Promoting healthy and sustainable diets in Scotland:
Insights from agent-based simulations

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The poor healthiness and sustainability of Scottish diets keeps causing concerns due to the limited success of policy interventions. The trade-offs between different food characteristics considered by consumers as well as households' budgetary constraints can represent obstacles to promoting better diets. In turn, social networks are critical for disseminating influence and could thus help achieve more positive outcomes. We develop an agent-based model of consumers heterogeneous in their food preferences, who interact via household and workplace networks. These are assumed to maximise a multi-attribute utility function under budgetary and caloric constraints, and to update their preferences by observing others' choices. We assess how information campaigns, regulatory and market-based interventions affect the healthiness and sustainability of their diets both during implementation and in the longer term. We find that campaigns have a persisting impact on stated preferences but this is barely translated into dietary change. In turn, removal of undesirable meals from workplace canteens, taxation of undesirable food, and subsidisation of desirable options generate statistically significant benefits on diets, which nevertheless do not persist after the interventions end. Subsidies have a small durable impact at a high costs for public finances. The most effective approach is represented by a mix of interventions, but further simulations are needed to identify the best policy design.

Keywords: agent-based modelling; food preferences; healthy and sustainable diets; price intervention; social networks; workplace canteens

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1. Introduction

The poor standards of Scottish diets in terms of healthiness and sustainability have been causing public concern in the last decades, but the interventions for improving them have only achieved partial success. Social networks are critical for establishing social norms to achieve long-term behavioural change, including in the food domain (Fletcher et al., 2011). We argue that the people we eat with (our "eating network") have the most influence on our food behaviours, and we use an Agent-based model (ABM) to assess the impact of networks on the effectiveness of interventions for improving diets. ABMs are a well-suited tool for simulating multiple scenarios and thus the effectiveness of interventions before implementation, avoiding the economic, environmental, and social costs of actual trials (DeAngelis and Diaz, 2019). We simulate different interventions: information campaigns, removal of meals from workplace canteens, market-based interventions (taxation or subsidies), and a policy mix. All interventions generate statistically significant improvements; however, the sustainability of their impact after withdrawal is limited. Therefore, policymakers must strike a balance between different intervention typologies, and run them for a long enough period.

The rest of the paper is structured as follows. Section 2 details the motivation and provides an overview of the literature. Section 3 describes the ABM developed to study the phenomenon, the data used to calibrate it, and our case studies. Section 5 presents and discusses the results, and Section 6 concludes.

2. Motivation and literature background

Bad diets affect individuals, the society, and the environment (Godfray et al., 2018). A high body mass index (a major outcome of unhealthy diets) is a significant health risk factor, and contributes to various conditions reducing life span and quality (Pi-Sunyer, 2009). Besides individual consequences, unhealthy diets generate high costs for the society, estimated at £3.2 billion for the UK National Health Service in 2002 figures (Allender and Rayner, 2007). Additionally, certain eating habits increase greenhouse gas (GHG) emissions and the overall environmental burden of agri-food systems. Springmann et al. (2016) suggest that food-related GHG emissions could be reduced by up to 70% by 2050 if more plant-based diets were adopted.

According to Food Standards Scotland (2018), the average Scottish diet lacks healthy portions of fruits and vegetables (Barton et al., 2015); 65% of the population and 32% of children were either overweight or obese in 2018, and these figures are expected to worsen (Keaver et al., 2020). In 2016 alone, around 10,000 people died of coronary health diseases and strokes, to which diets are identified as a major contributory factor (Food Standards Scotland, 2018). Furthermore, the ecological footprint of the average Scottish diet is 15-25% higher than what suggested by the FAO/WHO dietary guidelines (Kersting et al., 2005; Frey and Barrett, 2007). Food production accounts for nearly a quarter of Scotland's GHG emissions (Scottish Government, 2016), with a significant share of agricultural GHG emissions, especially methane, linked to red meat and other animal-based products.

There is strong public and policy support around improving Scotland's national diets, with about 90% of Scottish people stating their concerns about the healthiness of their diets (Food Standards Scotland, 2018). The Scottish Government has responded to such concerns with policies and campaigns like the Scottish Diet Action Plan (1996); the Hungry for Success campaign for school lunches (Scottish Executive, 2002) ; Healthy Eating, Active Living Action Plan (Scottish Government, 2008); and the National Food and Drink Policy (Scottish Government, 2009). The Good Food Nation bill (Scottish Government, 2014; 2019) is another major step to ensure individuals' right to healthy and sustainable food by law (Nourish Scotland, 2021). However, despite these efforts, the diet of the Scottish population have not improved (Wrieden and Barton, 2015).

To understand why the individual and policy desire for better diets does not translate into better food choices, the factors influencing individuals' dietary choices and receptiveness to interventions have to be understood first. These can be grouped into four sub-categories: demographics; personal attitudes and values; available resources in terms of income and time for food management; and individual social networks.

According to literature, age is the main demographic factor influencing dietary choices and aspirations. Age has been linked to healthier eating worldwide: fruit and vegetable intake was found to be greater among elderlies compared to younger individuals (Monteiro and Jaime, 2003; Lock et al., 2005). Older people were also found to be more willing to modify their diet to eat healthier (Miller and Cassady, 2012), while younger individuals were more open to making changes in their diets for sustainability reasons (Lorenz-Walther and Langen, 2020). Gender was also found to have an effect on dietary choices: women tend to consume less meat and more fruits and vegetables than men in Western countries, including in the UK (Fraser et al., 2000; Baker and Wardle, 2003; Kiefer et al., 2005; Prättälä et al., 2007; Arganini et al., 2012).

The level of education, usually a proxy for income and deprivation, is another factor influencing dietary choices. Fruits, vegetables and meat intake, and the overall healthiness and sustainability of diets were found to change with education levels (Fraser et al., 2000; Monteiro and Jaime, 2003; Hiza et al., 2013; Lehikoinen and Salonen, 2019). The place of residence is also linked with dietary quality: households living in deprived areas might experience less availability and accessibility of fresh food, and thus consume less fruit and vegetables (De Irala-Estevez et al., 2000; Danesh et al., 2011; Dowler and O'Connor, 2012).

Other important determinants of diets are a household's disposable income and the time available for food-related activities, as well as the convenience of different food alternatives. Researchers have found how combinations of disposable time and budget lead to different priorities when making food choices (Hamermesh, 2007; Short and Peterson, 2016).

Besides being influenced by these complex personal circumstances, food choices are also affected by an individual's social ties. The people an individual lives with, e.g., partner, parents, etc., influence their dietary choices (Patrick and Nicklas, 2005; Perry et al., 2016; Roudsari et al., 2017). Both online and offline social networks and peer groups have an impact on diets (Finnerty et al., 2010; Madan et al., 2010; Wouters et al., 2010; Robinson and Higgs, 2014; Higgs and Thomas, 2016; Hawkins et al., 2020). Social networks are critical in achieving, reinforcing, and maintaining long-term behavioural change, and in broadening the impact of campaigns across households, workplaces, and other environments where individuals interact (Maher et al., 2014; Hand et al., 2016; Shelton et al., 2019).

Information campaigns, nutritional guidelines, and educational programmes are examples of non-market, information-based interventions implemented by policymakers to promote better food choices across the public (Bailey and Harper, 2015). Information campaigns delivered in the form of radio and television broadcasts are advantageous for their extensive reach, comparatively lower implementation cost per target individual, and potentially long-term impact after the end of the intervention (Sassi et al., 2009). Besides information campaigns, which represent "suasive" interventions (Gupta et al., 2013), other possible types of interventions include: regulatory, market-based, or service provision (Ibid). Removing unhealthy or unsustainable options from workplace canteens is an example of non-financial, regulatory intervention in the form of forced choice restriction (Lombardini & Lankoski, 2013).

Workplaces serve as locations where individuals from different backgrounds and households come together and interact with each other. They have great potential to instil healthy and sustainable eating habits, and possibly have wider influence on employees' at-home food choices since the lunches eaten at workplace canteens are the main meal for many employees during the working week (Payne et al., 2012). Additionally, observing others' food choices in social settings like workplace canteens may affect one's food decisions (Gligorić et al., 2021).

The taxation of unhealthy and/or unsustainable options or the subsidisation of healthy and/or sustainable ones are market-based interventions in the form of (negative or positive) incentive. The taxes on sugary drinks are an example of commonly adopted intervention around the world (Thow et al., 2014). Taxation is favoured since it creates additional revenue for governments to finance initiatives for improving diets, while subsidies are less widely used and are more common in smaller-scale programmes (Pimpin et al., 2018).

Most countries run multiple interventions simultaneously to complement strengths and shortcomings, and achieve the desired impact on national diets. An example of multi-intervention approach is the one deployed on the food items sold at UK National Health Service hospital shops (Simpson et al., 2018). The cumulative effect and complex interactions between multiple interventions are yet to be fully researched (Brambila-Macias et al., 2011).

3. The model

Agent-based models (ABMs) are computational systems that simulate "a number of decision-makers (agents) and institutions interacting through prescribed rules" at different scales (Farmer and Foley, 2009). Differently from classical economic models which assume representative agents acting rationally to maximise their wellbeing, and isolated from their social context, ABMs describe the decision-making process at individual level and the interaction rules, allowing for heterogeneity of behaviours.

ABMs can be analysed through computer simulations, choosing a given parameter set and iterating the model's dynamics many times (Grainger et al., 2016), or by comparing different scenarios, e.g., interventions. Both the aggregate outcome and the agents' individual trajectories can be assessed comparatively using statistical methods and graphics such as plots and figures (Ibid).

3.1. Model description

Our model considers agent populations representative of the Scottish population. Each agent (individual) belongs to a household and may work or study. Workplaces gather together groups of working-age people belonging to different households, and may have a canteen with kitchen or a shared eating space. Agents are characterised by their socio-demographics (age, sex), working condition (employed, not employed, student), minimum daily caloric requirement, and a (household) budget constraint.

The model's time-steps are represented by meals, which can only be consumed at home, in the workplace, or at school. At breakfast, dinner, and in the weekend, everyone eats at home. During the week, working people eat their lunch at work, while university students and children eat at university and school canteens, respectively. During workdays at lunch, the household does not include working and studying members.

Each agent belongs to two eating networks: (1) their "household network"; (2) their "workplace network". Networks are symmetric. All agents in a workplace are connected with each other with links of different strength, which are used to determine the probability of sitting together and weigh the influence of others' food choices. In the household, weights are used to determine the importance of members' preferences in food choices: 0.33 for children, 0.67 for people aged 16-24, 1.00 otherwise.

Apart from their links and socio-demographics, agents present a set of preferences for six characteristics of their meals: caloric content, convenience in terms of preparation time, price, taste (hedonic), healthiness, and sustainability. All these factors influence all food choices, except convenience, which is not considered in workplace canteens. A meal is a vector of these characteristics, each measured on a 0-100 scale, and also has a price and a caloric content. For each available meal, its characteristics are inputted in a utility function, and an individual utility is calculated[1]. Agents choose randomly among the 10% of meals which yield the highest expected utility. Imprecise information is included in the form of an error in the estimation of the actual characteristics of the meals. Agents can overspend and recover later but cannot overcome their budget constraint indefinitely. Equally, they must reach their minimum daily caloric intake: if they are far from achieving it, their dinner choice takes into consideration this need. The budget and the caloric deficits are cumulated along timesteps.

Workplace canteens have a maximum capacity. The agents arrive in random order and choose the meal that maximises their utility subject to the above constraints, between four options with different characteristics. After choosing their meal, they decide where to sit based on the strength of their connections with the agents already sitting, and observe their choices. At home, a single meal is chosen for the entire household based on the weighted preferences of its members. At school, children are provided meals according to a weekly menu, and cannot choose.

After each new meal, agents review their food preferences based on the choice made. This mechanism is only applied after they reach an idiosyncratic "threshold of action", also used to define how far in the past they look. If the utility of a meal is *above* the median for that period, agents' preferences for the characteristics of that meal whose value is higher than the median meal increase, and vice versa. This effect is averaged for past meals, with weights decreasing as distance in time increases. The change is weighed by a "status quo bias": agents with a larger bias change less.

Agents also review their preferences based on the choices of their eating networks. This mechanism is activated only after the idiosyncratic "threshold of action" is met. All the meals which are more distant from one's preferences than an idiosyncratic "confirmation bias" are discarded. The mechanism works similarly to the one above, with agents comparing their and others' meals in terms of (expected) utility and (perceived) characteristics during a period equal to the "threshold of action", and with weights inversely proportional to distance in time, and directly to the strength of their links with colleagues. The "status quo bias" also applies.

After the preferences are updated, two additional rules apply: (1) a pulling mechanism to account for interactions between preferences; (2) an "inertia" mechanism to account for the tendency of preferences to return to their baseline value. The pulling mechanism is applied to the agents who experienced a change during the last step. The inertia mechanism is applied to the agents whose preferences moved less than the "status quo bias", otherwise the new value becomes the new baseline.

The model allows to test different types of interventions, which can be activated and withdrawn at any point in time. First, as *suasive* intervention, we test an information campaign: each day, a set proportion of households, randomly chosen, are hit by a message concerning the importance of food healthiness and/or sustainability, which corresponds to a "desirable" level of the preference for that characteristic. If the distance with the agent's current preference is smaller than the idiosyncratic "interaction threshold", the agent stores the message. After the "threshold of action" is met, an averaging mechanism is applied.

As *regulatory* intervention, we test a restriction in the availability of meals in workplace canteens: unhealthy or less sustainable options are removed from the menus. In terms of *market-based* interventions, we test price subsidies and taxes. In the *subsidy* setting, the prices of the meals with sustainability or healthiness above a set threshold are reduced by a certain rate. In the *taxation* setting, the meals whose sustainability or healthiness are below a set threshold, are increased by a certain rate instead. These interventions allow to store the cost or income for the decision-maker, and the gain or cost for each household.

At the onset of a cycle of simulations, *k* populations of *n* agents are generated. For each population, one simulation of *t* timesteps is run. The outputs of the model are the agents' preferences, the sustainability

[1] The utility is the sum of the square root (decreasing marginal utility) of all characteristics, weighed by the agent's preference for that characteristic.

and healthiness of their diets, and their aggregate value in the population, all averaged along one week. The model was developed in MATLAB (version R2019b).

3.2. Calibration

Before running extensive simulations, the model's parameters must be calibrated, i.e., set in a way to reproduce the characteristics of the population and environment of interest.

3.2.1. Agents' socio-demographic and psychological characteristics

The agents' socio-demographic characteristics are based on Scotland's 2011 Census.[2] First, 25 strata and their relative size were defined by cross-tabulating five household typologies with the quintiles of the 2020 Scottish Index of Multiple Deprivation (SIMD)[3] (Table 1). Each agent is assigned to one stratum, and their socio-demographic characteristics are defined using stratum-specific distributions.

Table 1. Population strata: definition and relative incidence.

SIMD quintile → Household typology ↓	SIMD1 (most deprived)	SIMD2	SIMD3	SIMD4	SIMD5 (least deprived)
Single person, >65	0.0138	0.0141	0.0125	0.0103	0.0094
Single person, <65	0.0292	0.0221	0.0189	0.0155	0.0128
2+ adults, all >65	0.0097	0.0135	0.0155	0.0157	0.0169
2+ adults, not all >65	0.0602	0.0677	0.0716	0.0720	0.0708
Households with children	0.0882	0.0818	0.0812	0.0856	0.0913

Each agent is assigned an age, sex, working condition, and education level. Afterwards, they are grouped into households, with heterosexual and same-sex couples represented proportionally to their incidence in the Scottish population. Households with children always include at least one adult. Then, employed people are assigned a workplace, students a school (universities are treated as workplaces).

The next characteristics to be calibrated are the *psychological constructs*: "interaction threshold", "status quo bias", "inertia", and "threshold of action". Given the limited literature, we use stylised facts on food behaviours and health campaigns, and on how people model their food choices on those of their eating partners. A detailed overview is available in Appendix. There is evidence that women and adolescents are particularly receptive to health messaging and to others' food choices, and would adapt theirs accordingly (de Bruijn et al., 2015; Salvy et al., 2007). Other studies suggest that people are more likely to model their choices on those of eating partners they share demographic characteristics with (Cruwys et al., 2015; Higgs and Thomas, 2016).

For each psychological construct, agents are assigned a value based on their gender and one based on their age, extracted from *triangular distributions* whose parameters are defined based on the stylised facts. For the "threshold of action", we use a Poisson distribution. The final constructs are calculated as weighted average between the gender- and age-based values.

Finally, each agent is assigned a minimum caloric intake based on their gender and age, derived from the SACN Dietary Reference Values for Energy (2011: 84-85),[4] and each household is assigned a weekly food expenditure from Kantar Food & Beverages Usage Panel data (provided by the Rowett Institute), referred to Scottish households, 2017-2018, and food consumed at home only.

[2] Scotland's Census. Census Results: https://www.scotlandscensus.gov.uk/search-the-census#/ (accessed 8 February 2024).
[3] Scottish Government. Scottish Index of Multiple Deprivation 2020: https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/ (accessed 8 February 2024).
[4] SACN Dietary Reference Values for Energy: https://www.gov.uk/government/publications/sacn-dietary-reference-values-for-energy (accessed 8 February 2024).

3.2.2. Food preferences

Agents' preferences for the six food characteristics are calibrated using stylised facts from the literature. Taste, price, and healthiness were found to influence food choices the most (Honkanen and Frewer, 2009; Glanz et al., 1998), whereas sustainability, caloric content, and convenience are of less importance (Lennernäs et al., 1997; Steptoe et al., 1995). We defined the relationship between the preferences for each food characteristic and six socio-demographic variables: age, gender, income, education, household composition, and working condition. Women are more concerned about healthiness, caloric content, and sustainability than men (Ellison et al., 2013; Lehikoinen and Salonen, 2019; Lennernäs et al., 1997). Young people are less concerned about healthiness and caloric content than the elderly, but more likely to value taste, price, and sustainability (Ellison et al., 2013; Glanz et al., 1998; Lehikoinen and Salonen, 2019; Lennernäs et al., 1997). People with higher income and higher education are more likely to prioritise healthiness and sustainability over price and convenience (Berg and Preston, 2017; Kearney et al., 2000; Lennernäs et al., 1997; Mallinson et al., 2016; Panzone et al., 2016; Steptoe et al., 1995). People in multi-person households were found to prioritise price and healthiness, whereas those in single-person households, convenience (Candel, 2001; Roos et al., 1998; Schliemann et al., 2019). Unemployed people prioritise price more and healthiness less than those in full-time employment (Lennernäs et al., 1997; Roos et al., 1998), while students are more likely to value price and convenience (Betts et al., 1997; Pollard et al., 1998). Further details are reported in Appendix.

For each food characteristic, agents were assigned a value (from -1 to +1) based on their socio-demographic characteristics found to be related with it. Like for the psychological constructs, the values were extracted from *triangular distributions*, and the final preferences were calculated as weighted average of the values.

Preferences for different food characteristics often intersected with each other. For instance, we found a negative correlation between health preferences and caloric content (Ellison et al., 2013). Moreover, people are forced to make trade-offs in their choices, e.g., young people value both price and sustainability, but in the presence of budget constraints, price is prioritised (Panzone et al., 2016). Steptoe et al. (1995) and Pollard et al. (2008) calculated pairwise correlation coefficients between food preferences in the UK. In the pulling mechanism, we use a matrix of pairwise correlations derived from their papers.

3.2.3. The meals: real-world and theoretical

In our model, we consider two sets of meals: 50 real-world meals, and 64 theoretical meals. The former are aimed at representing realistic food options, even if this means that not all potential trade-offs can be tested. The theoretical meals represent all potential high-low combinations of food characteristics, maximising the trade-offs. The meals for workplace menus are extracted from these lists.

Twenty real-world meals were selected from Belling's survey of favourite family meals in the UK from the 1960s to 2018.[5] The others are from a list compiled based on the National Diet and Nutrition Survey (Whyte, 2012), as well as from Giabbanelli and Adams (2017), Gibson and Gunn (2011), and Murakami et al. (2017). Each meal was assigned a score for each characteristic. Among others, the *caloric content* is based on the "energy density" (ratio of energy and portion size), and is also used to apply the caloric constraint; the *price* is the price of a 350 kcal portion, and is also used to apply the budget constraint.

The real-world meals do not change between different simulations. Hence, the variability and the number of combinations are limited. Instead, the theoretical meals cover all potential combinations of high-low levels of food characteristics, with actual values extracted from triangular distributions centred either at 25 and with range 0-50 (low) or at 75 and with range 50-100 (high). The results in Section 4 are based on the theoretical meals to better appreciate the trade-offs between attributes.

[5] 5pm.co.uk: https://blog.5pm.co.uk/2018/12/food-fashions-not-so-fickle (accessed 8 February 2024).

3.2.4. Workplaces and workplace networks

The number and sizes of workplaces are randomly extracted from a distribution specific for Scotland, using data from the UK Office for National Statistics.[6] To ensure that both small and large workplaces are represented despite the skewed distribution, before being assigned to a workplace, working agents are divided between those working in organisations of 10 or less employees (32.2% in Scotland), and those working in lager organisations. Then, sizes are extracted and "filled in" with random agents.

The strength of the links between employees in a workplace is set using a Blau space, which generates a multidimensional distance between two points based on the homophily principle. The dimensions of the space are four socio-demographic characteristics: sex, age, education level, and deprivation of an agent's area of residence. The strength of a link is the multiplicative inverse of pairwise distance, standardised in each workplace separately. Each time that two or more agents sit together, the network is updated, and the probability that they sit together again increases.

3.2.5. Policy case studies

We present six case studies (sets of simulations) corresponding respectively to the baseline dynamic of the model, the four interventions in turn (with sustainability and healthiness targeted jointly), and the policy mix. All the simulations are run for one year (52 weeks), and on 100 populations of 1,000 agents. The interventions start at week 11 to allow for the model to stabilise, and run until week 45. It is important to highlight that our results refer to these specific settings, and readers must refrain from generalising. For instance, besides the policy parameters, *longer* implementation could generate more persisting effects. In the future, extensive simulations will allow to test the robustness of the findings.

For the simulations presented in Section 4, the baseline is run with no policy intervention in place. In the *campaign* setting, the "*intensity*" of the message, which can theoretically range between -1 and +1, is set at +1, i.e., the maximum. This high level causes distant agents to ignore the campaign because of their "interaction threshold" but in exchange for larger individual improvements: creation of non-converging clusters is common in the opinion dynamics literature. In the *change in meal availability* setting, the *cutoff* for retaining a meal is set at 50 in terms of both sustainability and healthiness: the meals not meeting these standards are replaced with meals with values above the cutoff.

The *price subsidy* is defined by its *cut-off*, i.e., the value of the indices above which a meal is subsidised (set at 50) and the *subsidisation rate* (-20% of the original price). Equally, the *tax* is imposed on meals whose healthiness and/or sustainability is below a *cut-off* value (50), applying a *tax rate* (20%). When a subsidy or tax is introduced, the price of the meals affected is updated accordingly. Finally, the *policy mix* entails implementation of all the four interventions jointly.

4. Results

This section presents the results of extensive agent-based simulations of the above interventions, using figures as well as statistical analysis. The dietary outcome in each policy setting is then compared with the baseline adopting a difference-in-differences approach (Abadie, 2005).

4.1. Baseline

Figure 1 illustrates the evolution of preferences and dietary characteristics in the baseline setting. Dietary characteristics in key weeks of the year are shown in Tables 2 and 3. At the onset of the simulations, the agents lack a history of previous interactions, and stabilisation takes some weeks. Thus, the distributions are portrayed both at $t = 1$ and $t = 10$ (the week before the start of the interventions in other

[6] Dataset "UK business: activity, size, and location": https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/ukbusinessactivitysizeandlocation (accessed 8 February 2024).

settings). A "portrait" of the diets at t = 45 allows to appreciate the impact of each intervention before withdrawal; the portrait at t = 46 shows the immediate drop-off after removal; and at t = 52, whether the effect persists after some weeks' time. Obviously most of these are not relevant in the baseline.

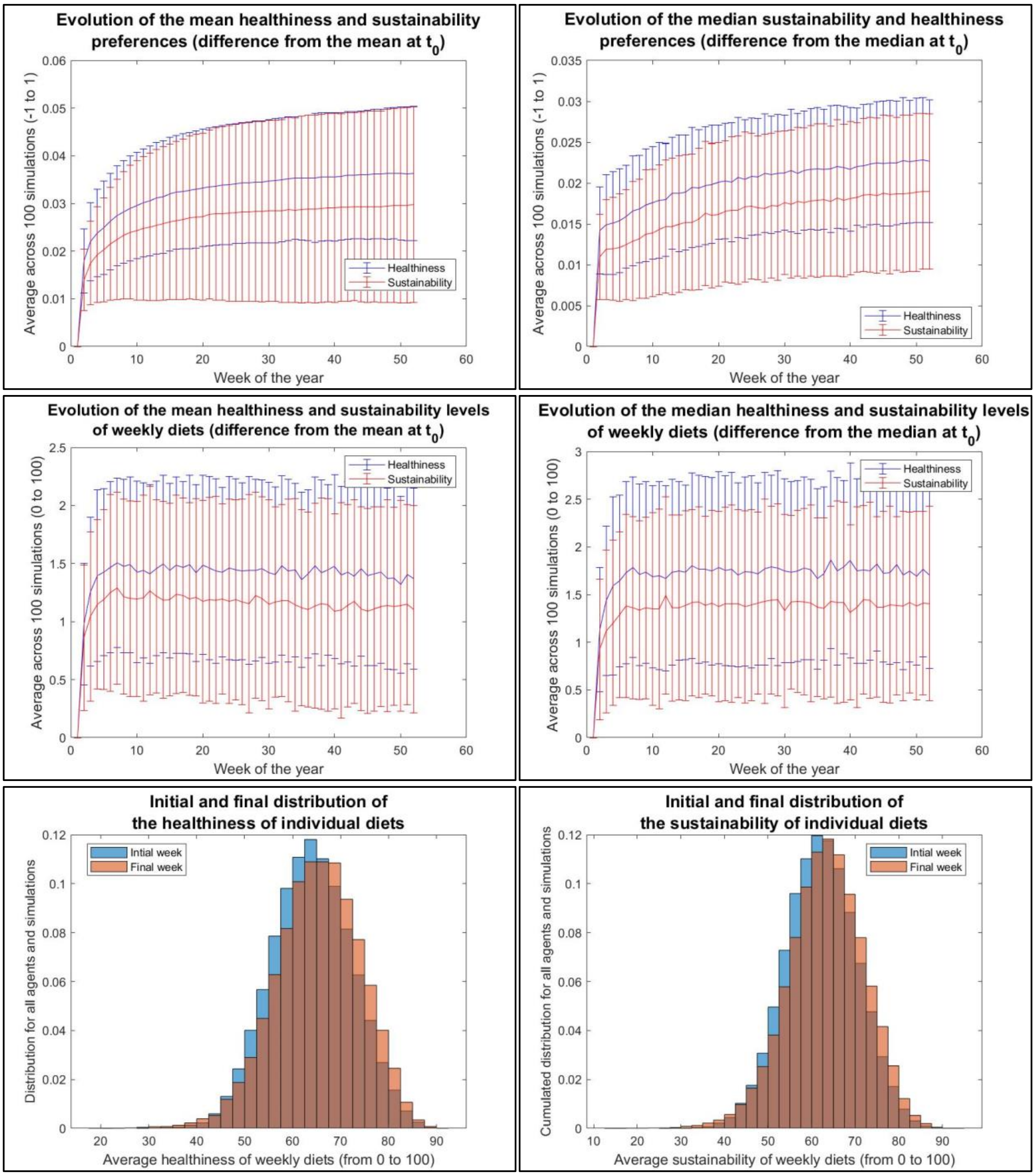

Figure 1. Healthiness and sustainability preferences and weekly diet indexes (baseline setting).

We observe a progressive increase in the preferences for healthiness and sustainability; however, the marginal increase slows down with time. Moreover, the variability across simulations widens with time, pointing to the increase in uncertainty as we move further in the future. The characteristics of weekly diets also show an upward trend, although they stabilise much earlier (after about five weeks), and the means show even a slight downward trend, which is not the case for their medians. On a 0-100 scale, the gain is between 1-1.5 points for the means, and 1.4-1.8 for the medians. The distributions of dietary characteristics across simulations confirms that there is an improvement, with a non-negligible number of agents moving towards the right of the distribution, although the left skewness is preserved.

Tables 2 and 3 confirm that there is an increase in the healthiness and sustainability of weekly diets, and that this increase is concentrated within the first 10 weeks. They also show that after a peak at around *t* = 10, there is a slight decrease, especially for sustainability. All the statistics (apart from the minimum) improve during the year, despite the slight downward trend after the initial steps.

Table 2. Summary statistics for the healthiness of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	41.96	38.26	37.71	34.33	33.93	33.41
1st decile	54.30	55.35	55.39	55.14	55.17	55.16
1st quartile	58.87	60.16	60.30	60.27	60.24	60.26
median	64.05	65.74	65.75	65.77	65.78	65.75
3rd quartile	69.27	71.06	71.05	71.12	71.12	71.09
9th decile	73.64	75.16	75.12	75.21	75.20	75.15
maximum	81.99	82.90	83.18	83.03	83.10	83.02
average	**63.95**	**65.38**	**65.39**	**65.34**	**65.36**	**65.32**
std. dev.	7.35	7.69	7.68	7.85	7.85	7.85
t-test [1]	-	0.0000	0.6110	0.1871	0.5928	0.1806
t-test [2]	0.0000	0.1468	-	-	-	-

Notes: [1] *p*-value for the difference between the step in the column and the step in the previous column. [2] *p*-value for the difference between the value in the column and the last step.

Table 3. Summary statistics for the sustainability of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.53	36.88	36.25	33.45	32.91	32.41
1st decile	53.10	53.86	53.92	53.54	53.43	53.49
1st quartile	57.43	58.53	58.59	58.50	58.48	58.47
median	62.28	63.63	63.63	63.65	63.68	63.69
3rd quartile	67.14	68.59	68.60	68.65	68.71	68.69
9th decile	71.34	72.88	72.79	72.84	72.88	72.92
maximum	81.26	82.27	82.13	82.26	82.30	82.32
average	**62.21**	**63.41**	**63.41**	**63.30**	**63.32**	**63.32**
std. dev.	7.03	7.40	7.39	7.65	7.67	7.69
t-test [1]	-	0.0000	0.8111	0.0073	0.5828	0.9306
t-test [2]	0.0000	0.0491	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 4 reports correlation coefficients between key variables based on the results of 100 simulations. This is aimed to assess if the change in preferences or diets is related to the psychological constructs. Most correlation coefficients are highly significant but small, especially for actual diets, whose change is mediated by the trade-offs between preferences. The "interaction threshold" is positively correlated with the change in preferences, negatively with the change in diets, meaning that longer memory triggers change in stated preferences, not necessarily behaviour. As expected, the "status quo bias", "inertia", and "threshold of action" are negatively related with change in preferences. Finally, being employed is positively related to change, since employed people are subject to external influence in workplace canteens, but the correlation is very small.

Table 4. Correlation between key agents' characteristics and target variables in the baseline simulations.

Variables	**Working (baseline: no)**	**Education**	**Interaction threshold**	**Status quo bias**	**Inertia**	**Threshold of action**	**Minimum caloric in-take**	**Budget con-straint**	**Initial health pref-erence**	**Initial sust. pref.**
Education (from 1 to 5)	**0.293*** **									
Interaction threshold	-0.096***	**-0.299*** **								
Status quo bias	0.101***	**0.300*** **	**-0.677*** **							
Inertia	0.084***	0.241***	**-0.612*** **	**0.653*** **						
Threshold of action	0.169***	**0.363*** **	**-0.624*** **	**0.649*** **	**0.568*** **					
Minimum caloric intake	**0.351*** **	**0.342*** **	**-0.254*** **	**0.327*** **	**0.367*** **	**0.333*** **				
Budget constraint	-0.007**	-0.154***	**0.311*** **	**-0.305*** **	-0.245***	**-0.314*** **	-0.105***			
Initial health preference	**0.365*** **	**0.731*** **	**-0.480*** **	**0.449*** **	**0.338*** **	**0.554*** **	**0.373*** **	**-0.308*** **		
Initial sust. pref.	**0.333*** **	**0.858*** **	**-0.386*** **	**0.344*** **	0.238***	**0.458*** **	**0.302*** **	**-0.317*** **	**0.894*** **	
Change in health pref. (abs.)	0.096***	0.022***	0.153***	-0.191***	-0.162***	-0.123***	0.102***	0.020***	0.053***	0.068***
Change in health pref. (rel.)	0.035***	-0.092***	**0.243*** **	**-0.271*** **	**-0.218*** **	**-0.230*** **	0.095***	0.057***	-0.181***	-0.088***
Change in sust. pref. (abs.)	0.076***	0.009***	0.106***	-0.127***	-0.111***	-0.082***	0.065***	0.015***	0.049***	0.044***
Change in sust. pref. (rel.)	0.038***	-0.092***	0.158***	-0.171***	-0.140***	-0.147***	0.055***	0.043***	-0.095***	-0.096***
Change in health diet (abs.)	0.033***	0.029***	-0.016***	0.020***	0.018***	0.020***	0.019***	0.015***	0.021***	0.023***
Change in health diet (rel.)	0.030***	0.015***	-0.004	0.008***	0.009***	0.007**	0.017***	0.023***	0.004	0.007**
Change in sust. diet (abs.)	0.024***	0.026***	-0.017***	0.025***	0.018***	0.020***	0.011***	0.007**	0.025***	0.023***
Change in sust. diet (rel.)	0.022***	0.011***	-0.006*	0.015***	0.010***	0.009***	0.010***	0.016***	0.011***	0.006*

Notes: Significance levels: * 0.10; ** 0.05; *** 0.01. Correlations whose absolute value is above 0.2 are in **bold**.

4.2. Information campaign

The first interventions simulated are campaigns promoting healthier and more sustainable diets. Starting from week 10, and for 35 weeks, every day a random 10% of the households is hit by the “radical” message, set at +1. Figure 2 shows that these campaigns are effective in raising agents’ preferences. The preferences start raising from the first week of intervention, and keep growing until the campaign stops. The subsequent drop-off is not large enough to return to the pre-campaign levels.

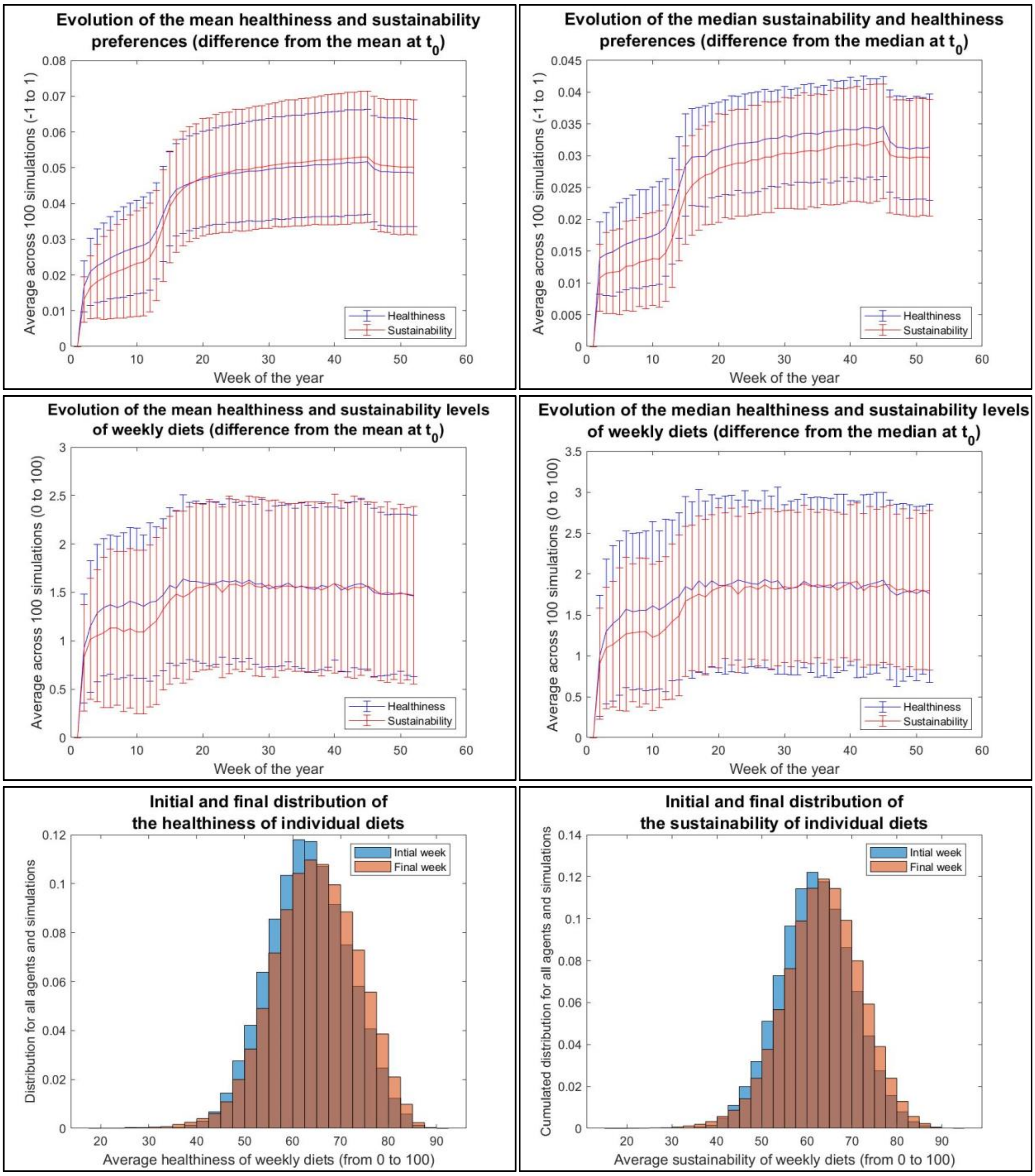

Figure 2. Healthiness and sustainability preferences and weekly diet indexes (information campaign).

The mean and median preferences for sustainability and healthiness come closer, but the former presents a more skewed distribution (Figure 2). Actual diets see a further improvement after the campaign starts, followed by a slight downward trend. The drop-off after the campaign stops is negligible, suggesting that the effect persists, in line with the literature on information campaigns’ influence lasting past their implementation period (Sassi et al., 2009). It is also important to highlight that sustainability improves more despite the initial values being lower, probably because both campaigns are initialised at +1. The campaign generates an increase close to 1.5 in the means, and 1.4-1.8 in the medians.

Table 5. Summary statistics for the healthiness of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	41.57	37.02	36.68	34.54	34.74	33.15
1st decile	53.55	54.56	54.52	54.58	54.49	54.52
1st quartile	58.21	59.46	59.40	59.71	59.59	59.59
median	63.38	64.99	64.94	65.30	65.18	65.14
3rd quartile	68.66	70.46	70.45	70.68	70.62	70.59
9th decile	73.09	74.77	74.72	74.86	74.93	74.87
maximum	81.78	82.66	82.88	82.80	82.90	82.79
average	**63.33**	**64.71**	**64.68**	**64.89**	**64.83**	**64.79**
std. dev.	7.42	7.82	7.85	7.92	7.95	7.97
t-test [1]	-	0.0000	0.2713	0.0000	0.1610	0.2513
t-test [2]	0.0000	0.0328	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 6. Summary statistics for the sustainability of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.97	35.90	36.07	33.82	32.66	32.82
1st decile	52.99	53.68	53.66	54.02	53.92	53.91
1st quartile	57.25	58.35	58.33	58.88	58.83	58.82
median	62.08	63.31	63.34	63.95	63.95	63.88
3rd quartile	66.86	68.25	68.26	68.80	68.76	68.68
9th decile	71.03	72.41	72.43	72.91	72.85	72.78
maximum	80.79	81.84	81.81	82.00	82.09	81.95
average	**62.01**	**63.10**	**63.10**	**63.57**	**63.53**	**63.48**
std. dev.	6.95	7.35	7.33	7.44	7.49	7.47
t-test [1]	-	0.0000	0.9774	0.0000	0.2239	0.1074
t-test [2]	0.0000	0.0000	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 5 and 6 show a progressive improvement in all parameters (apart from the minimum), larger by almost 2 points in the central part of the distribution. After the initial stabilisation, we observe a slight upward trend lasting until the end of the campaigns. The improvement in the means between the first and the last week of the campaigns is statistically significant, while the drop-off after removal is not. This results in a statistically significant improvement between week 10 and the end of the year, especially in terms of sustainability (0.38 points). To conclude, the effect of the campaign is persisting, but is also small compared to other interventions, as discussed below.

4.3. Change in meal availability

In the simulations presented, all the workplaces are assumed to have a canteen with kitchen. In Figure 3, we observe a relevant impact on diets of removing undesirable meals, which does not persist after the intervention is stopped. Counterintuitively, there is small drop in the preferences when the intervention is started, and a small increase after withdrawal. Lombardi and Lankoski (2013) also confirm that choice restriction might sometimes result in partly contradictory outcomes in the short term: the "mandatory vegetable day" initially led to reduced attendance of lunches at school canteens in Finland, but the resistance of the students weakened with time. The average healthiness and sustainability of diets jumps by around one point straight after the start of the intervention; the increase is even larger for the median. However, a slight downward trend starts afterwards, and an equal decline by one point is observed when the intervention ends. Hence, the final mean is lower than before, and the median returns to the previous level.

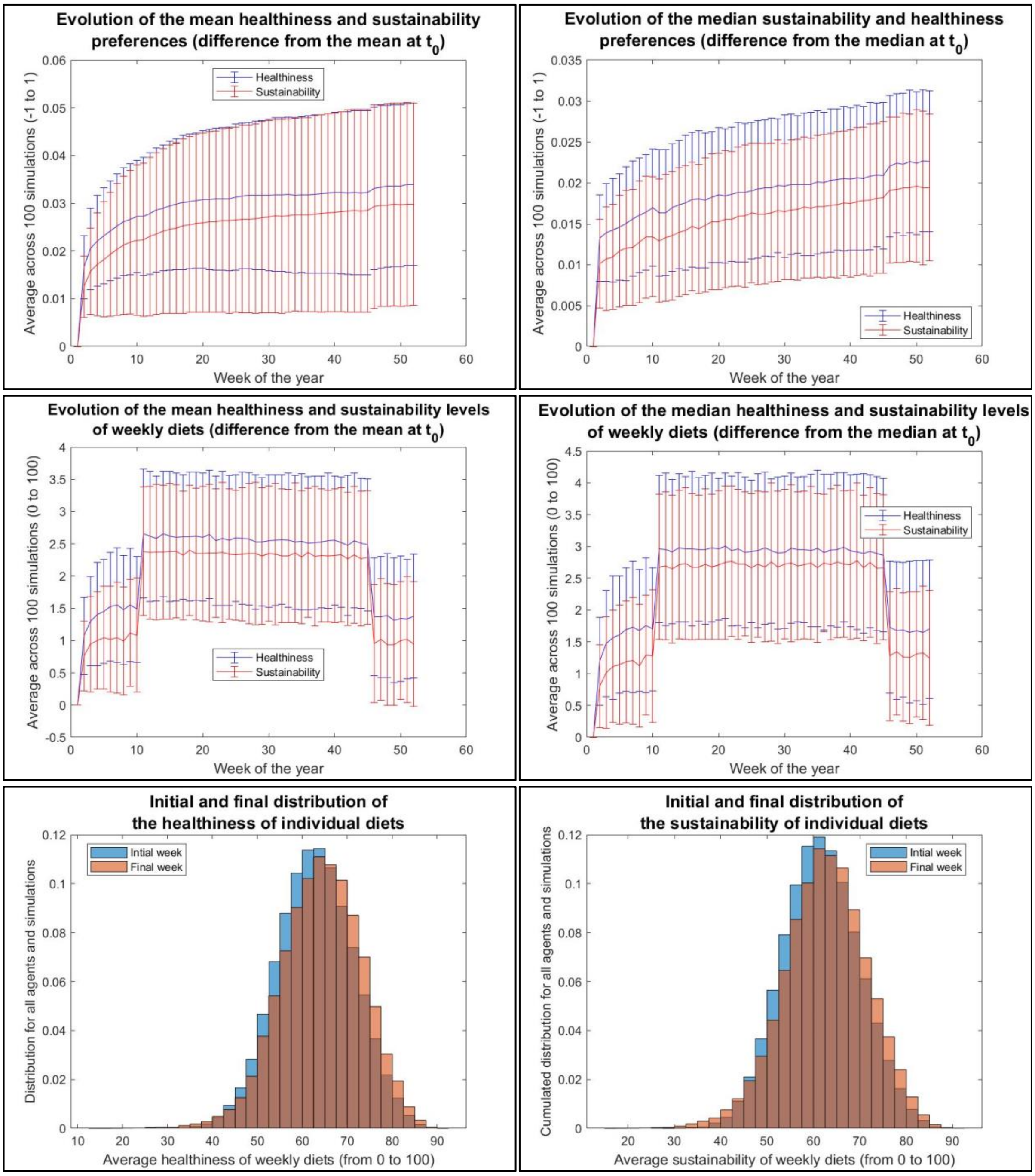

Figure 3. Healthiness and sustainability preferences and weekly diet indexes (meal restrictions).

The values in Tables 7 and 8 highlight an improvement from the start to the end of the year (except for the minimum). However, there is no further improvement after the initial jump. The decline between the start and the end of the intervention is statistically significant, like the decline between week 10 and the end of the year (0.1 points for healthiness and 0.14 points for sustainability). Thus, the removal of unhealthy and unsustainable meals from workplace canteens generates a strong short-term impact which does not persist after the intervention is stopped. In turn, Thorsen et al. (2010) found that decreasing the availability of unhealthy options and providing healthy and sustainable meals resulted in enduring increase in fruit and vegetable consumption by the employees in five workplace canteens in

Denmark. Similarly, the “mandatory vegetable day” achieved acceptance and success in the long term in Finland (Lombardi and Lankoski 2013).

Table 7. Summary statistics for the healthiness of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.50	36.63	39.83	35.00	31.75	31.55
1st decile	53.07	54.25	55.78	55.18	53.94	53.92
1st quartile	57.90	59.19	60.63	60.38	59.12	59.12
median	63.06	64.76	66.02	65.92	64.79	64.76
3rd quartile	68.27	70.11	71.18	71.20	70.13	70.16
9th decile	72.57	74.20	74.88	74.96	74.24	74.28
maximum	81.46	82.29	82.42	82.69	82.38	82.45
average	**62.91**	**64.39**	**65.57**	**65.39**	**64.28**	**64.29**
std. dev.	7.44	7.74	7.47	7.79	7.98	8.01
t-test [1]	-	0.0000	0.0000	0.0000	0.0000	0.7529
t-test [2]	0.0000	0.0119	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 8. Summary statistics for the sustainability of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.37	36.86	38.60	34.63	31.39	31.33
1st decile	52.51	53.20	54.62	54.35	52.70	52.74
1st quartile	56.86	57.99	59.44	59.38	57.83	57.86
median	61.73	63.01	64.41	64.40	63.01	62.98
3rd quartile	66.55	67.84	69.15	69.17	67.97	67.93
9th decile	70.77	72.03	73.07	73.11	72.14	72.14
maximum	80.36	81.48	81.54	81.95	81.54	81.42
average	**61.65**	**62.73**	**64.04**	**63.94**	**62.61**	**62.59**
std. dev.	7.02	7.33	7.20	7.43	7.68	7.69
t-test [1]	-	0.0000	0.0000	0.0293	0.0000	0.6800
t-test [2]	0.0000	0.0024	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

4.4. Subsidy

The third intervention consists in subsidising sustainable and healthy meals (by 20% if one indicator is above the cutoff, 40% if both are). Figure 4 shows the usual stabilisation pattern, followed by (decreasing) marginal improvements which seem to stop towards the end of the year. The slope of the trend line increases when the intervention is introduced, and the small drop-off following withdrawal is not enough to return to the levels before its start. The preferences for sustainability remain below those for healthiness. The outcome at end-year is better than with the previous intervention. In terms of dietary characteristics, a jump by more than one point is observed in both indicators right after the start of the subsidy, with sustainability benefitting relatively more; however, a large drop-off is seen after removal, thus the gains at end-year, although positive, are small.

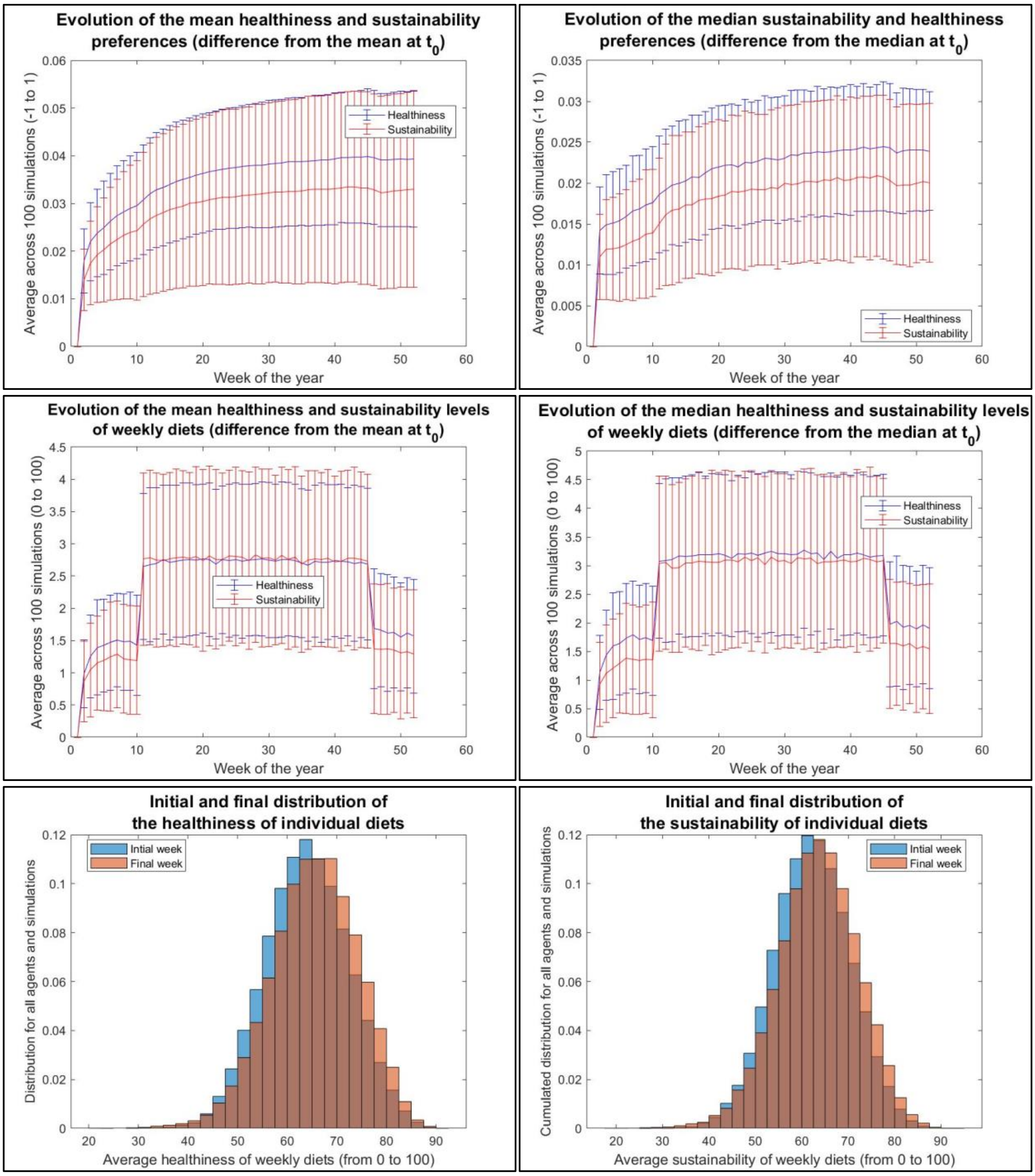

Figure 4. Healthiness and sustainability preferences and weekly diet indexes (subsidy setting).

All the indicators in Tables 9 and 10 (apart from the minimum and the first quartile for sustainability) present higher values at the end of the simulation compared to week 10. This difference is statistically significant for the averages but accounts for just 0.14 points in terms of healthiness and 0.09 points in terms of sustainability. In turn, the average healthiness and sustainability of the diets are 1.25 and 1.53 points higher before stopping the intervention: slightly more than when removing unhealthy and unsustainable meals from workplace canteens, and with the gain more evenly spread. The results of statistical tests suggest that the improvement is achieved immediately after the intervention starts.

Table 9. Summary statistics for the healthiness of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	41.96	38.26	39.69	36.30	35.17	34.81
1st decile	54.30	55.35	56.75	56.72	55.65	55.43
1st quartile	58.87	60.16	61.63	61.71	60.58	60.52
median	64.05	65.74	67.13	67.23	66.03	65.95
3rd quartile	69.27	71.06	72.19	72.31	71.28	71.21
9th decile	73.64	75.16	75.78	75.94	75.29	75.23
maximum	81.99	82.90	83.19	82.99	83.12	83.18
average	**63.95**	**65.38**	**66.59**	**66.63**	**65.63**	**65.52**
std. dev.	7.35	7.69	7.43	7.56	7.68	7.74
t-test [1]	-	0.0000	0.0000	0.2479	0.0000	0.0008
t-test [2]	0.0000	0.0008	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 10. Summary statistics for the sustainability of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.53	36.88	38.40	34.50	33.57	33.22
1st decile	53.10	53.86	55.77	55.61	53.92	53.79
1st quartile	57.43	58.53	60.40	60.43	58.79	58.67
median	62.28	63.63	65.32	65.37	63.92	63.83
3rd quartile	67.14	68.59	69.98	70.10	68.86	68.82
9th decile	71.34	72.88	73.95	73.97	73.01	73.00
maximum	81.26	82.27	82.34	82.33	82.25	82.40
average	**62.21**	**63.41**	**64.97**	**64.94**	**63.58**	**63.50**
std. dev.	7.03	7.40	7.10	7.31	7.53	7.58
t-test [1]	-	0.0000	0.0000	0.4015	0.0000	0.0277
t-test [2]	0.0000	0.0208	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

With the subsidy, the total yearly expenditure on food ranges between £919.97 for the most deprived households and £1,157.93 for the least deprived. Equally, the amount of money saved increases from £275.31 in the most deprived areas to £357.95 in the least deprived. Therefore, the share of expenditure saved is quite constant across SIMD levels: 31.16% to 32.00%. The total expenditure on food increases with increasing household sizes: £493.91 in one-person households, £1,018.08 in two-person households, then £1,396.49, etc. This equates to savings of £162.74, £316.03, £426.87, etc. The relative savings range from 33.37% for one-person households to 29.54% for 5-person households, and drop below 20% above seven members. The food budget at the end of the year is negative for only 0.3% of the households (all with more than five members). The result is not directly comparable with the baseline because agents could have selected other meals in the absence of the subsidy.

The cost of the subsidy for decision-makers varies considerably depending on the simulation. The median is £145,256, the mean £144,857, i.e., between £791.4 million and £793.6 million if reported to the whole Scottish population.

4.5. Tax

The outcome of taxation is shown in Figure 5. Food preferences show the usual stabilisation pattern, followed by an upward trend which slows down and stabilises towards the end of the year. The introduction of the tax causes a very limited increase, with a clear drop-off, although small, after its removal. Considering the actual characteristics of diets, we observe an immediate jump by 0.8-1 points when the tax is introduced, particularly large for sustainability; however, after this initial success, a slow but constant downward trend starts. Consequently, when the tax is removed, the agents' diets return to levels below those observed before its introduction. We can hypothesise that the tax is not enough to cause an internalisation of the new preferences, but causes a progressive deterioration of purchasing power.

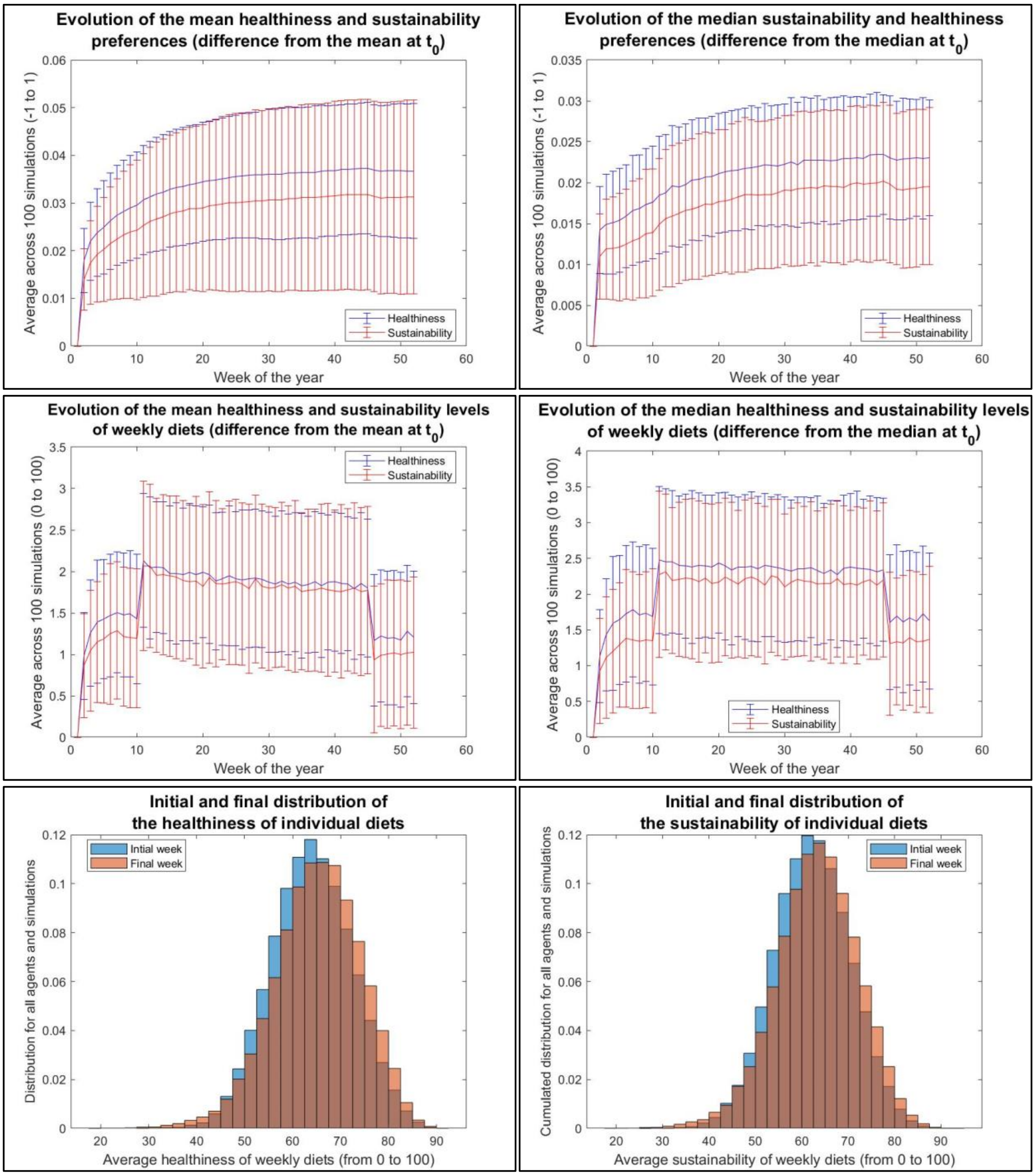

Figure 5. Healthiness and sustainability preferences and weekly diet indexes (taxation setting).

Based on Tables 11 and 12, the best outcome in terms of both indicators is achieved in week 11, i.e., right after introducing the tax. Then, the situation worsens, and in the final week, the diets are slightly less healthy and sustainable than in week 10 (-0.22 points the average healthiness, and -0.08 the average sustainability). Most of the decline happens while the tax is in place, not afterwards.

Table 11. Summary statistics for the healthiness of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	41.96	38.26	38.25	34.63	33.35	33.50
1st decile	54.30	55.35	56.01	55.18	54.56	54.70
1st quartile	58.87	60.16	61.02	60.66	59.97	60.08
median	64.05	65.74	66.53	66.39	65.66	65.67
3rd quartile	69.27	71.06	71.78	71.72	71.05	71.05
9th decile	73.64	75.16	75.67	75.68	75.20	75.14
maximum	81.99	82.90	83.27	82.89	83.13	83.11
average	**63.95**	**65.38**	**66.08**	**65.75**	**65.12**	**65.16**
std. dev.	7.35	7.69	7.63	8.05	8.09	8.06
t-test [1]	-	0.0000	0.0000	0.0000	0.0000	0.2352
t-test [2]	0.0000	0.0000	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 12. Summary statistics for the sustainability of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.53	36.88	37.08	34.00	32.93	32.83
1st decile	53.10	53.86	54.79	53.90	53.00	53.25
1st quartile	57.43	58.53	59.54	59.22	58.29	58.36
median	62.28	63.63	64.56	64.49	63.59	63.65
3rd quartile	67.14	68.59	69.43	69.44	68.62	68.65
9th decile	71.34	72.88	73.57	73.50	72.83	72.91
maximum	81.26	82.27	82.44	82.43	82.30	82.38
average	**62.21**	**63.41**	**64.28**	**63.98**	**63.15**	**63.23**
std. dev.	7.03	7.40	7.32	7.72	7.80	7.78
t-test [1]	-	0.0000	0.0000	0.0000	0.0000	0.0099
t-test [2]	0.0000	0.0005	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

With the tax, the yearly food expenditure ranges between £1,205.86 per household in the most deprived areas and £1,521.40 in the least deprived, i.e., around £300-400 higher than with the subsidy. The amount of tax paid increases for decreasing deprivation: from £71.87 in the first SIMD quintile (5.05% of the food expenditure) to £79.84 (4.38%) in the fifth one. Compared to the money saved thanks to the subsidy, the additional expenditure due to the tax is smaller since the demand switches towards less expensive products. This is in line with previous studies looking at the distributional effects of a tax on unhealthy choice: poor households would spend a greater proportion of their income on taxes in the UK (Nnoaham et al., 2009) and in France (Lacroix et al., 2010 and Allais et al., 2010).

The tax burden increases rapidly for larger households: £24.39 for one-person households, £62.11 for two-person households, then £91.83, £129.97, etc. The tax accounts for 3.65% of the food expenditure of one-person households, increasing to 4.45%, 5.11%, 5.90%, etc., for additional household members. This is the opposite of what observed with the subsidy, confirming that the elasticity of food expenditure is higher for smaller households, and that larger households bear the burden of a tax while benefiting less from a subsidy. The food budget at end-year is negative for around 1% of the households across all the simulations.

The Government's revenue from the tax varies hugely but is much smaller than the cost of the subsidy: £32,674 the median, £34,481 the average, equating to £178.5 million and £188.4 million when reported to the whole Scottish population (less than 25% the cost of a subsidy).

4.6. Policy mix

The graphs in Figure 6 show that the policy mix has a relevant impact on both food preferences and dietary characteristics. A sharp increase is observed after the introduction of the interventions, which continues during their implementation. Although a clear drop is observed after removal, the new preferences are much higher than before their introduction. Considering the actual dietary characteristics, there is an immediate jump by about four points when the interventions start, which benefits sustainability more. However, after the interventions are removed there is a huge drop which brings them at levels slightly above week 10. Such trends suggest that even complex policy mixes are not enough to achieve durable improvement in diets (at least, not after only 35 weeks).

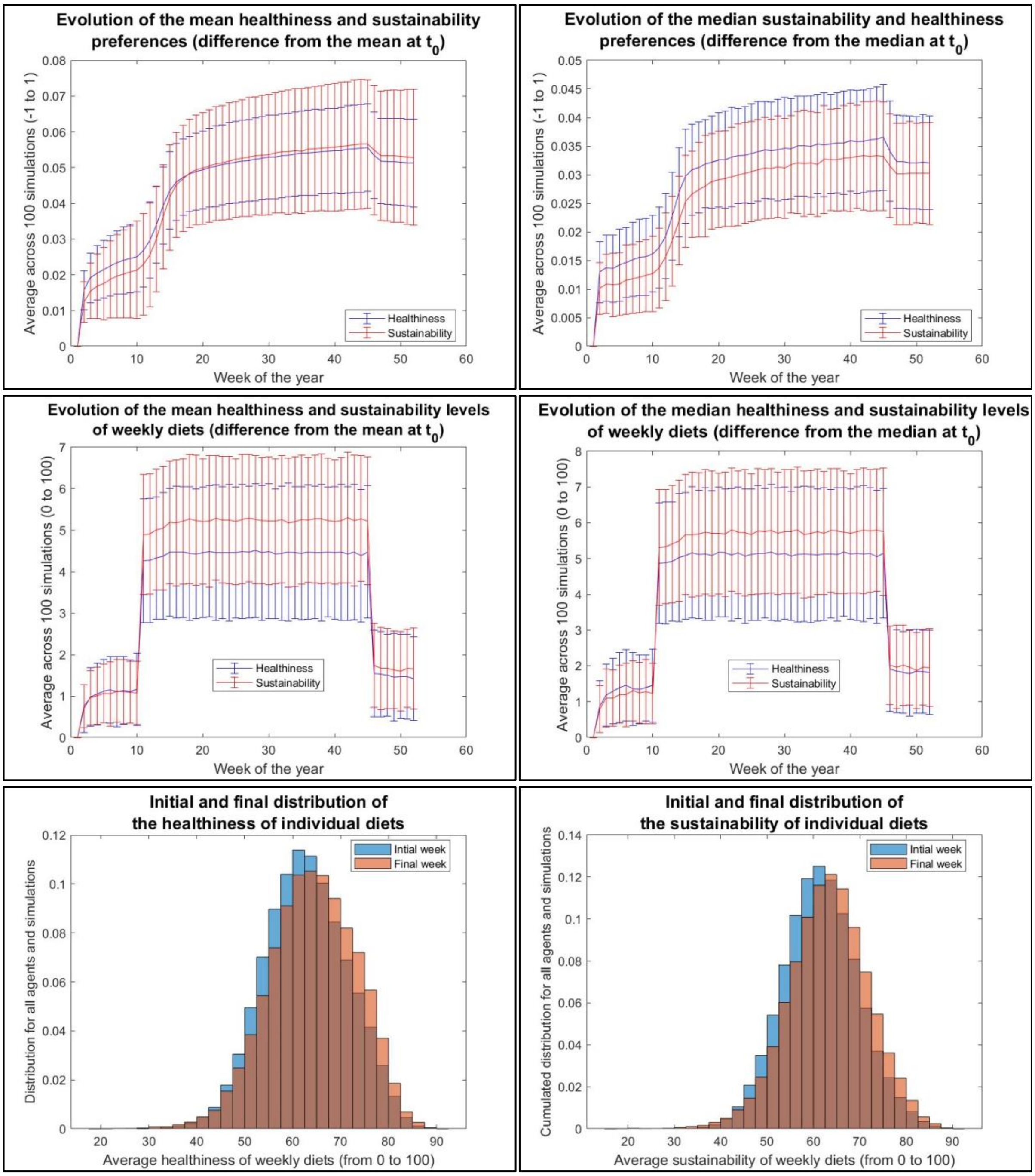

Figure 6. Healthiness and sustainability preferences and weekly diet indexes (joint intervention setting).

Tables 13 and 14 report that at end-year, healthiness is 0.26 points higher than at week 10, sustainability, 0.58 points higher. All the changes are statistically significant, including *during* implementation, and after removal.

Table 13. Summary statistics for the healthiness of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.72	36.45	41.50	39.82	33.40	33.35
1st decile	53.06	53.91	57.36	57.62	54.23	53.94
1st quartile	57.67	58.78	62.15	62.45	59.29	59.08
median	62.91	64.37	67.79	68.07	64.83	64.73
3rd quartile	68.17	69.63	72.60	72.81	69.98	69.97
9th decile	72.49	73.74	75.90	76.00	74.06	74.06
maximum	81.56	82.51	82.68	83.00	82.42	82.50
average	**62.81**	**63.97**	**67.07**	**67.29**	**64.35**	**64.23**
std. dev.	7.43	7.77	7.23	7.22	7.78	7.88
t-test [1]	-	0.0000	0.0000	0.0000	0.0000	0.0005
t-test [2]	0.0000	0.0000	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

Table 14. Summary statistics for the sustainability of weekly diets in relevant weeks of the simulation.

Statistic	t = 1	t = 10	t = 11	t = 45	t = 46	t = 52
minimum	40.48	34.95	40.41	38.47	33.59	33.76
1st decile	52.51	53.10	57.53	57.80	53.81	53.61
1st quartile	56.79	57.88	62.15	62.54	58.60	58.50
median	61.62	62.85	66.94	67.37	63.64	63.58
3rd quartile	66.44	67.84	71.47	71.86	68.56	68.52
9th decile	70.75	72.13	74.92	75.26	72.63	72.63
maximum	80.38	81.59	82.35	82.61	81.78	81.67
average	**61.58**	**62.66**	**66.47**	**66.80**	**63.32**	**63.24**
std. dev.	7.00	7.45	6.87	6.95	7.45	7.51
t-test [1]	-	0.0000	0.0000	0.0000	0.0000	0.0362
t-test [2]	0.0000	0.0000	-	-	-	-

Notes: [1] See Table 1; [2] See Table 1.

In the presence of taxes and subsidies jointly, the yearly expenditure on food ranges between £987.84 for the households in the most deprived areas and £1,266.08 in the least deprived ones. Only 0.5% of the households end up with a food expenditure above their planned budget, meaning that the cumulated impact of the subsidy and the tax is a saving for most household: £251.70 (27.58%) for the most deprived ones, and £333.32 (29.12%) for the least deprived ones.

The total food expenditure increases with the number of household members: £529.66 for one-person households, £1,097.32 for two-person households, then £1,504.78, £1,955.17, etc. The average gains compared to the actual prices range between £163.68 for one person-households and £556.38 for five-person households. The savings amount to 31.24% of the food expenditure for the smallest households, and progressively smaller percentages for larger households.

The decision-maker incurs in net costs that range between £64,535 and £242,718, depending on the simulation. The median is £139,226, the mean £134,389, equating to £711.5 million and £734.2 million if reported to the whole Scottish population.

4.7. Comparison of interventions

As a final step, we compare each policy intervention, or mix of thereof, to the baseline, using a difference-in-differences approach. This method assesses if the difference between the start and end points under specific interventions *differs* from the same difference in the baseline. The results using the values in the last week of implementation (t = 45) are reported in Tables 15 and 16, those in the end-year week (t = 52), which provide an indication of persistence, in Tables 17 and 18.

All the interventions, and their mix, generate a positive impact in terms of dietary healthiness as long as they are in place (Table 15). The best outcome is achieved when the four measures are implemented jointly, followed by the subsidy, the removal of meals from workplace canteens, the tax and, finally, the campaign. In most cases (except the tax and, partly, the campaign), the largest improvements are achieved in the lower part of the distribution. Also for sustainability, the impact of all the interventions and their mix compared to the baseline is positive (Table 16). The mix has the largest relative impact, followed by the subsidy, the removal of meals from canteens, the tax, and the campaign. These impacts are larger compared to those on healthiness.

Table 15. Difference in healthiness between t = 45 and t = 10: gap with the baseline setting.

Statistic	Campaign	Removal	Subsidy	Tax	Mix
minimum	1.464	2.312	1.971	0.306	7.306
1st decile	0.219	1.136	1.581	0.039	3.912
1st quartile	0.136	1.079	1.435	0.382	3.552
median	0.277	1.124	1.456	0.615	3.659
3rd quartile	0.149	1.031	1.184	0.599	3.119
9th decile	0.043	0.714	0.735	0.476	2.215
maximum	0.019	0.271	-0.040	-0.136	0.369
average	**0.204**	**1.031**	**1.290**	**0.405**	**3.344**
std. dev.	-0.053	-0.109	-0.293	0.203	-0.708
t-test (p-value) [1]	0.0004	0.0000	0.0000	0.0000	0.0000

Notes: [1] Here and in Tables 16-18, the t-test is implemented on the averages.

Table 16. Difference in sustainability between t = 45 and t = 10: gap with the baseline setting.

Statistic	Campaign	Removal	Subsidy	Tax	Mix
minimum	1.350	1.207	1.050	0.550	6.959
1st decile	0.657	1.466	2.069	0.362	5.021
1st quartile	0.562	1.423	1.930	0.724	4.693
median	0.617	1.373	1.715	0.832	4.501
3rd quartile	0.489	1.260	1.450	0.787	3.957
9th decile	0.540	1.110	1.125	0.654	3.161
maximum	0.166	0.473	0.066	0.166	1.032
average	**0.580**	**1.313**	**1.643**	**0.683**	**4.251**
std. dev.	-0.159	-0.150	-0.333	0.079	-0.748
t-test (p-value)	0.0000	0.0000	0.0000	0.0000	0.0000

The situation changes slightly when considering the residual impact after removal of the interventions. For healthiness (Table 17), the mix is still the best performing intervention, followed by the subsidy and the campaign. The impact of removing the meals from workplace canteens is non-significant, while the tax on unhealthy food seems to be counterproductive, since its impact on the average is negative and significant (-0.17). Regardless of the intervention, the residual impact after removal is very limited.

Table 17. Difference in healthiness between t = 52 and t = 10: gap with the baseline setting.

Statistic	Campaign	Removal	Subsidy	Tax	Mix
minimum	0.987	-0.225	1.400	0.097	1.754
1st decile	0.148	-0.146	0.271	-0.461	0.207
1st quartile	0.029	-0.167	0.262	-0.178	0.206
median	0.136	-0.018	0.200	-0.079	0.343
3rd quartile	0.096	0.017	0.114	-0.044	0.308
9th decile	0.110	0.079	0.081	-0.011	0.326
maximum	0.010	0.035	0.154	0.084	-0.136
average	**0.132**	**-0.046**	**0.195**	**-0.165**	**0.312**
std. dev.	-0.001	0.111	-0.106	0.207	-0.044
t-test (*p*-value)	0.0117	0.4033	0.0005	0.0034	0.0000

The dynamics observed for healthiness are confirmed for sustainability (Table 18). The largest impact is generated by the policy mix, followed by the campaign, and the subsidy. Neither the meal removal, nor the tax generate significant impact. Compared to healthiness, the improvement is stronger in the lower section of the distributions, regardless of the measure implemented.

Table 18. Difference in sustainability between t = 52 and t = 10: gap with the baseline setting.

Statistic	Campaign	Removal	Subsidy	Tax	Mix
minimum	1.387	-1.056	0.807	0.421	3.278
1st decile	0.607	-0.089	0.303	-0.240	0.880
1st quartile	0.521	-0.079	0.199	-0.110	0.674
median	0.514	-0.087	0.141	-0.043	0.666
3rd quartile	0.331	-0.014	0.130	-0.039	0.572
9th decile	0.324	0.057	0.084	-0.010	0.457
maximum	0.055	-0.113	0.077	0.060	0.023
average	**0.470**	**-0.052**	**0.187**	**-0.084**	**0.670**
std. dev.	-0.176	0.068	-0.107	0.092	-0.237
t-test (*p*-value)	0.0000	0.4103	0.0025	0.1982	0.0000

5. Conclusions and further research

Using an ABM, we simulated the impact of different interventions on the healthiness and sustainability of Scottish diets accounting for the influence of "eating networks". We found that *information campaigns* favour an improvement in people's preferences but due to trade-offs between food characteristics and to budgetary and caloric constraints, this is hardly translated into action. Therefore, despite being more persistent than other interventions, their final impact on diets is small. In turn, the *removal of unhealthy and unsustainable meals from workplace canteens* has an immediate positive impact that is not sustained after the intervention stops. *Subsidising* healthy and sustainable meals results in sizeable improvements in diets; after removing the subsidy, the impact remains statistically significant but becomes much smaller. The financial benefits for households are large (-30% in food expenditure) but come at high cost for public finances (£145 per person). *Taxing* unhealthy and unsustainable food generates limited improvements in the short term followed by a progressive worsening which, summed to the drop-off after the tax is removed, results in outcomes worse than before the intervention. The tax generates a revenue for public finances (£33-34 per person), but the burden is larger for larger households and in more deprived areas. The best outcome is achieved by running all the interventions together. Despite a drop-off after their end, the improvement in healthiness and sustainability is 0.3 and 0.7 points larger than in the baseline on a 0-100 scale. The cost for public finances is £134-139 per person, and the households' food expenditure decreases.

These results suggest that policymakers should strike a balance between different typologies of interventions: those aimed at changing consumers' attitudes (campaigns) generate a persisting impact on preferences which is seldom translated into action; those changing the relative cost of different choices, or removing unwanted options altogether, have sizeable short-term effects but are less persistent. Although avoided healthcare costs are not factored in, subsidies generate large costs for public finances. Ideally, policymakers could combine campaigns with regulatory interventions, while targeting the meals that show extreme values (i.e., very unhealthy or unsustainable) by means of market-based measures.

The six scenarios modelled represent only a small subset of the potential combination of parameters, and thus policy designs. Besides changing the parameters, the time during which the interventions are run might be prolonged or shortened, and the interventions might focus on healthiness or sustainability only. Extensive simulations would allow to assess the relative effectiveness of each parameter combination.

Future efforts could also be devoted to fine-tuning the rules of the model, primarily the utility function. This could be replaced with a *Cobb-Douglas*, where the sum of the preference parameters is fixed, or an *ordinal* utility function, where agents select their meals based on high-ranking attributes, in line with Satter's (2007) concept of "hierarchy of food needs". The *influence mechanisms* could also be refined, e.g., by limiting the revision process to a subset of preferences at each step, or by introducing an "opinion dynamics" process – not foreseen because previous research (van Geffen et al., 2017) highlighted the importance of descriptive rather than injunctive norms. Such changes require better grounding of the *psychological mechanisms* via questionnaires or direct observation. Afterwards, the interventions emerging as most promising could be tested through randomised controlled trials.

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Author contribution statement

Conceptualisation: TC, SP, NC; Methodology: SP, TC; Software: SP, SR; Validation: SP, SR; Formal analysis: SP, SR; Investigation: SP, NC, FB; Resources: TC, SR; Data curation: SP, NC; Writing – original draft: SP, NC; Writing – review and editing: TC; Visualisation: SP; Supervision: TC; Project administration: TC; Funding acquisition: TC.

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Appendix: Stylised facts

Convenience preferences

Demographic variable	Stylised fact	References	Country	Evidence	Notes
Gender	No significant relationship between convenience and gender	(Glanz et al., 1998)	US	Quantitative analyses based on survey	Mixed evidence about association between gender and preference for convenience – if it exists, likely to be quite weak.
		(Candel, 2001)	The Netherlands	Regression model based on survey	
	Women prioritise convenience more than men	(Schliemann et al., 2019)	Ireland	Regression models based on survey	
		(Piggford et al., 2008)	Australia	Regression model based on survey	
		(Buckley et al., 2007)	UK	Descriptive statistics based on survey	
	Women consume convenience products less often than men	(Brunner et al., 2010)	Switzerland	Regression model based on survey	
	Men more likely to report convenience as a motive than women	(Blanck et al., 2007)	US	Regression model based on survey	
Age	Convenience less of a priority for older customers	(Buckley et al., 2007)	UK	Descriptive statistics based on survey; age measured in six groups (16-24, 25-34, 35-44, 45-54, 55-64, 65-75)	
	Convenience important for younger people	(Glanz et al., 1998)	US	Quantitative analyses based on survey	
	Age biggest predictor for consumption of convenience products; older respondents consume convenience products less often than younger respondents	(Brunner et al., 2010)	Switzerland	Regression model based on survey	
	No significant relationship between convenience and age	(Candel, 2001)	The Netherlands	Regression model based on survey	
Income	Convenience an important priority for consumers with lower incomes	(Steptoe et al., 1995)	UK	Quantitative analyses based on survey; annual income split into six groups (<£5000; £5000-10000; £10000-15000; £15000-20000; £20000-30000; >£30000)	

		(Glanz et al., 1998)	US	Quantitative analyses based on survey	
	People from lower social grades (C2 and DE) more likely to prioritise convenience	(Buckley et al., 2007)	UK	Descriptive statistics based on survey; social grade measured in four groups (AB, C1, C2, DE)	
	Groups which value convenience have lower incomes than groups which do not value convenience	(Mallinson et al., 2016)	UK	Quantitative analyses based on survey; annual household income measured in £	
Education	No significant relationship between convenience preferences and education level	(Candel, 2001)	The Netherlands	Regression model based on survey	Little research on the relationship between education level and convenience preferences.
	Group with lowest preference for convenience foods had highest proportion of respondents educated to at least undergraduate level	(Mallinson et al., 2016)	UK	Quantitative analyses based on survey; education measured in five groups (GSCE; AS/A Level; further education (diploma etc); degree; postgraduate)	
	Group that valued convenience the most were the least educated				
Household composition	People with children consume fewer convenience products than people without children	(Brunner et al., 2010)	Switzerland	Regression model based on survey	
	People with children less likely to prioritise convenience	(Candel, 2001)	The Netherlands	Regression model based on survey; presence of children measured as yes/no	
	Household size the socio-demographic variable most closely related to convenience orientation; single households more convenience oriented than multi-person households	(Candel, 2001)	The Netherlands	Regression model based on survey; household size measured in five groups (1, 2, 3, 4, ≥ 5)	
Working condition	People working part-time more likely to value convenience	(Conner et al., 2010)	US	Quantitative analyses based on survey; working condition measured in three groups (full-time, part-time, retired)	Mixed evidence about relationship between hours worked and convenience preferences, but students likely to value convenience and (Brunner et al., 2010)
	Convenience very important for students; less important for recent graduates	(Betts et al., 1997)	US	Quantitative analyses based on survey; participants split into three	

				groups (students, graduates and non-students)	suggest older people value convenience because more likely to be retired and therefore have more time.
	Working full-time reduced convenience product consumption	(Brunner et al., 2010)	Switzerland	Regression model based on survey	
	People who work ≥ 30 hours a week the most convenience oriented	(Candel, 2001)	The Netherlands	Regression model based on survey; working status measured in five groups (no paid job; ≤ 9 hours employed; 10-19 hours employed; 20-29 hours employed; ≥ 30 hours employed)	
	No significant relationship between convenience and number of hours worked	(Piggford et al., 2008)	Australia	Regression model based on survey; weekly work hours measured in five groups (1-10; 11-20; 21-30; 31-40; 40+)	

Caloric content preferences

Demographic variable	Stylised fact	References	Country	Evidence	Notes
Gender	Men's portion sizes are larger than women's	(Sharma et al., 2002)	UK	Quantitative analyses based on survey	Men have higher energy needs than women (Spence et al., 2016); therefore, it is unsurprising that there is clear relationship between gender and quantity/calorie consumption/portion sizes.
	Women choose smaller portion sizes than men	(Rangan et al., 2009)	Australia	Quantitative analyses based on survey	
	Gender the strongest demographic contributor to meal portion size	(Spence et al., 2016)	Denmark/Ireland	Quantitative analyses based on survey	
	Women more likely to make low-calorie food choices	(Ellison et al., 2013)	US	Regression model based on study	
	Women more likely to cite weight control as an influence on food choices than men	(Vorage et al., 2020)	Australia	Regression model based on survey	
Age	Younger people had larger portion sizes than older people	(Spence et al., 2016)	Denmark/Ireland	Quantitative analyses based on survey; age measured in four groups (18-29; 30-49; 50-64; 65+)	Evidence to suggest that quantity priorities decline with increasing age.
	Older adults have smaller appetites and therefore prefer smaller portion sizes	(Whitelock and Ensaff, 2018)	UK	Qualitative study based on semi-structured interviews; participants aged between 63 and 90	

	Portion sizes decrease with increasing age	(Rangan et al., 2009)	Australia	Quantitative analyses based on survey; age measured in four groups (19-29; 30-49; 50-69; 70+)	
	Young adults more likely to make medium- or high-calorie food choices	(Ellison et al., 2013)	US	Regression model based on study; age measured in three groups (18-35; 35-55; 55+)	
	Older adults more likely to make low-calorie food choices				
	May be differences between young people; those aged 17-20 more likely to cite weight control as an influence on food choices than those aged 21-29	(Vorage et al., 2020)	Australia	Regression model based on survey; age measured in two groups (17-20; 21-29)	
Income	Low-income participants make up the greatest proportion of medium- and high-calorie diners	(Ellison et al., 2013)	US	Regression model based on study; income measured in three groups (<$25,000; $25,000-$100,000; ≥$100,000)	Given that energy-dense diets usually cheaper than diets containing less energy (Waterlander et al., 2010), we might expect there to be more evidence supporting relationship between income levels and quantity preferences.
	High income participants more likely to be low-calorie diners				
	No relationship between income and preferences for weight control (low in calories, low in fat, helps to control weight)	(Steptoe et al., 1995)	UK	Quantitative analyses based on survey; annual income split into six groups (<£5000; £5000-10000; £10000-15000; £15000-20000; £20000-30000; >£30000)	
	No relationship between income and the energy density of diets	(Waterlander et al., 2010)	Netherlands	Quantitative analyses based on two studies; income measured differently in each study	
Education	People with a bachelor's degree made up greater proportion of low-calorie diners	(Ellison et al., 2013)	US	Regression model based on study; education measured as bachelor's degree/no degree	Not enough evidence to suggest relationship between education level and quantity preferences.
Working condition	University students made up larger proportion of medium- and high-calorie diners than non-students	(Ellison et al., 2013)	US	Regression model based on study; student status measured as current student/not student	Little evidence of relationship between working condition and quantity preferences, but evidence on age

					can be used to understand preferences of students and retired.

Price preferences

Demographic variable	Stylised fact	References	Country	Evidence	Notes
Gender	Women more concerned about price than men, perhaps because women often responsible for household shopping	(Steptoe et al., 1995)	UK	Quantitative analyses based on survey	Honkanen and Frewer (2009) seem to be the exception – given that the study is Russian, perhaps this anomaly could be explained by cultural differences.
	Women more likely to cite price as an influence on food choices than men	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey	
		(Glanz et al., 1998)	US	Quantitative analyses based on survey	
		(Schliemann et al., 2019)	Ireland	Regression models based on survey	
	Men more likely to be price sensitive than women	(Honkanen and Frewer, 2009)	Russia	Quantitative analyses based on survey	
Age	People aged over 55 the most likely age group to cite price as an influence on food choice	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey; age measured in three groups (15-34, 35-54, 55+)	Lennernäs et al. (1997)'s findings could be explained by association between retirement and prioritisation of price (see below).
	Younger respondents most likely to cite price as a priority	(Glanz et al., 1998)	US	Quantitative analyses based on survey	
		(Blanck et al., 2007)	US	Regression model based on survey; age measured in four groups (18-34; 35-44; 45-54; 55+)	
Income	People with higher incomes less likely to consider food prices very important	(Bowman, 2006)	US	Descriptive statistics based on survey; income measured in three groups (low, medium, high)	
	People with lower incomes more concerned about price	(Steptoe et al., 1995)	UK	Quantitative analyses based on survey; annual income split into six groups (<£5000; £5000-10000;	

				£10000-15000; £15000-20000; £20000-30000; >£30000)	
		(Glanz et al., 1998)	US	Quantitative analyses based on survey	
Education	People with lower levels of education more likely to cite price as an influence on food choices	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey; education measured by highest level achieved (primary, secondary, tertiary)	
		(Honkanen and Frewer, 2009)	Russia	Quantitative analyses based on survey; education measured in three groups (lower education; middle; higher education)	
	People with higher level of education choose price as an influencing factor less frequently than those with lower levels of education	(Blanck et al., 2007)	US	Regression model based on survey; education measured in four groups (not specified; high school; some college; college graduate)	
Household composition	People with children under 18 in the household more likely to be concerned about price	(Honkanen and Frewer, 2009)	Russia	Quantitative analyses based on survey; presence of children under 18 in the household measured by yes/no	Effect of marriage status on price preferences unknown.
	People with children more concerned about price than those without children	(Schliemann et al., 2019)	Ireland	Regression models based on survey; parental status measured in two groups (children; no children)	
Working condition	Price the most important factor when making food choices for the unemployed and retired	(Lennernäs et al., 1997) EU,	EU	Descriptive statistics based on survey; employment status measured by five groups (working, housewife, still in education, unemployed and retired)	
	Unemployed more likely to consider price important than those in full-time employment	(Bowman, 2006)	US	Descriptive statistics based on survey; employment status measured in four groups (full-time employed; part-time employed; not employed; other)	
	Students value price more than non-students	(Pollard et al., 1998)	UK	Regression models based on survey	

	The more hours worked; the less price sensitive respondents were	(Piggford et al., 2008)	Australia	Regression model based on survey; weekly work hours measured in five groups (1-10; 11-20; 21-30; 31-40; 40+)	

Taste preferences

Demographic variable	Stylised fact	References	Country	Evidence	Notes
Gender	Taste valued more by men	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey	Overall, there is slightly more evidence to suggest that women are more concerned with taste than men are – interesting considering that women are also more concerned about healthy eating than men.
		(Kearney et al., 2000)	Ireland	Regression model based on survey	
	Women more likely to prioritise nutrition over taste	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey	
	Taste more important to women	(Glanz et al., 1998)	US	Quantitative analyses based on survey	
		(Kourouniotis et al., 2016)	Australia	Quantitative analyses based on survey	
		(Pollard et al., 1998)	UK	Quantitative analyses based on survey	
	Women less willing to compromise on taste for potential health benefits	(Urala & Lähteenmäki, 2004)	Finland	Quantitative analyses based on survey	
	Men and women have different taste patterns; men prefer salt, umami, fat, bitter foods, whereas women prefer sweet, fat, and sour foods	(van Langeveld et al., 2018)	Netherlands	Quantitative analyses based on survey	
Age	Taste valued more by youngest age group	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey; age measured in three groups (15-34, 35-54, 55+)	Taste becomes less of a priority with increasing age.
		(Kearney et al., 2000)	Ireland	Regression model based on survey; age measured in three groups (15-34, 35-54, 55+)	

	Younger people more likely to cite taste as an influence on food choices	(Blanck et al., 2007)	US	Regression model based on survey; age measured in four groups (18-34; 35-44; 45-54; 55+)	
	Younger people less willing to compromise on taste for potential health benefits	(Urala and Lähteenmäki, 2004)	Finland	Quantitative analyses based on survey; age measured in five groups (≤ 29; 30-39; 40-49; 50-59; ≥ 60)	
	Taste patterns vary by age; youngest age group prefer sweet and sour food, whereas oldest age group prefer bitter foods	(van Langeveld et al., 2018)	Netherlands	Quantitative analyses based on survey and study; different measures of age used in survey and study	
Income	People with lower incomes value taste less because they tend to prioritise price and convenience	(Steptoe et al., 1995)	UK	Quantitative analyses based on survey; annual income split into six groups (<£5000; £5000-10000; £10000-15000; £15000-20000; £20000-30000; >£30000)	Some evidence to suggest relationship between income and taste preferences; (Candel, 2001) suggests that convenience and taste preferences are related – since we know that people with lower incomes prioritise convenience, we could assume that they value taste less.
Education	Sensory appeal is the most important influence on food choices, regardless of education level	(Honkanen and Frewer, 2009)	Russia	Quantitative analyses based on survey; education measured in three groups (lower education, middle, higher education)	Does not appear to be a significant relationship between education level and taste preferences.
	No significant differences in dietary taste patterns by education	(van Langeveld et al., 2018)	Netherlands	Quantitative analyses based on survey; education measured in three groups (low, medium, high)	
Household composition	Married people less likely to value taste; single people had strongest preference for taste	(Kearney et al., 2000)	Ireland	Regression model based on survey; marital status measured in three groups (single; married; widowed/separated)	Little evidence on relationship between taste preferences and marriage status/children.

Working condition	Students are the working group most likely to value taste	(Kearney et al., 2000)	Ireland	Regression model based on survey; working condition measured in five groups (working; housewife; student; unemployed; retired)	Makes sense that students value taste more and retired value taste less, given strong relationship between taste preferences and age (see above).
	Students value taste less than non-students, perhaps because they prioritise price	(Pollard et al., 1998)	UK	Quantitative analyses based on survey; working status measured in five groups (student; employed; unemployed; household manager; retired)	
	Retired are less likely to value taste than students, unemployed and workers	(Kearney et al., 2000)	Ireland	Regression model based on survey; working condition measured in five groups (working; housewife; student; unemployed; retired)	

Healthiness preferences

Demographic variable	Stylised fact	References	Country	Evidence	Notes
Gender	Female students value nutrition more; male students more likely to value price and convenience	(Morse and Driskell, 2009)	US	Descriptive statistics based on survey	
	Women's diets more in line with recommendations than men's, eat more fruit and vegetables	(Roos et al., 1998)	Finland	Regression model based on survey	
	Women more likely to cite health and nutrition as an influence on their food choices	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey	
Age	Older people more likely to cite health and nutrition as an influence on their food choices	(Kearney et al., 2000)	Ireland	Regression model based on survey; age measured in three groups (15-34, 35-54, 55+)	Many articles about student eating habits yet surprisingly little about young adults who are not students, though Betts et al.'s
		(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey; age measured in three groups (15-34, 35-54, 55+)	

	Importance of health as a reported motive increased with age in women but not men	(Steptoe et al., 1995)	UK	Quantitative analyses based on survey; age is a discrete measure	study suggests their attitudes towards healthy eating are similar.
	Students and non-students between 18 and 24 do not prioritise nutrition, though graduates do	(Betts et al., 1997)	US	Quantitative analyses based on survey; age is a discrete measure from 18 to 24	
Income	People in higher socioeconomic classes eat more fruit and vegetables	(Irala-Estévez et al., 2000)	Across Europe	Review of food habit surveys	Association between income and healthy eating seems relatively weak, although evidence to suggest that diets may differ between socioeconomic groups. More consistent evidence linking fruit and vegetable consumption to socioeconomic status.
	People in higher socioeconomic class more likely to cite health as an influence on food choices	(Kearney et al., 2000)	Ireland	Regression model based on survey; social class measured by six groups (professional/managerial/upper middle class; lower middle class; skilled working class; other working class; farmers with farms greater than 50 acres; farmers with farms less than 50 acres)	
	Low-income consumers with children equally concerned about nutrition as high-income consumers with children, but often had to prioritise price and taste	(Guthrie and Morton, 1999)	US	Descriptive statistics based on survey' participants split into low-income and high-income consumers	
	No clear relationship between socioeconomic status and healthy diets	(Groth et al., 2001)	Denmark	Univariate and multivariate analysis based on survey; income split into groups	
Education	More educated people more likely to follow dietary recommendations; effect stronger for men than women	(Roos et al., 1998)	Finland	Regression model based on survey; measured by time spent in education, split into three groups	Relationship between education and healthy eating seems to be stronger than relationship between income
	More educated people eat more fruit and vegetables	(Irala-Estévez et al., 2000)	Across Europe	Review of food habit surveys	

	More educated men eat healthier than less educated men; pattern for women less clear	(Groth et al., 2001)	Denmark	Univariate and multivariate analysis based on survey; education measured by highest level achieved (basic school; upper secondary school; vocational education; short higher education; medium higher education; long higher education)	and healthy eating, particularly for men.
	More educated people more likely to cite health as an influence on food choices	(Kearney et al., 2000)	Ireland	Regression model based on survey; education measured by highest level achieved (primary, secondary, tertiary)	
		(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey; education measured by highest level achieved (primary, secondary, tertiary)	
Household composition	Married people eat healthier than single or previously married people; association particularly strong for men	(Roos et al., 1998)	Finland	Regression model based on survey; marital status measured by three groups (married/cohabitating; single/never married; previously married); parental status measured by three groups (at least one child under 7; at least one child aged 7-16 and no children less than 7; no children less than 17)	
	Women with children have healthier eating behaviours than women without children; same effect cannot be observed for men				
Working condition	Unemployed people less likely to follow dietary guidelines because of price barriers	(Roos et al., 1998)	Finland	Regression model based on survey; employment status measured by five groups (employed, retired, unemployed, housewives and other non-employed)	Connection between retired people and healthy eating relatively weak, but makes sense given strong relationship between older age and healthy eating (see above).
	Students follow unhealthy diets because they prioritise price and convenience	(Betts et al., 1997)	US	Quantitative analyses based on survey; participants split into three groups (students, graduates, and non-students)	

	Some evidence to suggest that retired people are more likely to cite health and nutrition as an influence on food choices	(Lennernäs et al., 1997)	EU	Descriptive statistics based on survey; employment status measured by five groups (working, housewife, still in education, unemployed and retired)	

Sustainability preferences

Demographic variable	Stylised fact	References	Country	Evidence	Notes
General sustainability attitudes					
Gender	Women more concerned about the sustainability of their food than men	(Ede et al., 2011)	Australia, Canada, Germany, Sweden, UK, US	Quantitative analyses based on survey; qualitative analyses based on interviews and focus groups	
		(Lehikoinen and Salonen, 2019)	Finland	Quantitative and qualitative analyses based on survey	
		(Mohr and Schlich, 2016)	Germany	Quantitative analyses based on survey	
Age	Middle aged people least likely to eat sustainably	(Lehikoinen and Salonen, 2019)	Finland	Quantitative and qualitative analyses based on survey	Very conflicting evidence. Lehikoinen and Salonen's (2019) argument has slightly more support than Mohr's but the connection between age and sustainable attitudes is still unclear – to predict sustainable food choices it would be best to combine theories about attitudes with theories about meat consumption and local foods.
	Middle aged people most likely to have sustainable eating behaviours, and sustainable behaviours start to decrease after 56	(Mohr and Schlich, 2016)	Germany	Quantitative analyses based on survey	
	Some evidence to suggest that young people are more environmentally conscious than older people, but this does not necessarily result in sustainable eating behaviours	(Diamantopoulos et al., 2003)	UK	Quantitative analyses based on survey; qualitative analyses based on interviews and focus groups	
	Young people express more concern over the environment, but in practice, older consumers have more sustainable eating behaviours	(Panzone et al., 2016)	UK	Quantitative analyses based on surveys	
Education	People with higher education levels have a better understanding of	(Panzone et al., 2016)	UK	Quantitative analyses based on surveys	

	what makes food sustainable, allowing them to make more informed and sustainable purchasing choices				
	People with higher education levels more likely to be environmentalists, which can guide their eating behaviours	(Brown, 2003)	US	Quantitative analyses based on survey	
Household composition	No significant differences in environmental consciousness between those with children and those without	(Diamantopoulos et al., 2003)	UK	Quantitative analyses based on survey; qualitative analyses based on interviews and focus groups	Very little written about the effects of household composition on sustainable attitudes.
	No evidence that married people are more environmentally conscious than single individuals				
Working condition	Students have positive attitudes towards sustainability, but price or convenience are bigger priorities for them	(Ede et al., 2011)	Australia, Canada, Germany, Sweden, UK, US	Quantitative analyses based on survey; qualitative analyses based on interviews and focus groups	Students tend to be younger, so this fits in with the arguments related to age – that young people value sustainability but must offset this against their other priorities.
Meat attitudes and consumption					
Gender	Men more attached to meat consumption than women	(Graça et al., 2015)	Portugal	Quantitative analyses based on survey	
	Women more likely to be vegetarian	(Pfeiler and Egloff, 2018a)	Germany and Australia	Quantitative analyses based on survey	
	Women more likely to be open to reducing meat consumption and more likely to have already reduced consumption	(Tobler et al., 2011)	Switzerland	Quantitative analyses based on survey	
	Men eat more meat overall, though differences between different kinds of meat	(Daniel et al., 2011)	US	Quantitative analyses based on survey	

	Men have higher meat consumption, especially of red meats	(Aston et al., 2013)	UK	Quantitative analyses based on survey	
Age	Over 65s eat less meat than young people	(Dibb and Fitzpatrick, 2014)	UK	Review of literature on meat consumption	Some mixed evidence, though most seem to agree that meat consumption is higher for middle-aged people, with slightly lower consumption in younger and older adults.
	People aged between 18 and 24 are the age group most likely to be vegetarian				
	Younger individuals eat more meat and poultry but less fish	(Pfeiler and Egloff, 2018b)	Germany	Quantitative analyses based on surveys	
	Peak meat consumption for those aged between 20 and 49, with lower intakes for younger and older ages	(Daniel et al., 2011)	US	Quantitative analyses based on survey	
	Plant-based diets most popular for over 60s and under 30s	(Lehikoinen and Salonen, 2019)	Finland	Quantitative and qualitative analyses based on survey	
Income	Low-income households buy and eat more meat, especially lower-quality or processed meat; meat considered a more central part of the diet	(Wiig and Smith, 2009)	US	Quantitative and qualitative analyses based on survey	Mixed evidence as to relationship between income levels and amount of meat eaten. General agreement that different socioeconomic groups eat different kinds of meat.
	Consumption of lean meats and fish higher in higher income groups, whereas lower income groups have higher consumption of fatty meats	(Darmon and Drewnowski, 2008)	Europe, Canada, Australia, US	Review of literature on link between social class and diet quality	
	Different socioeconomic groups eat roughly same amount of meat, but higher income groups eat more carcass meat and less processed meat	(Dibb and Fitzpatrick, 2014)	UK	Review of literature on meat consumption	
	Lower socioeconomic groups more likely to eat meat than those from higher socioeconomic groups	(Chan and Zlatevska, 2019)	Australia	Quantitative analyses based on experiments	
	People from higher income groups more likely to be vegetarian	(Pfeiler and Egloff, 2018a)	Germany and Australia	Quantitative analyses based on survey	
Education	People with higher education levels eat less red processed meat	(Aston et al., 2013)	UK	Quantitative analyses based on survey	Evident that meat consumption patterns

	Higher levels of education associated with higher fish consumption but lower meat consumption	(Daniel et al., 2011)	US	Quantitative analyses based on survey	vary by education levels, but not clear if *amount* of meat consumed is related to education level.
		(Pfeiler and Egloff, 2018b)	Germany	Quantitative analyses based on survey	
Local food attitudes and consumption					
Gender	Women have more positive attitudes towards local foods than men	(Gracia et al., 2012)	Spain	Quantitative analyses based on experimental auction	
		(Weatherell et al., 2003)	UK	Quantitative analyses based on survey; qualitative analyses based on focus groups	
	Women more likely to visit farmers' markets	(Kezis et al., 1998)	US	Quantitative analyses based on survey	
Age	Participants over 50 spend more money on local food at farmers' markets	(Berg and Preston, 2017)	New Zealand	Quantitative analyses based on survey	
	Older people more likely to prefer local foods to younger people	(Tregear and Ness, 2005)	UK	Qualitative analyses based on interviews and focus groups; quantitative analyses based on survey	
	Older customers have a greater interest in supporting local farmers and local economy; inconvenience of buying local food of less concern for older customers	(Szmigin et al., 2003)	UK	Review of literature on farmers' markets	
Income	Higher income households more willing to spend money on local food	(Berg and Preston, 2017)	New Zealand	Quantitative analyses based on survey	
	People with lower incomes and part-time workers more likely to prioritise price and convenience over how local their produce is	(Conner et al., 2010)	US	Quantitative analyses based on survey	
	Local foods often expensive and inaccessible for those in lower income households	(Allen, 1999)	US	Review of literature on local food production	
	People with higher incomes more likely to shop at farmers' markets	(Kezis et al., 1998)	US	Quantitative analyses based on survey	

Education	People with higher education more interested in environmental issues and local foods	(Brown, 2003)	Brown	Quantitative analyses based on survey	There is a lack of strong evidence linking education levels to local food purchasing. However, there is quite convincing evidence linking it to income (see above). Since income and education are often related, we can assume that preferences for local foods increase with education.
	People with higher education more likely to shop at farmers' markets	(Kezis et al., 1998)	US	Quantitative analyses based on survey	
	No significant relationship between education and local food purchasing	(Tregear and Ness, 2005)	UK	Qualitative analyses based on interviews and focus groups; quantitative analyses based on survey	
Household composition	People without children more likely to shop at farmers' markets	(Kezis et al., 1998)	US	Quantitative analyses based on survey	
	People with children at home more likely to express preference for locally grown food	(Patterson et al., 1999)	US	Quantitative analyses based on survey	

Psychological Constructs

Demographic variable	**Stylised fact**	**Reference**	**Country**	**Evidence**	**Psychological construct**	**Notes**
Gender	Women are more likely to model their eating behaviours on the food choices of their eating partners, especially in terms of quantity	(Salvy et al., 2007)	US	Quantitative analyses based on study	Status quo bias/interaction threshold	Some evidence that women's food choices (particularly on health and quantity) are more likely to be influenced than men's, especially when eating with other women. Most studies on food modelling look exclusively at women and lack of research that compares modelling effects between men and women (Cruwys, Bevelander and Hermans, 2015), so difficult to make any conclusions.
	Women model the quantity of food they eat on the eating behaviours of their same sex eating partner	(Hermans et al., 2009)	Netherlands	Quantitative analyses based on study	Status quo bias/interaction threshold	
	Women eat less when in the presence of men than when in the presence of other women	(Higgs and Thomas, 2016)	N/A	Review	Status quo bias/interaction threshold	
	Men more likely to be influenced by normative information about fruit and vegetable consumption	(Croker et al., 2009)	UK	Quantitative analyses based on study	Interaction threshold	

	No differences in modelling food choices between boys and girls	(Cruwys et al., 2015)	N/A	Review	Status quo bias	
Age	Descriptive norms less effective in influencing food choices in adults than in adolescents and young adults	(de Bruijn et al., 2015)	N/A	Review	Interaction threshold	Evidence to suggest that children and adolescents are influenced by eating behaviours of others, but since most studies focus on children/students, it is difficult to compare their influences on older demographics (Cruwys et al., 2015).
Household composition	Newly married couples' eating behaviours converge after a year of marriage	(Bove et al., 2003)	US	Qualitative study	Threshold action/status quo bias	Suggests married people are influenced by eating behaviours of spouse, but not necessarily by others in their networks.

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