Appendix B.
Specification of the optimization model

This model describes a problem formulation to minimize the incremental costs, from an economic and climate perspective, of shifting diets towards adequate nutrition. Adequacy is considered for total calories and select micronutrients. The goal of this analysis is to examine the absolute costs, and trade-offs between different types of costs, in shifting people from current diets towards adequate nutrition, given that there are many different ways to alter diet.

This model is coded and solved in GAMS with CPLEX and Couenne solvers. GAMS model runs are executed through authors' R scripts. All interfaces between GAMS and R including GDX data processing/exchange are done through functions in R *gdxrrw* package.

B.1 Sets

Food item $i \in \mathbf{I}$ = {114 individual items from NSS} (See Appendix 1)

Food group $f \in \mathbf{F}$ = {cereal, fruit/vegetable, veg-protein, meat/fish, dairy, other}

Nutrient $n \in \mathbf{N}$ = {protein, iron, zinc, vitamin A}

Person type $p \in \mathbf{P}$ = {male-adult, female-adult, male-child, female-child}

$\forall i, \exists f$ s.t. $i \in f$

B.2 Parameters

c_i = calorie content per kg of food item (kcal per kg)

a_{in} = quantity of nutrient n in food item i (g/mg/mcg per kg)

pr_i = price of food i ($ per kg)

e_i = non-CO_2 emission factor of producing food i (kgCO_2e per kg)

r_{ip} = current annual consumption of food i by person of type p (kg)

$Fmin_p$ = minimum annual calorie intake for person of type p (kcal)

$Nmin_{np}$ = minimum annual nutrients of n for person of type p (mg)

B.3 Variables

x_{ip} = annual consumption of food i by person of type p

B.4 Objectives

These objectives are formulated as three single-criteria optimization problems, which are run separately subject to common constraints (4)-(9). For Objective 2, we additionally set a budget constraint shown in (10). For Objective 3, we also set the budget constraint (10), while removing the two constraints on the bounded consumption changes (7) and the fixed calorie shares by food group (9) .

Objective 1. Cost minimization

$$\min_{x_{ip}} Cost = \sum_{p} \sum_{i} pr_i x_{ip} \tag{1}$$

Objective 2. Emission minimization

$$\min_{x_{ip}} CO_2e = \sum_{p} \sum_{i} e_i x_{ip} \tag{2}$$

Objective 3. Deviation minimization

$$\min_{x_{ip}} \Delta kg = \sum_{p} \sum_{i} |x_{ip} - r_{ip}| \tag{3}$$

s.t. $\forall p$,

$$\sum_{i} c_i x_{ip} \geq max\left(\sum_{i} c_i r_{ip}, Fmin_p\right) \tag{4}$$

$$\forall n,\ \sum_{i} a_{in} x_{ip} \geq Nmin_{np} \tag{5}$$

$$\forall i \in \text{other},\ x_{ip} = r_{ip} \tag{6}$$

$$\forall i\ \notin \text{other},\ \frac{r_{ip}}{10} \leq x_{ip} \leq 100 r_{ip} \tag{7}$$

$$\frac{r_{i_{PDS},p}}{r_{i_{nPDS},p}} = \frac{x_{i_{PDS},p}}{x_{i_{nPDS},p}},\ i = \{\text{rice, wheat}\} \tag{8}$$

$$\forall f \in \mathbf{F} - \{\text{other}\},\ \frac{\sum_{i \in f} c_i r_{ip}}{\sum_f \sum_{i \in f} c_i r_{ip}} = \frac{\sum_{i \in f} c_i x_{ip}}{\sum_f \sum_{i \in f} c_i x_{ip}} \tag{9}$$

$$\sum_p \sum_i pr_i x_{ip} \leq \sum_p \sum_i pr_i r_{ip} \tag{10}$$

Each constraint translates to:

(4) The calorie intake of each household member should be the higher of the minimum calorie requirement and the baseline level.

(5) Each member should consume the minimum requirements of each nutrient.

(6) Some miscellaneous food items (categorized as 'other' group) are held constant.

(7) Changes in consumption of each food item are bounded.

(8) Households consume a fixed share of rice and wheat from PDS and non-PDS, equivalent to the baseline.

(9) Households consume fixed same shares of calories from each food group as in the baseline.

(10) Total expenditure on food should not exceed the baseline level.