again. In the following paragraphs we describe the game using the parametrisation that was employed in the experiment for further clarity. Figure 1 provides a flow chart of the AG for reference.

In the experiment, a group of 4 players shares a common pool, G, which starts off containing $G_0 = 1300$ tokens. In each round, each player must decide independently on an integer number of tokens between 1 and 18 to consume from the common pool. That is, player i's consumption in tokens from the common pool in round t is $1 \leq x_{i,t} \leq 18 \in \mathbb{Z}$. Each player has a private fund which accumulates their own tokens over all rounds, such that player i's private fund at time t is given by $Y_{i,t} = \sum_t x_{i,t}$. Once all players have decided on their consumption for the round, i.e. at the end of the round, the common pool contains

$$G_{\mathrm{t}} = \min(G_{\mathrm{t-1}} + 20, G_0) - \sum_{\mathrm{i=1}}^{4} \mathrm{x_{i,t}} \qquad \textbf{(Eq.1)}$$

tokens. The first term of Eq.1 means that the common pool has the capacity to recover a maximum of 20 tokens from the end of one round to the start of the next, without ever exceeding its original size $G_0 = 1300$. Then, this starting size of the resource will be reduced by the sum of all players' extractions that round, as shown by the second term of Eq.1. The reason why this is important, is that G_{t} will determine a probability of moving onto the next round according to the following expression

$$p_t = \frac{G_t}{G_0} = \frac{G_t}{1300} \qquad \textbf{(Eq. 2)}$$

meaning that with probability $1 - p_t$ an Armageddon event will take place. If an Armageddon event takes place at any time during the game, all private funds are emptied, and the game is

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terminated abruptly for all 4 players of the group (i.e. a catastrophic outcome for everyone). It is essentially the "end of the world". On the other hand, provided an Armageddon event does not take place, the common pool is replenished according to the rule described by Eq.1 and the next decision phase begins. In sum, the AG is a dynamic CPR extraction game since players are faced with the decision phase not just once, but once every round. Moreover, it is not just a repeated game since the outcomes of one round will determine the starting conditions for the next.

At the beginning of the game, a round number is chosen at random and unknown to all players (and in the context of the experiment also to the experimentalist), which we call the **final round**. Once a group completes the final round, provided that they move onto the next (i.e. an Armageddon event doesn't take place), the game ends and players keep the contents of their private funds. **Payment 1** is equal to the monetary value of the contents of a player's private fund when the game ends, which is calculated using the exchange rate 10 tokens = 1€. This means that players whose group completes the final round will receive a **Payment 1** given by Eq.3 below

$$Payment\ 1_i = \frac{1}{10}\left(\sum_{t=1}^{T} x_{i,t}\right) € \qquad \textbf{(Eq.3)}$$

where T here is the final round. On the other hand, if a group does not reach and complete the final round, which is any case in which an Armageddon event takes place, all private funds are emptied. Thus, in this case all players would receive a reward of 0€ for **Payment 1**.

By only offering the opportunity to receive any kind of reward through survival over the whole duration of the game, that is **Payment 1**, players would be forced to try to survive until the last round if they wanted any chance at earning anything at all. Therefore, on top of **Payment 1**, a second reward is designed into the game to avoid inducing a bias towards unrealistically forward-looking behaviour. This is achieved by giving each individual extraction a value of its own, which is not dependent upon the survival of the world. At the end of the game, one of the rounds played by the group is selected at random, we call this the **payment round**, τ. A player's extraction in round τ will determine **Payment 2** using the same exchange rate between tokens and euros as shown in Eq.4.

$$Payment\ 2_i = \frac{x_{i,\tau}}{10} € \qquad \textbf{(Eq.4)}$$

At the end of the game, the **Total Payoff**, for any given player is given by the sum of payments 1 and 2 for the same player (and, in the experimental setting, the show-up fee of 3.5€ which is paid to all participants regardless of the outcome of the game). Hence,

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$$Total\ Payoff_i = Payment\ 1_i + Payment\ 2_i$$
$$= \begin{cases} \frac{1}{10}\left(\sum_{t=1}^{T} x_{i,t}\right) + \frac{x_{i,\tau}}{10} € & \text{if Armageddon} = FALSE \\ 0 + \frac{x_{i,\tau}}{10} € & \text{if Armageddon} = TRUE \end{cases} \quad \textbf{(Eq. 5)}$$

so players have an incentive to increase their token consumption per round to increase both the size of their private fund and the return from **Payment 2**. However, they also have an incentive, opposing the first, to reduce their consumption and, in turn, keep the probability of survival large enough, and hence avoid losing their private funds to an Armageddon event.

In the experiment, the final round number is determined at random but confined to lie between 35 and 40, which provides an objectively similar chance of earning a non-zero **Payment 1** to all groups of participants. However, participants are not made aware of the exact interval of possible values for the final round, so that no end-game dynamics are expected. Additionally, in the experimental implementation of the game, another round is chosen at random for each group at the beginning of the game, which we call the **Z-Round**, $15 \leq t_z \leq 25$. Up to period t_z, the probability of an Armageddon event taking place is kept at zero. From and beyond round t_z, the probability of an Armageddon event taking place is p_t, as shown in Eq.2. The role of this period is twofold. First, it ensures that all groups play a minimum of 15 rounds, which makes all data collected comparable up to that round. Second, it increases the probability of reaching and completing the final round, very significantly for groups who behave sustainably on average but mildly for groups who do not. Again, the value of t_z is unknown to participants, so they are expected to play as if an Armageddon event was possible at any round. Especially given that, while before t_z the probability of survival is always 1, beyond that, the probability of survival depends on the size of the common pool G_t, which is determined by all previous rounds, regardless of whether they took place before or after t_z. As such, groups who behave more unsustainably before round t_z, are still almost certain to experience an Armageddon event before reaching the final round.

B. A utility-theoretical model of the Armageddon game

A utility-theoretical model is developed here to provide a set of benchmark solutions. Namely, the static Nash equilibrium, whereby other payer's behaviour is taken as given and individual profit is maximised, and the static collective optimal strategy, in which collective profit is maximised and cooperation/equal behaviour may be assumed from all agents.

As mentioned previously, we look for static solutions, i.e. solutions where agents are assumed to repeat the same decision in every period, such that an arbitrary player i extracts the same amount, x_i, in all periods. Since two different payments can be obtained by agents (see Section 3), their profit (utility) will comprise a term corresponding to payment 1 and another to payment 2. The former will vary with the world's survival probability and the size

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of the extraction, which under the assumption of static behaviour remains constant over time. Similarly, the latter term is a fixed x_i (as shown below) since agents are guaranteed to earn exactly one of their extractions during the game. We write player i's utility *from* some round t as follows:

$$u_{i,t} = p_t x_i + \frac{1}{T} x_i \quad \textbf{(Eq. 6)}$$

Here, T is the number of rounds played, which we will assume is the final round without loss of generality. Since one of the T rounds played is guaranteed to be the payment round and there is an equal probability that any of them will be the payment round, it follows that said probability is $1/\mathrm{T}$. This is captured in the second term of Eq. 6. On the other hand, the first term relates to payment 1, and is defined as the player's consumption weighted (multiplied) by the probability of survival of the world (i.e. the probability of moving on to the next round, or earning their extractions if the round played is the final one). In other words, survival being more probable increases individual utility and so does a greater individual consumption. However, since said probability decreases as individual extractions increase, there is a sort of trade-off between the two, which leads to the desired social dilemma.

Given the foundations of the AG, a player in a group that does not reach the final round will only receive profit from payment 2. In other words, an Armageddon event taking place ensures that no utility is gained from the accumulated extractions. Under the sole assumption that reaching the final round is more desirable than not under all circumstances[7], we model the case of reaching the final round to find meaningful benchmark solutions. We define player i's total utility at the final round as the sum of all local utilities as given by Eq.6 up to the final round:

$$U_{i,T} = \sum_{t=1}^{T} u_{i,t} = x_i \sum_{t=1}^{T} p_t + x_i \quad \textbf{(Eq. 7)}$$

Since we are considering static behaviour of all players, and the common pool regenerates at a constant rate per round of 20 tokens, a group's collective consumption, C, can be sustainable, if $C \leq 20$, or unsustainable, if $C > 20$. This allows us to write the size of the common fund at time t (i.e. Eq.1) as a function of the common pool's original size G_0, rather than as a recurrence relation between a round and the one preceding it. The resulting expression is as follows:

$$G_t = \begin{cases} \mathrm{G}_0 - (X_j + \mathrm{x}_\mathrm{i}) & \text{if } \mathrm{C} \leq 20 \\ \mathrm{G}_0 + 20(t-1) - t(X_j + \mathrm{x}_\mathrm{i}) & \text{if } \mathrm{C} > 20 \end{cases} \quad \textbf{(Eq. 8)}$$

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[7] The final round's minimum possible value is 35, and the minimum possible extraction per round is 1 token. Therefore, even when minimising all extractions, reaching the final round will result in a higher utility (i.e. 35+1 tokens) than not reaching it while maximising payment 2 (i.e. 0+18 tokens).

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Where $X_j = \sum_{j \neq i}^{4} x_j$ is the sum of other players' consumption at any given round (since behaviour is assumed to be static), such that $X_j + x_i = \sum_{i=1}^{4} x_i$. Therefore, player i's total utility at the final round, i.e. Eq.7, can be written as follows:

$$U_{i,T} = \begin{cases} x_i \left(\sum_{t=1}^{T} \frac{G_0 - (X_j + x_i)}{G_0} + 1 \right) & \text{if } C \leq 20 \\ x_i \left(\left(\sum_{t=1}^{T} \frac{G_0 + 20(t-1) - t(X_j + x_i)}{G_0} \right) + 1 \right) & \text{if } C > 20 \end{cases} \quad \textbf{(Eq. 9)}$$

$$= \begin{cases} x_i \left(T \frac{G_0 - (X_j + x_i)}{G_0} + 1 \right) & \text{if } C \leq 20 \\ x_i \left(T + \frac{20}{G_0} \left(\frac{T(T-1)}{2} \right) - \frac{T(T+1)}{2G_0} X_j - \frac{T(T+1)}{2G_0} x_i + 1 \right) & \text{if } C > 20 \end{cases}$$

Taking the partial derivative of the total utility, $U_{i,T}$, with respect to arbitrary player i's consumption, x_i, gives the following:

$$\frac{\partial U_{i,T}}{\partial x_i} = \begin{cases} T \left(1 - \frac{X_j}{G_0} - \frac{2x_i}{G_0} \right) + 1 & \text{if } C \leq 20 \\ T \left(1 + \frac{20(T-1)}{2G_0} - \frac{(T+1)}{2G_0} X_j - \frac{(T+1)}{G_0} x_i \right) + 1 & \text{if } C > 20 \end{cases} \quad \textbf{(Eq. 10)}$$

The *reaction function*, i.e. an expression which defines an arbitrary player's individual utility-maximising consumption decision in term of other people's behaviour, is obtained by setting $\frac{\partial U_{i,T}}{\partial x_i} = 0$ and solving for x_i to give the following:

$$x_i = \begin{cases} \frac{G_0}{2} + \frac{G_0}{2T} - \frac{X_j}{2} & \text{if } C \leq 20 \\ \frac{G_0}{(T+1)} + \frac{10(T-1)}{T+1} + \frac{G_0}{T(T+1)} - \frac{X_j}{2} & \text{if } C > 20 \end{cases} \quad \textbf{(Eq. 11)}$$

Setting $x_{Nash} = x_i = x_j, \forall i, j \in I$, where $I = \{1, 2, 3, 4\}$ is the indexing set for players in a group, and solving for x_{Nash}, gives the following static Nash equilibrium:

$$x_{Nash} = \begin{cases} \frac{\frac{G_0(T+1)}{(N+1)}}{} & \text{if } C \leq 20 \\ \frac{1}{(N+1)} \left(\frac{2G_0}{T} + \frac{20(T-1)}{T+1} \right) & \text{if } C > 20 \end{cases} \quad \textbf{(Eq. 12)}$$

We now look for the static *collective optimal* (CO) strategy to compute a benchmark solution which may allow for unsustainable but cooperative behaviours. In this case, rather than through its sustainability or lack thereof, cooperation will be operationalised in terms of the

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group's joint profits. Therefore, we begin by defining collective profit as the sum of all the individual total utilities, $U_{i,T}$, that is:

$$\Pi_T = \sum_{i=1}^{4} U_{i,T} \quad \textbf{(Eq. 13)}$$

Since this pertains to cooperative behaviour, we may assume that all players will split the collective profit in equal parts. In other words, all players may be assumed to consume the same amount, $x_{Co} = x_i = x_j, \forall i,j \in I$. Therefore, we may write:

$$\Pi_T = \begin{cases} \sum_{i=1}^{N}\left(x_{Co}(T+1) - \frac{NT}{G_0}{x_{Co}}^2\right) & \text{if } C \leq 20 \\ \sum_{i=1}^{N}\left(x_{Co}\left(T + \frac{20T(T-1)}{2G_0} - \frac{NT(T+1)}{2G_0}x_{Co} + 1\right)\right) & \text{if } C > 20 \end{cases} \quad \textbf{(Eq. 14)}$$

$$= \begin{cases} N(T+1)x_{Co} - \frac{N^2T}{G_0}{x_{Co}}^2 & \text{if } C \leq 20 \\ Nx_{Co}\left(T + \frac{20T(T-1)}{2G_0} - \frac{NT(T+1)}{2G_0}x_{Co} + 1\right) & \text{if } C > 20 \end{cases}$$

Finally, by solving $\frac{\partial \Pi_T}{\partial x_{Co}} = 0$ for x_{Co} it follows that the CO strategy is as follows:

$$x_{Co} = \begin{cases} \frac{G_0(T+1)}{2N} & \text{if } C \leq 20 \\ \frac{1}{2N}\left(\frac{2G_0}{T} + \frac{20(T-1)}{T+1}\right) & \text{if } C > 20 \end{cases} \quad \textbf{(Eq. 15)}$$

The benchmark solutions

It follows from Eq. 12 and 15 that, both in the case of sustainable and unsustainable group-level consumption, $x_{Co} = \frac{N+1}{2N}x_{Nash}$. Since the factor by which the CO strategy and the Nash equilibrium differ is $\frac{N+1}{2N} < 1 \Rightarrow x_{Co} < x_{Nash}$, the model predicts a tragedy of the commons outcome, whereby the maximisation of individual profit requires a higher consumption, and consequent resource depletion, than would be optimal for the collective. As expected in a CPR game where the tragedy of the commons comes into play, the model predicts that these strategies will differ increasingly as the number of players sharing the resource, N, increases. It is worth clarifying at this point that this is only one of many possible behavioural models of the game. Rather than predicting behaviour in the experiment, it aims to serve as a basis for comparison of the observed behaviours with a set of realistic individualistic and cooperative levels of consumption, given the model and its underlying assumptions.

To compute numerical values for x_{Co} and x_{Nash}, we must substitute in Eq. 12 and 15 in accordance with the parametrisation employed in the experiment. Namely, there are four

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agents per group, $N = 4$, the final round lies between 35 and 40 allowing us to pick a value of $T = 40$, and the starting size of the common pool is $G_0 = 1300$. This parametrisation leads to the following benchmark solutions:

$$x_{Nash} = \begin{cases} 10660 & \text{if } C \leq 20 \\ 17 & \text{if } C > 20 \end{cases} = 17 \quad \text{(Eq. 16)}$$

$$x_{Co} = \begin{cases} 6662.5 & \text{if } C \leq 20 \\ 10.65 & \text{if } C > 20 \end{cases} = 11 \quad \text{(Eq. 17)}$$

Not surprisingly, given the myopic representation of the utility model, even the cooperative solution is over 100% above the sustainable threshold of 5 tokens.

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