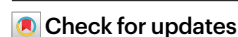


Low-cost climate-change informational intervention reduces meat consumption among students for 3 years

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Evidence on the impact of information campaigns on meat consumption patterns is limited. Here, using a dataset of more than 100,000 meal selections over 3 years, we examine the long-term effects of an informational intervention designed to increase awareness about the role of meat consumption in climate change. Students randomized to the treatment group reduced their meat consumption by 5.6 percentage points with no signs of reversal over 3 years. Calculations indicate a high return on investment even under conservative assumptions (~US\$14 per metric ton CO₂eq). Our findings show that informational interventions can be cost effective and generate long-lasting shifts towards more sustainable food options.

Meat consumption contributes to climate change, accounting for roughly 15% of all anthropogenic greenhouse gas emissions (GHGs)¹. By contrast, GHGs from plants are substantially lower². Many scientific committees encourage shifts towards more sustainable plant-based diets, particularly in the rich developed world, where meat consumption has plateaued, albeit at historically high levels³. Such dietary shifts could improve public health since overconsumption of meat is associated with increased risks for heart disease, type-2 diabetes and some types of cancer^{4,5}. Additionally, intensive animal agriculture, the main source of meat production, can lead to low levels of animal welfare⁶. Given the urgency of the climate crisis, scientific bodies are now calling on researchers to evaluate the effectiveness of interventions that steer people away from meat and towards more sustainable plant-based alternatives^{7,8}.

In this Brief Communication, we examine the long-term effects of an informational intervention that raises awareness about the benefits (that is, climate change and health) of reduced meat consumption. Public awareness about the link between meat and global warming is low⁹. Studying the effects of increased education on meat consumption is important, partially, because policies that raise awareness garner greater public support than more intrusive interventions, such as reduced availability, advertising bans or price increases¹⁰. Broader societal understanding is also probably a pre-condition for stronger action. To measure the effects of an educational intervention on meat

consumption, we partnered with a residential US college. We acquired individual-level food purchase data from the college dining facilities to track the meal selections of study participants, that is, students. We randomized undergraduate courses into treatment and control groups. In the middle of the fall 2017 semester, students in the treatment, but not in the control, group listened to a 50 min talk about the role of meat consumption in global warming, along with information about the health benefits of reduced meat consumption. In previous research, we measured the 6 month effect of this intervention and found that it reduced meat consumption, in favour of plant-based alternatives¹¹. In this study, we examine the effects of this educational intervention for an additional two academic years, 3 years in total (through May 2020), to determine the persistence of these dietary changes. Measuring the long-term effects of food policy interventions is important for understanding their social return. Our dataset amounts to more than 100,000 meal selections over 3 years. This randomized controlled trial uses real-world consumption data to measure the long-term impact of a meat reduction intervention^{12,13}. Our study builds on other recent research that uses real consumption data from college dining facilities to examine the effectiveness of interventions to shift people away from meat and towards plants^{14–18}.

Column 1 in Fig. 1 displays average marginal treatment effects from difference-in-differences logit regressions, measuring changes in food purchase behaviour in the treatment group relative to the control

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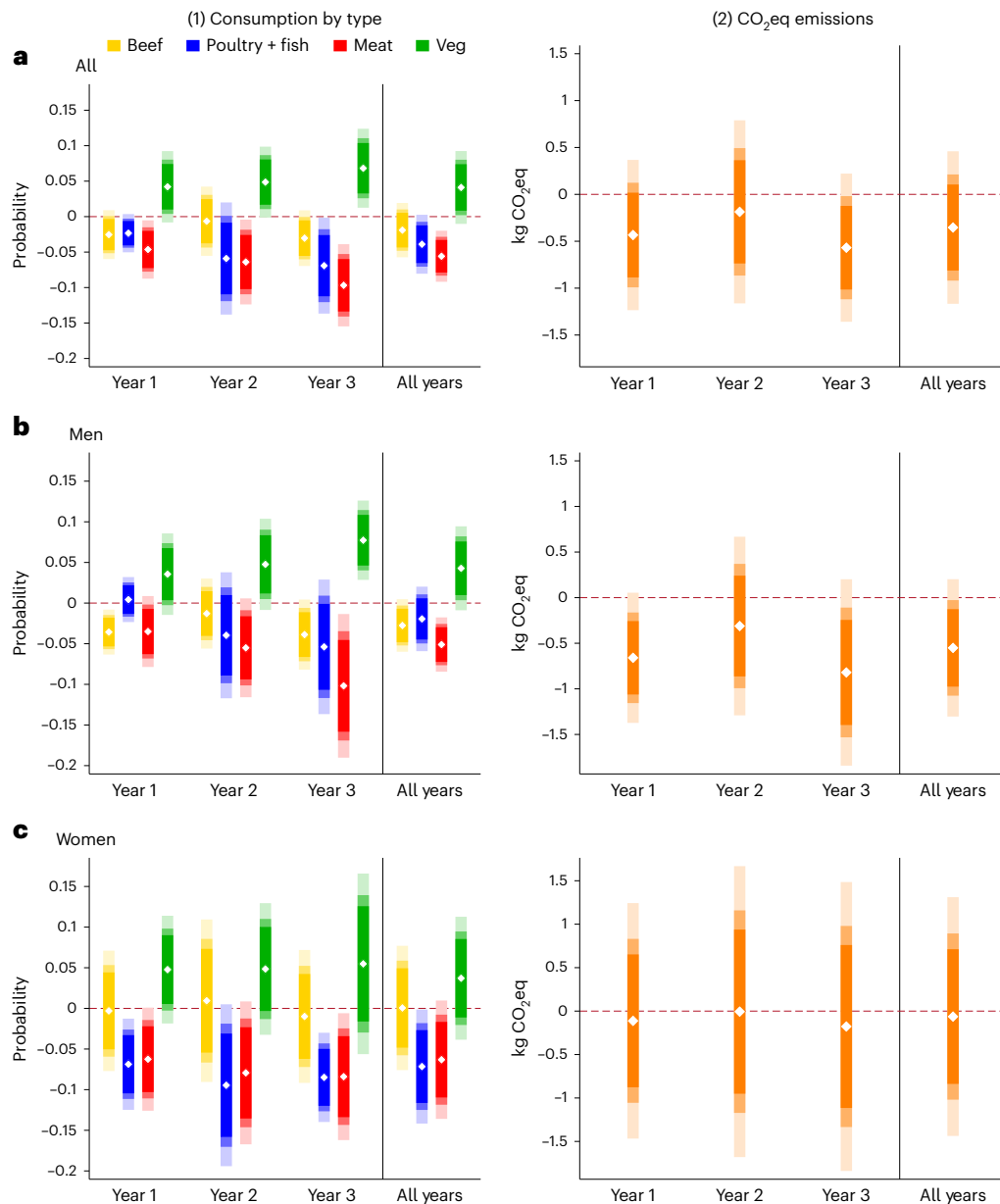


Fig. 1 | Long-term treatment effects on diet and CO₂eq. a–c, Diamonds represent logit average marginal treatment effects for column 1 and ordinary least squares treatment effects for column 2. All regressions control for individual, date and hour fixed effects. The sample size consists of 103,375 meal purchases across 213 students over 3 years (years 1, 2 and 3 correspond to the 2017–2018, 2018–2019 and 2019–2020 academic years, respectively, and ‘all years’ corresponds to the full window from 2017–2020). The estimation period includes the pre-intervention period in year 1 and the post-estimation period

of the indicated time window. Coloured bars represent confidence intervals at levels, from darkest to lightest: 0.9, 0.95 and 0.99. Confidence intervals are computed from robust standard errors, clustered at the unit of randomization, the class level. Column 1 shows the treatment effects on beef (yellow), poultry + fish (blue), meat (red) and veg (green) meals. Column 2 shows the treatment effects on CO₂eq per meal, measured in kg, for the overall effects (a) and results for men (b) and women (c).

group after the intervention. Outcome measures are indicator variables that equal 1 when the main course selected by study participants is beef (high GHGs), poultry or fish (medium GHGs) or vegetarian/vegan (veg) (low GHGs). Meat is a summary variable for overall meat consumption. Figure 1a shows the results for all study participants. In response to the intervention, over the next three academic years (‘all years’), the probability of beef, poultry + fish, and meat fell by 1.9, 3.9 and 5.6 percentage points (p.p.), respectively, whereas the probability of veg increased by 4.1 p.p. Dividing these treatment effects by the average consumption level in the pre-intervention period reveals that beef, poultry + fish, and meat fell by 11%, 9% and 9%, respectively, and veg increased by 20%. The effects show no signs of fading. Disaggregating the results by year

(‘year 1’, ‘year 2’ and ‘year 3’) reveals that dietary changes persisted and, in some cases, grew modestly over time. According to surveys administered after the intervention, 82% of students in the treatment group reported trying to reduce their meat consumption, with climate change (64%) and health (33%) cited as motivating factors (26% listed both). The food purchase data reveal that these motivations translated into long-lasting behavioural changes. In response to a 50 min talk, study participants reduced their meat consumption for years.

Men and women responded to the intervention differently (Fig. 1b,c). Both men and women reduced their overall meat consumption and increased their veg consumption, but only men reduced their consumption of beef (−2.8 versus 0.2 p.p., ‘all years’), whereas both

men and women reduced their consumption of poultry + fish, albeit by substantially larger amounts for women (−1.9 versus −7.1 p.p., ‘all years’). Before the intervention, men consumed far more beef than women (22% versus 13%), so they had greater room to reduce. Men switched from beef towards veg, rather than to poultry + fish. The intervention emphasized that beef has the highest GHGs and plant-based meals the lowest (analyses of additional subgroups, based on observable student characteristics, are in Supplementary Tables 5, 6 and 8–10.)

Column 2 examines the impact of our educational intervention on the average carbon footprint of study participants’ meals. It presents treatment effects, based on difference-in-differences ordinary least squares regressions, where the outcome variable is the carbon footprint of each meal’s main course, measured in terms of kilogram of carbon dioxide equivalents (CO₂eq). To estimate the carbon footprint of each course, we use data from Poore and Nemecek (2018) on average GHGs per 100 g of protein and the US Department of Agriculture on grams of protein per ounce (for more details, see Supplementary Information, Section 8)^{2,19}. Figure 1a shows the results for all study participants. Over all 3 years, in response to the intervention, the average carbon footprint of study participants’ meals fell by 0.354 kg CO₂eq. As CO₂eqs differ substantially by type of meat (Supplementary Table 11) and because men and women responded by reducing different types of meat, Fig. 1b,c disaggregates the results by gender. The estimated impact is much larger for men than for women because men, but not women, reduced their consumption of beef, the type of meat with the highest carbon footprint. On average, each meal selected by men and women had 0.551 and 0.063 fewer kg CO₂eq, respectively (‘all years’). According to a recent detailed analysis, the diets of men, on average, have 41% more GHGs compared with women, primarily due to their larger per capita consumption of red meat²⁰. Our findings indicate that men are willing to reduce their beef consumption in response to information about climate change and health, and that dietary interventions that target men, the highest consumers of beef, may have a larger scope for reducing agricultural GHGs. According to the survey responses, 80% of men in the treatment group reported trying to reduce their meat consumption, with climate change (65%) and health (33%) cited as motivating factors (27% listed both).

We also calculated the returns on investment (ROI). After the intervention, men and women in the treatment group purchased 27,508 and 17,222 meals, respectively, in the college dining facilities. Multiplying the number of meals by the treatment effects, disaggregated by gender and summing across men and women imply a reduction in GHGs of 16,242 kg CO₂eq, with the bulk of the decline coming from the fall in beef among men. Given a cost of US\$44.77 per lecture, or US\$223.85 across five treatment lectures, the ROI from our educational intervention is 72.56 kg CO₂eq per dollar, or US\$13.78 per metric ton CO₂eq, a cost-effective intervention, given a social cost of carbon of US\$31 per metric ton, according to conventional estimates²¹. This baseline ROI estimate is probably a lower bound since it is based only on meals we observe, that is, weekday lunches and dinners at the dining facilities through May 2020. The ROI increases if the effects hold outside of the college dining facilities and/or persist beyond 3 years. For example, assuming these average marginal effects extend outside of the meals we observe at the dining facilities to all lunches and dinners over the same window, that is, October 2017 to May 2020, implies a reduction in GHGs of 64,806 kg CO₂eq and an ROI of 290 kg CO₂eq per dollar, or US\$3.45 per metric ton. Under this assumption, for each year that the effects persist, the impact is an additional fall in GHGs of 25,353 kg CO₂eq and an additional increase in the ROI of 113 kg CO₂eq per dollar (for example, if the effect persists for 5 years, the ROI would be 566 kg CO₂eq per dollar, or US\$1.77 per metric ton). Furthermore, these estimates do not include the additional returns the intervention yields from other environmental benefits (reduced land and water use), better health and the possibility of improved animal welfare (for more

details about cost estimates and ROI calculations, see Supplementary Information, Section 8).

Supplementary Tables 4, 14 and 15 contain additional analyses. Our results are robust to changes in the specification of our regression and alternative inference methods. Treatment effects do not vary with baseline levels of meat consumption. The frequency of meal purchases does not differ between the control and treatment groups, neither before nor after the intervention.

This study shows that a climate-change educational intervention can have long-term effects. By using real-world food purchase data to measure behavioural change over a prolonged period, our work bolsters the findings of recent research on the effectiveness of health and climate-change messaging to reduce meat consumption²². Our results indicate that messages that emphasize the dual benefits of reduced meat consumption—similar to the ‘win-win’ messaging campaign (‘good for the planet and good for you’) endorsed by the EAT–Lancet Commission—may be particularly effective. For similar interventions to work elsewhere, policymakers may need to ensure that tasty and affordable plant-based options are readily available, similar to the host college. While the dietary changes in this study are statistically significant and strongly persistent, the magnitude—a roughly 9% decline in meat consumption—is substantially smaller than what is necessary for high-income countries, such as the United States, to meet sustainability targets⁸. This finding suggests that increased education, while an important starting point, is unlikely to be sufficient by itself to achieve climate change goals.

We acknowledge the study limitations: we were unable to track the effects of the intervention after graduation or outside of the college dining facilities, and our sample consisted of college students who may not be representative of the average population. Nevertheless, our findings, including our strong internal validity, hold great promise for policymakers. Businesses, corporations and other organizations (for example, hospitals, K–12 schools, colleges and universities) interested in reducing their environmental footprint could implement similar informational interventions to steer community members towards more sustainable, healthy food choices.

Methods

We recruited students to participate in our study from ten classes at the host college during the fall 2017 semester. We randomized these classes into control and treatment groups. We used class time for the intervention and administration of surveys, as a means of boosting participation and survey response rates. Study participants in the treatment group listened to a 50 min talk about the consequences of meat consumption for climate change, alongside information about the health benefits of reduced meat consumption (for a detailed description of the intervention, along with more details on our methodology, please see our prior paper or Supplementary Information)¹¹. Study participants in the control group listened to a 50 min talk about a placebo topic unrelated to food choices (income inequality). We tracked study participants’ food purchases at the college dining facilities over three academic years, that is, fall 2017 to spring 2020 semester. The guest talk occurred more than halfway through the fall 2017 semester (17–24 October 2017). The gender, racial and age composition, as well as food purchase behaviour based on 12,562 meals before the intervention, of the control and treatment groups is similar (Supplementary Tables 1 and 2).

At each food station at the dining facilities, students select a main course amongst a set of choices (the sides are usually the same). Each station has a vegetarian or vegan option (beans, lentils, tofu or meat substitutes), alongside meat option(s) (beef, poultry and fish). Students pay for meals using their ID card. The college requires students living on campus (80% of the student body) to have a meal plan, and most students living off campus also obtain a meal plan. The dining facilities are the only locations on campus for students to purchase

meals. Prices remained constant before and after the intervention and were usually the same for meat and non-meat options, that is, on average, US\$2.50 per meal.

We analysed four food outcome measures: beef, poultry + fish, meat and veg. We derive these measures from the buttons on the cashiers' registers. At the point of purchase, cashiers record the main course using one of four buttons (beef, poultry, fish or veg). Each of our food outcome variables takes on a value of '1' when the main course belongs to that specific category. 'Beef' includes meals whose main course is red meat. 'Poultry + fish' includes meals whose main course is poultry (chicken or turkey) or fish. Meat is a summary measure for overall meat consumption and is the sum of 'beef' and 'poultry + fish'. 'Veg' includes meals whose main course is vegetarian or vegan. In explaining variation in GHGs among protein sources, our educational intervention grouped together poultry and fish, which have comparable GHGs per gram of protein, under the heading of 'medium' GHGs, separate from beef ('high' GHGs) and plants ('low' GHGs). As the talk allotted beef, poultry + fish, and veg into these high, medium and low groupings, we transfer over these categories to our econometric work.

We confine our analysis to meals where we can distinguish between veg and meat main courses: lunch on weekdays and dinners on Mondays to Thursdays. On Friday dinners and over the weekends, the cashiers do not distinguish between meat and veg options since the dining facilities restructure meals as a buffet, rather than a la carte. Cashiers also do not record meat versus non-meat selections at breakfast. We omit salad bar purchases as an outcome variable since the salad bar contains meat options, and the cashiers do not distinguish between salads with and without meat. We include only food purchases that are main courses and, thereby, exclude snacks. Since the registers have four buttons (beef, poultry, fish and veg), the cashiers mark lamb and pork as 'beef' and vegetarian and vegan options as 'veg'. While we are unable to distinguish between beef and lamb or pork, the overwhelming majority are beef since the dining facilities serve beef daily, but pork and lamb infrequently. Likewise, while we are unable to distinguish between vegetarian and vegan selections, most of these 'veg' options are either vegan or a meal available in both a vegan or vegetarian form.

We administered surveys to collect data on study participants. Consent forms to students revealed that participation entailed three aspects: watching a guest talk, filling out surveys and allowing the researchers access to data from student ID cards. We did not disclose to students we would be examining their food purchase data. Nearly all students (that is, >99%) consented to participate in the study. We pre-registered our study in the American Economic Association's registry for randomized controlled trials (RCT ID AEARCTR-0002536). The institutional review board of Occidental College authorized the study (Jali-F17046).

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Individual participant data that underlie the results reported in this article, after de-identification, will be made available to researchers who provide a methodologically sound proposal. Proposals should be directed to corresponding author at jali@oxy.edu; to gain access, data requestors will need to sign a data access agreement. Additional data/materials, that is, GHG data, ROI calculations, informed consent form and intervention materials (handouts, surveys and slides), may be found at <https://doi.org/10.17605/OSF.IO/5H8U7>.

Code availability

The code used for this analysis is available from the corresponding author on request.

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Author contributions

A.J.J., J.T. and A.V.B. conceived the idea. A.J.J. and J.T. collected and analysed the data. A.J.J. designed the intervention and wrote the paper. J.T. and A.V.B. edited the paper.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s43016-023-00712-1>.

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Human research participants

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Reporting on sex and gender	Results disaggregated by gender. Data on gender from surveys.
Population characteristics	Undergraduate college students. Average age: 19.
Recruitment	We recruited students to participate in our study from ten economics classes at the host college during the fall 2017 semester. We randomized these ten classes into control and treatment groups. We chose ten core economics classes that must be taken sequentially, guaranteeing no overlap between treatment and control groups since students cannot take more than one of these classes in a semester. We used class time for the intervention and administration of surveys, as a means of boosting participation and survey response rates. Nearly all students (i.e. >99%) consented to participate in the study, so any potential self-selection bias is negligible.
Ethics oversight	Occidental College, Human Subjects Research Review Committee

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Study description	Randomized controlled trial to examine the effects of an informational intervention on the meal selections of study participants, i.e. students. Data: Quantitative, i.e. food purchases. Qualitative surveys as well.
Research sample	Undergraduate students at a residential U.S. college. College students differ from the broader population, in terms of being younger (the average age of participants in our study is 19) and more educated. Our sample represents a diverse student population, in terms of gender (38% female, 62% male) and race/ethnicity (40% nonwhite, 60% white).
Sampling strategy	We recruited students at the host college who were taking non-overlapping economics classes, as a means of ensuring no overlap between control and treatment groups. Our sample size of 213 students led to a dataset of 103,375 meal purchases over three years, a sufficiently large dataset for statistical analyses.
Data collection	We collected data on food purchases from student ID card swipes. The cashiers at the cash registers record the food purchases at the point of transaction. The professors of the classes were present for the intervention, along with the researcher. The researcher was not blind to experimental condition because the treatment group listened to a 50-minute talk on the consequences of meat consumption for health and climate, and the control group listened to a placebo talk on an unrelated topic.
Timing	Sep 2017 to May 2020
Data exclusions	No exclusion
Non-participation	More than 99% of students consented to participate in the study.
Randomization	Block randomization.

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