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How information, social norms, and experience with novel meat substitutes can create positive political feedback and demand-side policy change

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ABSTRACT

The food system causes more than a third of the global anthropogenic greenhouse gas emissions, of which half are from livestock. Shifting towards plant-based diets could significantly reduce deforestation, protect biodiversity, and contribute to achieving the Sustainable Development Goals and Paris climate targets. Arguably, large-scale shifts in meat consumption require ambitious policy change. Yet, deep-rooted eating habits, pleasure, cultural status, and personal freedom are just a few of many obstacles to adopt ambitious demand-side policies and reduce meat consumption. Here, we hypothesize that technological innovation in meat substitutes, if effectively combined with social norm and factual informational triggers for behavioral changes, can foster positive political feedback to transform the food system. To test our hypothesis, we conducted survey experiments with citizens (N = 2590) in China and the US – the globally largest meat markets – and analyzed data using different machine learning methods. Our findings show that personal experience with novel plant-based meat substitutes strongly predicts individuals' intentions to reduce their meat consumption, eat more substitutes, and support public policies to catalyze a transition to more plant-based diets. We also find that in both countries factual and social norm information about the benefits of more plant-based diets can increase citizens' behavioral change intentions and support for meat reduction policies. Overall, however, social norm information had no significant additional effects on the outcomes compared to the simple factual information treatments. In the US, prior experience with innovative meat substitutes potentially can boost the positive effects of informational campaigns on public support for meat reduction policies. The results offer promising implications for a policy sequencing strategy to create positive political feedback and enable socio-technical tipping dynamics for sustainable food system transformation.

1. Introduction

Food consumption has an enormous impact not only on human health but also on the planetary health (Willett et al., 2019). The food system is responsible for a third of global anthropogenic greenhouse gas emissions and is a major source of biodiversity loss (Clark et al., 2020; Crippa et al., 2021; Poore & Nemecek, 2018; Springmann et al., 2018). It is also the largest emitter of methane – a powerful short-lived greenhouse gas which can be largely attributed to livestock farming (Fesenfeld et al., 2018; Hayek et al., 2021). Without transforming the food system, the goal of limiting the global temperature rise to 1.5 °C would be hardly achievable even if all other sectors were to rapidly drive emissions down to net-zero (Clark et al., 2020; Milkoreit et al., 2018; Sharpe & Lenton, 2021). In particular, the shift to plant-based diets offers a cost-effective and environmentally integer solution to mitigate agricultural emissions, substantially reducing global deforestation and saving a few hundred gigatonnes of CO_2 from the atmosphere by 2050 (Brunner et al., 2018; Carlsson et al., 2022; Hayek et al., 2021; Parodi et al., 2018; Springmann et al., 2018; Xu et al., 2021). The production and consumption of meat is also linked to human health (Godfray et al., 2018), contributing to the outbreak of pandemics like Covid-19 and to increased risk of mortality due to cardiovascular diseases, cancer, and

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diabetes. Thus, changing meat consumption habits is key for transforming the food system and achieving the Sustainable Development Goals (SDGs) (Barrett et al., 2020; Godfray et al., 2018; He et al., 2018; Parodi et al., 2018).

However, reducing global meat consumption is no easy task. Even though consumption in some industrial countries has begun to decline, demand in many other countries, including developing and emerging countries, remains high or is even increasing rapidly (FAO, 2020; Sahlin et al., 2020). In fact, different factors, such as deep-rooted eating habits (de Boer & Aiking, 2017), perceived necessity (Demartini et al., 2022), pleasure, cultural status symbols and personal freedom, can hinder reducing meat consumption (Fesenfeld et al., 2020). Given these existing barriers for change and the simultaneous urgency of the sustainability transition, this prompts the question of how to accelerate reductions of meat consumption in different socio-political contexts.

Arguably, speeding up the transition of deep-rooted consumption patterns in the food sector requires a more holistic 'system thinking approach', accounting for interactions and feedback between technological, behavioral, social norm, and policy changes (Fesenfeld, Schmid, et al., 2022). While technological innovation, for instance in meat substitutes, might be an important enabling factor for food system transformation (Carlsson et al., 2022; Herrero et al., 2020; Siegrist & Hartmann, 2020), the transformation of deep-rooted consumption patterns relies on social norm and behavioral changes (Hartmann & Siegrist, 2017; Michel et al., 2021; Robinson et al., 2014; Siegrist & Hartmann, 2020; Tziva et al., 2020). To achieve large-scale changes in social norms and food consumption behaviors, the adoption of demand-side public policies is central (Bonnet et al., 2020; Clark et al., 2020; Crippa et al., 2021; Faccioli et al., 2022; Fesenfeld, 2020; Funke et al., 2022; Poore & Nemecek, 2018; Roosen et al., 2022). However, such demand-side food policies, like increased taxes on meat, might face low public support and thus a lack of political feasibility (Fesenfeld, 2020; Fesenfeld, Rudolph, et al., 2022; Fesenfeld, Schmid, et al., 2022; Van Loo et al., 2020). Thus, we need more research on the political feasibility and public support for demand-side food policies (Fesenfeld, 2023). Here we propose that interactions between technological, behavioral, and social norm changes might positively feed back into public opinion about food policies (Fesenfeld, 2020; Fesenfeld, Rudolph, et al., 2022; Fesenfeld, Schmid, et al., 2022). This, in turn, could reduce public backlash and increase the political feasibility of adopting meat reduction measures with visible cost implications in citizens' everyday lives (Fesenfeld, 2020). Thus, to understand the specific mechanisms for accelerating the reduction of meat consumption, it is essential to empirically investigate the feedback effects of growing information and experience with technological innovations in meat substitutes on public opinion about dietary transformations. A comparative perspective is moreover needed to account for the potential context-dependencies of such feedback effects. To address this important research gap, we take a comparative research approach and empirically assess how (factual and social norm) information about and experience with novel plant-based meat substitutes[1] affect individuals' intentions to reduce their own meat consumption, eat more substitutes, and support respective public policies in two distinct countries. In doing so, we conducted two large-N survey experiments with citizens (N = 2590) in China and the US and use different machine learning techniques in the data analysis.

China and the US are not only the largest producers and consumers of meat globally (in absolute terms) (FAO, 2020), but also differ substantially in their socio-political, economic, and cultural context. Amongst others, research has shown that Asian countries, including China, have rather collectivist cultures valuing group integration over self-realization, as opposed to the rather individualistic cultures in Western countries, including the US (Hofstede, 2001). Moreover, food consumption traditions (Happer & Wellesley, 2019) as well as the market developments of innovative plant-based meat substitutes (Polaris Market Research, 2020) differ in these two countries. In China, plant-based protein sources, such as soy protein, have a long tradition (USDA - FAS China, 2021), while traditionally in the US plant-based meat alternatives are less prominent (Neff et al., 2018). Yet, within the past few years, both countries have seen an increase in demand for novel meat substitute products, especially in the US, which has led substitute producers to develop new products using novel ingredients and technologies increasingly capable of reproducing the flavor, texture, and appearance of meat (Polaris Market Research, 2020; USDA - FAS China, 2021). Finally, meat consumption differs between China and the US in both magnitude and trend: while China has experienced a sharper increase in meat production and consumption in recent decades driven by the growing urban middle-class (FAO, 2020; He et al., 2018), its per capita meat consumption is still below that of an average US citizen (He et al., 2018; Wiedenhofer et al., 2017).

In the following, we first present our argument and hypotheses before outlining the research design and discussing our results.

2. Creating positive political feedback from information and experience with novel meat substitutes

In recent years, innovative plant-based meat substitutes such as meat-free burgers have experienced an exponential market growth (Polaris Market Research, 2020). Yet, the market for plant-based meat substitutes is still very small compared to the global meat market and meat is on average perceived in a more positive way compared to plant-based meat substitutes, in particular regarding its taste, texture and price (Michel et al., 2021; Taylor et al., 2022). Nevertheless, plant-based substitutes are perceived on average more positively regarding aspects such as animal welfare, health and environmental impact (Michel et al., 2021; Taylor et al., 2022). Today, it is still uncertain if the purchase of plant-based meat substitutes leads to reduced meat purchases and meat alternatives do truly have the intended substitution effect (Cuffey et al., 2022; Neuhofer & Lusk, 2022; Zhao et al., 2022). Yet, due to technological learning and economies of scale, these new substitutes are becoming more readily available and affordable for a larger number of consumers around the globe, as well as more meat-like regarding their texture and taste. In addition, several restaurants, including major US and Chinese fast food chains, have incorporated plant-based meat substitutes in their menus over the last years. In the US, such restaurant sales accounted for about 40 percent of the meat substitute product sales in 2020 (Statista, 2020a). The increasing availability of substitute products in supermarkets and restaurants can in turn influence the overall familiarity and potential experiences with novel substitute products.

In the present study, we argue that a growing experience with plant-based meat substitutes products coupled with growing information about the impacts of meat consumption and the benefits of meat substitutes can alter individuals' attitudes about meat consumption and policies, thus creating positive political feedback. We expect that exposure to factual and social norm information about plant-based meat substitutes, as well as prior personal tasting experience can increase the perceived benefits of eating such meat alternatives and reduce individuals' perceived utility loss when facing meat reduction policies. In turn, public support for demand-side food policies is likely to increase and hence to create positive political feedback. This expectation builds on dual-process models of human decision-making (Chaiken & Trope, 1999; van der Linden, 2014), which suggest that humans use two different processes when making decisions. First, the affective (experiential) system that makes rather unconscious and fast conclusions with low cognitive effort based on learned behavior and experience. Second,

[1] Plant-based meat substitutes are foods that try to replicate the texture, flavor, and/or nutritional value of meat, often sold as vegetarian burgers, minced meat, sausages, or chicken nuggets. Plant-based meat substitutes are usually made of ingredients such as peas, wheat, vegetable oils, mushrooms, and other plants.

the deliberative (analytical) system that makes conscious and reflected decisions with high cognitive effort based on logic, knowledge, and the information received. (Godfray et al., 2018).

Arguably, food-related decisions tend to be rather subconscious (Happer & Wellesley, 2019) and are often habitual and normative (Schösler et al., 2012; Siegrist & Hartmann, 2020), especially for people with low involvement in food purchasing decisions. Simple decision heuristics that are based on individuals' prior experience with substitute products (Siegrist & Hartmann, 2020) are therefore likely to be an important predictor of individuals' intentions to consume more meat substitutes and less meat (Carlsson et al., 2022). Moreover, positive experiences with meat substitutes might alter individuals' subjective cost-benefit ratio when it comes to supporting policies aiming at meat reduction (Hartmann & Siegrist, 2017; Hoek et al., 2013; Zeiske et al., 2018). If individuals perceive substitutes to be of high quality and see no strong utility decrease when consuming these meat alternatives, there will be a higher probability for them to support policies that reduce meat consumption and incentivize meat substitute consumption (Fesenfeld, 2020; Fesenfeld, Schmid, et al., 2022). Thus, we expect that *growing experience with meat substitutes increases citizens' intentions to reduce their own meat consumption, eat more meat substitutes, and support respective policies (H1)*.

While meat substitute experience is likely to be a key factor in driving public opinion, past research also highlights the role of factual information (analytical system) in increasing people's knowledge and awareness about the health and sustainability aspects of their diets, especially in closing the knowledge gap about meat consumption and climate change (Apostolidis & McLeay, 2016; Brunner et al., 2018; Carlsson et al., 2022; de Boer & Aiking, 2017; Fesenfeld et al., 2020; Fesenfeld, Sun, Wicki, & Bernauer, 2021; Graham & Abrahamse, 2017; Happer & Wellesley, 2019; Lemken et al., 2018; Pechey et al., 2022; Van Loo et al., 2017; Wellesley et al., 2015; Willett et al., 2019). This line of research is also aligned with discussions around Bayesian updating concerning climate change (Druckman & McGrath, 2019). For instance, Van Loo, Hoefkens and Verbeke (2017) argue that the inability of people to directly observe health and sustainability attributes of food products justifies using informational campaigns as instruments to increase awareness and knowledge in earlier stages of the transition towards more plant-based diets. Apostolidis and McLeay (2016) further suggest that information campaigns can be effective in encouraging people to substitute meat, especially for health- and environmentally conscious consumers. However, while the current literature mainly focuses on providing information about the impacts of meat consumption, we still lack experimental and comparative evidence if information related to the benefits of meat substitutes could increase individuals' intentions to move towards more plant-based diets and support related policies (Fesenfeld et al., 2021). Based on such research about information effects on meat consumption (Cordts et al., 2014; Fehrenbach, 2015; Fesenfeld et al., 2020; Fesenfeld, Sun, Wicki, & Bernauer, 2021; Graham & Abrahamse, 2017; Happer & Wellesley, 2019; Pechey et al., 2022; Scrimgeour, 2012; Wellesley et al., 2015), we expect that *growing information about the impacts of meat consumption and the benefits of meat substitutes increases citizens' intention to reduce their own meat consumption, eat more meat substitutes, and support respective policies (H2)*.

In addition to factual information, perceived social norms can also play an important role in changing consumer habits and policy attitudes (Andreoni et al., 2021; Fesenfeld, Rudolph, et al., 2022; Nyborg, 2018; Nyborg et al., 2016; Rinscheid et al., 2021). However, there is little empirical evidence on such effects in the context of food policymaking, particularly in respect to meat and meat substitutes, although existing literature underlines the importance of the social environment and individuals perceived social norms in shaping food-related decisions (Fesenfeld, Rudolph, et al., 2022; Markowski & Roxburgh, 2019; Mollen et al., 2013; Robinson et al., 2014; Sparkman et al., 2021; Ye et al., 2021). According to the theory of planned behavior (Ajzen, 1991), the more a person believes that other people, so called social referents, approve or do not approve of a certain behavior, the stronger this person will adhere to these subjective social norms. For instance, research in environmental psychology has found that social norm appeals, i.e., statements intended to appeal to the perceived social norms of an individual, can be more effective in motivating environmentally friendly behavior than economic cost-benefit appeals that operate mainly through individuals' self-interest (Bolderdijk et al., 2013; Huber et al., 2018; Steinhorst et al., 2015). In general, social norm appeals can be injunctive, stating what ought to be done, or descriptive, stating what is done by others such that individuals infer the group norm by themselves (Huber et al., 2018). Depending on the context, peer-group-led, celebrity-led, or government-led appeals that combine injunctive and descriptive norms can be particularly effective in promoting environmental behavior change (Çoker et al., 2022; Huber et al., 2018; Salmivaara et al., 2021; Seah et al., 2022; Sharps et al., 2021; Sparkman & Walton, 2017). Social norms can also enable policy change by creating the necessary public support for interventions (Fesenfeld, Rudolph, et al., 2022; Nyborg, 2018; Nyborg et al., 2016; Rinscheid et al., 2021). We thus expect that a *social norm appeal, including both injunctive and descriptive social norm messages, combined with factual information about the impact of meat consumption and the benefits of meat substitutes, increases citizens' intentions to reduce their own meat consumption, eat more meat substitutes, and support respective policies (H3)*. Given the importance of social norms in food consumption (Alló & Loureiro, 2014; Fesenfeld, Rudolph, et al., 2022; Mollen et al., 2013; Robinson et al., 2014), we expect that *the combination of factual information and a social norm appeal has larger effects than factual information alone (H3a)*.

Finally, building on dual-process models of human decision-making (Chaiken & Trope, 1999; van der Linden, 2014), we explore whether informational and social norm campaigns, respectively, interact with individuals' experiences with innovative meat substitutes in a way that generates positive synergies and increase support for policies to transform the meat system. We expect that the interplay of humans' analytical and associative systems is essential for changing individuals' behaviors and policy support in the food domain because people can relate their personal experiences (affective system) to the information (analytical system) about benefits of plant-based diets and meat substitutes. Thus, we formulate an explorative hypothesis that personal experience and (social norm) information regarding meat substitutes positively interact: *Hence, this interaction can amplify citizens' intentions to reduce own meat consumption, eat more meat substitutes, and support respective policies (H4)*.

3. Methods

3.1. Survey sample

We test our arguments via a survey-embedded experiment with a representative sample of 2590 respondents in China and the US fielded in December 2020 and January 2021. After pretesting the survey with a student panel (N = 80), an internet panel from a commercial provider of sampling services (Lightspeed Research, Kantar TNS Group, Munich, Germany) was used to recruit the study participants. The respondents were told that they are participating in a study about food choices and product preferences, and they received a financial reward for their participation if fully completing the survey. We only included full completes in our analysis. The Kantar TNS Group is a leading company for online surveys and maintains large panels with over 1.3 million

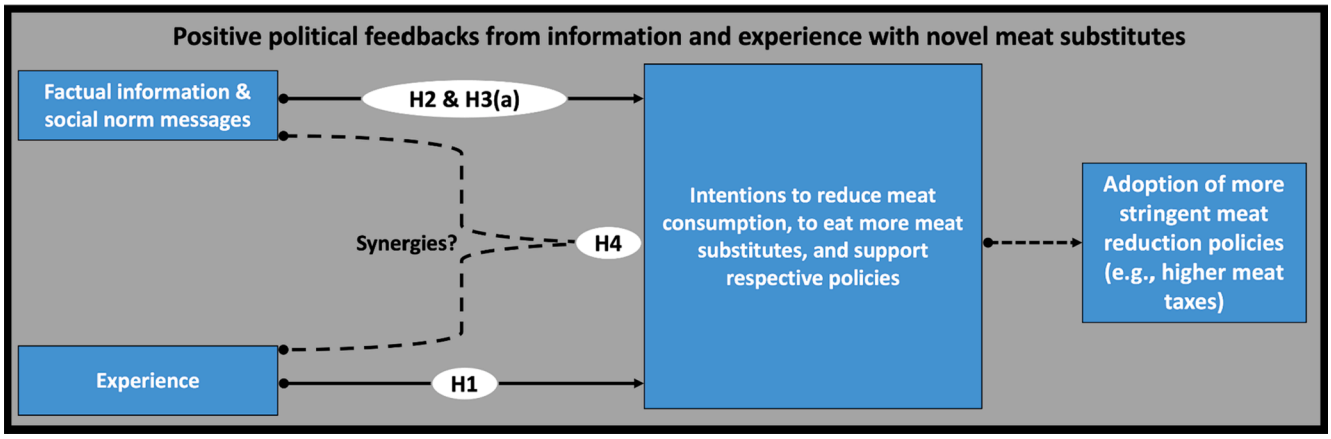

Fig. 1. Creating positive political feedback from information and experience with novel meat substitutes: The figure outlines the proposed argument and hypotheses H1-H4 that growing information about and experience with such meat substitutes positively affects individuals' attitudes about meat consumption reduction and respective policies and thus can create positive political feedback enabling the adoption of more stringent meat reduction policies. Please see Method section and Fig. 2 (below) for further details about the experimental design and operationalization of the different variables.

registered panelists in China and the United States. Quota sampling was used based on interlocked quotas on gender, education, and age in the US (United States Census Bureau, 2019) and on gender and age in China (National Bureau of Statistics of China, 2020). During data collection, participants that were younger than 18 years old and/or that were not allowed to vote in the last US election in November 2020 were screened out from the survey right in the beginning, as their answers would be less relevant for the policy-related questions. To ensure high response quality we set a speeder limit (<40 % of median response time) and excluded respondents falling below this threshold. As an additional quality check, after the survey completion, the sum of the duration in seconds of all matrix questions in the survey was calculated for all participants and everyone who took less than half of the median time to answer the matrix questions was excluded, as this is an indicator for straightlining survey response behavior. We used forced-choice questions to prevent missing values.

The final sample consisted of N = 1360 participants in the US and N = 1230 participants in China. The sample distribution closely follows the national population statistics for the 18 + voting age population of US citizens (see Appendix A table A1), while in China the urban, higher-income, and younger generation is somewhat overrepresented in our sample (see Appendix A table A2). Yet, due to differently paced economic developments within China, the Chinese sample in this study represents the most relevant subgroup in the country considering meat consumption and sustainability, i.e., the urban middle-class, since their food consumption patterns have the greatest impact on the countries' environment (He et al., 2018; Wiedenhofer et al., 2017). Moreover, the samples from both the US and China are representative of the politically and economically relevant population, since the respondents in the US sample represent the voting age population and the respondents in the Chinese sample represent the urban middle-class that is on average younger, has a higher education, and a higher income.

3.2. Survey Procedure/Measures

We used Qualtrics, an online survey software, to design the survey experiment and to collect the data. The median survey completion time in US sample was about 18 min as compared to about 31 min in the Chinese sample. The longer median completion time of the Chinese survey was due to some issues with the survey being hosted on Qualtrics, which resulted in longer page loading times of the graphics for the Chinese respondents. As our robustness checks indicate, this had no significant effects on survey response quality.

At the start of the survey, after the screening and the first part of the demographical questions, we asked different questions related to our key explanatory variable of interest, namely individuals' previous experience with plant-based meat substitutes, and various control variables. To measure individuals' personal experience with plant-based meat substitutes we used the following item (Statista, 2020b):

Within the last year, how frequently have you eaten **plant-based meat substitute products** (see definition below)?

Plant-based meat substitutes are foods that try to replicate the texture, flavor, and/or nutritional value of meat, often sold as vegetarian burgers, minced meat, sausages, or chicken nuggets. Plant-based meat substitutes are usually made of ingredients such as peas, wheat, vegetable oils, mushrooms, and other plants.

- Every day
- Several times a week
- About once a week
- Several times a month
- About once a month
- Rarely
- Never

In addition, we selected the following control variables since they have been identified in the food consumption literature as the most relevant predictors of meat consumption and the willingness to switch to more plant-based diets as well as respective policy support. Hence, in addition to basic sociodemographic variables (e.g., age, gender, education, income, household size) we also asked questions on: a) participants diets because meat consumption habits affect the willingness to eat more plant-based products (Graça et al., 2019); b) their food shopping criteria, especially how much emphasis they put on sustainability criteria such as animal welfare and environmental impacts of food products (Fesenfeld et al., 2020; Fesenfeld, Sun, Wicki, & Bernauer, 2021); c) the amount of substitutes consumed, e.g., by friends, family etc. to analyze the degree of socialization of eating plant-based meat substitutes in their closer environment (Graça et al., 2019; Markowski & Roxburgh, 2019); d) their food neophobia to determine the degree of reluctance to try new

foods using the original Food Neophobia Scale (Pliner & Hobden, 1992; Siegrist & Hartmann, 2020); e) their perceived ability to cook with meat substitutes as a proxy for the participants ability to switch to more plant-based diets (Graça et al., 2019; Schösler et al., 2012); f) their perceived availability of meat substitute products when shopping which has been shown to be a barrier to changing the diet accordingly (Apostolidis & McLeay, 2016); g) their household characteristics influencing the likelihood of following more plant-based diets (Graça et al., 2019; Koch et al., 2019; Markowski & Roxburgh, 2019); h) their shopping behavior, i.e., the frequency of them going food shopping by themselves, as a predictor of higher or lower involvement in food purchasing (Apostolidis & McLeay, 2016); i) their use of a shoppinglist as a proxy of translating purchasing intentions into actual behavior (Kamm et al., 2015) (see the detailed question wording in the questionnaire in Appendix J).

Then the respondents were randomly assigned to one of three groups (also see Fig. 1): 1) a control group including only a graphical and textual definition of plant-based meat substitutes; 2) a factual information group receiving the same definition plus a graphical and textual message about the negative impacts of meat and positive impacts of meat substitutes on human health, animal welfare, and the environment; 3) a social norms group receiving the same definition and factual information combined with a social norms appeal, consisting of a statement saying that a vast majority of the population, as well as celebrities start to reduce their meat consumption, for example by eating plant-based meat substitutes (descriptive social norm), as well as a statement saying the official dietary guidelines recommend that meat consumption should be reduced and people should switch towards more plant-based diets (injunctive social norm). As factual manipulation checks, measuring respondents' factual understanding and reinforcing the information received in the treatments, the participants then had to answer short multiple-choice questions on the information received (see questionnaire in Appendix J). The graphics below show the design of the control group and the treatments:

After the treatments, we used 7-point Likert scales to assess our dependent variables of interest, namely, respondents' intentions to reduce their meat consumption, to eat more substitutes and to support different types of food policies with the following items (based on survey items from Fesenfeld et al. (2020; 2021)):

- DV1a: How likely or unlikely is it that you increase your consumption of plant-based meat substitutes in the next two weeks? (Extremely unlikely – Extremely likely)
- DV1b: How likely or unlikely is it that you reduce your meat consumption within the next two weeks? (Extremely unlikely – Extremely likely)
- DV2a – general meat reduction policy support: Would you support or oppose government policies to reduce the consumption of meat products in the US/China? (Strongly oppose – Strongly support)
- DV2b – general meat substitute incentive policy support: Would you support or oppose government policies to increase the consumption of plant-based meat substitutes in the US/China? (Strongly oppose – Strongly support)
- DV2c – specific meat reduction policy support: Would you support or oppose the following government policies to reduce meat consumption in the US/China? (Strongly oppose – Strongly support)
  - o Taxes on meat products increasing the price of meat
  - o Two mandatory meat-free days per week in public cafeterias (like in universities, hospitals, government agencies)
  - o Elimination of financial support (subsidies) for meat producers
- DV2d – specific meat substitute incentive policy support: Would you support or oppose the following government policies to incentivize the consumption of plant-based meat substitutes in the US/China? (Strongly oppose – Strongly support)
  - o Lower taxes on plant-based meat substitutes decreasing their price

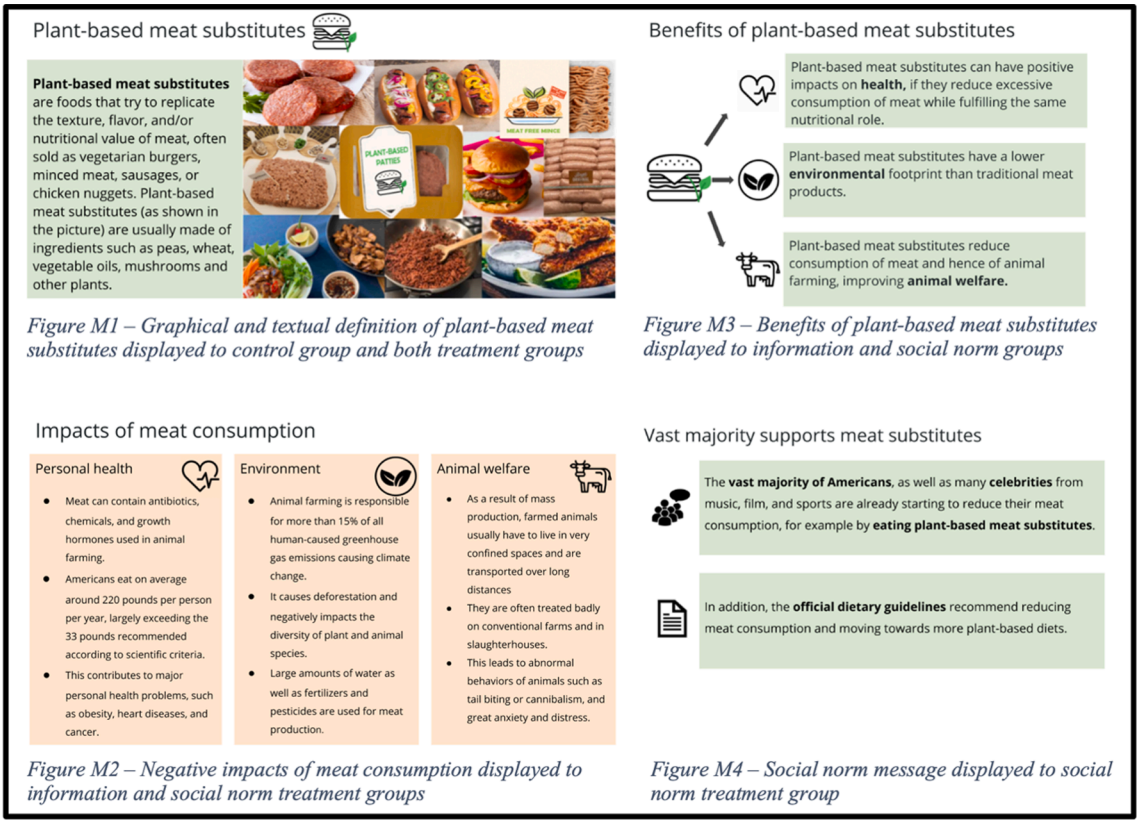

Figure M1 – Graphical and textual definition of plant-based meat substitutes displayed to control group and both treatment groups

Figure M3 – Benefits of plant-based meat substitutes displayed to information and social norm groups

Figure M2 – Negative impacts of meat consumption displayed to information and social norm treatment groups

Figure M4 – Social norm message displayed to social norm treatment group

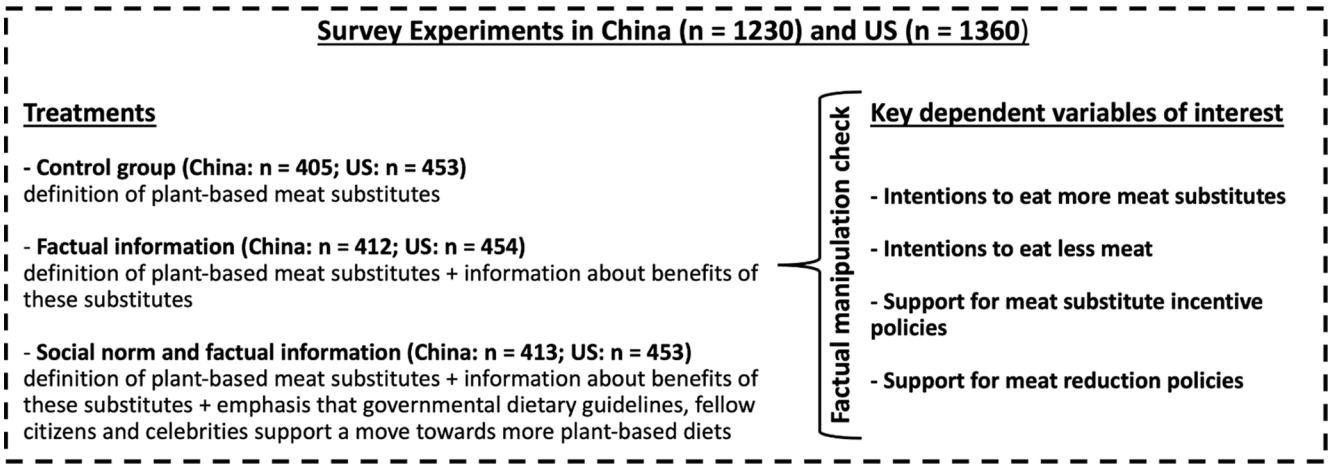

Fig. 2. Survey experimental design: In both China and the US, we implemented the same survey experiment including a control group, a factual information treatment group, and a social norm & factual information treatment group. In the control group, individuals were only presented with a definition of plant-based meat substitutes and a graphical illustration of such products (see Methods for details). In the two treatment groups, respondents received not only the definition but also factual information about the negative impacts of meat and positive impacts of meat substitutes on human health, animal welfare, and the environment. In the social norm treatment, respondents additionally received a statement about national governmental dietary guidelines, fellow citizens, and celebrities supporting a reduction of meat and increase of meat substitute consumption (see Methods for details). After a factual manipulation and information credibility check, respondents then answered a series of outcome variables, namely their intentions to start eating more meat substitutes and reducing their meat consumption within the next two weeks as well as their support for governmental policies to incentivize meat substitute and reduce meat consumption.

- o Two mandatory days per week in which public cafeterias (e.g. in universities, hospitals, government agencies) serve plant-based meat substitutes
- o Introduction of financial support (subsidies) for plant-based meat substitute producers

As robustness check for general policy support, we also used the specific policy support items to build an additive index for meat reduction and meat substitute incentive policies by adding the respective specific policy items together and dividing the sum by the number of items (three in each case).

Further as additional variables of interest we asked the participants to answer questions attempting to reveal their attitudes towards plant-based meat substitutes and towards the reduction of meat consumption, as well as questions that should reveal the strength and credibility of the information received in the treatments. Finally, the participants in the US sample had to answer some short questions to reveal their political ideology before the survey ended with the second part of the demographical questions.

3.3. Machine learning analysis

To test our first hypothesis on the effects of meat substitute experience, controlling for potential confounding variables, we conducted different machine learning analyses. As part of the first analysis, we used ML-based variable selection methods to avoid overfitting the regression models with too many control variables, since there are several potentially important predictors of food consumption behavior and policy support according to the existing literature (see above). First, we applied the Bayesian machine-learning based variable selection method LASSOplus (Ratkovic & Tingley, 2017) to test the relative importance of the experience variable compared to the other potentially important predictors identified in the literature. LASSOplus performs variable selection using a regularization parameter to improve the prediction accuracy and interpretability of statistical models in settings with many predictor variables. By selecting the scale type "TTX" in the sparsereg package in R, the model also automatically creates and thus controls for interactions between each level of the treatment variables and between every control variable added to the regression (Ratkovic & Tingley, 2017). The LASSOplus algorithm then selects those variables that are robust and relevant predictors of the dependent variables in both, the US and the Chinese sample, among the larger set of potentially predictive control variables and their potential interactions. To enable the selection and comparison of coefficients, we z-transformed all predictors, i.e., all the control variables, including demographics, from the survey. The LASSOplus analysis yields specific posterior median estimates for each selected variable and is thus a first step to determine how strongly and in which direction prior experience with meat-substitute products affects the outcome variables of interest compared to the other potential predictor variables.

Table 1
Reported experience with plant-based meat substitutes: Chinese and US respondents self-reported their personal experience with plant-based meat substitutes using the following survey question: "Within the last year, how frequently have you eaten plant-based meat substitute products? Please note: Plant-based meat substitutes are foods that try to replicate the texture, flavor, and/or nutritional value of meat, often sold as vegetarian burgers, minced meat, sausages, or chicken nuggets. Plant-based meat substitutes are usually made of ingredients such as peas, wheat, vegetable oils, mushrooms, and other plants.".

	Non-users	**Light users**			**Heavy users**		
User frequency	Never	Rarely	About once per month	Several times per month	About once per week	Several times per week	Every day
China (N = 1230)	19 %	18 %	8 %	18 %	14 %	19 %	4 %
	(237)	(219)	(94)	(226)	(171)	(231)	(52)
US (1360)	49 %	20 %	7 %	5 %	7 %	9 %	3 %
	(668)	(273)	(98)	(75)	(86)	(115)	(45)

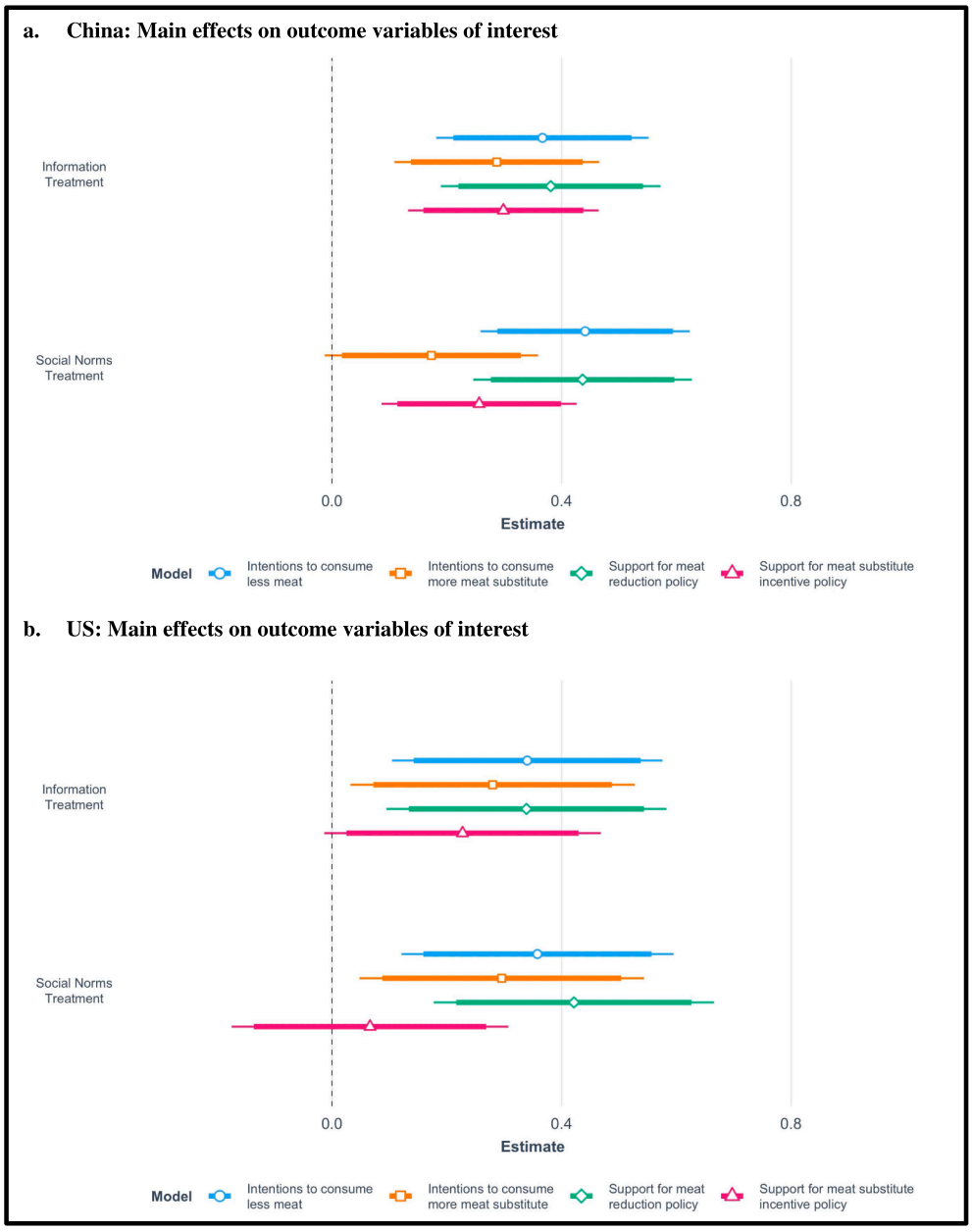

Fig. 3. Main effects: The figure outlines the main effects of the factual information and social norm treatment group compared to the control group (dashed baseline). Fig. 3a present the effects for the Chinese sample, while Fig. 3b for the US sample. In the four different colors, we present the effects on the different outcome variables, namely the intentions to consume less meat (blue; US: control group mean = 3.01, control group std. deviation = 1.71; China: control group mean = 4.54, control group std. deviation = 1.31), intentions to consume more meat substitutes (orange; US: control group mean = 2.92, control group std. deviation = 1.86; China: control group mean = 4.81, control group std. deviation = 1.32), support for policies to reduce meat consumption (green; US: control group mean = 3.13, control group std. deviation = 1.76; China: control group mean = 4.70, control group std. deviation = 1.42), and support for policies to incentivize meat substitute consumption (red; US: control group mean = 3.73, control group std. deviation = 1.77; China: control group mean = 5.14, control group std. deviation = 1.25). We measured all outcome variables on a 7-point Likert scale with higher values indicating higher intentions to change personal consumption and higher policy support. The error bars represent the 90 percent (thicker lines) and 95 percent (thinner lines) confidence intervals based on OLS regressions with robust standard errors. The respective regression output tables can be seen in Appendix D. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

However, LASSOplus is a parametric method; therefore, the functional form of the true underlying model must be assumed. As there is no guarantee that the true underlying model is linear, we also use the random forest method to validate the relative importance of the experience variable from LASSOplus and add more robustness to our findings. Random forest (Breiman, 2001) is a nonparametric ensemble learning method that randomly creates decision trees. For regression tasks, random forests return the average results of all decision trees to avoid overfitting. The permutation importance method (Breiman, 2001) is used to assess the feature importance of the random forest. In the permutation importance method, the values of single features are shuffled randomly to break the dependency between the feature and the dependent variable. For important features, this shuffling will decrease the accuracy of the model. The random forest is implemented with the Python package scikit-learn and uses 1000 trees per forest. To compute the permutation feature importance, the package eli5 was used. It shuffles the values of each feature 50 times and measures how much the accuracy of the model changes for each shuffling. This package returns the feature importance, which is the mean decrease of the model score when a feature is permuted and its standard deviation. Combining the complementary benefits of both approaches thus yields very robust prediction outcomes and ensures that we can estimate the predictive effects of meat substitute experience while controlling for a large number of potential confounders.

3.4. Experimental study

Following the machine learning analyses, three main regression models with robust standard errors were calculated for each dependent variable:

Linear model 1:.

$$Y = \beta_0 + \beta_1 * Information\ Group + \beta_2 * Social\ Norms\ Group + \varepsilon$$

In the first model to estimate the main treatment effects (compare Fig. 3), Y stands for the dependent variable and Group is a factor variable indicating treatment assignment with 1 control group, 2

information group and 3 social norms group. Since the assumption of constant error variances cannot be justified, robust standard errors were used throughout the analysis. To determine whether there is a significant impact of the treatment assignment on the dependent variables, non-parametric Kruskal Wallis rank-sum tests were conducted followed by Dunn's tests for post-hoc pairwise comparisons. Those tests were chosen instead of an analysis of variance (ANOVA) followed by post hoc TukeyHSD tests, since the ANOVA assumptions of homogeneity of the variances between the treatments, as well as normality of the residuals (Feir-Walsh & Toothaker, 1974) are not met. As robustness check for the policy support outcomes, we also used the additive policy support index variables (see above). The results of our robustness check analyses support the findings from the main regression outcomes.

Linear model 2:.

$$Y = \beta_0 + \beta_1 * Information\ Group + \beta_2 * Social\ Norms\ Group + \beta_3 * experience + \beta_4 * (Information\ Group * experience) + \beta_5 * (Social\ Norms\ Group * experience) + \varepsilon$$

In the second model to estimate interaction effects between the treatments and experience (compare Fig. 4), Y stands for the dependent variable, Group is a factor variable indicating treatment assignment with 1 control group, 2 information group and 3 social norms group, and experience is an ordinal numeric variable indicating substitute consumption frequency ranging from 0 never to 6 every day.

Linear model 3:.

$$Y = \beta_0 + \beta_1 * Information\ Group + \beta_2 * Social\ Norms\ Group + \beta_3 * experience + \beta_4 * (Information\ Group * experience) + \beta_5 * (Social\ Norms\ Group * experience) + control\ variables + \varepsilon$$

Lastly, in the third model, as a robustness check, we included additional control variables to see whether the interaction effects estimated in model 2 are robust. We included only those control variables that were identified to have a strong (significant) relationship with the dependent variables in the LASSOplus regressions as well as core socio-demographic variables (age, gender, education, income, region). These robustness check tests could not confirm the significant interaction effects identified in the US sample (see Appendix F table F1a).

4. Results and discussion

4.1. Machine learning results: Meat substitute experience key factor for meat reduction

First, in Table 1, we show the reported experience with plant-based meat substitutes. Among the Chinese respondents, 37 percent can be classified as heavy users (i.e., eating substitutes several times a month or more), 44 percent can be classified as light users (i.e., eating substitutes rarely or about once a month), while about 19 percent of respondents are non-users (i.e., never ate substitute products before). In contrast, among the US respondents, 19 percent can be classified as heavy users, 32 percent can be classified as light users, and 49 percent never consumed any substitute products. Overall, Chinese respondents are more likely than US respondents to already have tried plant-based meat substitutes.

Second, we assess the importance of key predictors of intentions to eat more of these substitutes, to reduce their meat consumption, and to support policies that incentivize meat substitute consumption or policies that reduce meat consumption identified by past studies. For example, we included individuals' sustainability-related shopping criteria (Fesenfeld et al., 2020; Fesenfeld, Sun, Wicki, & Bernauer, 2021), food neophobia (Pliner & Hobden, 1992; Siegrist & Hartmann, 2020), their perceived meat substitute product availability of and ability to cook such products (Apostolidis & McLeay, 2016; Graça et al., 2019), household characteristics and behaviors of family, friends, co-workers measuring perceived social norms (Apostolidis & McLeay, 2016; Graça et al., 2019), as well as general socio-demographic and ideological variables (Fesenfeld et al., 2020; Fesenfeld, Sun, Wicki, & Bernauer, 2021) (please see Method section for further details). Given the large number of potentially relevant predictors of the dependent variables of interest, fitting models including all those predictors might result in overfitting and biased estimates (Beiser-McGrath & Beiser-McGrath, 2020). As describe in the methods section, we thus use machine-learning-based Bayesian sparse-regression LASSOplus models (Ratkovic & Tingley, 2017) and random forests (Breiman, 2001) to explore the relative importance of individuals' experience with plant-based meat substitutes in predicting the various outcome variables of interest compared to these other theory-based and carefully selected predictors. Using both these complementary variable selection approaches increases the robustness of our results and prevents overfitting models while controlling for a large number of potentially confounding factors (please see Method section for further details).

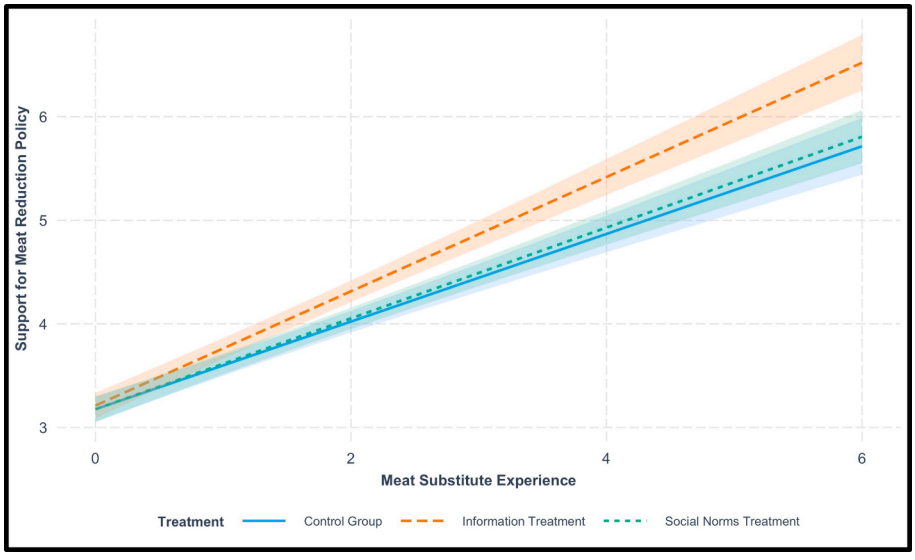

Fig. 4. Interaction effects US sample: The figure outlines the predicted effects of the control, factual information, and social norm treatment group on respondents support for meat reduction policies for different levels of plant-based meat substitute experience. Meat substitute experience was measured on a 6-point Likert scale (see Table 1 above, control group mean = 1.34) while the support for meat reduction policies was measured on a 7-point Likert scale (control group mean = 3.13) with higher values indicating higher policy support. The shaded error bars represent the 95 percent confidence intervals based on OLS regressions with robust standard errors.

Through the sparse regression and random forest analyses, we found that in both China and the US individuals' experience with plant-based meat substitutes is selected as one of the four most important predictors of individuals' intentions to eat more substitutes and reduce their meat consumption (see Appendix C, G, and H). In the US, it is by far the most important predictor of individuals' intentions to change their personal behavior (see Appendix C, G, and H). Our findings also add to recent results from the analysis of US household food purchasing data (e.g., via food scanners) that cast some doubt on the substitution effects of meat alternatives (Cuffey et al., 2022; Neuhofer & Lusk, 2022; Zhao et al., 2022). The present study contributes to this line of research by using ML-based approaches to control for potentially confounding factors that can affect meat and meat substitute consumption. Further, the current study considers product purchases in supermarkets but also consumption experiences across various settings (e.g., at home, in restaurants, cafeterias etc.). Especially, restaurant sales are essential to consider as they account for about 40 percent of the meat substitute product sales in the US (Statista, 2020a). Future research should overcome the limits to causal inferences of this and other existing studies by randomly varying the degree of meat substitute experiences in field experiments and measuring the longitudinal effects on individuals' consumption and policy attitudes.

Such future field experiments can also build on our sparse regression and random forest analysis of policy attitudes, which indicates that experience with plant-based meat substitutes belongs to the two most important predictors of US respondents' support for policies to reduce meat consumption and incentivize more plant-based meat substitute consumption (see Appendix C, G, and H). Only general ideological beliefs on state intervention still outperform meat substitute experience when predicting policy support in the US. In China, however, consumers' sustainability shopping criteria rather than their personal experiences with meat substitutes are selected as the key predictors of support of policies targeted at reducing meat consumption and incentivizing meat substitute consumption (see Appendix C, G, and H). This indicates an interesting divergence between the two country contexts.

4.2. Experimental results: Social norm messages and information about the benefits of meat substitutes can shift behavioral intentions and policy support to reduce meat consumption

Next, in both China and the US, we conduct survey-embedded experiments with the same framing experimental design including a control group, a factual information treatment group, and a factual information treatment that also included a social norm appeal (see treatment design in Fig. 2). The results of our factual manipulation check (Kane & Barabas, 2019) clearly indicate that most respondents in both countries understood the respective treatments well. Also, our balance checks indicate that random assignment to treatments worked as expected. Moreover, people perceive the received information as credible, which is an important prerequisite for engaging in a conscious information updating process (Druckman & McGrath, 2019). We do not find any significant differences in these credibility evaluations across the different treatment groups (see Appendix B table B2a & B2b).

Fig. 3 presents the main treatment effects of our experiments in China (Fig. 3a, also see Appendix D) and the US (Fig. 3b, also see Appendix D). In both countries, we find that the treatments significantly affect most of the dependent variables compared to the control group. This supports hypotheses 2 and 3. In China and the US, the factual information treatment significantly increased individuals' intentions to change their personal consumption towards more plant-based diets and their support for respective policies (effects range from 0.23 to 0.38 on a 7-point Likert scale). Only in the US, the effect of the information treatment on the support for policies to incentivize meat substitute consumption is not significant at the 5 percent but only the 10 percent significance level ($p = 0.06$), while all other treatment effects are significant at the 5 percent level ($p < 0.01$). In general, for both country samples we find slightly larger information treatment effects for the outcome variables focusing on meat reduction rather than meat substitute consumption. Nevertheless, these differences are not significant.

Concerning the factual information treatment that also included a social norm message, we find some cross-country variation. In China, all treatments are significant (effects range from 0.17 to 0.44 on a 7-point Likert scale, $p < 0.01$, except for intentions to eat more meat substitutes $p = 0.06$). Yet, in the US, the social norm frame does not have any significant effects on citizens' support for policies to incentivize meat substitute consumption, while it still affects all other outcome variables (effects range from 0.30 to 0.42 on a 7-point Likert scale, $p < 0.01$).

In China, we also find clear evidence that the social norm frame has larger effects on intentions to reduce meat consumption (0.44, $p < 0.01$) and support meat reduction policies (0.44, $p < 0.01$) than on intentions to eat more meat substitutes (0.25, $p < 0.01$) and support respective policies (0.25, $p < 0.05$). Also in the US, including social norms in the treatment tends to affect slightly more the outcomes concerning meat consumption reduction (effects range from 0.36 to 0.42 on a 7-point Likert scale, $p < 0.01$) than those concerning intentions to consume more meat substitute (0.29, $p < 0.05$) and support policies to incentivize meat substitute consumption (0.06, $p = 0.59$).

Comparing the effects of the two treatments – the factual information and the social norm message – we however do not find any statistical differences between the two treatments (read more in Appendix I). This is in contrast to our hypothesis 3a. For example, while in China the social norm frame does not have a statistically significant treatment effect at the 5 % level on the intentions to consume more meat substitutes, whereas the simple factual information treatment has such a significant effect, the differences between the two treatment effects are not statistically significant. Also, in the US the effect of the social norm frame for the support of policies that incentivize meat substitute consumption is smaller than the effect for the factual information treatment. However, the effect difference is again not statistically significant. Overall, this result implies that in our experiment in both countries the social norm frame did not have any additional positive effects on the outcome variables compared to the factual information treatment. Given that our manipulation checks indicate no statistical difference in the perceived credibility between the factual information and social norm frame, we can conclude that a lack of credibility of the social norm frame is not the reason for the non-significant treatment differences. However, future field-experimental research should investigate if repeated social norm treatments and feedback in realistic social contexts (e.g., cafeterias and restaurants) have a stronger effect than pure factual information. Both injunctive and descriptive norm signals might be stronger if repeated and linked to a situation in which respondents face significant social referents (e.g., co-workers, family members, friends) (Sparkman et al., 2021; Sparkman & Walton, 2017).

Finally, in line with our hypothesis 4, we analyzed if an increase in respondents' personal experience with such products positively interacts with any of the treatments. Fig. 4 shows that in the US there is indeed a significant interaction effect between individuals' degree of meat substitute experience and the factual information treatment (but not the social norm treatment) on the support of meat reduction policies. In essence, we find that increasing meat substitute experience by one unit increases the positive effect of receiving the information treatment on individuals' support for meat reduction policy by about 0.13 points ($p < 0.05$). We find a similar positive interaction effect between the information treatment and meat substitute experience for US respondents' support of meat substitute incentive policies (see Appendix E table E1a) but not for any of the outcomes on intentions to shift personal behaviors. In contrast, in China we do not find any significant interaction effects. This partially confirms hypothesis 4. However, these results should be interpreted with some caution because when running robustness check analyses with additional control variables, as well as using ML-based LASSOplus regressions, we cannot support the significant interaction

effects in the US case. These effects might thus be caused by an omitted interaction bias (Beiser-McGrath & Beiser-McGrath, 2020; Blackwell & Olson, 2022; Fesenfeld, Sun, Wicki, Beiser-McGrath, et al., 2021).

5. Implications for policymaking and future research: Harnessing positive political feedback

Our study sheds light on how technological innovation and behavioral change interact and potentially feed back into the politics of food system transformation. We empirically investigate the mechanisms through which increased consumer experience with and information about innovative meat substitutes alter public opinion on meat consumption and substitutes and respective policy interventions to reduce meat consumption and production. In essence, we find evidence for positive political feedback effects of information on and experience with novel meat substitutes that might enable the adoption of policies to reduce meat consumption. We conducted surveys with 2590 respondents in China and the US, the globally largest meat markets. Using machine-learning-based Bayesian sparse regression and nonparametric ensemble learning methods, we find that growing personal experience with new plant-based meat substitutes strongly predicts individuals' intentions to reduce their meat consumption, eat more substitutes, and support respective public policies. Using survey-embedded experiments we also find that information about the benefits of plant-based diets can increase citizens' behavioral change intentions and policy support. Further, we also investigate how meat substitute experience affects policy support. Moreover, we provide information on both the benefits of plant-based meat substitutes as well as the impact of meat consumption. Comparing the effects between the factual information treatment and an additional social norm frame in both countries shows that the social norm frame did not have any additional significant treatment effect on the various outcomes. Yet, we show that emphasizing social norms in favor of plant-based diets has particularly strong effects on respondents' support for policies to reduce meat consumption compared to policies supporting meat substitute uptake. Lastly, we show that in the US, prior experience with innovative meat substitutes can boost the positive effects of informational and social norm campaigns on public support for meat reduction policies but these interaction effects are explorative and require further research to check for their robustness and external validity.

Overall, the results suggest that policymakers can harness such political feedback effects to transform the food system. The main takeaway for policymakers is that information on and experience with plant-based meat-substitutes are positively associated with public support for more stringent meat reduction policies. Strategically designing policies to induce positive feedback by fostering information about and widespread experience with meat substitutes might enable positive socio-technical tipping points in food system transformation (Farmer et al., 2019; Fesenfeld, Schmid, et al., 2022; Meckling et al., 2015, 2017; Otto et al., 2020; Pahle et al., 2018; Rosenbloom et al., 2020; Schmidt & Sewerin, 2017; Sharpe & Lenton, 2021; Smith et al., 2020). Socio-technical tipping points can be defined as points in a system "at which a small quantitative change inevitably triggers a non-linear change […], driven by self-reinforcing positive-feedback mechanisms, that inevitably and often irreversibly lead to a qualitatively different state of the social system" (Milkoreit et al., 2018). Following lessons from the burgeoning literature on climate policy sequencing (Fesenfeld, Schmid, et al., 2022; Meckling et al., 2015, 2017; Pahle et al., 2018; Schmidt & Sewerin, 2017), we suggest that first (at t_1) policymakers could use targeted subsidies to induce technological learning and reduce the economic costs of sustainable meat substitutes, thus lowering the economic barrier for people to consume meat alternatives. Second (at t_2), in combination with demand-side policies (e.g., social norm and information campaigns, public procurement standards to increase the uptake of substitutes in public canteens, VAT reductions for sustainable food products, and food labels) such innovation-oriented measures can thus foster consumer experience with and information about the benefits of meat substitutes. Third (at t_3), such increased experience and information, as shown by our findings, can then lead to higher public support for more stringent meat reduction policies (e.g., higher meat taxes) and thus reduce public backlash against food system transformation.

There are several avenues for further research. First, future studies could investigate in more depth how such political feedback effects unfold across different political and cultural contexts. For example, while the market of innovative plant-based meat substitutes, such as vegetarian burgers and minced meat, is growing faster in the US than in China (Polaris Market Research, 2020), we find that Chinese respondents report more frequently to have had experience with consuming meat substitute products. This is likely to result from cultural differences in cuisine and food habits of plant-based food products.

Second, in our survey experimental research design we could not randomly vary the degree of experience with meat substitutes. Future field experiments could use different nudging interventions to randomly induce varying levels of meat substitute experience and measure how this difference in meat substitute exposure affects meat consumption and policy attitudes. Using field experimental designs, for example in larger supermarkets and public cafeterias, would also allow increasing the ecological validity of the study and measure revealed behavior changes over time. Such field experimental studies would contribute novel causal inferences to the growing economic literature on the substitution effects of meat-substitute and meat purchases (Cuffey et al., 2022; Neuhofer & Lusk, 2022; Taylor et al., 2022; Tonsor et al., 2022; Zhao et al., 2022). These field experiments would also address an important limitation of our study, namely that we only investigate intentions to reduce meat consumption rather than actual behavior changes. Recent studies show that informational treatments about the negative impacts of meat can indeed lead to actual reductions in meat consumption (Jalil et al., 2020; Schwitzgebel et al., 2020, 2021). While these findings are in line with our results, additional field experimental studies should extend the external validity of our findings. Our findings also somewhat contradict previous findings highlighting the importance of social norm messages on actual meat consumption (Sparkman et al., 2020; Sparkman & Walton, 2017). While our robustness checks indicate high credibility of our social norm treatments, the real-world effectiveness of our social norm messages might still be limited. More effective social norm messages could for example highlight relevant social referents of individuals (e.g., friends, family members, co-workers etc.) rather than institutions and celebrities. Also, repeated and dynamic social norm messages in the direct consumption context could increase the effectiveness (Sparkman et al., 2020; Sparkman & Walton, 2017). Moreover, social norm treatments might become more effective once behavior changes of significant others become more visible to respondents. Thus, future field experimental studies should scrutinize if adding different types of social norm messages to factual information treatments has a larger (smaller) effect in social contexts where relevant social referent groups are (not) present and have changed behavior. Further, investigating how political feedback from information and experience of novel meat substitutes unfold over time requires a panel research design that measures direct treatment and respective feedback effects for the same respondents over time. To address the shortcomings of stated preference measures, future research should also measure revealed policy preferences and increase the external validity of results. Such longitudinal and field-experimental designs are also necessary to empirically assess if feedback effects truly enable positive tipping for an acceleration of food system change.

Third, arguably, public opinion change is a necessary but not sufficient condition for enabling a fundamental change in meat consumption levels given the importance of interest groups in the food system (De Schutter, 2017; Fesenfeld, 2020, 2023; Fesenfeld et al., 2020; Swinnen, 2010, 2018). Future research could use other methods, including discourse network analysis and natural language processing, to explore potential feedback effects of food technology innovations on shifts in

policy debates, interest group coalitions, and its interactions with public opinion.

In conclusion, our study offers an example for how to empirically investigate the conditions and mechanisms that enable positive tipping dynamics and the acceleration of meat reduction. The results show that policymakers can embrace and strategically foster experience with and information about meat substitutes to reduce political, economic, and behavioral barriers to transform the food system in line with the SDGs. We hope this triggers further fruitful discussion and research about the political feedback effects of information about and experience with novel meat substitutes.

6. Code availability statement

The R codes used to analyze the datasets during the current study will be made available upon publication in the Harvard Dataverse public repository.

7. Contributions

L.F. and M.M. contributed equally to this study. L.F. and A.K. acquired the grant funding for data collection. L.F. had the lead in conceptualizing the study design and developing the theoretical argument. All authors contributed equally to designing the survey and survey embedded experiment. L.F. and M.M. had the lead in gathering the data. M.M. had the lead in preparing the data for analysis. M.M., L.F., and N.S. jointly analyzed the data. L.F. and M.M. had the joint lead in writing the paper. All other authors contributed to writing the paper.

CRediT authorship contribution statement

Lukas Paul Fesenfeld: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing, Visualization. **Maiken Maier:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing, Visualization. **Nicoletta Brazzola:** Methodology, Writing – review & editing. **Niklas Stolz:** Methodology, Formal analysis, Writing – review & editing, Visualization. **Yixian Sun:** Conceptualization, Methodology, Writing – review & editing. **Aya Kachi:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The datasets generated during and/or analyzed during the current study and relevant study documentation will be made available upon publication in the Harvard Dataverse public repository.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2023.102445.

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