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## ABSTRACT

This study uses behavioral science to develop recommendations for incentivizing lower-polluting consumer choices. To achieve this, we first sought to understand the motivations that underpin consumers' choices of higher-polluting products and services. We used the Green Bundle framework as a guide to evaluate and synthesize the published research literature on statistically significant behavior interventions for promoting environmentally conscious consumer choices. We analyzed a decade of research published between 2012 and 2023, focusing on behavioral interventions that reduce polluting consumption behavior and reported quantitative data. We found that successful interventions often emphasize private benefits, such as higher product quality, financial incentives, and positive social aspects, rather than solely focusing on environmental benefits. One way policymakers can promote sustainable consumption is through public education campaigns that highlight the individual advantages of eco-friendly choices. These campaigns can leverage multiple communication platforms, including websites, social media, and advertisements, to educate consumers about the personal benefits of sustainable practices, such as cost savings and improved health. By enhancing consumer awareness and knowledge, these initiatives empower individuals to make informed decisions that align with their interests. In addition to developing policy recommendations, we used framing, a tool from behavioral science to design experiments that evaluate the efficacy of different email message wordings in increasing research seminar attendance behavioral intentions. We found that combining altruistic and self-interest motivations was the most effective approach. We conclude that policymakers and organizations should communicate information about the personal benefits of eco-friendly behavior, design communication messages that incorporate a combination of altruistic and self-interest motivations, and enhance the visibility of green behavior to others to encourage more sustainable and less polluting consumer actions. This study's findings can inform policymakers and organizations in developing effective policies and communication strategies to promote eco-friendly consumer behavior.

# EXECUTIVE SUMMARY

## *Background*

A major issue today is overconsumption, which has been connected to the global environmental crisis (MacKinnon, 2021; Waters, 2021). Increased consumption tends to negate the positive environmental effects of technological advancements (Haberl et al., 2020), necessitating that lifestyle changes accompany technological progress (Wiedmann et al., 2020). Altering behavior and consumption patterns can significantly decrease energy usage and related emissions (Edenhofer et al., 2014). The 2022 Intergovernmental Panel on Climate Change (IPCC) report emphasizes the importance of socio-cultural factors—such as individual choices, behavior, lifestyle changes, social norms, and culture—in driving demand-side mitigation efforts. The IPCC report suggests this includes shifting demand towards sustainable consumption, teleworking, adopting diets that reduce food waste and overconsumption, and engaging in energy-saving social practices. We devised a framework to investigate consumer behaviors most relevant to the adoption of lower-polluting products. This framework outlines the concepts prevalent in the existing literature and the underlying assumptions regarding drivers of pro-environmental consumer behavior. It serves as a guide for our evaluation and synthesis of the statistically significant published research literature. By comprehending strategies that have successfully influenced consumer behavior towards eco-friendliness, we are better equipped to formulate policy recommendations that encourage environmentally conscious consumer choices.

## *Objectives and Methods*

This research develops recommendations, based on behavioral science, for better information-based interventions to facilitate lower-polluting product and service choices by consumers. Secondly, it designed a communication campaign informed by insights from the systematic review.

Our search terms were selected to identify research focusing on statistically significant behavioral interventions that promote environmentally conscious consumer choices. We specifically targeted interventions such as field experiments, nudges, and randomized controlled trials, as we sought to understand how behavior could be influenced through these approaches.

We analyzed a decade of research by searching the Web of Science for articles published between 2012 and 2023. Our inclusion criteria encompassed studies that investigated methods for reducing polluting consumption behavior and reported statistically significant quantitative data. The postdoctoral researcher independently reviewed all titles and abstracts from the search results, consulting the full article text when abstracts were insufficient for making an inclusion decision. They then classified each article as either included or excluded. Similarly, teams of two or three research assistants independently completed the full assessment process, met to discuss and resolve discrepancies in their classification decisions, and reached a final consensus.

This consensus was then compared with the postdoctoral researcher's classification decision.

To analyze the data, we employed the Green Bundle framework, which emphasizes the importance of recognizing the private benefits that consumers gain from making environmentally-friendly purchasing decisions. It underscores that sustainable consumption behaviors are often driven by a combination of environmental and private benefits, and both of these factors must be considered to promote sustainable consumption effectively. Private benefits can include things like convenience, cost-effectiveness, social status, and personal satisfaction. By considering the private benefits that consumers derive from sustainable products, the Green Bundle framework helps to create a more nuanced understanding of consumer behavior. It recognizes that consumers make decisions based on a range of factors beyond just environmental considerations and that these factors can be leveraged to encourage sustainable consumption.

Accordingly, we coded the specific private benefit information used to alter consumer behavior. Additionally, we conducted two experiments on Amazon Mechanical Turk (MTurk) to evaluate the efficacy of various email message phrasings in increasing hypothetical research seminar attendance.

## *Results*

Our analysis of the studies aligns with the Green Bundle framework, which posits that successful interventions typically emphasize private benefits rather than solely focusing on environmental or planetary advantages. Quality, financial, and social aspects were the most frequently employed behavior change techniques. The quality category within the Green Bundle pertains to actual or perceived consumer benefits of a product and reduced costs associated with selecting eco-friendly items or adopting a sustainable behavior. Financial aspects involve monetary savings or rebates obtained through behavior changes. Social factors concern the social status gained by purchasing and consuming products endorsed by in-group members or adhering to social norms and expectations. Less frequently used interventions include information about health benefits (such as those associated with vegetarian or organic food) and emotional returns (such as being in a positive mood). Our findings suggest that effective interventions often highlight private benefits, while the few studies that do not, rely on hypothetical or self-reported data. Studies relying on self-reported behavior are generally considered to be less reliable or of lower quality compared to studies that report actual behavior because self-reports are subjective and susceptible to biases, social desirability, memory distortions, and individual interpretation, whereas direct observation or measurement of actual behavior provides more objective and accurate data.

Implementing policies that showcase the financial benefits of environmentally friendly behavior can be a successful approach. Enhancing the visibility of green behavior to others and designating green options as the default can significantly influence people's actions, leading to more frequent green choices. To summarize, the Green Bundle framework emphasizes taking a more comprehensive approach to sustainable consumption by considering private benefits. Information policy strategies that highlight private benefits and make green options visible and accessible can encourage sustainable choices. However, the emphasis on the specific private benefits depends on the type of behavior being targeted. For example, public transportation will have different private benefits than food.



For our second objective, we devised a communication campaign to enhance CARB's capacity to widely disseminate its funded research findings. The first experiment's results did not demonstrate any positive effects of using "don't miss out" and "human connection" phrasings for increasing the intention to attend a hypothetical online research seminar. These wordings were inspired by common business practices—fear of missing out and loss aversion. In contrast, the second experiment, which was directly informed by insights from the systematic review, emphasized the importance of combining egoistic and altruistic motivations. The phrase "We need your insights, inputs, and ideas" significantly increased intention to attend a hypothetical online research seminar. While we recognize that this phrasing might not apply to research seminars presented to the public, where CARB doesn't seek input, it might be more applicable to in-house seminars. These results further underscore the relevance of the Green Bundle framework in modifying behavior across various domains.

### *Conclusion*

The Green Bundle framework, which is supported by the reviewed studies, suggests that effective interventions should incorporate information about both private benefits and environmental benefits, rather than relying solely on the latter. However, the studies analyzed do not explicitly investigate the exact distinction between public and private benefits, as they did not take into account the significance of the Green Bundle framework. Consumers are frequently unaware of the personal benefits associated with greener behavior. Providing information about quality, social status, health, financial advantages, and emotional returns can encourage more sustainable and less polluting consumer actions. Utilizing a combination of altruistic and self-interest motivations can effectively drive behavior change in some cases. Designing communication messages that incorporate this blend can be an efficient way to modify consumer behavior. As an example, our suggested message, "We need your insights, inputs, and ideas," exemplifies how these motivations can be effectively employed to increase participation in research seminars.

## FRAMEWORK FOR RESEARCH INTO CONSUMER BEHAVIOR: THE GREEN BUNDLE

One major problem today is overconsumption, which has been linked to the planet's environmental crisis (MacKinnon, 2021; Waters, 2021). Because increasing consumption has counteracted environmental impact improvements from improved technology (Haberl et al., 2020), lifestyle changes must complement technological advancements (Wiedmann et al., 2020). Changing behavior and consumption patterns has the potential to substantially reduce energy use and associated emissions (Edenhofer et al., 2014). According to the 2022 Intergovernmental Panel on Climate Change (IPCC) report, socio-cultural factors (which are associated with individual choices, behavior, lifestyle changes, social norms, and culture) play an important role in demand-side mitigation efforts. According to the IPCC report, this includes shifting demand towards sustainable consumption (e.g., intensive use of long-lasting repairable products), teleworking, dietary shifts to avoid food waste and overconsumption, and social practices that result in energy savings. The current review examines the effectiveness of existing successful interventions to reduce overconsumption behavior.

While other literature reviews have examined how to promote sustainable behavior, they have not emphasized the importance of private or personal benefits for encouraging eco-friendly behavior. In contrast, our literature review utilizes the Green Bundle framework, which highlights the significance of considering both environmental and private benefits to promote sustainable consumption. By utilizing this framework, which serves as a unifying principle for understanding this literature, we can gain a more comprehensive understanding of how to encourage eco-friendly behavior. For example, Abrahamse et al. (2005) looked at intervention studies aimed at household energy conservation and found that the majority of the research focused on changing individual knowledge or perceptions about energy use with little focus on financial rewards. Steg and Vlek (2009) provided an overview of how environmental psychologists have studied interventions aimed at promoting pro-environmental behavior. They underscored the significance of employing experimental designs and measuring actual behavior, while also emphasizing the need for interdisciplinary collaboration, as environmental problems encompass ecological, technological, and socio-cultural dimensions in addition to psychological factors. Byerly et al. (2018) reviewed 160 experimental interventions relevant to environmental impact and found that providing information about social norms and altering decision contexts can promote environmentally friendly actions, particularly regarding water conservation, sustainable land management, and decreased meat consumption. Rau et al. (2022) concluded that the most effective interventions combine multiple intervention types (e.g., improved infrastructure, education, feedback) or make sustainable options the default. A recent review by Constantino et al. (2022) considers the use of social norms for climate action.

None of these articles, however, consider the fundamental importance of private or personal benefits, beyond economic rewards, for increasing green purchasing behavior. Our use of the Green Bundle framework addresses this research gap as a new way of conceptualizing this line of research and predicts that interventions will be less successful if they focus purely on benefits to the planet and not benefits to the consumers themselves.













































## *Discussion*

Overconsumption is the strongest determinant of increased global environmental and social impact (Wiedmann et al., 2020), and reducing consumption plays an important role in demand-side climate change mitigation efforts (IPCC, 2022). Understanding how to create effective behavioral interventions for reducing consumption is therefore critical to reducing this environmental impact. Effective interventions use information about private benefits to change consumer behavior and reduce consumption.

The most frequently used type of behavior change technique is social, and these were almost always in the form of descriptive norms that conveyed information about others' behavior. According to the Green Bundle framework, social status benefits. Social status is defined as "the perceived or actual standing of an individual relative to others on a dimension of social relevance (e.g., traits, economic standing, abilities)" (Rose & Vogel (2020), p. 4754). The effectiveness of different social norm information on changing behavior would therefore be expected to vary as a function of how much people are being observed (or think they are being observed) by others. For example, Delmas and Lessem (2014) found that publicly posting the relative standing of different residence hall rooms' electricity consumption was effective to reduce electricity usage in contrast to the same information provided privately to the individuals. The ineffectiveness of private messaging might be explained because this experiment did not involve any monetary rewards. The students are not paying their electricity bill separately but rather as part of their residence fees. This is in contrast to most utility bills that would contain similar social norm information about households' consumption relative to neighbors' consumption. Monetary incentives such as reduced electricity bills can enhance the influence of private information. However, these incentives may also diminish the reputation-based signal of conservation, as individuals might be perceived as conserving solely to save money.

If people behave in line with social norms simply because they believe that they are being observed by others, this is known as public compliance (Festinger, 1953). Public compliance typically occurs when behavior can be publicly observed, regardless of whether or not individuals privately accept that others' behavior is the right thing to do (Aronson et al., 2013). However, if individuals do privately accept that the descriptive norm information represents the correct way to behave, the behavior would be likely to occur regardless of how much the behavior can be observed by others. For instance, if someone determines that adopting more environmentally friendly practices is morally correct after receiving social norm information, they would subsequently be inclined to maintain such behavior even when it cannot be publicly observed.

Behaving in a manner consistent with personally held beliefs ties into the debate about whether people behave prosocially due to altruistic or egoistic motivations. Pure altruism, is driven solely by a concern for the well-being of others, while egoist behavior is motivated by self-interest. It is important to note that behavior that appears purely altruistic on the surface can often be influenced by egoistic motivations as well. According to Andreoni (1990), social pressure, guilt, sympathy, or simply a desire for a 'warm glow', which stems from the self-esteem boost derived from improving the welfare of others, may play important roles in the decisions of individuals to make donations to privately provided public goods, such as charity. Egoistic motivations for pro-social behavior are the basis of the Green Bundle framework, which states that seeking self-benefits is a powerful driver of pro-social behavior. These prosocial self-benefits have been described as gaining praise, enhancing self-image, improving mood, avoiding sanctions for norm

violations, avoiding guilt, and avoiding shame (Batson et al. 2011).

Findings from the studies we examined are broadly in line with the Green Bundle framework, which states that successful interventions generally use information about private benefits rather than focusing solely on benefits to the planet or environment. Only one study (Brunner et al., 2018) measured actual consumer behavior and utilized only environmental benefits (in the form of color-coded carbon footprint labels). Although not directly examined by the authors, the effect could be due to people wanting to avoid any social stigma from purchasing items marked as environmentally unfriendly at an urban university cafeteria. Any decisions where an item is purchased and displayed publicly would be more likely to fall in line with social norms. Examining differences between in-store and online purchases—which may be less subject to social desirability decisions—would be an area worth further exploration. Critically, these decisions need behavioral measures because the current literature already suggests that hypothetical online decisions still show patterns consistent with social desirability defined as behaving in a manner that is consistent with what is perceived as desired by salient others (Kuncel & Tellegen, A. (2009). Although, perhaps these patterns of online decisions could be due to enhancing self-image or improved mood rather than avoiding sanctions for norm violations.

One additional consideration that is worth further study is whether sustainable consumption that enhances self-image or improves mood could be undermined by explicitly referring to these private benefits. In other words, the purchase provides these private benefits to consumers only to the extent that people are not overtly aware that their true motivation is for egoistic rather than altruistic reasons. Perhaps behavioral interventions that strongly imply these private benefits without making them explicit would be ideal in this type of scenario.

The Green Bundle framework and the studies examined in this review support the idea that increasing consumer awareness of private benefits such as quality, social status, health, monetary savings, and emotional returns are important for successfully making consumer behavior more environmentally friendly and reducing overconsumption. Information interventions based on this framework can complement technological improvements to reduce pollution and the harmful environmental impact of overconsumption.

### *Recommendations*

Green Bundle framing interventions have emerged as an effective tool to promote sustainable consumption patterns by emphasizing the private benefits that environmentally friendly products can provide. These interventions aim to promote the adoption of sustainable behaviors by leveraging the psychological principles of decision-making. However, there are important factors that need to be considered before implementing these strategies. These factors include both product attributes and situational context.

When implementing these interventions, it is important to consider the specific needs satisfied by the product category. Appeals that closely match these needs are more persuasive for consumers than less relevant appeals as shown in the marketing literature more generally (Schmidt, 1999). For example, emotional value will be highly salient for consumers when purchasing items with experiential characteristics because of the complementarity between the emotionally driven purchase experience and the value source (D'Souza et al., 2007). In contrast, for product categories that are functional, functional attributes and rational thoughts dominate the decision-making process. Therefore, complementarities will be best when the environmental attributes



enhance the performance of a product (e.g., increased efficiency).

While we didn't find studies specifically testing the combination of the different elements of the Green Bundle, it is possible that combining the elements of the Green Bundle, such as quality and social, could enhance their effectiveness in promoting environmentally-friendly behavior. For instance, by highlighting the exclusivity or premium nature of environmentally-friendly products, they can attract consumers who value high status. However, it is important to note that some combinations of the Green Bundle categories might have the opposite effect, such as combining emotion and money, which can work against each other. Therefore, one needs to be careful in combining the different categories of the Green Bundle.

The relevance of sustainability benefits also varies depending on the situational context. The perception of functional, social, health, or emotional benefits associated with sustainability is moderated by situational aspects. For example, health benefits from environmental improvements may be more important during critical junctures in consumers' lives (Delmas & Colgan, 2018). Consumers may become more aware of the connection between environmental damage and health when starting a family, having children, or getting sick and wanting to understand the cause.

Another important factor is the social or cultural context. Framing interventions could be more effective when the environmental benefits are emphasized in situations where there is high public awareness of environmental issues (Bolderdijk et al., 2013; Whitmarsh & O'Neil, 2010; Schultz et al., 2005). In contrast, private co-benefits would be more persuasive when the decision-making context is personal, and the consumer has a strong sense of identity associated with the product. For example, a person who identifies strongly as an environmentalist may be more motivated to purchase a product that has environmental benefits, even if the private co-benefits are minimal.

The articles in this literature review are derived from developed countries, but many of the interventions described have relevance for other economic or cultural contexts. Monetary savings and durability are two attributes that are particularly relevant for consumers in developing countries. However, stated motivations are not always what drives conservation behavior—we need to be careful with overgeneralizations. For example, Chen et al. (2017) asked about 2,000 Indians living in urban areas what motivated them to conserve energy. Money was the most frequently cited motivation. Health was among the least common motivations. Overall, for respondents who stated they engage in energy conservation behaviors, 84 percent cited saving money and only 9 percent of respondents cited the health of themselves or their family as a motivating factor for engaging in energy conservation.<sup>4</sup> However, when the researchers provided Indian households with real-time information about their electricity usage framed in terms of cost savings, they didn't conserve energy. When the issue was framed in terms of air pollution, on the other hand, they reduced usage significantly. Despite statements to the contrary, the health benefits of saving energy were a better motivator. Similar results were seen in the United States, showing that similar motivations sometimes work across cultures. The context matters, but it needs to be carefully assessed in each information campaign.

Our approach focuses on the importance of emphasizing private benefits to motivate the adoption of lower-polluting products. The existing literature provides some evidence supporting this idea, although few studies have directly compared private benefits with and without public benefits. Consequently, it is challenging for us to draw definitive conclusions regarding the

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<sup>4</sup> This was calculated as the number of respondents who cited each motivation divided by the number of respondents who engage in any energy conservation behavior always or often.

circumstances in which private incentives should complement or substitute public benefits. In light of this, we propose several hypotheses that require empirical testing.

Behavioral science research suggests that financial incentives may crowd out altruism. In such cases, it may be more effective to solely highlight the private benefits of environmentally friendly products. Additionally, individuals may harbor doubts about the actual effectiveness of green products. Questions may arise regarding whether these products genuinely deliver the claimed environmental benefits or if the claims are exaggerated. Concerns about the overall environmental impact of green products, such as their carbon footprint throughout the lifecycle, can shape people's perceptions and skepticism. Sometimes, environmental information can send irrelevant, confusing, or even detrimental messages to consumers, particularly when it detracts from addressing consumer needs. For instance, in the wine industry, an environmental message might be misinterpreted as an indication of low product quality (Delmas & Lessem, 2017).

In cases where environmental benefits are difficult to communicate and may confuse consumers, it is best to avoid mentioning them altogether. This is what 2/3 of eco-certified wineries in California have done by letting the quality of their wine speak for itself (Delmas & Grant, 2014), and what Tesla did by emphasizing performance over environmental benefits. Despite criticism of electric cars emitting more carbon in states that rely on coal for electricity generation, Tesla's sales continued to dominate the market with 65% of the market share in 2022 (S&P Global Mobility, 2022).

Furthermore, as we mentioned earlier, trust is crucial for effective communication of public benefits. If consumers lack trust in these public benefits, it may be more advantageous to focus on private benefits. This is supported by the fact that consumers' reluctance to purchase green products can be attributed, in part, to skepticism regarding corporate environmental claims (Furlow, 2010).

This skepticism can be rooted in various factors. Firstly, individuals may question the motives of corporations in promoting their environmental initiatives, suspecting profit-driven or marketing strategies rather than genuine environmental concerns. This skepticism is fueled by instances of "greenwashing," where companies make misleading or exaggerated environmental claims (Lyon & Montgomery, 2015; de Freitas Netto, 2020). Secondly, mistrust can stem from doubts about the transparency and accuracy of information provided by corporations. Consumers often struggle to verify the truthfulness of environmental claims, leading to skepticism. Moreover, past incidents of corporate environmental misconduct, pollution, or unethical practices contribute to general suspicion. Such incidents erode trust and cause consumers to question the credibility of corporate environmental claims.

To overcome this reluctance, companies need to provide transparent and reliable information about their environmental initiatives and product claims. Third-party certifications, independent audits, and comprehensive reporting can help build trust and credibility. Open communication channels and consumer engagement can address knowledge gaps and alleviate concerns. Ultimately, companies must demonstrate their commitment to sustainability and substantiate their environmental claims with concrete evidence to counteract general suspicion surrounding corporate environmental claims. However, it is important to acknowledge that contested environmental claims can pose challenges in this regard.

In situations where private benefits are minimal, developing effective interventions for consumers becomes more limited. In such cases, it may be more beneficial to create policies that encourage manufacturers to change their products rather than solely relying on consumer

behavior change. However, if manufacturers produce environmentally friendly products with lower quality, these products are unlikely to gain significant market share. Hence, incentivizing manufacturers to develop products that provide both environmental and private benefits would be preferable.

Our examination of the literature reveals the significance of emphasizing private benefits to incentivize the adoption of lower-polluting products. However, the literature lacks extensive research comparing private benefits with and without public benefits, making it challenging to determine when these incentives should complement or substitute each other. Various factors such as skepticism, concerns about product effectiveness, and trust in corporate claims impact consumer perceptions and decision-making. To overcome these challenges, transparent and credible information, third-party certifications, and active consumer engagement are vital. Additionally, interventions may need to focus on both manufacturers and consumers, incentivizing the development of environmentally friendly products that offer compelling private benefits. Ultimately, a multi-faceted approach is necessary to effectively promote sustainable consumption and drive positive environmental change.

In conclusion, the reviewed literature has shown that behavioral interventions that leverage private benefits have proven to be effective in reducing overconsumption. Specifically, social norms that convey information about others' behavior are the most commonly used behavior change technique, and effective interventions focus on private benefits such as social status, improved health, and monetary savings. While emotion was also considered a viable option in some studies, because there were fewer studies, there was less information on the context under which this element would be applicable. In summary, the Green Bundle framework provides a useful framework for understanding the principles that underlie effective interventions. To implement these strategies successfully, it is important to consider the specific needs satisfied by the product category and the situational context. Behavioral interventions can complement technological improvements in reducing pollution and the harmful environmental impact of overconsumption.

While we identified effective interventions that use information about private benefits to change consumer behavior and reduce consumption, there are still areas that need further exploration. For example, we pointed out that it is important to consider the specific needs satisfied by the product category when implementing Green Bundle framing interventions. The situational context is also crucial when considering the perception of functional, social, health, or emotional benefits associated with sustainability. Therefore, further research is needed to examine the effectiveness of Green Bundle framing interventions in different product categories and situational contexts, both in-store and online, to understand how to promote sustainable behaviors effectively. It is also important to investigate how sustainable consumption that enhances self-image or improves mood could be undermined by explicitly referring to these private benefits. Further studies could also investigate the moderating role of social or cultural context on the effectiveness of Green Bundle interventions. These studies, along with testing the combination of different motivators, could provide important insights into how to design effective interventions for reducing overconsumption and promoting sustainable behaviors.

## *Conclusion and Policy Implications*

Overall, we recommend taking the Green Bundle approach that frames consumer benefits for lower-polluting choices. Providing information about the various benefits such as quality, social status, health, financial benefits, and emotional returns can be one way to make consumer behavior greener and lower-polluting.

Implementing policies that enable consumers to easily view any financial savings associated with green behavior can be an effective strategy. Additionally, mandating the labeling of environmentally friendly items as "green" or items with a high environmental impact as such could also be a way to influence behavior, especially when consumers observe the decisions made by others. It is crucial to closely monitor the impact of these policies to ensure that they reinforce green social norms and not the opposite. Green labeling can amplify existing environmental attitudes, making some social norms more apparent to others. If certain communities do not already have pro-environmental attitudes, changing these attitudes may be a critical step before promoting environmentally unfriendly behavior in the community.

Policies that increase the perceived private benefits and lower the costs of going green are expected to be the most likely to be successful. These costs and benefits, however, do not always need to be substantial from a purely economic perspective. Behavioral science research can help policymakers to better understand the psychological costs and benefits. For example, setting green options as the default can substantially change behavior toward the default option. Even though the cost of switching in terms of effort is generally low, the psychological cost of switching can be substantial.

Policymakers can launch public education campaigns that emphasize the private benefits of sustainable consumption. These campaigns can utilize various channels, such as websites, social media, or advertisements, to inform consumers about the cost savings, health advantages, and other personal benefits of eco-friendly choices. By increasing awareness and knowledge, consumers can make more informed decisions that align with their interests. For example, they can highlight the cost savings associated with driving electric vehicles such as lower operating costs, reduced maintenance needs, and cheaper electricity compared to gasoline. Or the enjoyable driving experience with instant torque, responsive performance, and quieter operation. Or better describe the incentives and rebates offered by governments and jurisdictions to make electric cars more affordable, providing additional financial benefits to owners. They can also establish labeling or certification programs for eco-friendly products, similar to energy labels. These labels can highlight the private benefits, such as cost savings or health improvements, associated with using the certified products. For example, a label on a cleaning product can indicate that it is environmentally friendly, non-toxic, and contributes to better indoor air quality.

# SURVEY OF THE TARGET AUDIENCE

## *Introduction*

The California Air Resources Board funds and hosts online research seminars on a variety of topics. Despite the importance of the research findings presented in many of these seminars, they are not as widely attended as they could be. Approximately, 5000 people receive email invitations to these research seminars, but only ~100 people attend. One of the main advantages of online seminars is their convenience and accessibility. Unlike in-person seminars that require attendees to potentially travel long distances, online seminars can be accessed from anywhere with an internet connection, making them accessible to people from all over the world. Additionally, online seminars can be more environmentally friendly, as they do not require any travel.

Despite the benefits of online research seminars, they might not have the same perceived limited availability as in-person seminars. In-person seminars generally have one set date and time, which creates a sense of urgency for attendees to plan and attend. The limited availability can motivate attendees to prioritize this event over other items on their to-do lists. In contrast, online seminars that are recorded and available to watch later can be watched at any date and time. This could lead to procrastination and the seminar never being made a high priority. People might not attend the seminar at the scheduled time because they know it will be available later. After missing the live-online seminar, they might forget to watch the recording and lose interest over time.

Online research seminars also lack much of the human connection element of in-person events. In-person seminars provide an opportunity to interact with the presenters and other attendees, wherein attendees can exchange ideas, build relationships, and potentially discover new collaboration opportunities. In contrast, online seminars mostly rely on one-way interactions where the presenter speaks to the audience without much opportunity for feedback or interaction with other audience members. Even when organizers encourage audience participation, potential attendees may not be aware of the advantage of attending the seminar live at the scheduled time rather than waiting to watch a recording later. Nevertheless, behavioral science can provide tools to improve attendance at these seminars.

Recent work in the behavioral sciences literature suggests that “reserved” framing can be a powerful tool for increasing virtual conference registrations. One study found that emails saying that an early registration discount is “reserved for you” significantly increased conference sign-ups (Bogard, Fox, & Goldstein, 2021). Other work has demonstrated that text messages saying that a flu shot is “reserved for you” is an especially effective way to increase flu vaccination rates (Milkman et al., 2021). This type of wording implies that the product or service is not available to everyone, which creates a sense of urgency and scarcity.

Based on this literature, we proposed that CARB emails could use messaging to imply limited availability, such as: *We have reserved a spot for you to see the researchers present their work.*

After consulting with CARB staff, however, we were informed that this message would not be possible to use because CARB as a state agency would not want to imply that its research

seminars are available to only some people and not to everyone. We, therefore, considered other ways to modify the wording of research seminar emails to increase attendance.

One reason that people may not attend online seminars is that they lack the urgency of in-person seminars because they are recorded and available to watch at any time after the event.

Individuals tend to be loss-averse (Brown et al., 2021; Kahneman & Tversky, 1979; Tom et al., 2007) and may feel a sense of loss if they are unable to attend an event that they are interested in. However, if they know that a recording of the event will always be available, they may no longer feel loss by not attending. Another related psychological driver of behavior is the fear of missing out (Akbari et al., 2021; Tandon et al., 2021).

One way of attempting to create a sense of urgency would be to say: *Don't miss your chance to see the researchers present their work*. This statement, however, is likely to be undermined by people's knowledge about previous seminars being recorded and available to watch later. People would be unlikely to believe that they are missing their chance to see the researchers present their work when a recording will be made available later.

The other reason that people may not attend online seminars is that they lack much of the human connection element of in-person events. According to Anderson and Chen (2002), "the motivation that is perhaps most regularly identified as a basic human motivation is the need for human connection" (p. 625). The presence or absence of social connections can impact an individual's cognitive processes, emotional states, and actions (Baumeister & Leary, 1995; Leary et al., 1995; Markus & Kitayama, 1991; Smith, Murphy, & Coats, 1999; Waytz et al., 2013).

One way to increase this human connection element would be to say: *This is your chance to interact with the researchers and ask your questions*. Potential attendees may feel more motivated to attend the online seminar if they are assured of a more interactive and engaging experience rather than simply being talked at in one-way communication. Moreover, such interactions would only be available during the live scheduled meeting and would not be possible for those who opt to watch the recorded version later. A sense of urgency can therefore be added to this human connection message by saying: *Don't miss your chance to interact with the researchers and ask your questions*. The human connection element would be available for only a limited time even if a recording of the seminar is available on-demand after the fact.

## *Experiment 1*

To get additional information about the effectiveness of these different email wordings, we ran a study on Amazon's Mechanical Turk (MTurk). We preregistered this study at [https://aspredicted.org/WGF\\_DT7](https://aspredicted.org/WGF_DT7).<sup>5</sup>

## *Method*

### *Participants*

A total of 1,241 participants were tested using MTurk. Some participants (235) answered the pre-

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<sup>5</sup> Given the data patterns that were observed, the preregistered analyses are not especially informative. For purposes of transparency, however, we will still report them in the results section below.

registered attention-check question incorrectly and were excluded. Participants were each paid \$0.50 for completing the task. The sample size was determined based on the objective of achieving at least 80% power to detect an effect size of Cohen's  $d = 0.05$ . The data were collected from Month Day, 2022 through Month Day, 202.

### *Materials and procedure*

After agreeing to the statement about informed consent from the UCLA Office of the Human Research Protection Program (OHRPP), all participants were asked to:

Imagine that you receive an email for an upcoming online research presentation on a topic that interests you. Each email begins with a slightly different message. Please rate each of these messages on how likely you would be to attend the research presentation after reading each message.

Participants then rated their likelihood of attending for each of the following statements. This was done with a slider that could be set to a value from 1–100. Each statement is labeled in parentheses afterward for purposes of describing the conditions to readers; participants were not shown this label.

1. This is your chance to see the researchers present their work. (Control)
2. This is your chance to interact with the researchers and ask your questions. (Human Connection)
3. Don't miss your chance to see the researchers present their work. (Don't Miss Out)
4. Don't miss your chance to interact with the researchers and ask your questions. (Human Connection + Don't Miss Out)
5. We have reserved a spot for you to see the researchers present their work (Reserved)
6. We want to make sure you're reading this; please place the slider between the values of seventy and eighty. (Attention Check)

All statements were presented on the same page. The order for each statement was randomized for each participant except the Attention Check statement, which was always presented last.

### *Results*

The two main a priori comparisons of interest were: (1) Control vs. Human Connection + Don't Miss Out and (2) Reserved vs. Human Connection + Don't Miss Out. A paired-samples t-test showed that the likelihood of attending ratings did not differ significantly for the Control ( $M = 64$ ) and Human Connection + Don't Miss Out ( $M = 63$ ) conditions,  $t(1005) = 1.684$ ,  $p = .092$ . The likelihood of attending ratings did not differ significantly for the Reserved ( $M = 63$ ) and Human Connection + Don't Miss Out ( $M = 63$ ) conditions,  $t(1005) = 0.552$ ,  $p = .581$ . A Bayesian paired-samples t-test using the default Cauchy distribution with the scale of 0.707 as the prior, gives 24.187:1 odds in favor of the null hypothesis. Figure 2 shows the average ratings for how likely a person thought they would be to attend the online research presentation for the different email wording conditions that were tested.

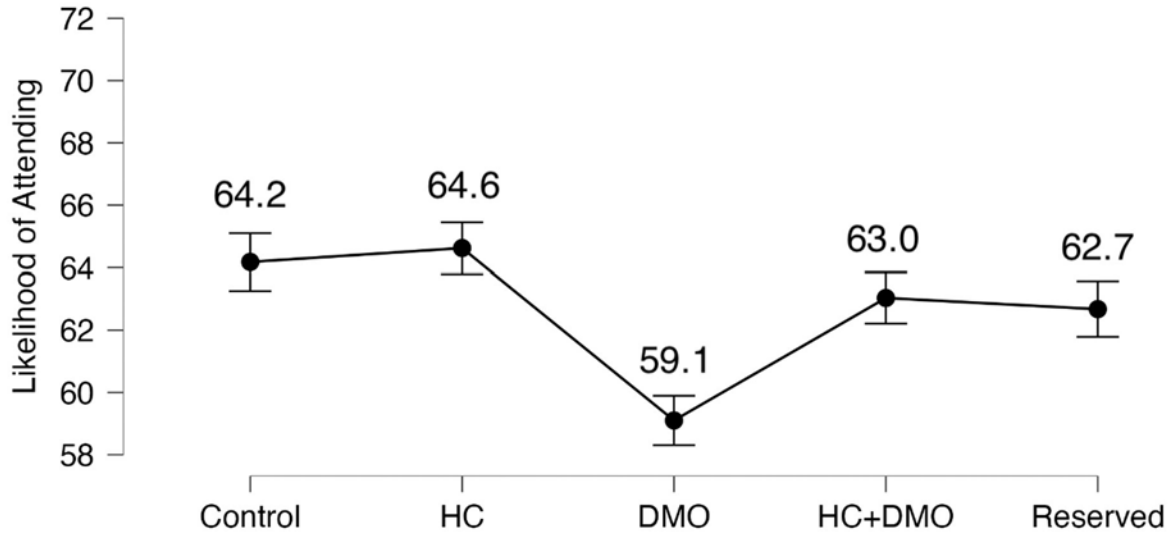


Figure 2: Average likelihood of attending ratings given to the different email wording messages used in Experiment 1. Error bars represent 95% confidence intervals. HC: Human Connection; DMO: Don't Miss Out

Table 11: Post-hoc Comparisons for the Different Email Wording Messages.

		Mean Difference	SE	t	P <sub>bonf</sub>
Control	HC	-0.445	0.614	-0.725	1.000
	DMO	5.075	0.614	8.260	< .001***
	HC+DMO	1.140	0.614	1.856	0.635
	Reserved	1.498	0.614	2.438	0.148
HC	DMO	5.520	0.614	8.985	< .001***
	HC+DMO	1.585	0.614	2.581	0.099
	Reserved	1.943	0.614	3.163	0.016*
DMO	HC+DMO	-3.934	0.614	-6.404	< .001***
	Reserved	-3.577	0.614	-5.822	< .001***
HC+DMO	Reserved	0.358	0.614	0.582	1.000

Note. P-value adjusted for comparing a family of 10

\* p < .05, \*\* p < .01, \*\*\* p < .001

To check that the observed results were not mainly due to within-subject contrast effects, we examined only the initial statement that was presented to each participant. Similar to the previous analysis, none of the statements showed a significant increase in the likelihood of attending ratings compared to the Control condition (see Figure 3). And once again, the Don't Miss Out wording performed the worst.















### *Alternative primary analysis for the proposed experiment*

A behavioral economist at CARB conducted a simulation demonstrating that registration data may have greater statistical power than email registration clicks in detecting differences between the experimental and control groups by accounting for serial correlation because registration is observable at the individual level whereas clicks are observable at the treatment level. We are including this analysis in Appendix 8. Registrations may have higher power for the reasons shown in this detailed analysis conducted by CARB staff. The UCLA team favors email clicks as the method of measurement because each participant's assigned experimental condition is unambiguous. The clicks occur directly on the email for each condition. In contrast, registrations necessitate matching names and email addresses with the list, which could lead to potential inaccuracies if participants register using an email address that differs from the one on the mailing list. This could result in a biased estimate of the treatment effect (relative likelihood of clicking on the registration button) if the treatment wording causes recipients to change the email address used to register. The UCLA team prioritizes obtaining an unbiased estimate of the effect over an unbiased  $p$ -value for the test of any treatment effect across experiments and no statistical evaluation of the overall treatment effect. However, the UCLA team also sees the value of the simulations conducted by CARB staff and is including this alternative primary analysis for consideration in Appendix 8.

## GENERAL DISCUSSION

Overconsumption significantly contributes to global environmental and social impact, necessitating effective behavioral interventions for reducing consumption in climate change mitigation efforts. These interventions often leverage private benefits to change consumer behavior and lower consumption.

Social behavior change techniques, particularly descriptive norms, are commonly used to convey information about others' behavior. The Green Bundle framework suggests that improved social status is a key private social benefit, and the effectiveness of social norm information depends on the level of observation by others. For instance, Delmas and Lessem (2014) discovered that publicizing dormitory electricity consumption rankings, in addition to privately provided information on consumption, was crucial for reducing usage. Notably, this was for college students who were not financially responsible for consumption.

Public compliance, or conforming to social norms due to perceived observation, is more likely when behavior is publicly visible. However, if people privately accept descriptive norm information as correct behavior, their actions may align with social norms even without observation. This private acceptance could represent a shift in moral beliefs, potentially operating on a different Green Bundle principle, like emotion.

The debate surrounding prosocial behavior questions whether motivations are altruistic or egoistic. Egoistic motivations offer personal benefits aligning with the Green Bundle framework, such as praise, self-image enhancement, improved mood, and avoidance of guilt and shame.

The proposed communication campaign employs the phrase “We need your insights, inputs, and ideas” in a strategic blend of altruistic and egoistic motivations, as recommended by the Green Bundle framework. This approach is expected to effectively change behavior.

Consumer awareness of private benefits, including quality, social status, health, monetary savings, and emotional returns, is crucial for promoting environmentally friendly behavior and reducing overconsumption. Behavioral interventions can augment technological advancements to minimize pollution and environmental harm caused by overconsumption.

## SUMMARY AND CONCLUSIONS

The systematic literature review investigates peer-reviewed academic research on behavioral interventions that successfully promote lower-polluting consumer choices. Our focus is on interventions, field experiments, nudges, and randomized control trials that reveal drivers of eco-friendly consumer choices, informing policy recommendations. Examined consumer choices involve purchasing or using cleaner vehicles, public transportation, energy-efficient appliances, low-carbon footprint food, organic products, and adopting energy and food conservation practices.

We employ the Green Bundle framework by Delmas and Colgan (2018) to categorize articles based on personal benefits—quality, social status, health, monetary savings, and emotional returns. The framework posits that consumers are more inclined to choose green products when they offer private benefits. We considered articles from the psychology, management, and economics fields.

Our findings suggest that successful interventions often utilize information about private benefits, while successful studies that do not use such information tend to rely on hypothetical or self-reported data. Implementing policies that highlight the financial benefits of green behavior can be an effective strategy. Enhancing the visibility of eco-friendly behavior and establishing green options as the default can significantly influence people's actions, leading to more frequent green choices.

The Green Bundle approach emphasizes the use of both altruistic and egoistic motivations to drive behavior change, which is exemplified in the "We need your insights, inputs, and ideas" email wording. Our survey indicated that this wording significantly increased behavioral intentions for attending a hypothetical online research seminar. The Green Bundle framework serves as a valuable tool for changing behavior.

## RECOMMENDATIONS

Policy implications for promoting environmentally friendly consumer transportation behavior include increasing gasoline and diesel prices via taxation (Zimmer & Koch, 2017), funding intelligent transportation systems to reduce congestion and fuel waste (Cheng et al., 2020), and making electric vehicles (EVs) readily available for test drives (Brückmann, 2022). Policies encouraging dealerships to maintain a certain number of EVs for test drives may boost sales.

Effective strategies for promoting green behavior include making financial savings visible, requiring that environmental impact be labeled honestly, and monitoring the policy effects of reinforcing green social norms. Before increasing the visibility of environmentally unfriendly behavior, it may be necessary to change attitudes in communities without strong pro-environmental values.

The Green Bundle approach, which combines information about consumer benefits with eco-



friendly choices, is recommended. Successful policies tend to increase (both real and perceived) benefits and decrease the costs of going green, though these factors don't always have to be substantial from a purely financial perspective. Behavioral science research can help policymakers understand psychological costs and benefits, such as setting green options as the default to encourage adoption. The psychological cost of switching can be substantial, even if the monetary cost is low.

Increased psychological benefits may be achieved when consumers observe friends and neighbors adopting green behavior and have opportunities to showcase their own environmentally friendly choices. Often, consumers are unaware of the personal benefits of greener behavior. Providing simple information about quality, social status, health, financial benefits, and emotional returns can promote more sustainable and less polluting consumer behavior.

Leveraging a blend of altruistic and egoistic motivations is a powerful way to drive behavior change. Crafting communication messages that utilize this combination can be an effective means of altering consumer behavior. As an illustration, our proposed message, "We need your insights, inputs, and ideas," demonstrates how these different motivations can be effectively utilized.

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## APPENDIX

### *Appendix 1. Word search and inclusion/exclusion criteria*

AB=("consumer behav\*" OR purchas\* OR "consumption")

AND AB=(intervention OR "field experiment" OR "randomized control trial" OR nudg\* OR "behav\* change" OR "choice architecture")

AND AB=("environmentally friendly" OR green OR "low\* pollut\*" OR "energy efficien\*" OR sustainab\* OR "electric vehicle\*" OR "car" OR "active mobility" OR "renewable energy" OR "solar" OR "transport\*" OR "organic")

Publication years: 2012-2023

Search engine: Web of Science

Date of last search: 02/11/2023

#### Requirements for Inclusion

- Experimental/Quasi-experimental design
  - The study must have either participants/households/communities being randomly assigned to conditions OR an intervention is implemented and the dependent variable is measured both pre and post intervention.
  - Studies without random assignment and only measures post intervention should not be included.
  - Studies that include only correlations (e.g., correlation between green purchasing behavior and water usage) should not be included.
- Experimental manipulation is designed to affect household environmental behavior (e.g., green purchases; electricity, water, gasoline usage; food wasted, trash generated; recycling contamination)
- The dependent variable is a behavioral measure (as opposed to attitude); can include purchase intentions/willingness to pay
  - Examples of what to include: kilowatt-hours of electricity used, gallons of water used, pounds of trash used, miles driven, rates of recycling contamination, number of green products purchased, willingness to pay for a green product
  - Examples of what not to include: attitudes toward recycling, how much someone likes a product, how much someone thinks they will recycle
- If an article reports multiple interventions, only significant differences will be included, and the effect will be coded as significant. If an article reports only non-significant findings, the effect will be coded as non-significant.

*Appendix 2. List of journals included in the analysis*

American Journal of Agricultural Economics Appetite  
Applied Economic Perspectives and Policy Business Strategy and the Environment Ecological Economics  
Energy Economics Energy Policy  
Energy Research & Social Science Environment and Behavior Environmental & Resource Economics  
European Review of Agricultural Economics Food Policy  
Information Systems Research International Journal of Consumer Studies  
International Journal of Contemporary Hospitality Management Journal of Business Ethics  
Journal of Business Research Journal of Consumer Research  
Journal of Environmental Economics And Management Journal of Environmental Psychology  
Journal of Marketing  
Journal of Retailing and Consumer Services Journal of Sustainable Tourism  
Journal of the Association of Environmental and Resource Economists Journal of the European Economic Association  
Journal of Transport Geography Mis Quarterly  
Nature Climate Change Nature Energy  
Nature Sustainability  
Proceedings of The National Academy of Sciences of The United States Of America Psychology & Marketing  
Technological Forecasting and Social Change Transportation Research Part A-Policy and Practice  
Transportation Research Part F-Traffic Psychology and Behaviour

### *Appendix 3. Behaviors*

The dependent variables for most articles measure actual behavior rather than relying on self-reported behavior or behavioral intentions. This is illustrated in Table A1, with 68% of articles reporting measured behavior.

**Table A1. Type of Behavior**

<b>Type of Behavior</b>	<b>Number of Articles</b>	<b>% of Articles</b>
Measured behavior	48	68%
Behavioral Intention	16	23%
Self-reported behavior	7	10%
Total	71	100%

#### *Appendix 4. Length of Intervention*

Table A2 shows the length of each intervention. Approximately half (48%) were completed in a day or less with relatively few (14%) taking longer than a year.

**Table A2. Length of Intervention**

<b>Length of Intervention</b>	<b>Number of Articles</b>	<b>% of Articles</b>
Day or less	34	48%
Day–Week	4	6%
Week–Month	3	4%
Month–Year	20	28%
Longer than a year	10	14%
Total	71	100%

### Appendix 5. Location of the study

As shown in Table A3, most of the studies are field studies conducted in the *real-world* (56%), and in most of these field studies participants were *unaware* (58%) that they were being observed as part of a research study.

**Table A3. Geographical Location of Study**

<b>Location of Study</b>	<b>Number of Articles</b>	<b>% of Articles</b>
Real-world (unaware)	23	32%
Real-world (aware)	17	24%
Online	14	20%
In-lab	11	15%
Real-world data	6	8%
Total	71	100%

## *Appendix 6. Study Randomization Design*

Most studies (73%) had random assignment to condition and are therefore considered to be “true” experiments rather than quasi-experiments (See Table A4).

**Table A4. Study Randomization Design**

<b>Random Assignment</b>	<b>Number of Articles</b>	<b>% of Articles</b>
Experiment	52	73%
Quasi-experiment	19	27%
Total	71	100%



## *Appendix 7. Articles included in the systematic review*

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## Appendix 8. Alternative primary analysis for the proposed experiment

There are four outcome variables: the number of opened emails, the number of clicks on the registration button in the email, registrations, and attendance.

**Opens:** An open is when an email recipient opens the email, counted once per individual. This is observed at the treatment level.

**Clicks:** The email has a button to register for the seminar. The number of clicks is the number of unique individuals that click on the registration button, regardless of whether they register. This is observed at the treatment level.

**Registrations:** Individuals must register to participate in the seminar. They may register with any email address, which means that the address may not match an address from the mailing list.

Registrations are observed at the individual level.

**Attendance:** Attendance includes a name and email. The email should match the registration email but may not match the email in the mailing list.

These outcomes are sequential—anyone who attends must register (the people presenting are excluded from the experiment), anyone who registers must click the registration button, and anyone who clicks the registration button must open the email. The point at which the treatment is applied is either immediately before the open or immediately before the click, depending on the preview settings of the individual’s email. In our model the likelihood of an individual clicking is dependent on the treatment, but the likelihood of progressing from the click step to the register step (and the email they use to register) is independent of the treatment. We also assume anyone who registers or attends does so with the same email address each time, though this email may not match their email on the email list.

*Clicks* are observed at the treatment level, which invalidates the standard errors if multiple experiments are run with a shared population due to potential serial correlation because appropriate clustering is not possible. We bound the potential effect of clustering by creating two counterfactuals based on the observed individual-level *registrations*. For *clicks* that cannot be accounted for with *registrations* (unaccounted *clicks*) the counterfactuals assign *clicks* to be either disperse or clustered. This is explained in the example below.

Suppose there are two experiments with six total invitees (1, 2, 3, 4, 5, 6). Four are invited to Experiment one (1, 2, 5, 6) and four are invited to Experiment 2 (3, 4, 5, 6). Individual level clicks are known for those who register. Suppose we observe that for Experiment 1, subjects 1 and 5 register but there are three clicks. For Experiment 2, subject 4 registers but there are two clicks. Table 1 shows that some subjects could not have registered or clicked because they were not invited (indicated by X), and others are known to have registered and therefore clicked (indicated by O for observed) because we can match their email to the email list. There is one unaccounted click in each experiment. In the disperse counterfactual, we assign clicks to individuals who were not observed to register, spreading the clicks across different subjects when possible: subjects 2 and 3 are assigned a hypothetical click (D). For the clustered hypothetical, the unaccounted clicks are assigned within-subject when possible. Here we assign both unaccounted clicks to subject 6, indicated by C. Both hypotheticals have the same total number of clicks but represent the extremes with respect to serial correlation.

Subject	Exp 1 Click	Exp 1 Reg	Exp 2 Click	Exp 2 Reg
1	O	O	X	X
2	D		X	X
3	X	X	D	
4	X	X	O	O
5	O	O		
6	C		C	

Table A8.1: Example disperse counterfactual clicks.

Serial correlation, or the likelihood of individuals taking correlated actions across multiple experiments, affects standard errors because the observations are not independent. Individuals could have idiosyncratic preferences for attending seminars which have a substantial impact on their likelihood of attending any seminar. Later we show the extent to which serial correlation affects results, but first we discuss the simulation and regression model.

### Simulation

We test power using simulations with the following data generating process for *clicks* and *registrations*.

Parameters (typical values): Number of experiments for each listserv, number of listservs (2), number of individuals on a listserv (4000), overlap of individuals across listservs (2000), likelihood of clicking for portions of the population (60% of population [low click likelihood] – 0.001%, 30% of population [medium click likelihood] – 1%, 10% of population [high click likelihood] – 10%), likelihood of registering conditional on clicking (65%), and treatment effect (0 to 1 percentage point increase in the likelihood of clicking, independent of original click likelihood). We run 500 simulations for each parameter set presented.

The treatment effect is modeled as a percentage point increase in the likelihood of *clicking*, and therefore a corresponding likelihood of *registering* as a function of the likelihood of registering which did not vary by treatment. Using the observed *registration* and the known number of *clicks* for each treatment for each experiment, we generate the hypothetical disperse and clustered distributions of *clicks* discussed above.

### Model Specification

Each outcome variable is binary for individuals. Clicks and opens are not observed at the individual level but they are modeled as binary actions for the individual. Two models we consider are the Linear Probability Model (LPM) and Logistic regression (logit). We use the LPM as the primary specification due to ease of interpretation and because the domain of covariates is limited

such that the primary issue with the LPM (that it could produce results outside of the unit interval) is not a concern. We have no covariates for individual attributes aside from treatment assignment and experiment session. We will provide logit results for robustness. The LPM and logit provide practically identical power in our simulations (Figures A8.1 and A8.2). Further, our simulation shows that the LPM applied to registrations and clicks is unbiased. The literature supports selecting the LPM over logit for binary outcomes under some conditions, finding that the LPM is preferred when events are rare (fewer than 25% of one outcome).<sup>6</sup>

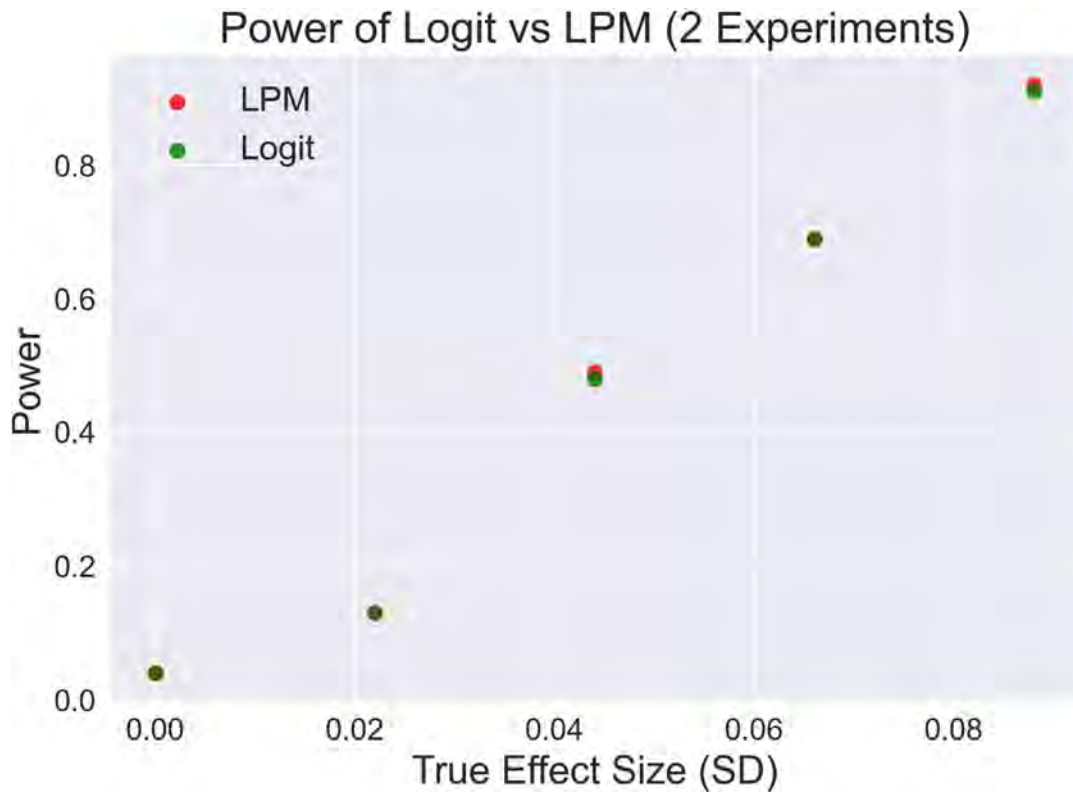


Figure A8.1: LPM and logit power for two experiments.

<sup>6</sup> Timoneda JC. Estimating group fixed effects in panel data with a binary dependent variable: How the LPM outperforms logistic regression in rare events data. Soc Sci Res. 2021 Jan;93:102486. doi: 10.1016/j.ssresearch.2020.102486. Epub 2020 Oct 29. PMID: 33308684



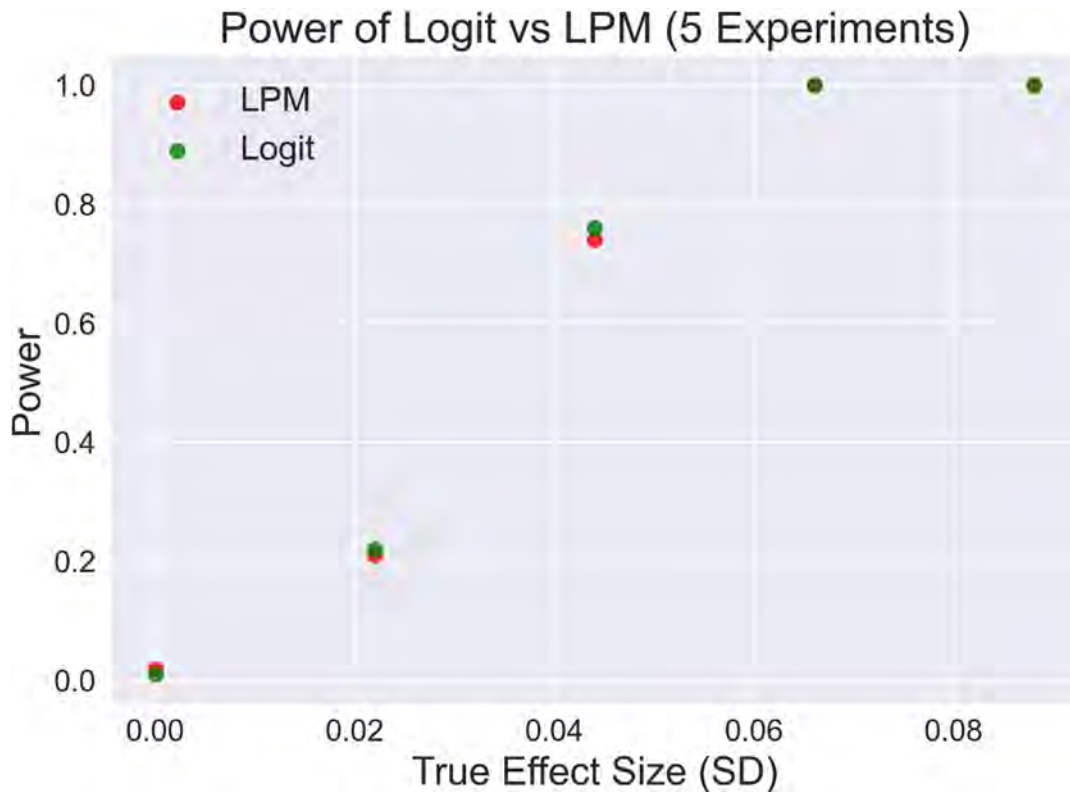


Figure A8.2: LPM and logit power for five experiments. The regression is:

$$C_{ie} = \beta_0 + \beta_1 Treatment_i + \beta_3 Experiment_e + \epsilon_{ie}$$

Where  $C_{ie}$  is the hypothetical *click* outcome for subject  $i$  in experiment  $e$ ,  $Treatment_i$  is the treatment assigned to subject  $i$ , and  $Experiment_e$  is the vector of indicators for each experiment. This model is fit with a random effects LPM. The random effects model provides a more powerful estimate of the treatment effect than would a fixed effects model and is justified because the treatment variable is randomly assigned by design.

### Serial Correlation

Above we discussed how we provide bounds for serial correlation of the *clicks* variable by generating hypothetical distributions of *clicks* by assuming either highly disperse or highly clustered distributions of unaccounted *clicks*. The difference between the two distributions depends largely on the proportion of unaccounted *clicks*: when there are more unaccounted clicks, assuming a highly clustered distribution reduces power. This is shown in Figures A8.3, A8.4, and A8.5, which show how power varies as the registration likelihood varies while high *click* likelihood individuals have a 10% chance of clicking, without treatment. In Figures A8.6, A8.7, and A8.8 we show analogous results when high *click* likelihood individuals have a 20% chance of clicking, without treatment. Figure A8.9 emphasizes that for the same effect size, as measured by standard deviation (SD), there is greater power when the likelihood of *clicking* is lower.

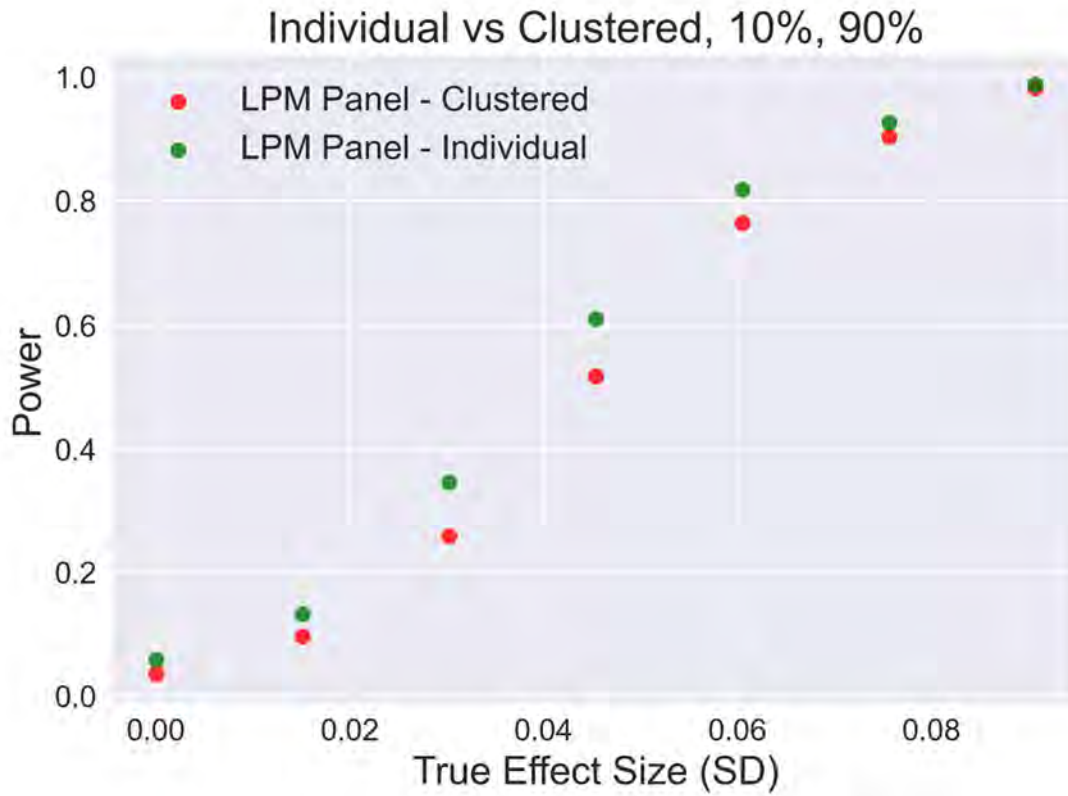


Figure A8.3: Comparison of the effects of the disperse (individual) and clustered distribution assumptions on power for a 10% chance of *clicking* for high *click* likelihood individuals and a 90% chance of *registering* conditional on *clicking*.

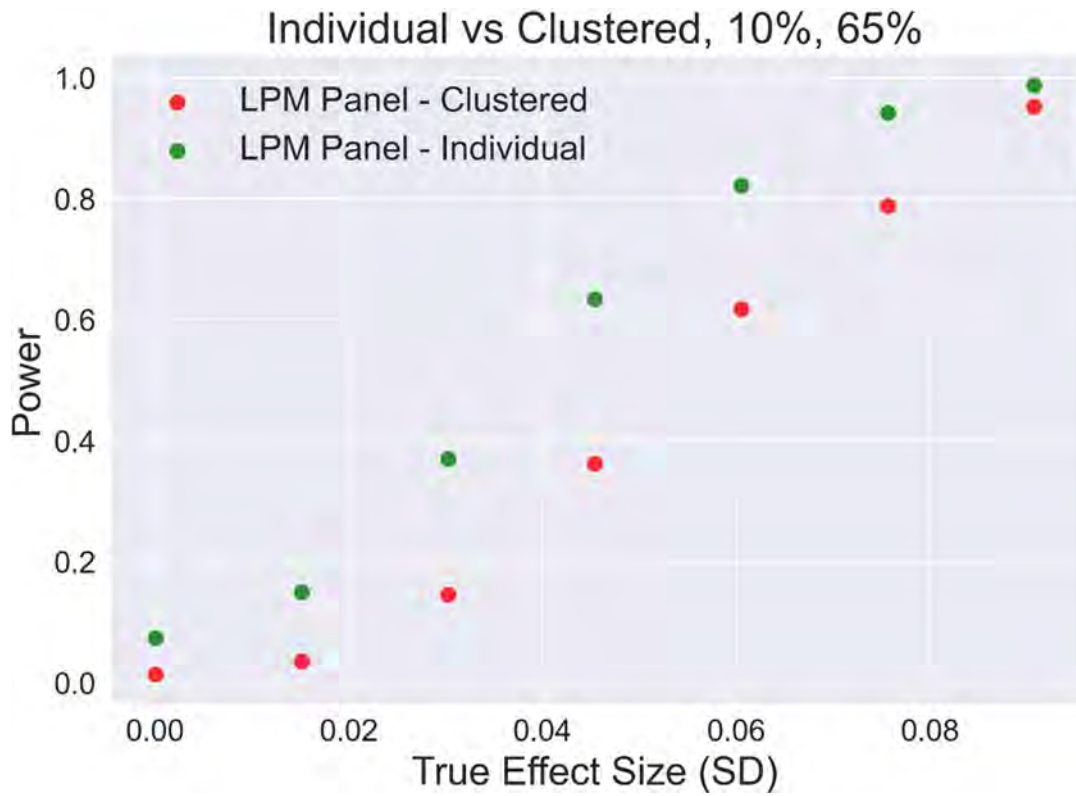


Figure A8.4: Comparison of the effects of the disperse (individual) and clustered distribution assumptions on power for a 10% chance of *clicking* for high *click* likelihood individuals and a 65% chance of *registering* conditional on *clicking*.

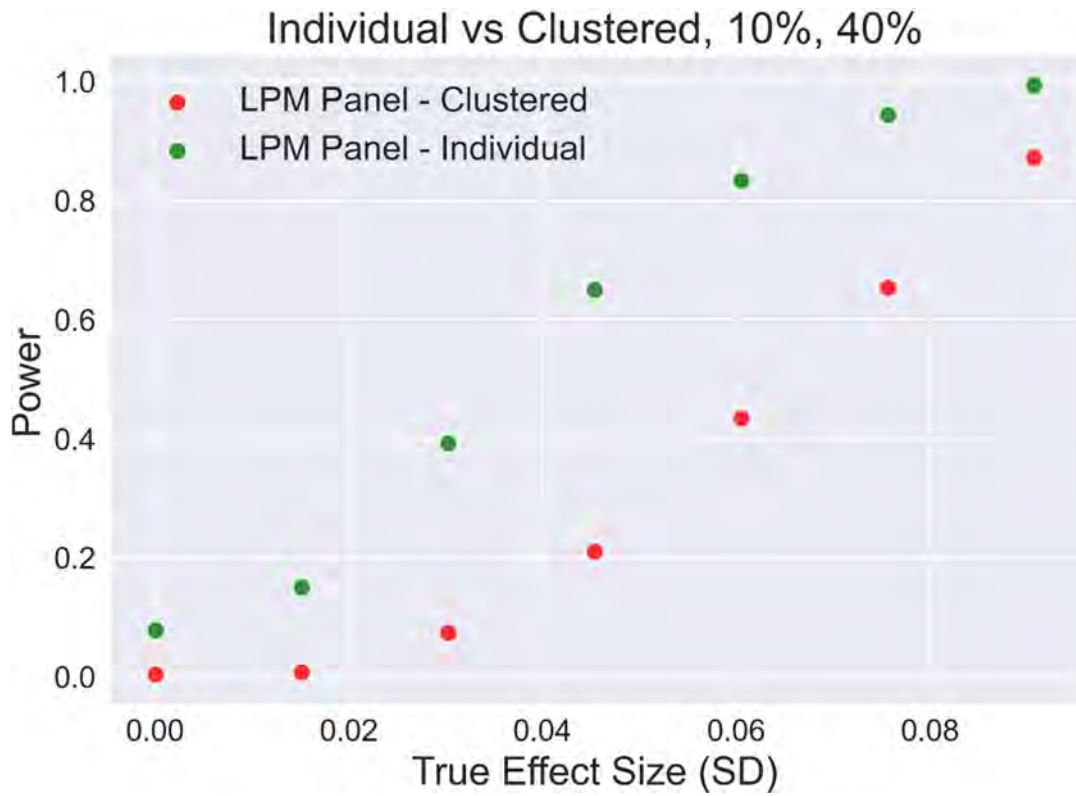


Figure A8.5: Comparison of the effects of the disperse (individual) and clustered distribution assumptions on power for a 10% chance of *clicking* for high *click* likelihood individuals and a 40% chance of *registering* conditional on *clicking*.

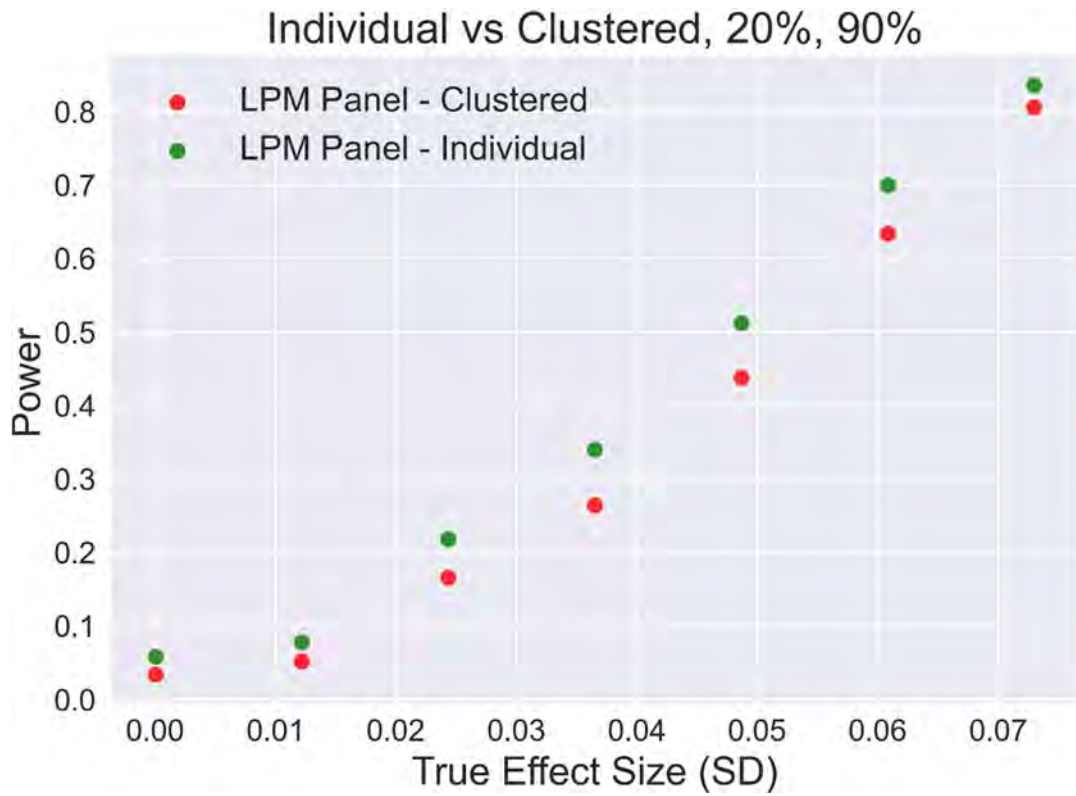


Figure A8.6: Comparison of the effects of the disperse (individual) and clustered distribution assumptions on power for a 20% chance of *clicking* for high *click* likelihood individuals and a 90% chance of *registering* conditional on *clicking*.

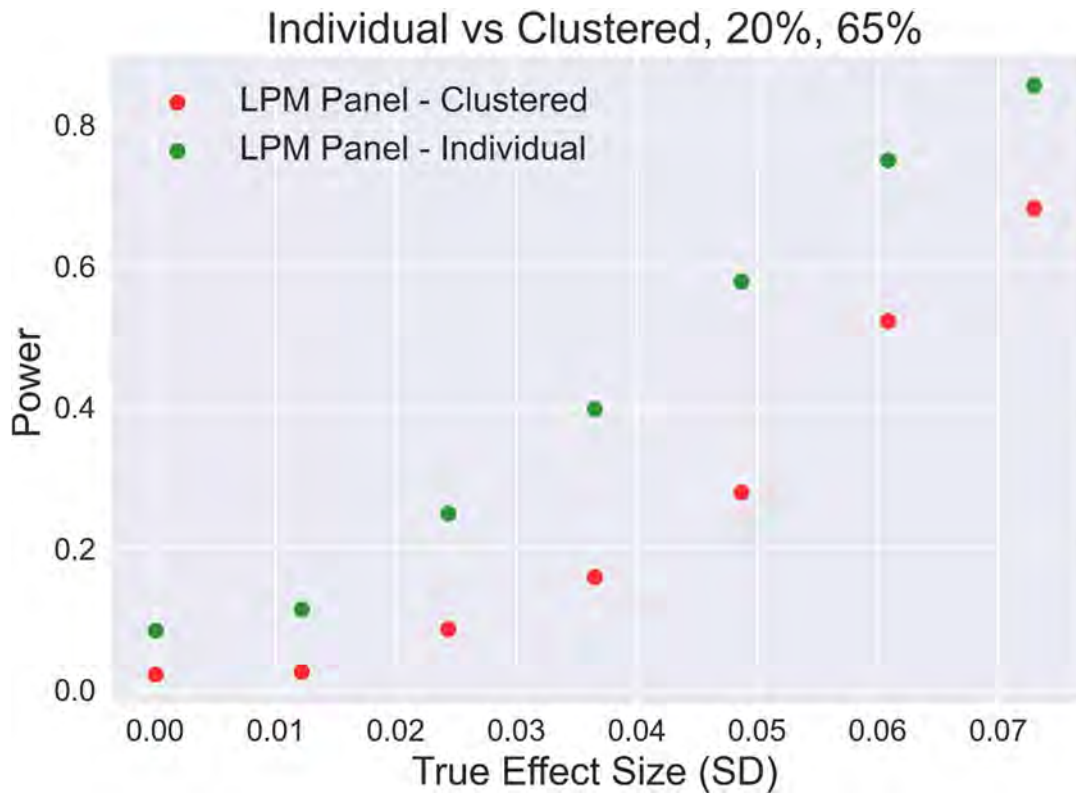


Figure A8.7: Comparison of the effects of the disperse (individual) and clustered distribution assumptions on power for a 20% chance of *clicking* for high *click* likelihood individuals and a 65% chance of *registering* conditional on *clicking*.

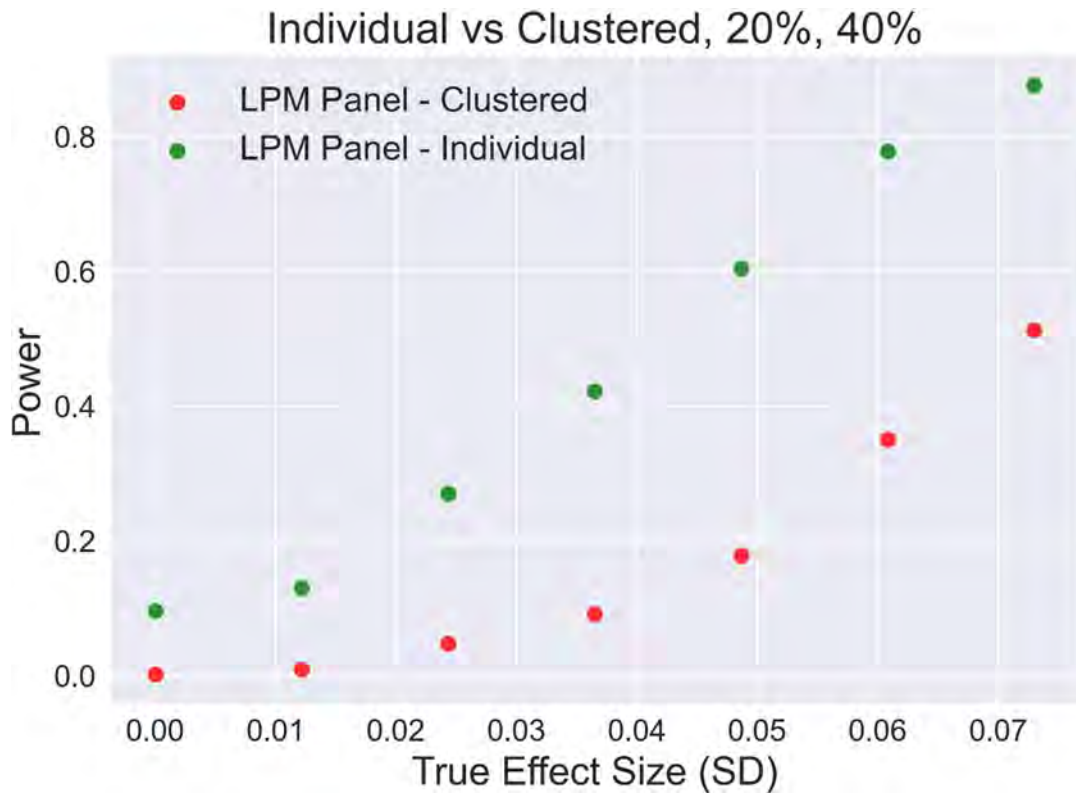


Figure A8.8: Comparison of the effects of the disperse (individual) and clustered distribution assumptions on power for a 20% chance of *clicking* for high *click* likelihood individuals and a 40% chance of *registering* conditional on *clicking*.



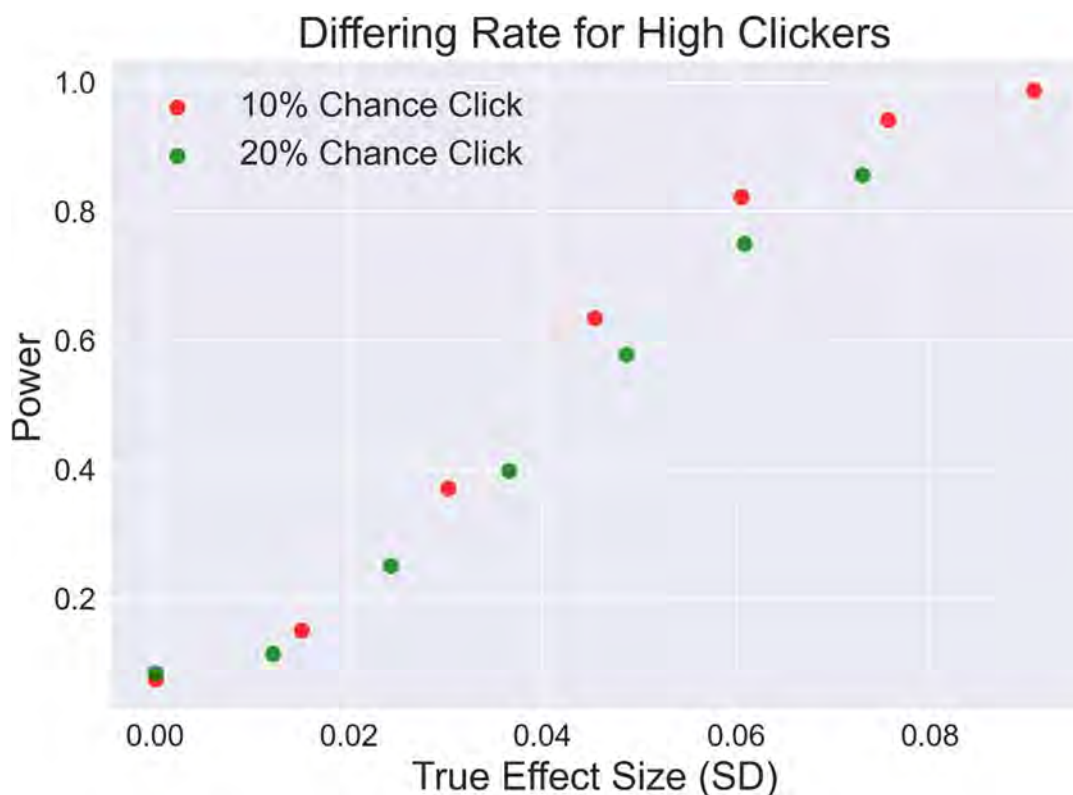


Figure A8.9: Comparison of a 10% vs 20% chance of *clicking* for the high *click* group.

We choose to use panel data methods with hypothetical distributions of clicks, as shown above, rather than the alternative of a “combined methods” which combines the p-value from individual experiments using Fisher’s method and then divides by the number of experiments to adjust for potential serial correlation, which although we do not have an analytical justification for this adjustment, numerically it appears to be sufficiently conservative. Panel methods provide substantially greater power, however, the combined methods approach modeled here is not the final approach used in this report. The approach used in this report does not adjust divide the p-value by the number of experiments, and therefore has higher power but is also more than 5% likely to commit a Type 2 error of falsely rejecting the null. Further, note that the null tested under the combined methods approach (Fisher’s method) is not a test of the overall effect and does not have an accompanying estimate of the overall effect size. Figure A8.10 compares the panel methods approach using the clustered assumption and Fisher’s combined method when there is a 65% chance of registration conditional on clicking. Figure A8.11 shows same comparison under the disperse (individual) assumption, which increases the power of the panel method but is invalid with serial correlation. The relative advantage of panel methods increases as the likelihood of registration increases. This is expected because, as above, we can bound serial correlation at a lower level. This effect is shown in Figure A8.12, which replicates the conditions of Figure A8.10 with a higher chance of registration. Figure A8.13 shows that at a registration likelihood of 40%, panel methods are roughly as powerful as Fisher’s combined method. As the likelihood of registration approaches 100%, the disperse distribution approaches the individual distribution until all clicks are accounted for.



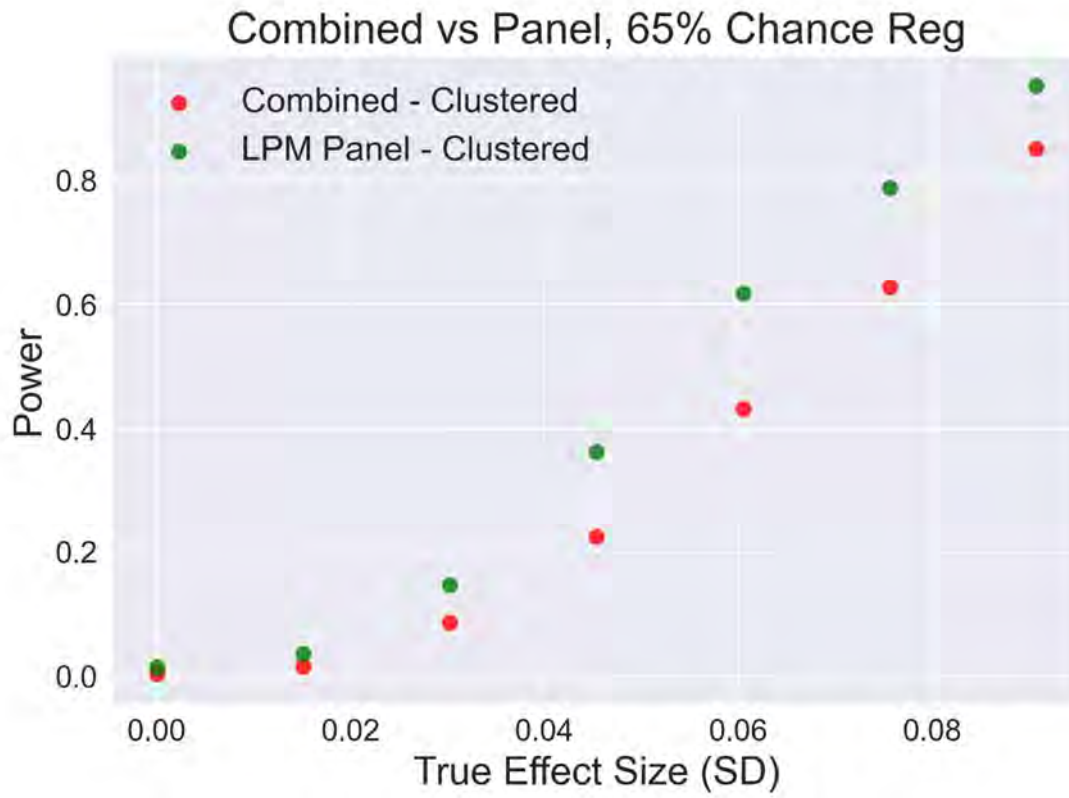


Figure A8.10: Combined and panel methods compared for a combined methods approach that adjusts for serial correlation, which is not the final method recommended in the report.

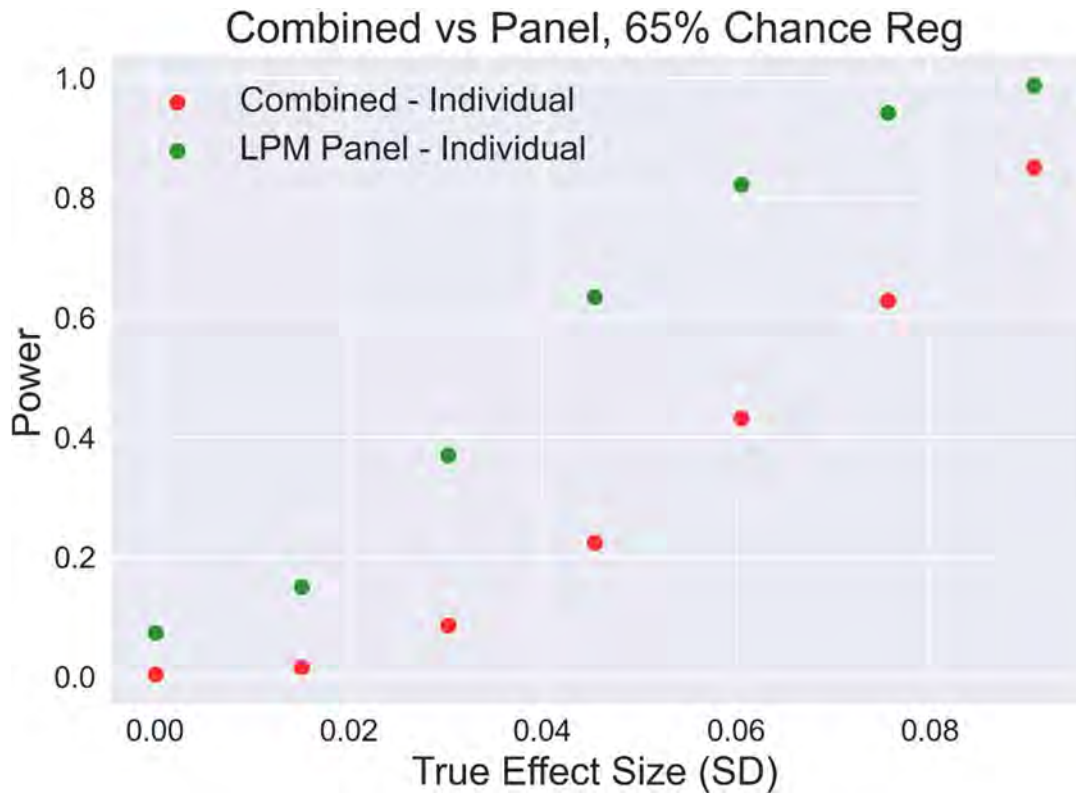


Figure A8.11: Combined and panel methods compared for a combined methods approach that adjusts for serial correlation, which is not the final method recommended in the report.

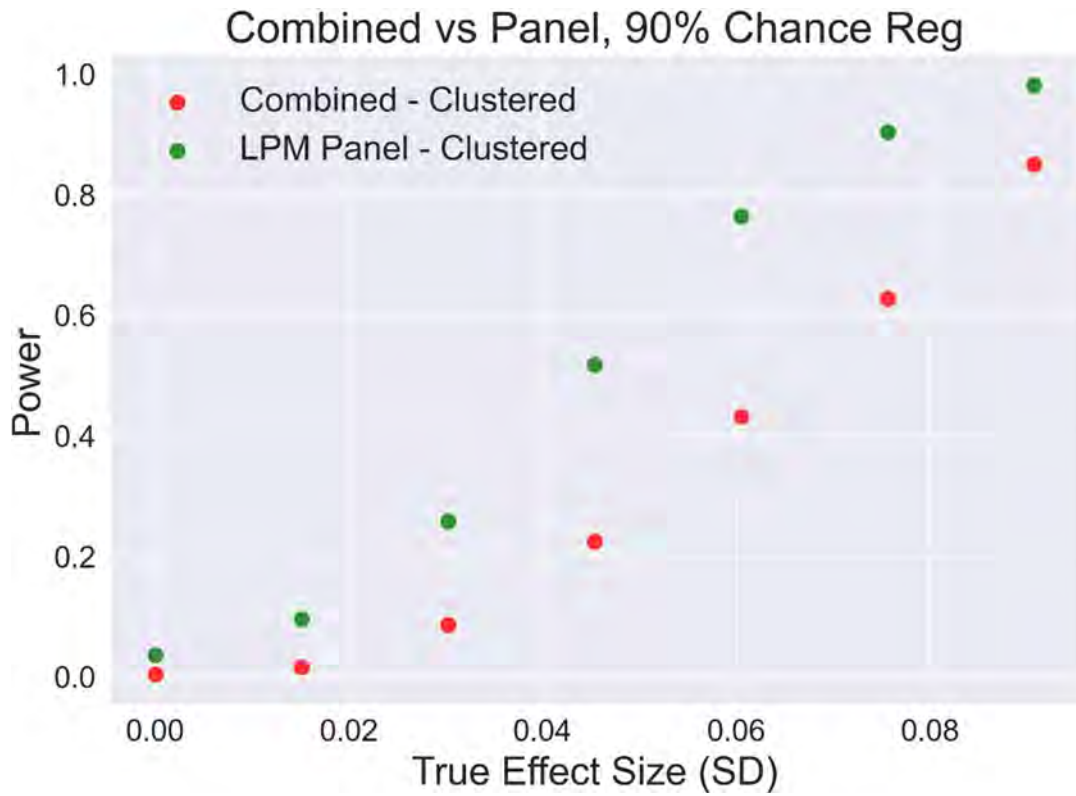


Figure A8.12: Combined and panel methods compared for a combined methods approach that adjusts for serial correlation, which is not the final method recommended in the report.

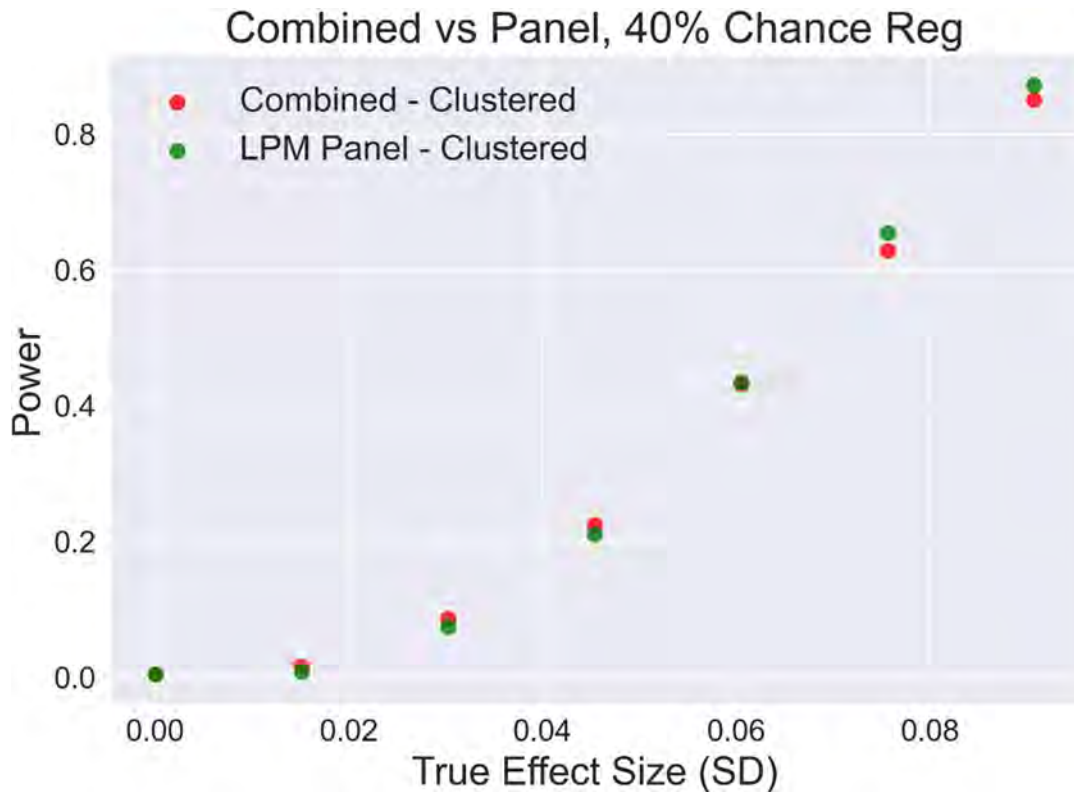


Figure A8.13: Combined and panel methods compared for a combined methods approach that adjusts for serial correlation, which is not the final method recommended in the report.

Based on these simulations we choose to use panel methods since they provide more power than Fisher’s combined method. Further, panel methods provide a preferable interpretation, including an estimate of the overall effect size with a confidence interval.

### *Outcome Variables*

Under most conditions, registrations is the most powerful outcome variable, even under the assumption that the treatment effect has no effect on registrations conditional on clicks. As noted above, we also assume that the treatment has no effect on the email address used to register. Figure A8.14 shows that registrations is more powerful than the clustered LPM for clicks unless the treatment effect is so large that both specifications have high power.

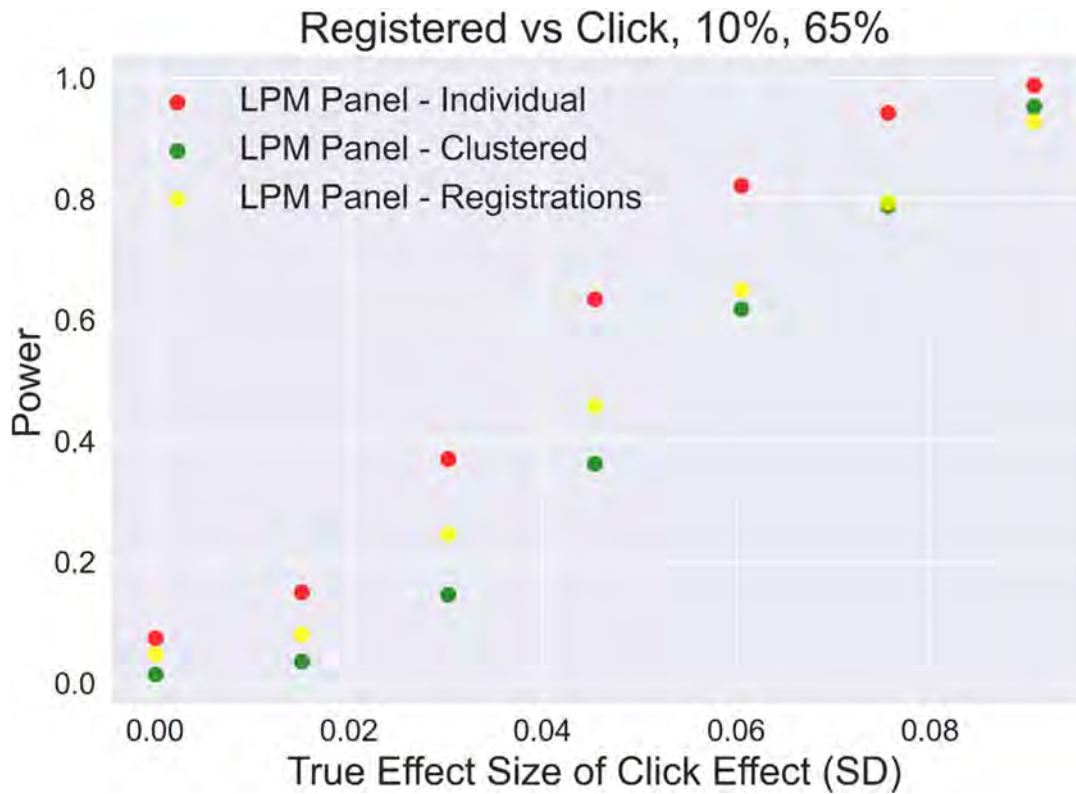


Figure A8.14: *Registrations* compared to *clicks* with the horizontal axis measured as the effect size on *clicking*.

When the horizontal axis is measured as the effect size with respect to the measured variable (effect on clicking and effect on registering), the power of registrations approaches the power of clicks under the disperse assumption, as shown in Figure A8.15. The power advantage for registrations comes from being able to directly account for serial correlation and therefore not needing the additional caution applied to unaccounted clicks.

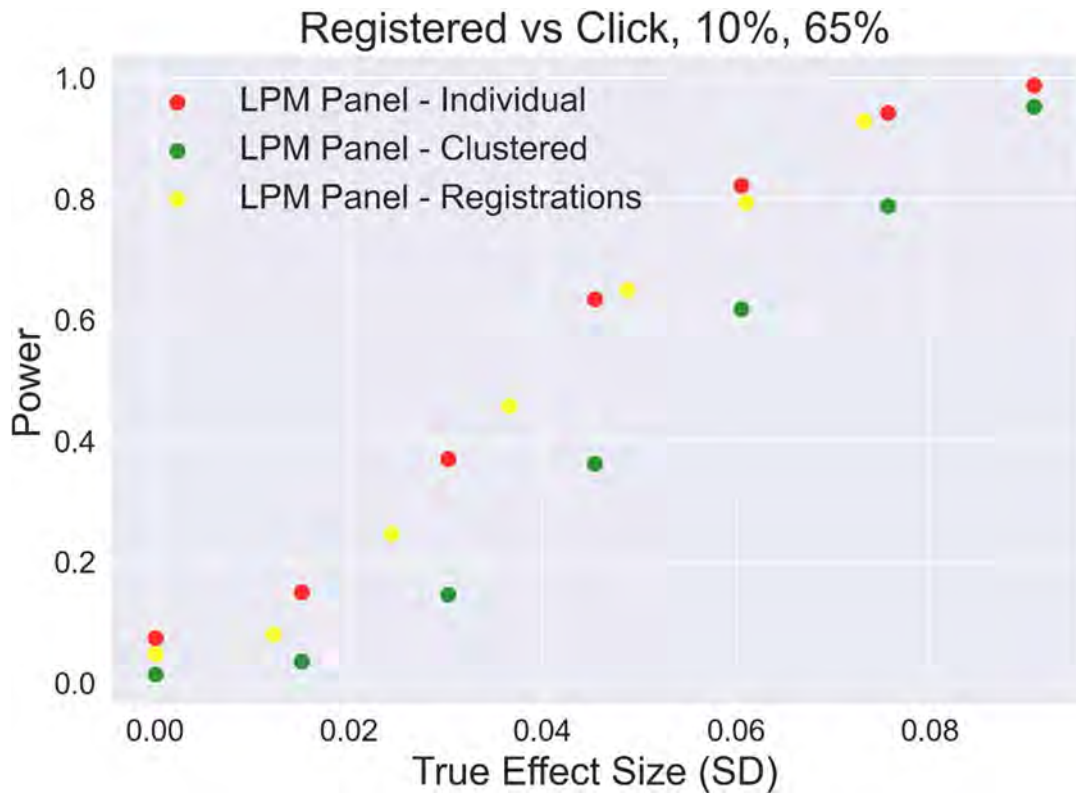


Figure A8.15: *Registrations* compared to *clicks* with the horizontal axis measured in the respective effect size.

The advantage of *registrations* as an outcome variable holds when compared to *clicks* using Fisher's combined method, as shown in Figure A8.16.

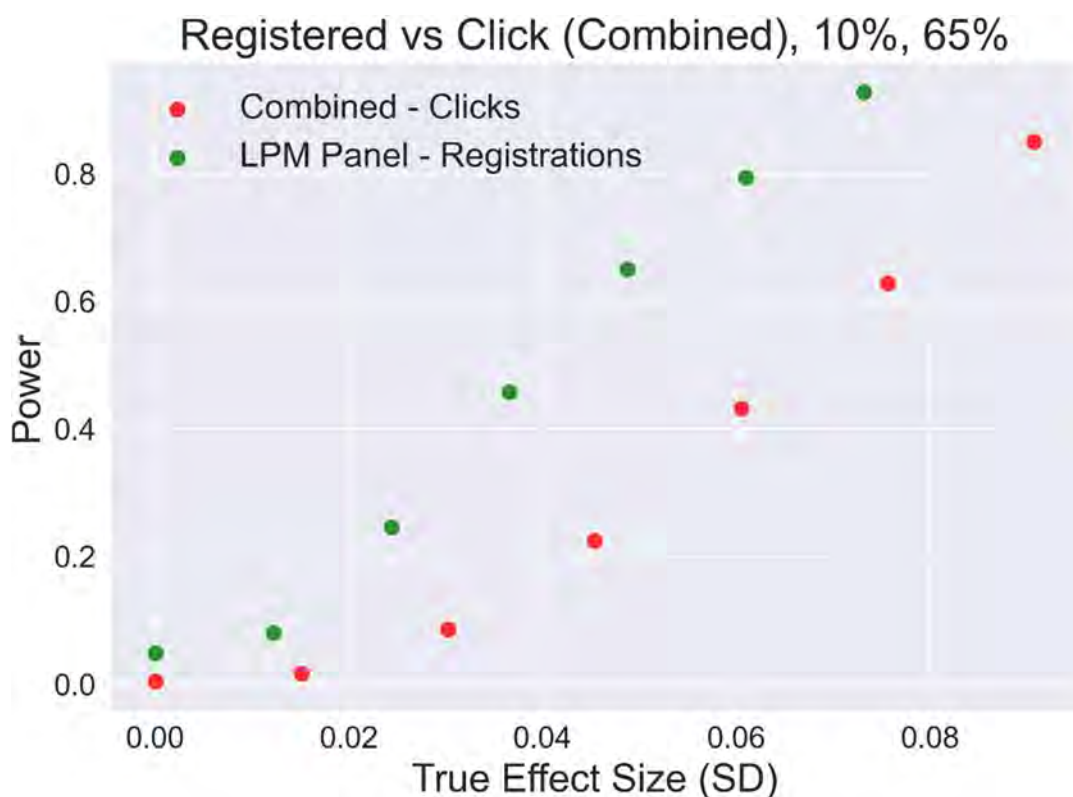


Figure A8.16: *Registrations* using panel methods compared to *clicks* using Fisher’s combined method for a combined methods approach that adjusts for serial correlation, which is not the final method recommended in the report.

For datasets with low serial correlation and low likelihood of registering conditional on clicking, the LPM with the disperse assumption may be a reasonable, if slightly optimistic, estimate. If we suspect unobserved serial correlation, the disperse assumption is not appropriate and instead we must use the more conservative clustered assumption. Relative to registrations, the LPM with the clustered assumption for clicks has lower power for the regions of the treatment effect where there is considerable variability in power across methods. Further, if there is a treatment effect on the likelihood of registering beyond the effect on clicking, which would be important for policy purposes since it may result in greater attendance which is the policy goal, registrations would be an even more powerful metric.

Attendance is the most important policy metric and, like registrations, can be directly estimated with the LPM. If we examine this and another metric we can adjust for multiple hypotheses testing with the Benjamini-Hochberg procedure.