nature food

Brief Communication

https://doi.org/10.1038/s43016-023-00712-1

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

In the format provided by the authors and unedited

Supplementary information

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

Andrew J. Jalil[1,], Joshua Tasoff[2], Arturo Vargas Bustamante[3]*

Last revised 5 February 2023, for publication in *Nature Food*

This file contains:

Authors' information
[1] Occidental College, 1600 Campus Road, Los Angeles, CA 90041.
[2] Claremont Graduate University, Harper E. 204, 160 E. Tenth Street, Claremont, CA 91711.
[3] Fielding School of Public Health, University of California, Los Angeles, 650 Charles E. Young Drive South, Los Angeles, CA 90095.

*Corresponding author: Email: jalil@oxy.edu

Meat consumption contributes to climate change and environmental degradation, increases the risk of non-communicable diseases (NCDs) and raises important ethical issues about animal welfare. The livestock sector is a leading driver of global warming, accounting for roughly 15% of all anthropogenic greenhouse gas emissions (GHGs), more than those from the global transportation sector[1–3]. Because plants have far lower GHGs, many scientific committees and organizations are now advocating for dietary shifts away from meat towards more sustainable plant-based diets[4–8]. A recent analysis from the EAT-Lancet commission concludes that for high-income countries to meet sustainability targets, consumption of meat, in particular red meat, must fall by more than 50% and consumption of plants must increase by more than 100%[9]. In the rich developed world, where meat consumption has plateaued at excessive levels, such dietary shifts could also improve public health since overconsumption of meat is associated with increased risks for heart disease, type-2 diabetes and some types of cancer[10]. The current global scale of meat consumption—70 billion farmed animals per year—also raises important ethical issues since the vast majority are raised on industrial factory farms under conditions that result in great pain and suffering[11]. Policy interventions that steer people away from meat, in favor of plant-based diets, could mitigate climate change, improve public health, and reduce animal suffering.

1. Additional Details on the Intervention and Choice Setting

Our educational intervention lasted roughly 50 minutes. For approximately the first 25 minutes, the intervention focused on the role of meat consumption in climate change. The talk briefly began by motivating the seriousness of climate change, before turning to the topic of meat consumption. Students learned that meat consumption accounts for roughly 15% of global greenhouse gas emissions (GHGs), more than the transportation sector, and that the current scale of meat consumption is unsustainable. The talk stressed that on average, meat has higher GHGs than plants (i.e. lentils, beans, peas, whole grains, fruits, vegetables, seeds, nuts) and that some types of meat (i.e. beef) have higher GHGs than other types (i.e. poultry, seafood). The talk explained that meat has such high GHGs for a few reasons: (1) ruminants emit methane, a potent GHG, (2) animal manure, a byproduct of livestock, releases nitrous oxide, another potent GHG, and (3) meat production requires large resources (land, feed, water) and is a leading driver of deforestation, resulting in a range of GHGs. For the next roughly 20 minutes, the intervention then pivoted to the public health benefits of reduced meat consumption because prior research indicates that many people have health misconceptions about meat that need to be addressed before initiating behavioral change, e.g. many people mistakenly believe that meat must be a part of a healthy diet and that plant-based sources of protein are inferior. This portion of the talk emphasized that (1) people in the U.S. eat three times more meat than experts consider healthy, (2) meat consumption is not necessary for optimal health, and (3) shifts away from meat and towards plants, in rich developed countries, are associated with reduced rates of non-communicable diseases, e.g. heart disease, type-2 diabetes, some types of cancer. The intervention cites reputable scientific sources, including the U.S. Dietary Guidelines, Kaiser Permanente, and the World Health Organization. This portion of the talk emphasized a simple "win-win" message: Reducing meat consumption can be good both for you and the planet. Throughout the talk, the intervention utilized videos, images, infographics, handouts, and at one point, a game in which study participants selected the food item, amongst a set of choices, with the lower carbon footprint. Study participants also received a list of plant-based meals available at the college dining halls. The talk ended by encouraging participants to reduce their meat consumption, in favor of plant-based alternatives, to fight climate change.

We spend time on both climate change and health (25 and 20 minutes, respectively) because prior research shows that health misconceptions may be a barrier to reductions in meat consumption. In focus group interviews among a diverse set of countries, Chatham House documents that many people mistakenly perceive plant-based sources of protein to be inadequate and inferior to meat[3]. In pretesting our intervention prior to implementation, students reported similar misconceptions. Policymakers likely need to counter such misconceptions with credible health information before people are willing to reduce their meat consumption. For this reason, our intervention centers on the dual climate-health benefits of reduced meat consumption, in favor of plant-based options. The intervention, including time spent completing surveys, is roughly 55 minutes, the length of one class period. Please see our prior paper for more details[12].

Our informational intervention also emphasizes a climate change-health message, given its importance in the international food policy debate. In a recent report on healthy and sustainable food systems, the EAT-Lancet Commission encourages dietary changes via a "win-win" messaging strategy, i.e. "good for the planet and human health"[9]. Other organizations and scientific committees also endorse messages that connect human health and climate change to reduce meat consumption. Prior research from Chatham House, based on focus groups, finds that messages that emphasize multiple reasons to curb meat consumption (i.e. health and climate change) are more likely to lead to behavioral changes than messages that center on only one issue[3]. Our prior paper (Jalil et al. 2020) describes in greater depth the reasons our intervention focused on a climate change-health message[12]. Notably, despite its prominence in the international food policy debate, our study is the first in this literature to examine the effectiveness of such a messaging strategy at reducing meat consumption in the long term, using actual food purchase data.

Recent scholarship has concluded that most people rationalize the consumption of meat on the grounds of the "four N's", i.e. that it is "natural, normal, necessary, and nice"[14]. According to this work, many people are morally conflicted about eating meat, but justify it based on one of these four rationalizations. Our intervention, by emphasizing the negative consequences of meat consumption for both health and climate change, counters the notion that meat is necessary and nice. Other studies show that graphic health warning labels, by eliciting disgust, and credible environmental information, by raising fear about climate impacts, reduce intentions to consume meat via protection motivation theory[15,16]. Recent work within the field of economics also emphasizes the role of prosocial behavior, i.e. actions that benefit the whole of society, in motivating change[17]. Our intervention attempts to induce long-term behavioral change by equipping people with knowledge about the health and climate change consequences of meat consumption, and by making a prosocial appeal to take actions for the greater good—a messaging strategy that reduces the "4N" justification for consuming meat.

From an economic theory perspective, we conceptualize our intervention as having two distinct elements. First, it is a form of information. Under the classical rational actor model in economics, people make decisions in an uncertain environment to maximize their expected utility (see for e.g. Mas-Collel, Whinston and Green, 1995)[18]. In our context, study participants face uncertainty about the consequences of their dietary choices. Our intervention is an informative signal that allows individuals to Bayesian update their beliefs about the consequences of their food choices (see Hirshleifer and Riley, 1992)[19]. As long as study participants have some concern about the impact of their actions on climate change or their health, and put some positive probability that the information in our guest lecture is accurate, they should change their beliefs in the direction of the information (i.e. that meat is a cause of global warming and a health risk factor). The second element of our intervention is an exhortation to eat less meat. Ambuehl, Bernheim, and Lusardi (2022), for example, show that exhortation absent of decision-relevant information can still effectively change behavior[20]. Our study contributes to this literature by testing, with real-world data, how people respond to an informational intervention in terms of their food purchasing behavior.

In terms of the choice setting, the meal offerings at the dining facilities remained relatively constant throughout the duration of our study. This point is important to note since another recent study finds a large increase in the sales of vegetarian meals due to a doubling of options[21]. Specifically, the dining facilities at the host college of our study have a menu of meal offerings, available on a rotating basis, at different food stations. Each station serves a different meal, which varies over time. Each station has at least one vegetarian/vegan main course, along with meat main course(s), from which students choose (for instance, the meat option may be chicken at one station, but fish or beef at another). Students can select a meal from any station. The menus that generate these rotating offerings did not change in an appreciable way during our study. In particular, the number or type of "veg" offerings did not change. Hence, any changes in food purchase behavior in the treatment, relative to the control, group after the intervention should not be driven by changes in meal offerings. As an added precaution, date fixed effects in our regressions should capture any idiosyncratic changes in meals on any given day.

2. Surveys

We use surveys to filter students by gender and race/ethnicity to examine heterogenous treatment effects. We administered surveys during classroom visits, i.e. on the day of the intervention, to collect demographic information. Both the experimental and control groups completed a survey, which asked about demographic characteristics (i.e. gender, race/ethnicity, age, grade level). To analyze heterogenous treatment effects, we use data on gender, minority status, and grade level from our surveys. Men and women could respond differently to interventions designed to reduce meat consumption. Prior research suggests that on average, men consume more meat than women do, at least in part, to cultural associations between meat and masculinity [22]. According to cross-national surveys, men in high-income countries are also less likely to report concern about climate change than women [23]. We use minority status to take into account population heterogeneity between white and nonwhite study participants and other unobserved differences that could influence meal selections (e.g. cultural, socioeconomic). We include grade level at the time of the intervention to determine whether younger versus older students were more responsive to the intervention.

3 Regression Analysis

We adopt a difference-in-differences framework to estimate average treatment effects. This framework allows us to identify movements in the experimental group, relative to the control group, after the intervention. Specifically, we use the following logit regression:

$$(1) \qquad \log\left(\frac{F_{m,i,d,h}}{1-F_{m,i,d,h}}\right) = \alpha + \beta_0 T_m + \beta_1 A_m + \beta_2 T_m A_m + \rho_i + \gamma_d + \delta_h + \varepsilon_{m,i,d,h}$$

where F is one of four food dummy variables that equals one if the meal, *m*, belongs to that category (beef, poultry+fish, meat, or veg) for individual *i,* on day *d*, at hour *h.* T_m is a dummy variable for meals purchased by individuals in the treatment group and A_m is a dummy variable for meals purchased after the intervention. The main variable of interest, the interaction term T_m*A_m, estimates treatment effects, i.e. changes in our food outcome variable after the intervention in the treatment group, relative to the control group. It measures the impact of the intervention on meal selections. In addition, we include individual (ρ_i), date (γ_d), and hour (δ_h) fixed effects.

In our baseline analysis, we estimate this regression for all three years. We also disaggregate the results by year to examine changes over time. To examine effects on CO_2eq per meal, we replace the dependent variable in equation (1) with the average carbon footprint of the main course selected by study participants and use an ordinary least squares (OLS) regression. The key benefit of a difference-in-differences framework is that it allows us to compare movements after the intervention in the treatment group, relative to the control group. Such a framework assumes that the control and treatment group follow parallel trends. This should hold due to random assignment. In our prior paper, we found evidence supporting parallel trends: Based on bin scatterplots of food purchase behavior in the control and treatment groups, after the intervention, food purchase behavior for the treatment group changes suddenly, with no noticeable changes in food purchase behavior in the control group pre- vs post- intervention.

To examine heterogenous treatment effects, we include interaction terms for gender, minority status, and grade level. Equation 2 shows the form of the regression:

$$\log\left(\frac{F_{m,i,d,h}}{1-F_{m,i,d,h}}\right) = \alpha + \beta_0 T_m + \beta_1 A_m + \beta_2 T_m A_m + \beta_3 A_m H_i + \beta_4 T_m A_m H_i + \rho_i + \gamma_d + \delta_h + \varepsilon_{m,i,d,h} \quad (2)$$

The term H_i represents the dimension of heterogeneity. It takes on the value of 1 when the individual has the attribute (e.g. female). The new term of interest is β_4, which is the coefficient on the triple interaction term. The average marginal effects of this term represent the additional treatment effect on individuals with that attribute. Finally, we also include the $\beta_3 A_m H_i$ term as a control for time variation in the outcome for individuals with the attribute. (Note: There is no need for a $T_m H_i$ term as this is subsumed by individual fixed effects.)

4. Sample Characteristics

Supplementary Tables 1 and 2 show data for the control and treatment groups. It presents two samples: full and fixed. The full sample includes all study participants, i.e. those who were present in year 1 and consented to participate in the study. The fixed sample is restricted to those subset of study participants who were present and made meal purchases all three years (years 1, 2, and 3). Some students, e.g. upper-class students, graduate and exit our study in years 2 and 3 since they are no longer on campus. In the analysis that follows, we present the results for both the full and fixed samples. Doing so helps us to determine whether changes over time are the result of changes in effect sizes or in the composition of study participants. In the main body of the paper, we show the results based on the full sample.

Supplementary Table 1 presents demographic data. The full sample includes the 213 study participants who consented to participate in the study in year 1. Amongst those, the fixed sample includes the 145 study participants who were present and made food purchases all three years. The gender, racial and age composition of the control and treatment groups are similar in both samples. Study participants in the full sample are, on average, older than those in the fixed sample since older students are more likely to be upperclassmen who graduate and drop out of the study in years 2 or 3. Our sample represents a diverse student population, in terms of gender and race/ethnicity

Supplementary Table 1. Treatment and Control Characteristics

	Full			Fixed		
Variable	Control	Treatment	p-value	Control	Treatment	p-value
Female	0.342	0.431	0.249	0.355	0.464	0.105
	(0.477)	(0.498)		(0.482)	(0.502)	
Non-white	0.423	0.373	0.493	0.382	0.290	0.110
	(0.496)	(0.486)		(0.489)	(0.457)	
Age	19.2	19.0	0.758	18.9	18.5	0.089
	(1.080)	(1.274)		(0.754)	(0.656)	
# students	111	102		76	69	

Notes: The table reports the share of students who are female and non-white and the average age of participants. Non-white includes students who self-identified as American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, or as of Hispanic or Latino origin. Standard deviations are in parentheses. The last column displays the p-value for a test of equality of means between the control and treatment groups.

Supplementary Table 2 shows summary statistics on meal purchases prior to the intervention. For both the full and fixed samples, the control and treatment groups are similar before the intervention, with meat consumption slightly lower and veg consumption slightly higher in the treatment group. In the treatment and control groups, meat purchases are roughly three times more frequent than veg purchases. The number of meals in the pre-intervention period is 12,562 for the full and 8,783 for the fixed sample. The variables beef, poultry+fish, and veg sum to less than one since we omit the category, salad bar (we do not directly examine salad bar purchases since the salad bar contains meat options, and the cashiers do not distinguish between salads with and without meat).

Supplementary Table 2. Summary Statistics: Frequency of a Given Meal Type Before Intervention

	Full			Fixed		
Variable	Control	Treatment	p-value	Control	Treatment	p-value
Beef	0.202	0.177	0.088	0.207	0.179	0.072
	(0.402)	(0.382)		(0.405)	(0.383)	
Poultry+Fish	0.453	0.415	0.140	0.434	0.416	0.403
	(0.498)	(0.493)		(0.496)	(0.493)	
Meat	0.655	0.592	0.105	0.641	0.595	0.182
	(0.475)	(0.491)		(0.480)	(0.491)	
Veg	0.186	0.207	0.553	0.192	0.202	0.793
	(0.389)	(0.405)		(0.394)	(0.402)	
# meals	6,560	6,002		4,826	3,957	

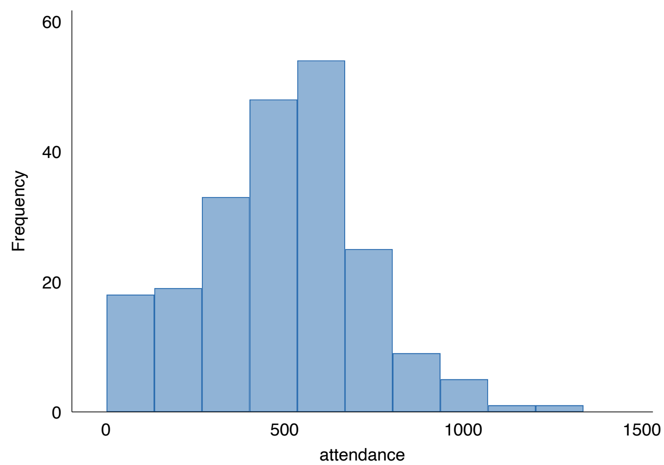
Notes: The table reports the frequency, by food category, before the intervention. The "meat" variable aggregates beef, poultry, and fish. Standard deviations are in parentheses. The last column displays the p-value for a test of equality of means between the control and treatment groups.

While all students who live on campus are required to possess a meal plan, students may select whatever meals they prefer, and we had no dietary requirements for inclusion in our study. In our sample, the number of self-reported vegetarians (<5%) and vegans (~1%) is small. We do not drop those students for two reasons. First, we find, in examining individual-level food purchase data, that self-reported vegetarians occasionally purchase meat, so they have scope for reductions. Second, in our regression, the inclusion of individual-level fixed effects control for any propensity, among individual students, to purchase less meat. Our difference-in-differences regression framework examines whether students in the treatment group, relative to the control group, reduced their meat consumption after the intervention, compared to their consumption levels prior to the intervention.

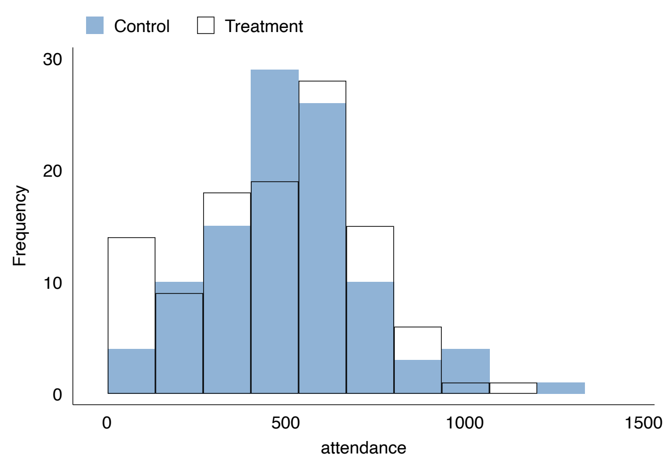
To give a sense of student use of the dining facilities, Supplementary Figure 1 presents a histogram, showing the frequency of meal purchases (Panel A: overall; Panel B: control and treatment groups). The average number of meal purchases per student is 485 (474 and 497 in the control and treatment groups, respectively) throughout the duration of our study.

Supplementary Figure 1. Histogram of Student Meal Purchases at Dining Facilities

Panel A: All students, all three years.



Panel B: Control and Treatment Groups, All Three Years



5. RCT Results: Average Treatment Effects

The top row of Supplementary Table 3 shows the average treatment effects over the full three-year period. Relative to the control group, study participants in the experimental group reduced their meat consumption and increased their consumption of veg meals after the intervention. The probability of beef, poultry + fish, and meat fell by 1.9, 3.9, and 5.6 percentage points, respectively. By contrast, the probability of veg increased by 4.1 percentage points. Three of the four coefficients—those for poultry+fish, meat, and veg—are statistically significant.

Supplementary Table 3. Logit Average Treatment Effects: By Year, Full Sample

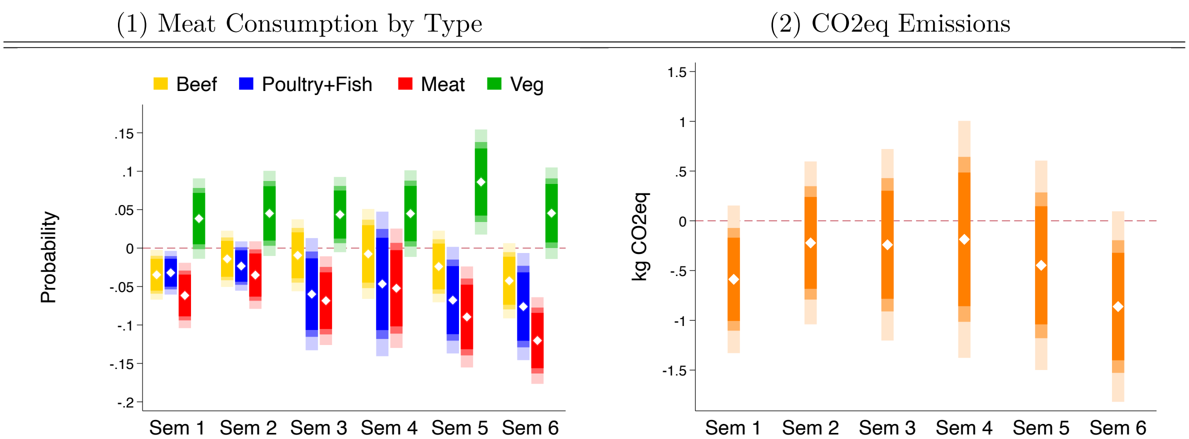
	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
All Years				
Treated	-0.019	-0.039**	-0.056***	0.041**
	(0.015)	(0.016)	(0.014)	(0.020)
	[0.200]	[0.016]	[0.000]	[0.039]
Mean DV	0.176	0.446	0.622	0.221
Pseudo R2	0.109	0.090	0.129	0.123
# meals	103,301	103,338	103,324	103,248
Year 1				
Treated	-0.025*	-0.023**	-0.046***	0.042**
	(0.013)	(0.010)	(0.016)	(0.020)
	[0.058]	[0.025]	[0.004]	[0.031]
Mean DV	0.174	0.444	0.619	0.215
Pseudo R2	0.113	0.098	0.147	0.142
# meals	49,127	49,126	49,123	49,052
Year 2				
Treated	-0.006	-0.059*	-0.064***	0.049**
	(0.019)	(0.031)	(0.023)	(0.019)
	[0.733]	[0.054]	[0.006]	[0.012]
Mean DV	0.179	0.445	0.624	0.218
Pseudo R2	0.113	0.093	0.129	0.128
# meals	47,739	47,755	47,754	47,690
Year 3				
Treated	-0.030**	-0.069***	-0.097***	0.068***
	(0.015)	(0.026)	(0.022)	(0.022)
	[0.046]	[0.008]	[0.000]	[0.002]
Mean DV	0.185	0.441	0.626	0.215
Pseudo R2	0.118	0.089	0.124	0.121
# meals	31,439	31,578	31,565	31,496

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. In the full sample, the control and treatment groups have 111 and 102 students, respectively. *p<0.1; **p<0.05; ***p<0.01

The bottom three rows of Supplementary Table 3 disaggregate the results by year, with separate regressions corresponding to particulars year. The regressions in this table restrict the post-intervention period to that specific year, allowing us to examine how average treatment effects vary over time (the pre-intervention period is the same across all regressions). The coefficients for meat and veg are strongly significant and grow in size in each successive year. Meat probability fell by 4.6, 6.4 and 9.7 percentage points and veg probability increased by 4.2, 4.9, and 6.8 percentage points in years 1, 2, and 3, respectively. The coefficients for beef are negative and significant in years 1 and 3, but roughly zero in year 2, indicating that the effect for beef temporarily disappears in year 2, before returning in year 3 (the campus dining facilities did not meaningfully change the menus during the three years of our study, so changes in the composition of menus are unlikely to explain this result). The coefficients for poultry+fish are negative and significant in all three years and grow in magnitude in each year.

Figure 1 in the main body of the paper presents these effects over time, with confidence intervals, by year. Supplementary Figure 2 reproduces Figure 1, but with a more disaggregate time scale, i.e. by semester (fall and spring) for all three years.

Supplementary Figure 2. Long-Term Treatment Effects, by Semester



Notes: The diamonds represent logit average marginal treatment effects for Col (1) and OLS treatment effects for Col (2). All regressions control for individual, date, and hour fixed effects. The sample size consists of 103,375 meal purchases across 213 students. The estimation period includes the pre-intervention period in Year 1 and the post-estimation period of the indicated time window. Colored bars represent confidence intervals at levels, from darkest to lightest, 0.9, 0.95, and 0.99. Confidence intervals are computed from robust-clustered 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.

These baseline disaggregated results by year, reported in the preceding paragraphs and in the main body of the paper, use the pre-intervention period of year 1 and the post-intervention period restricted to that particular year, i.e. year 1, 2, or 3. A strength of this approach is that the post-intervention period for both the control and treatment is restricted to that same year. However, as a robustness check, we also examine the results using an alternative approach that interacts the treatment dummy with post-treatment dummies by year. Supplementary Table 4 reports the results based on this alternative approach for all study participants for the four food outcome variables. The results do not change in a meaningful way. The treatment effect is statistically significant for the four food outcome variables (beef, poultry+fish, meat, and veg) and none of the year-interaction dummies are significant, revealing that effects persisted over time (the sole exception is beef in year 2, where the effect disappears, before returning in year 3). These results (including those for beef) are the same as those found using the approach that relies on disaggregated subsamples.

Supplementary Table 4. Logit Average Treatment Effects with Year Interaction Terms: Full Sample

	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
Treated	-0.027*	-0.026**	-0.049***	0.044**
	(0.014)	(0.010)	(0.015)	(0.019)
	[0.054]	[0.011]	[0.001]	[0.021]
Treated x Year 2	0.022***	-0.028	-0.008	-0.004
	(0.008)	(0.021)	(0.016)	(0.012)
	[0.005]	[0.172]	[0.590]	[0.701]
Treated x Year 3	-0.003	-0.014	-0.017	-0.008
	(0.008)	(0.018)	(0.019)	(0.013)
	[0.740]	[0.421]	[0.394]	[0.547]
Mean DV	0.176	0.446	0.622	0.221
Pseudo R2	0.110	0.090	0.129	0.123
Year 2 p-value	0.794	0.044	0.001	0.048
Year 3 p-value	0.025	0.047	0.000	0.157
# meals	103,301	103,338	103,324	103,248

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. We interact indicator variables for years 2 and 3 with the treated to examine effects over time. In the full sample, the control and treatment groups have 111 and 102 students, respectively. *p<0.1; **p<0.05; ***p<0.01

Supplementary Table 5 reestimates the regressions from Supplementary Table 3, but restricts the analysis to the fixed sample that includes only those study participants who made meal purchases all three years. Doing so helps us to examine whether the growing magnitudes of these coefficients are the result of changes in effect sizes or in the composition of study participants over time. Each year, some students graduate and drop out of our sample. Upper-level students, who are more likely to exit our sample in years 2 and 3 due to their shorter window to graduation, could respond differently to the intervention. The fixed sample holds constant study participants. Over the full three-year period, the coefficients for poultry+fish, meat and veg are larger and more statistically significant in this fixed sample, relative to the full sample: -7.0 vs -3.9, -8.4 vs -5.6, and 7.1 vs 4.1, respectively. The larger magnitudes of the coefficients for the fixed, than for the full, sample suggest that those study participants who were present all three years responded more strongly to the intervention than students who dropped out in years 2 or 3. The coefficients, disaggregated by year, also vary less in this fixed sample, suggesting relatively constant effects over time among study participants who were present all three years (e.g. the coefficients vary between -7.5 and -9.7 for meat and 6.8 and 7.6 for veg).

Supplementary Table 5. Logit Average Treatment Effects: By Year, Fixed Sample

	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
All Years				
Treated	-0.018	-0.070**	-0.084***	0.071***
	(0.016)	(0.028)	(0.022)	(0.015)
	[0.264]	[0.012]	[0.000]	[0.000]
Mean DV	0.175	0.438	0.612	0.229
Pseudo R2	0.114	0.0917	0.129	0.131
# meals	83,374	83,415	83,405	83,374
Year 1				
Treated	-0.028**	-0.053***	-0.075***	0.076***
	(0.013)	(0.020)	(0.019)	(0.012)
	[0.035]	[0.007]	[0.000]	[0.000]
Mean DV	0.173	0.432	0.606	0.225
Pseudo R2	0.120	0.101	0.146	0.158
# meals	35,046	35,045	35,046	35,036
Year 2				
Treated	-0.003	-0.078**	-0.079***	0.068***
	(0.022)	(0.036)	(0.028)	(0.016)
	[0.888]	[0.028]	[0.004]	[0.000]
Mean DV	0.177	0.436	0.614	0.226
Pseudo R2	0.119	0.096	0.133	0.135
# meals	38,148	38,153	38,154	38,138
Year 3				
Treated	-0.031**	-0.069***	-0.097***	0.071***
	(0.015)	(0.026)	(0.022)	(0.020)
	[0.047]	[0.008]	[0.000]	[0.001]
Mean DV	0.185	0.439	0.625	0.218
Pseudo R2	0.119	0.088	0.122	0.121
# meals	27,656	27,780	27,769	27,764

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. In the fixed sample, the control and treatment groups have 76 and 69 students, respectively. *p<0.1; **p<0.05; ***p<0.01

Supplementary Table 6 further explores whether effects differ by year (i.e. 1, 2, and 3) or cohort (e.g. first years versus seniors) for our main outcome variable: meat. We divide study participants into four cohorts, based on the number of years in college at the time of the intervention: first-, second-, third-, and fourth-years. In addition to the standard controls of individual, date, and hour fixed effects, we now also include cohort×post-intervention dummies. Column (1) reports the baseline results. For the full three-year period, meat falls by 6.2 percentage points (p-value<0.01). Column (2) interacts indicator variables for years 2 and 3 with our treatment variable. The coefficients for these interactions, -0.008 and -0.016, are negative, but small in magnitude and statistically insignificant. These insignificant interactions, alongside the statistically significant treatment variable of -0.056 (p-value<0.01), suggest that effects did not differ significantly over time, but rather hovered at roughly the same level in all years.

Supplementary Table 6. By Cohort and Year.

	(1)	(2)	(3)
	Meat	Meat	Meat
Treated	-0.062***	-0.056***	0.006
	(0.015)	(0.017)	(0.052)
	[0.000]	[0.001]	[0.902]
Treated x Year 2		-0.008	
		(0.016)	
		[0.593]	
Treated x Year 3		-0.016	
		(0.020)	
		[0.408]	
Treated x Third-Years			-0.070
			(0.057)
			[0.218]
Treated x Second-Years			-0.071
			(0.048)
			[0.137]
Treated x First-Years			-0.070
			(0.048)
			[0.145]
Year 2 p-value		0.000281	
Year 3 p-value		0.000249	
Third-Year p-value			0.046
Second-Year p-value			0.00121
First-Year p-value			0.0119
# meals	103,324	103,324	103,324

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. All columns control for individual, date, hour, and cohort×post-intervention fixed effects. Each cohort has 91 (first-year), 78 (second-year), 29 (third-year) and 15 (fourth-year) students. *p<0.1; **p<0.05; ***p<0.01

Column (3) in Supplementary Table 6 examines heterogenous treatment effects by cohort. It interacts indicator variables for third-, second-, and first-year students with our treatment variable. The coefficient for our treatment variable, which measures the effects of the intervention on fourth-year students (the omitted category), is roughly zero and statistically insignificant, suggesting that fourth-year students, i.e. those in their final year of college, did not respond to the intervention (though our sample size is much smaller for fourth-year students due to low enrollments in introductory economics courses). The interaction terms, which measure the effects of the intervention on the other three cohorts, are large, negative, statistically significant and hover at roughly the same level (-0.070, -0.071, and -0.070 for cohorts 2, 3, and 4 respectively), suggesting that the three younger cohorts responded to the intervention similarly.

6. Cumulative Distribution Functions

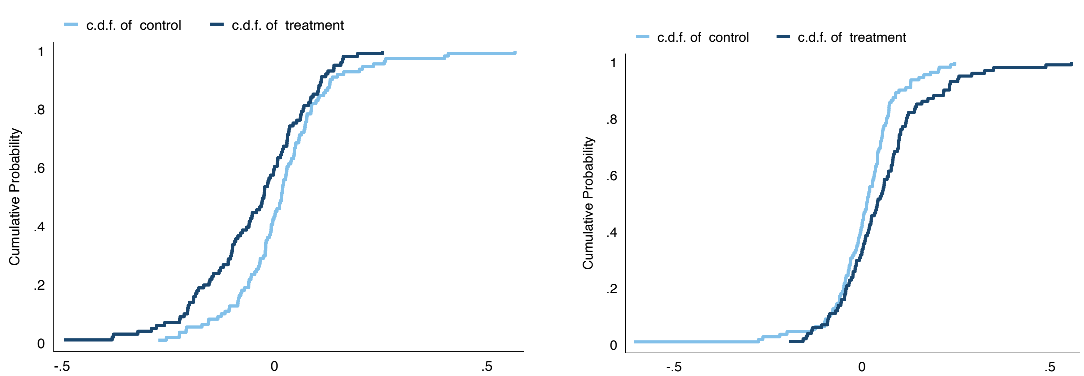
To assess whether some participants shifted more than others, Supplementary Figure 3 displays the cumulative distribution functions for individual-level changes in meat (Panel A) and veg (Panel B) consumption after the intervention (all three years and disaggregated by year). Individual-level changes are computed by taking post-intervention meat or veg consumption rate minus the respective pre-intervention rate. For the control group, the distributions are centered at roughly zero, suggesting no changes in meat or veg consumption for the median participant. For the treatment group, the distribution for meat (veg) is consistently to the left (right) of the distribution for the control group, revealing reductions in meat (increases in veg), relative to the control group, at virtually every point along the distribution. The cumulative distribution functions look similar across all three years, illustrating the persistence of the dietary changes. The gaps between the distributions for the control and treatment groups increase towards the tails, revealing heterogenous treatment effects: large dietary changes towards the tails, more moderate (but sizable) changes in the middle, and small or nonexistent changes at the other ends of the distributions.

Supplementary Figure 3. Cumulative Distribution Functions

All three years.

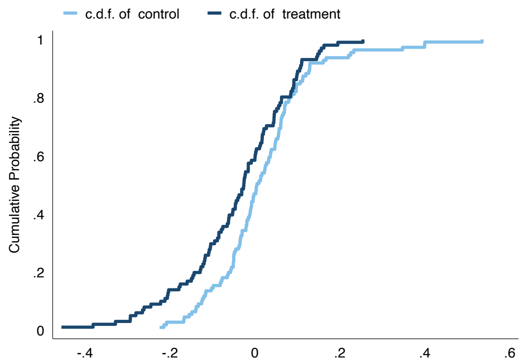
Panel A: Meat

Panel B: Veg

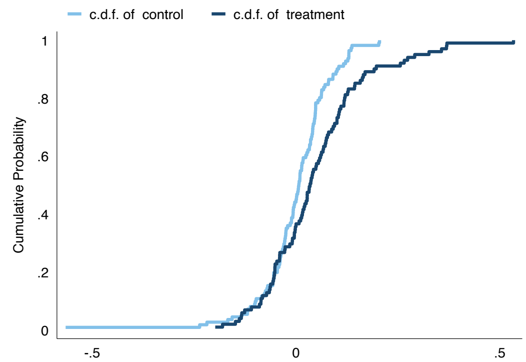


Year 1.

Panel A: Meat

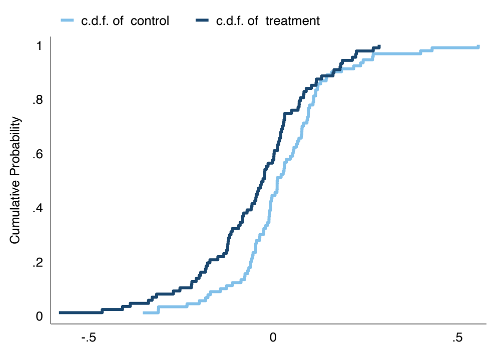


Panel B: Veg

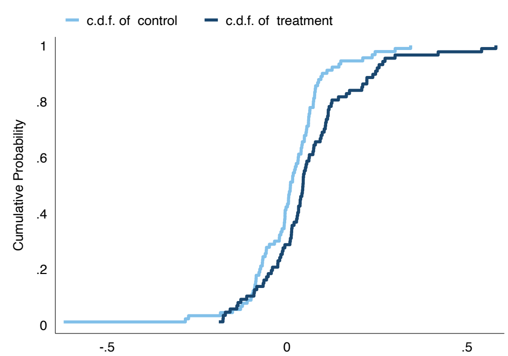


Year 2.

Panel A: Meat

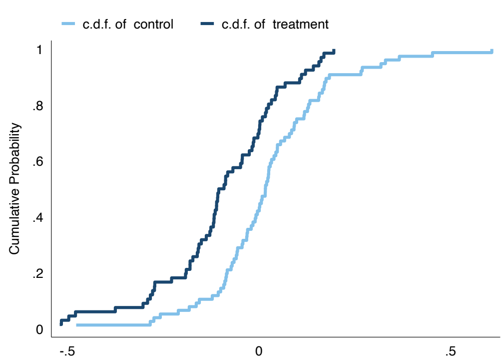


Panel B: Veg

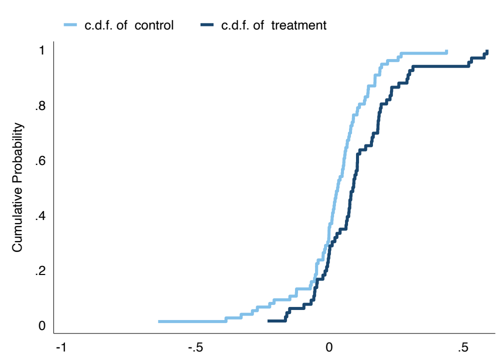


Year 3.

Panel A: Meat



Panel B: Veg



Notes: The figure shows the cumulative distribution function (c.d.f) of individual-level changes in the average daily frequency of meat- and veg-based meals after the intervention

7. Heterogenous Treatment Effects

The cumulative distribution functions indicate that the treatment effects varied across study participants. To determine whether the effects differed on the basis of observable characteristics, such as gender or minority status, we interact indicator variables for these observables in our logit model.

Supplementary Table 7 shows the results (all three years and each year individually) for gender for the full sample. Over all three years, men and women reduced their meat consumption and increased their veg consumption. Meat probability fell by 5.1 and 6.3 percentage points and veg probability increased by 4.3 and 3.7 percentage points for men and women, respectively. Men and women responded differently in terms of type of meat. Women reduced their consumption of poultry+fish (7.1 percentage points), whereas men reduced their consumption of beef and poultry+fish (2.8 and 1.9 percentage points, respectively). Other than some relatively modest changes, the results do not vary much across years. The results are similar for the fixed sample (Supplementary Table 8).

Supplementary Table 7. Gender. Logit Average Treatment Effects: By Year, Full Sample

	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
All Years				
Male	-0.028**	-0.019	-0.051***	0.043**
	(0.013)	(0.015)	(0.013)	(0.020)
	[0.028]	[0.206]	[0.000]	[0.033]
Female	0.002	-0.071***	-0.063**	0.037
	(0.031)	(0.027)	(0.028)	(0.029)
	[0.949]	[0.009]	[0.026]	[0.194]
Male=Female p-value	0.283	0.054	0.693	0.842
Pseudo R2	0.109	0.090	0.129	0.123
# meals	103,301	103,338	103,324	103,248
Year 1				
Male	-0.036***	0.004	-0.035**	0.036*
	(0.011)	(0.011)	(0.017)	(0.019)
	[0.001]	[0.687]	[0.039]	[0.067]
Female	-0.001	-0.068***	-0.062**	0.047*
	(0.031)	(0.022)	(0.025)	(0.025)
	[0.986]	[0.002]	[0.012]	[0.062]
Male=Female p-value	0.205	0.005	0.301	0.618
Pseudo R2	0.113	0.098	0.147	0.142
# meals	49,127	49,126	49,123	49,052
Year 2				
Male	-0.013	-0.040	-0.055**	0.048**
	(0.017)	(0.030)	(0.024)	(0.022)
	[0.441]	[0.188]	[0.020]	[0.029]
Female	0.010	-0.095**	-0.079**	0.048
	(0.040)	(0.039)	(0.034)	(0.030)
	[0.799]	[0.015]	[0.021]	[0.110]
Male=Female p-value	0.529	0.068	0.464	0.981
Pseudo R2	0.113	0.093	0.129	0.128
# meals	47,739	47,755	47,754	47,690
Year 3				
Male	-0.039**	-0.054*	-0.102***	0.077***
	(0.017)	(0.032)	(0.034)	(0.019)
	[0.021]	[0.094]	[0.003]	[0.000]
Female	-0.007	-0.085***	-0.085***	0.057
	(0.035)	(0.022)	(0.029)	(0.038)
	[0.840]	[0.000]	[0.003]	[0.134]
Male=Female p-value	0.447	0.193	0.695	0.624
Pseudo R2	0.118	0.089	0.124	0.121
# meals	31,439	31,578	31,565	31,496

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. In the full sample, the control and treatment groups have 73 and 58 men, and 38 and 44 women, respectively. *p<0.1; **p<0.05; ***p<0.01

Supplementary Table 8. Gender. Logit Average Treatment Effects: By Year, Fixed Sample

	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
All Years				
Male	-0.029***	-0.035	-0.068**	0.066***
	(0.010)	(0.027)	(0.029)	(0.014)
	[0.005]	[0.188]	[0.017]	[0.000]
Female	0.005	-0.117***	-0.104***	0.073***
	(0.041)	(0.030)	(0.029)	(0.028)
	[0.903]	[0.000]	[0.000]	[0.009]
Male=Female p-value	0.380	0.000	0.318	0.836
Pseudo R2	0.114	0.092	0.129	0.131
# meals	83,374	83,415	83,405	83,374
Year 1				
Male	-0.041***	-0.008	-0.053*	0.062***
	(0.007)	(0.018)	(0.029)	(0.013)
	[0.000]	[0.632]	[0.063]	[0.000]
Female	-0.000	-0.112***	-0.103***	0.085***
	(0.039)	(0.025)	(0.025)	(0.021)
	[0.993]	[0.000]	[0.000]	[0.000]
Male=Female p-value	0.299	0.000	0.190	0.333
Pseudo R2	0.120	0.101	0.147	0.158
# meals	35,046	35,045	35,046	35,036
Year 2				
Male	-0.013	-0.046	-0.061**	0.063***
	(0.016)	(0.036)	(0.030)	(0.017)
	[0.419]	[0.202]	[0.043]	[0.000]
Female	0.017	-0.126***	-0.104***	0.070**
	(0.049)	(0.038)	(0.039)	(0.035)
	[0.722]	[0.001]	[0.008]	[0.043]
Male=Female p-value	0.500	0.001	0.293	0.851
Pseudo R2	0.119	0.096	0.133	0.135
# meals	38,148	38,153	38,154	38,138
Year 3				
Male	-0.039**	-0.054*	-0.102***	0.077***
	(0.017)	(0.032)	(0.034)	(0.019)
	[0.023]	[0.091]	[0.003]	[0.000]
Female	-0.008	-0.086***	-0.086***	0.062*
	(0.035)	(0.022)	(0.029)	(0.037)
	[0.815]	[0.000]	[0.003]	[0.095]
Male=Female p-value	0.462	0.193	0.707	0.708
Pseudo R2	0.119	0.088	0.122	0.121
# meals	27,656	27,780	27,769	27,764

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. In the fixed sample, the control and treatment groups have 49 and 37 men, and 27 and 32 women, respectively. *p<0.1; **p<0.05; ***p<0.01

Both men and women reduced their meat consumption, in favor of plant-based alternatives. Similar to our previous study, men and women responded differently to the intervention in terms of type of meat[12]. Men, but not women, reduced their consumption of beef. In our prior study, we hypothesized that this differential response to beef consumption likely reflects differences in starting levels: Before the intervention, 22% of the meals that men consumed contained beef, compared to only 13% of the meals that women consumed. Men had much greater room to reduce their beef consumption than women. Our educational intervention emphasized that the GHGs of beef are larger, on average, than those of poultry+fish. Interestingly, men switched from beef toward veg, rather than to poultry+fish, most likely since the intervention emphasized that plant-based meals tend to have lower GHGs. Both men and women reduced their consumption of poultry+fish and increased their consumption of veg. The decreases in poultry+fish were much larger for women than for men.

Supplementary Table 9 shows the results (all three years and each year individually) by minority status for the full sample. Over all three years, white and nonwhite study participants reduced their meat consumption (7.6 and 2.6 percentage points) and increased their veg consumption (4.2 and 3.5 percentage points, respectively). In terms of type of meat, poultry+fish fell for white participants (5.9 percentage points) and beef fell for white and nonwhite participants (2.4 and 1.3 percentage points). For white participants, the coefficients are similar across years, other than some relatively modest changes. For nonwhite participants, the negative coefficient for meat consumption is statistically insignificant in year 1, but the coefficients are larger in magnitude and statistically significant in years 2 and 3. The results are similar for the fixed sample (Supplementary Table 10).

Supplementary Table 9. Race. Logit Average Treatment Effects: By Year, Full Sample

	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
All Years				
White	-0.024	-0.059**	-0.076***	0.042**
	(0.015)	(0.028)	(0.026)	(0.020)
	[0.115]	[0.033]	[0.004]	[0.032]
Non-White	-0.013	-0.008	-0.026**	0.035*
	(0.018)	(0.019)	(0.011)	(0.020)
	[0.476]	[0.678]	[0.025]	[0.081]
White=Non-White p-value	0.496	0.174	0.116	0.737
Pseudo R2	0.110	0.090	0.130	0.124
# meals	103,301	103,338	103,324	103,248
Year 1				
White	-0.032**	-0.045**	-0.068***	0.050***
	(0.014)	(0.022)	(0.026)	(0.018)
	[0.028]	[0.040]	[0.008]	[0.005]
Non-White	-0.017	0.011	-0.013	0.026
	(0.017)	(0.011)	(0.015)	(0.021)
	[0.319]	[0.289]	[0.389]	[0.201]
White=Non-White p-value	0.378	0.066	0.056	0.195
Pseudo R2	0.113	0.098	0.147	0.142
# meals	49,127	49,126	49,123	49,052
Year 2				
White	-0.011	-0.073*	-0.080**	0.049**
	(0.021)	(0.041)	(0.034)	(0.022)
	[0.586]	[0.072]	[0.018]	[0.027]
Non-White	0.001	-0.034	-0.035**	0.040
	(0.021)	(0.032)	(0.017)	(0.025)
	[0.958]	[0.289]	[0.036]	[0.107]
White=Non-White p-value	0.560	0.386	0.191	0.759
Pseudo R2	0.113	0.093	0.130	0.128
# meals	47,739	47,755	47,754	47,690
Year 3				
White	-0.036*	-0.078*	-0.107***	0.061**
	(0.019)	(0.042)	(0.034)	(0.024)
	[0.058]	[0.061]	[0.002]	[0.012]
Non-White	-0.019	-0.046	-0.072**	0.064*
	(0.021)	(0.035)	(0.035)	(0.038)
	[0.366]	[0.188]	[0.039]	[0.093]
White=Non-White p-value	0.547	0.611	0.502	0.949
Pseudo R2	0.118	0.089	0.124	0.122
# meals	31,439	31,578	31,565	31,496

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. In the full sample, the control and treatment groups have 64 and 64 white and 47 and 38 nonwhite students, respectively. *p<0.1; **p<0.05; ***p<0.01

Supplementary Table 10. Race. Logit Average Treatment Effects: By Year, Fixed Sample

	(1) Beef	(2) Poultry+Fish	(3) Meat	(4) Veg
All Years				
White	-0.027	-0.077**	-0.094***	0.067***
	(0.018)	(0.037)	(0.031)	(0.017)
	[0.148]	[0.037]	[0.003]	[0.000]
Non-White	-0.001	-0.050***	-0.055***	0.062**
	(0.018)	(0.019)	(0.020)	(0.025)
	[0.959]	[0.009]	[0.006]	[0.015]
White=Non-White p-value	0.196	0.452	0.299	0.866
Pseudo R2	0.114	0.092	0.129	0.131
# meals	83,374	83,415	83,405	83,374
Year 1				
White	-0.038**	-0.065**	-0.090***	0.081***
	(0.016)	(0.029)	(0.027)	(0.011)
	[0.016]	[0.024]	[0.001]	[0.000]
Non-White	-0.006	-0.021*	-0.035**	0.049**
	(0.016)	(0.012)	(0.016)	(0.025)
	[0.734]	[0.091]	[0.032]	[0.046]
White=Non-White p-value	0.127	0.196	0.083	0.266
Pseudo R2	0.120	0.101	0.147	0.159
# meals	35,046	35,045	35,046	35,036
Year 2				
White	-0.011	-0.084*	-0.089**	0.063***
	(0.024)	(0.044)	(0.037)	(0.020)
	[0.667]	[0.057]	[0.015]	[0.002]
Non-White	0.011	-0.059**	-0.051**	0.064***
	(0.022)	(0.027)	(0.022)	(0.023)
	[0.617]	[0.030]	[0.020]	[0.006]
White=Non-White p-value	0.324	0.495	0.269	0.986
Pseudo R2	0.119	0.096	0.134	0.226
# meals	38,148	38,153	38,154	38,138
Year 3				
White	-0.036*	-0.078*	-0.108***	0.061**
	(0.019)	(0.042)	(0.034)	(0.024)
	[0.057]	[0.061]	[0.002]	[0.011]
Non-White	-0.019	-0.046	-0.071**	0.069*
	(0.022)	(0.035)	(0.035)	(0.037)
	[0.372]	[0.186]	[0.042]	[0.061]
White=Non-White p-value	0.549	0.603	0.497	0.873
Pseudo R2	0.119	0.088	0.122	0.122
# meals	27,656	27,780	27,769	27,764

Notes: The coefficients measure the average marginal treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. In the fixed sample, the control and treatment groups have 47 and 49 white and 29 and 20 nonwhite students, respectively.*p<0.1; **p<0.05; ***p<0.01

8. GHG Accounting

The previous analysis reveals that study participants in the treatment, but not in the control, group shifted away from meat, towards plants, after the intervention, and that the effects lasted all three years. We can use these empirical results to estimate the reduction in GHGs from our intervention. Such a calculation provides an estimate of the return to our educational intervention, in terms of mitigating climate change.

To begin, we estimate the average GHGs for a serving of the different main courses at the host college. The meals at the dining facilities have the same sides, with varying courses. Meat courses primarily include beef, poultry, and fish, whereas veg courses include mostly tofu and pulses (beans, lentils, peas). In a detailed meta-analysis, Poore and Nemecek estimate average greenhouse gas emissions, in terms of kg of carbon dioxide equivalents (CO_2eq) per 100 grams of protein (average kg CO_2eq in parentheses): beef (50), poultry (5.7), fish (6.0), tofu (2.0), and pulses (0.8)[4]. At the dining facilities, the serving size for a main course is 5 ounces. We use data from the USDA on grams of protein per ounce to convert these average GHGs in terms of 5 oz serving sizes (for example, for beef, a 5 oz serving has 36.6 grams of protein, so the GHGs for a 5 oz serving of beef are $\frac{50\ kg\ CO2eq}{100\ g\ protein} \cdot \frac{36.6\ g\ protein}{5\ oz}$ = 18.3 kg CO_2eq per 5 oz serving). Supplementary Table 11 shows these estimated average GHGs per 5 oz serving. Beef meals have, by far, the largest GHGs (18.3), followed by poultry and fish meals (1.8924 and 1.848, respectively), and then plant-based meals, such as tofu and pulses (0.27 and 0.0712, respectively), with the lowest. Switching from a beef to tofu main course would save 18.03 kg CO_2eq (=18.3-0.27), whereas switching from a poultry to pulses main course would save 1.8212 kg CO_2eq (=1.8924-0.0712).

Supplementary Table 11. Accounting: GHGs per Main Course.

	GHGs (kg CO_2eq) per 5 oz serving
Beef	18.3
Poultry	1.8924
Fish	1.848
Tofu	0.27
Pulses	0.0712

Notes: Main courses are 5 oz servings at the host college. We calculate average GHGs per 5 oz serving size based on data from Poore and Nemecek (2018) on average GHGs per 100 grams of protein and the United States Department Agriculture (USDA) on grams of protein per oz. Poore and Nemecek (2018) estimate average greenhouse gas emissions, in terms of kg of carbon dioxide equivalents (CO_2eq) per 100 grams of protein (average kg CO_2eq in parentheses): beef (50), poultry (5.7), fish (6.0), tofu (2.0), and pulses (0.8)[4]. Using the USDA Nutrient Lists from Standard Reference Legacy (2018), we examine food products belonging to these various categories (beef, chicken and turkey, fish, tofu, and pulses) and average within categories to estimate the average amount of protein per 5 oz serving: beef (36.6), poultry (33.2), fish (30.8), tofu (13.5), and pulses (8.9)[24]. We use these data to calculate average GHGs per 5 oz serving (for example, for beef: $\frac{50\ kg\ CO2eq}{100\ g\ protein} \cdot \frac{36.6\ g\ protein}{5\ oz}$ = 18.3 kg CO_2eq per 5 oz serving).

To calculate the impact of our intervention on the average carbon footprint of study participants' meals, we estimate an ordinary least squares (OLS) regression that replaces the outcome variable in equation (1) with the average carbon footprint of each main course, i.e. the CO_2eqs in Supplementary Table 11 (for veg meals, we average the GHGs of tofu and pulses, for 0.1706 kg CO_2eq—a weighting that reflects the roughly equal rotation between tofu and pulses as the veg option at the dining facilities of the host college). We report the results based on both the (1) full sample that includes all study participants and (2) the fixed sample of participants who made purchases all three academic years.

Supplementary Tables 12 and 13 report the results for all three years for the full and fixed samples, respectively. The average marginal treatment effects, shown in the table, measure the change in the average CO_2eq per meal after the intervention for study participants in the treatment, relative to the control, group. Row 1 shows the results for all study participants. For the full (fixed) sample, over all three years, in response to the intervention, the average carbon footprint of study participants' meals fell by 0.354 (0.348) kg CO_2eq. Because CO_2eqs differ substantially by type of meat and because men and women responded to the intervention by reducing different types of meat (beef in the case of men, poultry+fish in the case of women), rows 2 and 3 disaggregate the average treatment effects by gender. The point estimates are negative for both men and women, but much larger and only significant for men because men, but not women, reduced their consumption of beef, the type of meat with the highest carbon footprint. For the full (fixed) sample, in the treatment group, relative to the control group, after the intervention, each meal selected by men had, on average, 0.551 (0.594) fewer kg CO_2eq and each meal selected by women had 0.063 (0.074) fewer kg CO_2eq. With 2 meals (i.e. lunch and dinner) per day and 365 days in one year (i.e. 730 lunches and dinners per year), for the full (fixed) sample, these estimates imply that the intervention reduced annual per capita GHGs by 402 (434) kg CO_2eq for men, i.e. 730 meals times 0.551 (0.594) fewer kg CO_2eq per meal, and 46 (54) kg CO_2eq for women, i.e. 730 meals times 0.063 (0.074) fewer kg CO_2eq per meal, with the largest reductions coming from the fall in beef among men. Because the yearly average carbon footprint for the typical American is roughly 20 metric tons (i.e. 20,000 kg) CO_2eq[25,26], our educational intervention reduced the GHGs of men by ~2% and women by ~0.2%. For reference, agriculture accounts for 11% of GHGs in the United States, so these declines for men, from one 50-minute guest talk, are sizable[27].

Supplementary Table 12. Treatment Effects: GHGs. Full Sample.

	Year 1	Year 2	Year 3	All Years
All				
Treated	-0.434	-0.186	-0.569**	-0.354
	(0.246)	(0.300)	(0.243)	(0.250)
	[0.112]	[0.550]	[0.044]	[0.191]
Mean DV	4.094	4.179	4.271	4.121
R2	0.111	0.109	0.113	0.105
# meals	49,129	47,769	31,600	103,375
By Gender				
Male	-0.659**	-0.311	-0.820**	-0.551**
	(0.220)	(0.301)	(0.314)	(0.232)
	[0.015]	[0.329]	[0.028]	[0.041]
Female	-0.112	-0.006	-0.177	-0.063
	(0.417)	(0.515)	(0.511)	(0.423)
	[0.794]	[0.991]	[0.737]	[0.885]
Male=Female p-value	0.182	0.575	0.380	0.251
Mean DV	4.094	4.179	4.271	4.121
R2	0.111	0.109	0.113	0.105
# meals	49,129	47,769	31,600	103,375

Notes: The coefficients measure ordinary least squares (OLS) treatment effects, in terms of kg CO_2eq. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. The estimation period includes the full sample over all three years. In the full sample, the control and treatment groups have 111 (73 men and 38 women) and 102 (58 men and 44 women) students, respectively. *p<0.1; **p<0.05; ***p<0.01

Supplementary Table 13. Treatment Effects: GHGs. Fixed Sample.

	Year 1	Year 2	Year 3	All Years
All				
Treated	-0.474*	-0.138	-0.577**	-0.348
	(0.240)	(0.341)	(0.241)	(0.263)
	[0.080]	[0.696]	[0.040]	[0.218]
Mean DV	4.094	4.179	4.271	4.121
R2	0.117	0.114	0.114	0.109
# meals	35,048	38,164	27,802	83,449
By Gender				
Male	-0.763***	-0.311	-0.818**	-0.594**
	(0.231)	(0.264)	(0.318)	(0.212)
	[0.009]	[0.268]	[0.030]	[0.021]
Female	-0.169	0.052	-0.200	-0.074
	(0.506)	(0.651)	(0.509)	(0.543)
	[0.747]	[0.938]	[0.704]	[0.894]
Male=Female p-value	0.348	0.593	0.399	0.407
Mean DV	4.051	4.131	4.277	4.085
R2	0.117	0.114	0.114	0.109
# meals	35,048	38,164	27,802	83,449

Notes: The coefficients measure ordinary least squares (OLS) treatment effects, in terms of kg CO_2eq. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. The estimation period includes the fixed sample over all three years. In the fixed sample, the control and treatment groups have 76 (49 men and 27 women) and 69 (37 men and 32 women) students, respectively. *p<0.1; **p<0.05; ***p<0.01

To estimate the return on investment, we divide the aggregate reduction in GHGs, measured as the number of affected meals times the treatment effect per meal, by costs. The formula for return on investment, in terms of kg CO_2eq per dollar, is

$$R_{kg\ per\ dollar} = \frac{M * T}{C}$$

where M is the number of meals, T is the estimated average marginal treatment effects (kg CO_2eq reduced per meal) and C is the cost of the intervention in dollars. Because 1 metric ton = 1,000 kg, dividing 1,000 by $R_{kg\ per\ dollar}$ converts the return on investment into dollars per metric ton:

$$R_{dollars\ per\ metric\ ton} = \frac{1{,}000\ kg}{1\ metric\ ton} * \frac{1}{R_{kg\ per\ dollar}}$$

The number of meals, M, purchased by study participants in the treatment group after the intervention in the dining facilities during the study (i.e. the observation period) is 44,730 (27,508 and 17,222 for men and women, respectively). If the effects persist outside of the dining facilities and beyond the observation period, the return on investment would grow since M would increase. We estimate T, the average marginal treatment effects, from our difference-in-differences regression framework.

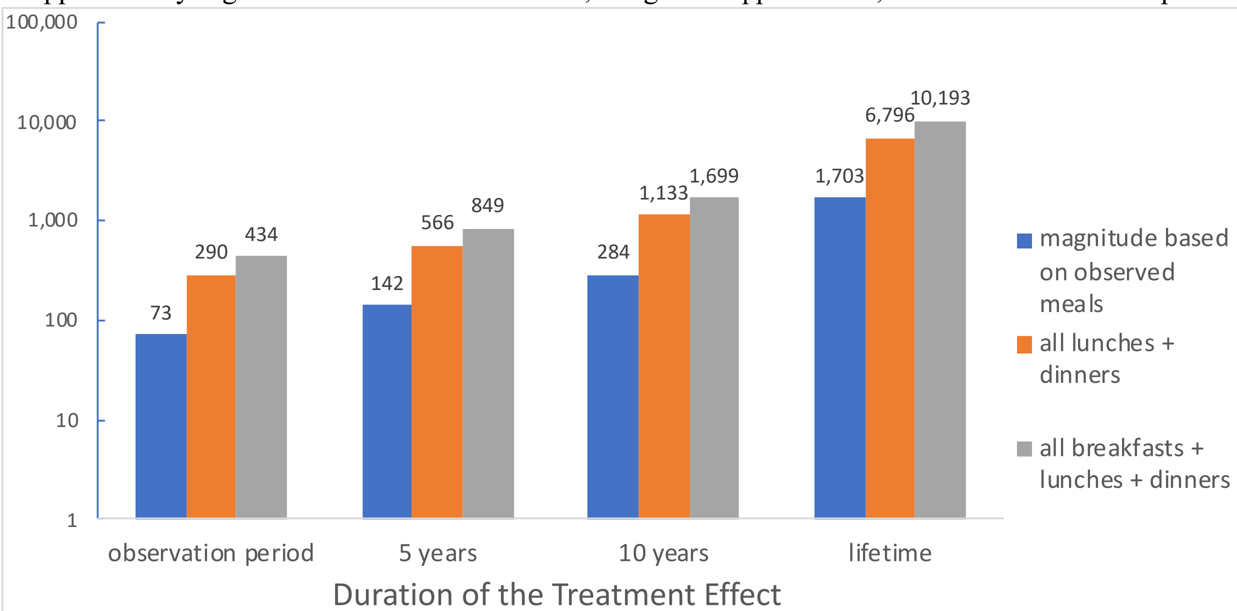
The cost, C, is an estimate based on communication with a nonprofit organization that delivers educational presentations in school settings about the effects of meat consumption on the environment, health, and animal welfare. We assume an annual compensation package of a presenter of $44,770 ($40,000 salary plus $4,770 in benefits and reimbursable work expenses), one hour spent presenting per lecture, 2000 hours in a work year (50 weeks times 40 hours per week), and half of the work time spent lecturing. Doing so yields a cost per lecture of $44.77, or a cost of $223.85 across five lectures (the number of lectures in our five treatment classes).

In terms of aggregate effects, after the intervention, men and women in the treatment group purchased 27,508 and 17,222 meals, respectively, in the college dining facilities. For the full (fixed) sample, multiplying the number of meals by the average marginal effects and summing across men and women imply a reduction in GHGs of 16,242 (17,614) kg CO_2eq, i.e. 0.551 (0.594) fewer kg CO_2eq per meal times 27,508 meals plus 0.063 (0.074) fewer kg CO_2eq per meal times 17,222 meals. Given a cost of $223.85 across five lectures, the ROI from our educational intervention is 72.56 (78.69) kg CO_2eq per dollar, or $13.78 ($12.71) per metric ton CO_2eq.

The ROI increases if the effects hold outside of the college dining facilities and/or persist beyond three years. For example, for the full sample, assuming these average marginal effects extend outside of the dining facilities (two meals per day, i.e. lunches and dinners, among 58 men and 44 women from Oct 17, 2017, the first day of the intervention, through May 7, 2020, the last day we collected data) implies a reduction in GHGs of 64,806 kg CO_2eq and an ROI of 290 kg CO_2eq per dollar, or $3.45 per metric ton. For each year that the effects persist, the impact is an additional fall in GHGs of 25,353 kg CO_2eq and an additional increase in the ROI of 113 kg CO_2eq per dollar. The ROI would grow if the number of study participants witnessing the intervention increases, assuming the effects of the intervention are unrelated to the size of the audience, since the numerator (GHGs reduced) would increase, but the denominator (costs) would remain roughly the same (other than trivial costs of photocopying additional handouts). The ROI would also grow if costs fall (e.g. a video, as opposed to a guest lecture, on the same topic), without treatment effects diminishing.

Supplementary Figure 4 illustrates the returns on investment, in terms of kg CO_2eq, under different assumptions about the magnitude and duration of the effect. The most restrictive assumption, shown in the leftmost blue bar, assumes that the effect extends only to those meals we observe during the observation period from Oct 17, 2017 to May 7, 2020. The orange bar to the right assumes that the treatment effect extends to all lunches and dinners during the observation period. The grey bar to the right assumes that the treatment effect extends to all breakfasts, lunches and dinners during the observation period. The next set of graphs extend the duration of these effects to 5 years, 10 years, and lifetime (assuming an average lifespan of 79 years). As the figure illustrates, the returns on investment grow substantially if the effects extend outside of the dining facilities and/or the duration of the study.

Supplementary Figure 4. Returns on Investment, in kg CO2eq per Dollar, under Different Assumptions



Notes: This figure shows the returns on investment of our intervention, in kg CO_2eq per dollar, under different assumptions about the magnitude and duration of the effects. The blue bars assume an effect magnitude based only on meals observed during the observation period, i.e. Oct 17, 2017 to May 7, 2020. The orange bars assume that the treatment effects extend to all lunches and dinners. The grey bars assume that the treatment effects extend to all breakfasts, lunches and dinners. We vary the duration in each of these scenarios: observation period, 5 years, 10 years, and lifetime (assuming an average lifespan of 79 years).

Lastly, we would like to acknowledge an important point. Our data on average greenhouse gas emissions (GHGs) by food product come from a meta-analysis of 570 studies by Poore and Nemecek (2018)[4]. While we do not have disaggregated data on the carbon mileage associated with the transportation of the different food products sold at the college dining facilities, such a limitation should barely affect our results since most agricultural greenhouse gas emissions come from the production, rather than the transportation, of food. For example, in the case of beef, Poore and Nemecek (2018) conclude that packaging, transport and retail contribute only between 1 and 9% of its average GHGs. In a comprehensive life-cycle analysis, Weber and Matthews (2008) calculate that 83% of the typical U.S. household's food-related emissions come from production, with only 11% from transportation[28]. These studies conclude that dietary shifts, i.e. from red meat towards plants, deliver much larger reductions in GHGs than buying local, given the much greater role of production in the emissions intensity of food products.

9. Additional Analyses

Baseline meat consumption

As an additional analysis, we examine whether the treatment effect varies in response to pre-intervention levels of meat consumption. One might hypothesize that "meat lovers", i.e. people who eat the most meat, could respond differently to the intervention. On the one hand, meat lovers may be more likely to reduce, given a larger scope for decline. On the other hand, meat lovers may be less likely to reduce, given a greater affinity towards meat. For example, recent research finds differential effects, in terms of increased purchases of vegetarian meals in response to interventions (i.e. changes in the relative price, a doubling in the number of veg options), based on prior levels of veg consumption[21,29]. To assess whether our treatment effects vary with respect to baseline meat consumption, we created Supplementary Table 14. Column 1 interacts the treatment with a linear term for baseline meat consumption (computed as the fraction of meals with meat before the intervention). This interaction term is statistically insignificant. In Column 2, we use as an indicator interaction term that takes on the value 1 for individuals who have above median baseline meat. This term too is insignificant. In Column 3 we interact the treated with quartile indicators for baseline meat consumption. These too are insignificant. These analyses indicate that the treatment effect is unrelated to baseline meat consumption.

Supplementary Table 14. Baseline Meat Consumption

	(1)	(2)	(3)
	Meat	Meat	Meat
Treated	-0.101*	-0.070**	-0.102**
	(0.052)	(0.022)	(0.032)
	[0.086]	[0.012]	[0.011]
Treated x Baseline Meat	0.053		
	(0.070)		
	[0.469]		
Treated x Meat Top Half		0.014	
		(0.026)	
		[0.615]	
Treated x Baseline Meat Q2			0.057
			(0.053)
			[0.309]
Treated x Baseline Meat Q3			0.065
			(0.051)
			[0.233]
Treated x Baseline Meat Q4			0.004
			(0.026)
			[0.879]
Mean DV	0.622	0.622	0.622
R2	0.162	0.162	0.162
# meals	103,375	103,375	103,375

Notes: The coefficients measure ordinary least squares (OLS) treatment effects. Standard errors, in parentheses, are clustered at the unit of randomization, the class level. P-values, based on two-sided tests, are in brackets. Mean DV: mean of the dependent variable. All columns control for individual, date, and hour fixed effects. "Baseline meat" is a variable, computed as the fraction of meals with meat before the intervention. "Meat top half" is an indicator variable that takes on the value 1 for individuals who have above-median baseline meat. Baseline Meat Q2, Q3 and Q4 are indicator variables for individuals in the second, third, and fourth quartiles of baseline meat consumption. The estimation period includes the full sample over all three years. In the full sample, the control and treatment groups have 111 and 102 students, respectively. *p<0.1; **p<0.05; ***p<0.01

Meals purchases before and after the intervention in the control and treatment groups

We also examine whether the intervention affected the number of meals purchased. Before the intervention, on average, at the dining facilities, each student purchased 59.9 (standard error: 2.1) and 58.8 meals (standard error: 2.1) in the control and treatment groups, respectively—a statistically insignificant difference in meal purchases per person (t-test for equality of means, p=0.932). After the intervention (i.e. over the next three years), on average, each student purchased 415.2 (standard error: 21.5) and 442.9 (standard error: 21.0) meals in the control and treatment groups, respectively—a statistically insignificant difference (p=0.361). We find no evidence of the treatment group purchasing fewer meals than the control group after the intervention.

Alternative inference methods

Similar to our prior study, as a robustness check, we show the results using two different methods for computing confidence intervals, recommended for regressions with clusters of 40 or less[30–32]. We estimate models with heterogenous treatment effects using both logit (reported in the main body of the paper) and linear probability models (reported in the Supplementary Information), clustering standard errors at the class level. We also employ the boottest package in Stata to calculate standard errors from linear probability models using wild-bootstrapped inference by class and again by class-individual[33]. The results do not differ much across these methods, other than some minor changes. Supplementary Table 15 reports 95% confidence intervals and p-values for the treatment effect on each of the outcome variables, using these alternative methods.

Supplementary Table 15. Alternative Inference Methods

Panel A: All

All Years

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.017	-0.039	-0.056	0.044	-0.370
	(0.015)	(0.015)	(0.014)	(0.018)	(0.253)
	[-0.050,0.017]	[-0.074,-0.005]	[-0.087,-0.024]	[0.003,0.085]	[-0.942,0.203]
	0.286	0.031	0.003	0.037	0.178
Bootstrap by class	[-0.055, 0.018]	[-0.081, -0.004]	[-0.088, -0.022]	[-0.005, 0.082]	[-1.012, 0.228]
	0.309	0.029	0.006	0.070	0.207
Bootstrap by class and individual	[-0.053, 0.020]	[-0.078, -0.001]	[-0.090, -0.021]	[-0.001, 0.089]	[-0.962, 0.239]
	0.322	0.046	0.005	0.054	0.203
Clusters	10	10	10	10	10
N	103,375	103,375	103,375	103,375	103,375
R2	0.097	0.113	0.161	0.139	0.105

Year 1

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.022	-0.025	-0.047	0.045	-0.446
	(0.014)	(0.009)	(0.016)	(0.018)	(0.253)
	[-0.054,0.009]	[-0.046,-0.004]	[-0.083,-0.011]	[0.003,0.087]	[-1.018,0.125]
	0.145	0.023	0.015	0.037	0.111
Bootstrap by class	[-0.058, 0.009]	[-0.051, -0.006]	[-0.084, -0.010]	[-0.010, 0.082]	[-1.069, 0.131]
	0.158	0.008	0.025	0.084	0.115
Bootstrap by class and individual	[-0.056, 0.012]	[-0.048, -0.002]	[-0.087, -0.008]	[-0.001, 0.090]	[-1.071, 0.177]
	0.175	0.039	0.024	0.053	0.138
Clusters	10	10	10	10	10
N	49,129	49,129	49,129	49,129	49,129
R2	0.101	0.122	0.182	0.157	0.111

Year 2

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.005	-0.059	-0.064	0.049	-0.186
	(0.018)	(0.030)	(0.023)	(0.017)	(0.301)
	[-0.046,0.037]	[-0.128,0.009]	[-0.115,-0.013]	[0.009,0.089]	[-0.867,0.495]
	0.804	0.081	0.019	0.021	0.551
Bootstrap by class	[-0.050, 0.039]	[-0.143, 0.008]	[-0.125, -0.012]	[-0.000, 0.089]	[-0.911, 0.547]
	0.814	0.064	0.018	0.053	0.576
Bootstrap by class and individual	[-0.049, 0.040]	[-0.137, 0.015]	[-0.119, -0.009]	[0.006, 0.092]	[-0.889, 0.538]
	0.813	0.107	0.028	0.031	0.570
Clusters	10	10	10	10	10
N	47,770	47,770	47,770	47,770	47,770
R2	0.101	0.116	0.161	0.142	0.109

Year 3

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.025	-0.070	-0.095	0.064	-0.569
	(0.015)	(0.027)	(0.022)	(0.017)	(0.244)
	[-0.058,0.009]	[-0.131,-0.010]	[-0.144,-0.046]	[0.025,0.104]	[-1.120,-0.017]
	0.127	0.027	0.002	0.005	0.045
Bootstrap by class	[-0.056, 0.012]	[-0.123, -0.001]	[-0.144, -0.041]	[0.019, 0.101]	[-1.077, 0.045]
	0.156	0.045	0.004	0.023	0.066
Bootstrap by class and individual	[-0.061, 0.012]	[-0.140, -0.002]	[-0.149, -0.040]	[0.021, 0.107]	[-1.164, 0.018]
	0.159	0.044	0.004	0.009	0.057
Clusters	10	10	10	10	10
N	31,600	31,600	31,600	31,600	31,600
R2	0.106	0.113	0.155	0.133	0.113

Panel B: Men

All Years

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.028	-0.020	-0.049	0.039	-0.551
	(0.014)	(0.016)	(0.012)	(0.016)	(0.232)
	[-0.060,0.003]	[-0.056,0.015]	[-0.076,-0.022]	[0.002,0.076]	[-1.075,-0.026]
	0.068	0.220	0.003	0.040	0.042
Bootstrap by class	[-0.060, 0.007]	[-0.057, 0.019]	[-0.077, -0.019]	[-0.003, 0.077]	[-1.092, 0.048]
	0.100	0.275	0.006	0.057	0.070
Bootstrap by class and individual	[-0.063, 0.006]	[-0.060, 0.018]	[-0.080, -0.018]	[-0.002, 0.080]	[-1.126, 0.026]
	0.096	0.261	0.007	0.057	0.059
Clusters	10	10	10	10	10
N	103,375	103,375	103,375	103,375	103,375
R2	0.097	0.113	0.161	0.139	0.105

Year 1

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.037	0.003	-0.033	0.032	-0.659
	(0.012)	(0.011)	(0.015)	(0.016)	(0.220)
	[-0.064,-0.009]	[-0.021,0.028]	[-0.068,0.002]	[-0.004,0.068]	[-1.157,-0.162]
	0.015	0.761	0.059	0.077	0.015
Bootstrap by class	[-0.065, -0.006]	[-0.022, 0.031]	[-0.068, 0.004]	[-0.010, 0.068]	[-1.167, -0.097]
	0.020	0.770	0.078	0.111	0.021
Bootstrap by class and individual	[-0.068, -0.006]	[-0.025, 0.032]	[-0.072, 0.007]	[-0.008, 0.072]	[-1.200, -0.114]
	0.025	0.779	0.087	0.103	0.024
Clusters	10	10	10	10	10
N	49,129	49,129	49,129	49,129	49,129
R2	0.101	0.123	0.182	0.158	0.111

Year 2

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.013	-0.040	-0.053	0.045	-0.311
	(0.018)	(0.030)	(0.023)	(0.018)	(0.302)
	[-0.055,0.028]	[-0.109,0.028]	[-0.104,-0.002]	[0.004,0.086]	[-0.994,0.372]
	0.486	0.218	0.042	0.036	0.330
Bootstrap by class	[-0.055, 0.034]	[-0.113, 0.030]	[-0.119, -0.008]	[-0.001, 0.086]	[-0.995, 0.478]
	0.496	0.258	0.020	0.055	0.352
Bootstrap by class and individual	[-0.059, 0.032]	[-0.115, 0.033]	[-0.110, 0.004]	[-0.001, 0.089]	[-1.069, 0.438]
	0.525	0.243	0.063	0.054	0.375
Clusters	10	10	10	10	10
N	47,770	47,770	47,770	47,770	47,770
R2	0.101	0.117	0.161	0.142	0.109

Year 3

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.040	-0.055	-0.095	0.067	-0.820
	(0.018)	(0.032)	(0.032)	(0.018)	(0.315)
	[-0.081,0.001]	[-0.128,0.018]	[-0.168,-0.022]	[0.027,0.107]	[-1.534,-0.107]
	0.053	0.122	0.016	0.004	0.029
Bootstrap by class	[-0.086, 0.007]	[-0.133, 0.021]	[-0.162, -0.011]	[0.031, 0.120]	[-1.629, -0.011]
	0.078	0.182	0.018	0.004	0.047
Bootstrap by class and individual	[-0.087, 0.006]	[-0.143, 0.028]	[-0.180, -0.010]	[0.023, 0.113]	[-1.630, -0.021]
	0.083	0.166	0.032	0.009	0.047
Clusters	10	10	10	10	10
N	31,600	31,600	31,600	31,600	31,600
R2	0.107	0.113	0.155	0.133	0.113

Panel C: Women

All Years

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	0.003	-0.070	-0.067	0.043	-0.063
	(0.024)	(0.026)	(0.032)	(0.032)	(0.423)
	[-0.051,0.057]	[-0.129,-0.011]	[-0.138,0.005]	[-0.029,0.115]	[-1.020,0.894]
	0.900	0.026	0.063	0.212	0.885
Bootstrap by class	[-0.055, 0.060]	[-0.134, -0.005]	[-0.132, 0.022]	[-0.040, 0.107]	[-1.045, 0.975]
	0.900	0.035	0.113	0.279	0.893
Bootstrap by class and individual	[-0.052, 0.062]	[-0.133, -0.003]	[-0.142, 0.012]	[-0.043, 0.121]	[-1.046, 1.000]
	0.907	0.042	0.085	0.265	0.890
Clusters	10	10	10	10	10
N	103,375	103,375	103,375	103,375	103,375
R2	0.097	0.113	0.161	0.139	0.105

Year 1

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	0.000	-0.068	-0.068	0.057	-0.112
	(0.023)	(0.021)	(0.028)	(0.028)	(0.418)
	[-0.053,0.053]	[-0.116,-0.019]	[-0.131,-0.004]	[-0.007,0.121]	[-1.058,0.833]
	0.995	0.012	0.039	0.074	0.794
Bootstrap by class	[-0.059, 0.057]	[-0.117, -0.020]	[-0.126, 0.009]	[-0.015, 0.112]	[-1.147, 0.898]
	0.996	0.023	0.068	0.105	0.807
Bootstrap by class and individual	[-0.055, 0.058]	[-0.120, -0.014]	[-0.135, 0.003]	[-0.021, 0.127]	[-1.109, 0.930]
	0.995	0.020	0.058	0.114	0.803
Clusters	10	10	10	10	10
N	49,129	49,129	49,129	49,129	49,129
R2	0.101	0.123	0.182	0.158	0.111

Year 2

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	0.008	-0.094	-0.086	0.051	-0.006
	(0.030)	(0.038)	(0.037)	(0.035)	(0.516)
	[-0.059,0.076]	[-0.180,-0.009]	[-0.170,-0.002]	[-0.028,0.131]	[-1.174,1.162]
	0.782	0.035	0.046	0.179	0.991
Bootstrap by class	[-0.061, 0.089]	[-0.191, -0.008]	[-0.162, 0.022]	[-0.052, 0.122]	[-1.195, 1.419]
	0.795	0.041	0.096	0.275	0.990
Bootstrap by class and individual	[-0.059, 0.084]	[-0.188, 0.001]	[-0.172, 0.006]	[-0.042, 0.138]	[-1.150, 1.333]
	0.788	0.052	0.064	0.231	0.991
Clusters	10	10	10	10	10
N	47,770	47,770	47,770	47,770	47,770
R2	0.101	0.117	0.161	0.142	0.109

Year 3

	(1) beef	(2) poultry+fish	(3) meat	(4) veg	(5) CO2eq
treated	-0.002	-0.086	-0.088	0.052	-0.177
	(0.028)	(0.021)	(0.033)	(0.044)	(0.513)
	[-0.066,0.063]	[-0.134,-0.038]	[-0.163,-0.013]	[-0.049,0.152]	[-1.338,0.984]
	0.953	0.003	0.027	0.273	0.738
Bootstrap by class	[-0.068, 0.071]	[-0.132, -0.026]	[-0.153, 0.006]	[-0.065, 0.146]	[-1.313, 1.164]
	0.957	0.020	0.068	0.350	0.770
Bootstrap by class and individual	[-0.066, 0.070]	[-0.137, -0.033]	[-0.164, -0.004]	[-0.064, 0.156]	[-1.344, 1.123]
	0.958	0.005	0.042	0.322	0.745
Clusters	10	10	10	10	10
N	31,600	31,600	31,600	31,600	31,600
R2	0.107	0.113	0.155	0.133	0.113

Notes: For each subtable, the first row shows ordinary least squares (OLS) treatment effects (controlling for individual, date, and hour fixed effects), with clustered standard errors beneath in parentheses. The three sets of brackets reflect 95% confidence intervals using clusters at the class level, wild bootstrap by class, and wild bootstrap by class-individual, respectively. P-values, based on two-sided tests, are beneath the confidence intervals.

10. Policy Implications

Educational interventions can have long-term effects on meat consumption. Our 50-minute talk led to dietary shifts that persisted for years. These findings indicate that soft policy interventions—ones that try to persuade people to make voluntary behavioral changes—can be effective at reducing the long-term demand for meat. Such policies are likely more politically palatable than more intrusive interventions that attempt to deter behavior via taxes, regulations, or other restrictions. Increased education may also be a precondition for additional interventions, which likely hinge on greater societal awareness.

The returns on educational investments—to raise awareness about the negative consequences of meat consumption for climate change—may be larger than many policymakers currently realize. Our results showing long-lasting effects suggest that people do not necessarily regress to old habits. Because the costs of our intervention occurred during the semester of implementation, but the effects persisted for years, rather than simply months, the returns on our educational investment are larger than our previous paper suggested[12].

Our study increases the evidence base supporting the use of health and climate-change messaging to reduce meat consumption. Other recent research has examined the willingness of people to reduce their meat consumption in response to information about climate change and/or health. Hunter and Röös (2016) analyze survey-level evidence to identify predictors of intentions to eat less meat in response to information about climate threats.[16] Macdiarmid, Douglas, and Campbell (2016) conduct focus-group and individual interviews to analyze public attitudes towards meat reduction, in the context of climate change.[34] Carfora et al. (2019) use food diaries to examine the effectiveness of daily text messages, centered on the health and/or environmental benefits of reduced consumption of processed and red meat.[35] By showing—with individual-level food purchase data—that sustained long-term behavioral change did, in fact, occur in response to our informational intervention, we add to this growing evidence that messages focused on climate change and health can be effective at shifting people towards more sustainable plant-based diets.

Dietary interventions that target men may have a larger scope for reducing agricultural greenhouse gas emissions. According to a recent detailed analysis of the dietary habits of a representative cross-section of the population from a high-income country (the U.K.), the diets of men, on average, have 41% more greenhouse gas emissions, compared to women, primarily due to their larger per capita consumption of meat—in particular, red meat[36]. The data from our study corroborate this assessment: Prior to the intervention, male study participants were consuming roughly 70% more beef (the food item with the highest carbon footprint), compared to women. In response to our policy intervention, the GHGs of men fell by more than those for women, primarily because men, but not women, reduced their consumption of beef. Policies that target the highest consumers of beef may deliver the greatest scope for reductions in meat-related GHGs. These results also suggest that men are willing to reduce their beef consumption, in response to information about climate change and health.

The long-term effects that we document here reinforce several of the policy implications that we highlighted in our previous paper. First, messages that emphasize the benefits to health and climate change of reduced meat consumption may be particularly effective. Other organizations, such as Chatham House and the EAT-Lancet commission, encourage similar 'win-win' messaging campaigns ("good for you and good for the planet") to promote the shift to healthy and sustainable diets. Second, supportive settings, with receptive audience members and plant-based options, are likely to elicit greater dietary changes in response to interventions. 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. Third, while the dietary changes in this study are statistically significant and strongly persistent, the magnitude—a roughly 9 percent decline in meat consumption—is substantially smaller than what is necessary for high-income countries, such as the United States, to meet sustainability targets. This finding suggests that increased education, while a useful starting point, is unlikely to be sufficient, by itself, to achieve climate change goals.

A growing body of research, using actual food purchase data, finds that some—but not all—policy interventions are effective at reducing the demand for meat. In two randomized controlled trials, Schwitzgebel, Cokelet and Singer (2020, 2021) find reductions in meat consumption among college students from classroom discussions about the ethics of eating meat[37,38]. Garnett et al. (2019, 2020) find increases in the sales of vegetarian meals from simple changes in the choice architecture, i.e. increasing the number of vegetarian options and repositioning vegetarian meals first[21,39]. Garnett et al. (2021) find modest dietary shifts after changes in the relative price of meat- vs plant-based meals[29]. Haile et al. (2021) find that animal welfare leafletting has no statistically significant long-term aggregate effects[40]. Lohmann et al.

(2022) find a reduction in sales of meat meals from carbon footprint labels[41]. Together, these findings indicate that content-based educational interventions (i.e. talks about climate change and public health, discussions about the ethics of eating meat), changes in the choice architecture, and carbon footprint labels at the point of purchase can steer people away from meat and towards plant-based alternatives. By contrast, other interventions, such as leafletting, where study participants may not engage as deeply with the materials as in a classroom presentation or discussion, seem less effective.

While limits to scalability exist for most interventions (see Al-Ubaydli et al. (2022) for an excellent overview)[42], our findings, including our strong internal validity, hold great promise for policymakers. Our results include statistically significant reductions in meat consumption for first- through third-year students, i.e. all class cohorts other than seniors (where our sample size was smaller due to low enrollment in introductory economics courses), offering hope that these behavioral changes would hold for a broad variety of students. Our results may be scalable to the broader population of residential college students, where the choice architecture is favorable (i.e. dining facilities with readily available and tasty plant-based meals). (That the intervention occurred amongst students enrolled in economics courses is unlikely to matter; most introductory students do not major in economics, and if anything, some research suggests that economics majors are less likely to engage in prosocial behavior than non-economics majors[43,44].) We encourage researchers to validate the effectiveness of similar interventions across a diverse range of educational institutions.

Beyond colleges and universities, businesses, corporations and other organizations (e.g. hospitals) could also implement similar informational interventions to steer community members towards more sustainable, healthy food choices. Many such organizations already implement wellness campaigns to improve the health of community members. According to a meta-analysis, these programs save roughly three dollars in healthcare costs for every dollar spent[45]. Such organizations may also be interested in reducing their environmental footprint through dietary change. Program administrators and researchers should study the effectiveness of similar informational sessions, in the context of meat reduction, in these types of settings. Such research could also examine what incentives, if any, help persuade community members to participate in such informational sessions. Such interventions could both improve environmental sustainability and promote public health.

The results of our study should also be a call for policymakers to examine the effectiveness of a range of interventions, perhaps in combination, to reduce the demand for meat. The campaign to tackle smoking in the second half of the twentieth century relied on a variety of policy interventions, in tandem, to effectively curtail cigarette use. Likewise, policy interventions to curb the demand for meat may reinforce and amplify one another. Banerjee et al. (2022) find evidence that nudges, in the context of meat reduction, become more effective when combined with a tactic that encourages deeper reflection (e.g.

information provision, thinking about a pledge)[46]. Recent findings from Lohmann et al. (2022) and Koch et al. (2022)—that carbon footprint and health warning labels reduce actual or intended meat consumption—raise the possibility that labels could enhance the effectiveness educational interventions by serving as a reminder at the time of purchase[15,41]. Many permutations of policies are possible. For example, the dramatic effects Garnett et al. (2019) find—increases in the sales of vegetarian meals by 40-78% from a doubling of options—might increase when combined with an educational intervention that further motivates change via compelling reasons (climate change, ethics, health)[21]. The promising findings from these isolated interventions should spur researchers to assess how policies interact with one another and what combinations are most effective at reducing meat consumption.

Policy interventions may take time to effect large-scale societal change. The campaign to curtail cigarette use required decades of outreach, via a variety of interventions, such as education, regulations, and taxes. Smoking fell over time, in response to myriad interventions, as societal awareness about the health hazards steadily increased. Similar success could happen in the context of meat consumption.

References

1. Gerber, P. J. *et al. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities.* (Food and Agriculture Organization of the United Nations (FAO), 2013).
2. Godfray, H. C. J. *et al.* Meat consumption, health, and the environment. *Science* **361**, eaam5324 (2018).
3. Wellesley, L., Froggatt, A. & Happer, C. Changing Climate, Changing Diets: Pathways to Lower Meat Consumption. *Chatham House, The Royal Institute of International Affairs* (2015).
4. Poore, J. & Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science* **360**, 987–992 (2018).
5. Schiermeier, Q. Eat less meat: UN climate-change report calls for change to human diet. *Nature* **572**, 291–292 (2019).
6. Springmann, M. *et al.* Options for keeping the food system within environmental limits. *Nature* **562**, 519 (2018).
7. Springmann, M., Clark, M. A., Rayner, M., Scarborough, P. & Webb, P. The global and regional costs of healthy and sustainable dietary patterns: a modelling study. *The Lancet Planetary Health* **5**, e797–e807 (2021).
8. Tilman, D. & Clark, M. Global diets link environmental sustainability and human health. *Nature* **515**, 518–522 (2014).
9. Willett, W. *et al.* Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet* **393**, 447–492 (2019).
10. Springmann, M., Godfray, H. C. J., Rayner, M. & Scarborough, P. Analysis and valuation of the health and climate change cobenefits of dietary change. *PNAS* **113**, 4146–4151 (2016).
11. Sanders, B. Global Animal Slaughter Statistics And Charts. *Faunalytics* https://faunalytics.org/global-animal-slaughter-statistics-and-charts/ (2018).
12. Jalil, A. J., Tasoff, J. & Bustamante, A. V. Eating to save the planet: Evidence from a randomized controlled trial using individual-level food purchase data. *Food Policy* **95**, (2020).
13. Bailey, R., Froggatt, A. & Wellesley, L. Livestock – Climate Change's Forgotten Sector: Global Public Opinion on Meat and Dairy Consumption. *Chatham House, The Royal Institute of International Affairs* (2014).

14. Piazza, J. *et al.* Rationalizing meat consumption. The 4Ns. *Appetite* **91**, 114–128 (2015).
15. Koch, J. A., Bolderdijk, J. W. & van Ittersum, K. Can graphic warning labels reduce the consumption of meat? *Appetite* **168**, 105690 (2022).
16. Hunter, E. & Röös, E. Fear of climate change consequences and predictors of intentions to alter meat consumption. *Food policy* **62**, 151–160 (2016).
17. Meier, S. *A survey of economic theories and field evidence on pro-social behavior.* (Mit Press, 2007).
18. Mas-Colell, A., Whinston, M. D. & Green, J. R. *Microeconomic theory*. vol. 1 (Oxford university press New York, 1995).
19. Hirshleifer, J., Jack, H. & Riley, J. G. *The analytics of uncertainty and information*. (Cambridge University Press, 1992).
20. Ambuehl, S., Bernheim, B. D. & Lusardi, A. Evaluating deliberative competence: A simple method with an application to financial choice. *American Economic Review* **112**, 3584–3626 (2022).
21. Garnett, E. E., Balmford, A., Sandbrook, C., Pilling, M. A. & Marteau, T. M. Impact of increasing vegetarian availability on meal selection and sales in cafeterias. *PNAS* **116**, 20923–20929 (2019).
22. Ruby, M. B. & Heine, S. J. Meat, morals, and masculinity. *Appetite* **56**, 447–450 (2011).
23. Bush, S. S. & Clayton, A. Facing Change: Gender and Climate Change Attitudes Worldwide. (2022).
24. Nutrient Lists from Standard Reference Legacy (2018) | Food and Nutrition Information Center| NAL | USDA. https://www.nal.usda.gov/legacy/fnic/nutrient-lists-standard-reference-legacy-2018.
25. Chandler, D. Leaving our mark. *MIT News | Massachusetts Institute of Technology* https://news.mit.edu/2008/footprint-tt0416 (2008).
26. UN Environment Program. *Emissions Gap Report 2019*. http://www.unep.org/resources/emissions-gap-report-2019 (2019).
27. US EPA, O. Sources of Greenhouse Gas Emissions. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (2015).
28. Weber, C. L. & Matthews, H. S. Food-Miles and the Relative Climate Impacts of Food Choices in the United States. *Environ. Sci. Technol.* **42**, 3508–3513 (2008).
29. Garnett, E. E., Balmford, A., Marteau, T. M., Pilling, M. A. & Sandbrook, C. Price of change: Does a small alteration to the price of meat and vegetarian options affect their sales? *Journal of Environmental Psychology* **75**, 101589 (2021).
30. Cameron, A. C., Gelbach, J. B. & Miller, D. L. Bootstrap-Based Improvements for Inference with Clustered Errors. *The Review of Economics and Statistics* **90**, 414–427 (2008).
31. Conley, T. G. & Taber, C. R. Inference with "difference in differences" with a small number of policy changes. *The Review of Economics and Statistics* **93**, 113–125 (2011).
32. MacKinnon, J. G. & Webb, M. D. Wild bootstrap inference for wildly different cluster sizes. *Journal of Applied Econometrics* **32**, 233–254 (2017).
33. Roodman, D., Nielsen, M. Ø., MacKinnon, J. G. & Webb, M. D. Fast and wild: Bootstrap inference in Stata using boottest. *The Stata Journal* **19**, 4–60 (2019).
34. Macdiarmid, J. I., Douglas, F. & Campbell, J. Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite* **96**, 487–493 (2016).
35. Carfora, V., Catellani, P., Caso, D. & Conner, M. How to reduce red and processed meat consumption by daily text messages targeting environment or health benefits. *Journal of Environmental Psychology* **65**, 101319 (2019).
36. Rippin, H. L. *et al.* Variations in greenhouse gas emissions of individual diets: Associations between the greenhouse gas emissions and nutrient intake in the United Kingdom. *PLOS ONE* **16**, e0259418 (2021).
37. Schwitzgebel, E., Cokelet, B. & Singer, P. Do ethics classes influence student behavior? Case study: Teaching the ethics of eating meat. *Cognition* **203**, 104397 (2020).
38. Schwitzgebel, E., Cokelet, B. & Singer, P. Students Eat Less Meat After Studying Meat Ethics. *Rev.Phil.Psych.* (2021) doi:10.1007/s13164-021-00583-0.

39. Garnett, E. E., Marteau, T. M., Sandbrook, C., Pilling, M. A. & Balmford, A. Order of meals at the counter and distance between options affect student cafeteria vegetarian sales. *Nature Food* **1**, 485–488 (2020).
40. Haile, M., Jalil, A., Tasoff, J. & Vargas Bustamante, A. Changing Hearts and Plates: The Effect of Animal-Advocacy Pamphlets on Meat Consumption. *Front. Psychol.* **0**, (2021).
41. Lohmann, P. M., Gsottbauer, E., Doherty, A. & Kontoleon, A. Do carbon footprint labels promote climatarian diets? Evidence from a large-scale field experiment. *Journal of Environmental Economics and Management* **114**, 102693 (2022).
42. Al-Ubaydli, O., Lee, M. S., List, J. A., Mackevicius, C. L. & Suskind, D. How can experiments play a greater role in public policy? Twelve proposals from an economic model of scaling. *Behavioural Public Policy* **5**, 2–49 (2021).
43. Bauman, Y. & Rose, E. Selection or indoctrination: Why do economics students donate less than the rest? *Journal of Economic Behavior & Organization* **79**, 318–327 (2011).
44. Frey, B. S. & Meier, S. Are Political Economists Selfish and Indoctrinated? Evidence from a Natural Experiment. *Economic Inquiry* **41**, 448–462 (2003).
45. Baicker, K., Cutler, D. & Song, Z. Workplace Wellness Programs Can Generate Savings. *Health Affairs* **29**, 304–311 (2010).
46. Banerjee, S., Galizzi, M. M., John, P. & Mourato, S. What Works Best in Promoting Climate Citizenship? A Randomised, Systematic Evaluation of Nudge, Think, Boost and Nudge+. SSRN Scholarly Paper at https://doi.org/10.2139/ssrn.4093689 (2022).