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Globalisation and national trends in nutrition and health: A grouped fixed-effects approach to intercountry heterogeneity

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Abstract

Using a panel dataset of 70 countries spanning 42 years (1970–2011), we investigate the distinct effects of social globalisation and trade openness on national trends in markers of diet quality (supplies of animal proteins, free fats and sugar, average body mass index, and diabetes prevalence). Our key methodological contribution is the application of a grouped fixed-effects estimator, which extends linear fixed-effects models. The grouped fixed-effects estimator partitions our sample into distinct groups of countries in order to control for time-varying unobserved heterogeneity that follows a group-specific pattern. We find that increasing social globalisation has a significant impact on the supplies of animal protein and sugar available for human consumption, as well as on mean body mass index. Specific components of social globalisation such as information flows (via television and the Internet) drive these results. Trade openness has no effect on dietary outcomes or health. These findings suggest that the social and cultural aspects of globalisation should receive greater attention in research on the nutrition transition.

KEYWORDS

nutrition transition, obesity, social globalisation, trade openness, grouped fixed-effects, panel data

1 | INTRODUCTION

High- and middle-income countries have experienced a profound shift in their population diet over recent decades. Food supply, as measured by the calories available for human consumption,[1] has increased significantly, which has improved food security (Thompson, Cohen, & Meerman, 2012). However, although a large share of the population in middle-income countries has escaped from hunger, the nutrition composition of national diets has also changed. The supply of carbohydrates other than sugar has risen a little whereas, on the contrary, the supplies of animal protein, free fat, and sugar have exhibited significant growth.[2] Popkin (1993) introduced the concept of nutrition transition to describe these dietary changes. Middle-income countries are currently experiencing their nutrition transition, with considerable growth rates in the supply of animal protein and fat.[3] The convergence to high-income countries over the past 40 years remains, however, only moderate.[4] High-income countries are

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[1] Due to data availability, we use the food supply available for human consumption as a proxy for calorie intake. This approach may overestimate actual calorie intake, as household food waste is ignored.
[2] Carbohydrates are the sugar and starches found in fruit, grains, and vegetables. Products rich in carbohydrates are cereals, pasta, rice, bread, corn, peas, and lentils. We put in the "free fat" category all fats available from oil, butter, and cream. These food items are used by individuals and firms essentially for the taste and chemical properties of their fats.
[3] This paper focuses on high- and middle-income countries. It does not consider low-income countries as these are at very early stages of the nutrition transition. Among middle-income countries, a distinction is made between upper and lower middle-income countries (see the World Bank classification).
[4] Convergence is defined as a reduction over time in the variance of the nutrition components measured in kcal/capita/day.

indeed at an advanced state of their nutrition transition but their growth rates in animal protein and fat supplies have not yet reached a plateau.

The nutrition transition poses important policy challenges for health. Epidemiological studies show that diets rich in sugar, certain types of fat (saturated or trans fats), salt, and fatty meat constitute important risk factors for noncommunicable diseases such as cardiovascular diseases (CVD), diabetes, a number of cancers, as well as for intermediate outcomes such as obesity. (Ezzati & Riboli, 2013; WHO, 2015b). In 2012, 17.5 million people died from CVD, making them the number one cause of death globally. More than three quarters of CVD deaths take place in low- and middle-income countries, causing substantial economic and welfare losses (WHO, 2015a). As a consequence, the World Health Organisation regards food-related chronic diseases as a growing threat all over the world, replacing traditional public-health concerns such as undernutrition and infectious diseases (WHO, 2000).[5]

The globalisation of national economies is usually seen as a key driver of the nutrition transition (Hawkes, 2006; Popkin, 2006; Bishwajit, Ide, Hossain, & Safa, 2014). However, the existing evidence for this claim consists mostly of case studies that link observed changes in diets to substantial changes in national food systems following trade openness (Hawkes & Thow, 2008; Thow & Hawkes, 2009; Thow et al., 2011) and significant foreign direct investment (FDI) in the food industry (Hawkes, 2006). These case studies typically focus on the economic aspects of globalisation and fail to take into account its multifaceted nature.

This paper looks at trends in nutrition and food-related diseases in a panel of 70 high- and middle-income countries observed between 1970 and 2011. Our empirical analysis relies on the theoretical model on cultural transmission developed by Olivier, Thoenig, and Verdier (2008). This predicts that social globalisation, defined as social interactions between individuals of different countries through migration, tourism, and communication technologies, produces convergence in food cultures. Trade openness, which describes the integration of a country into the world economy, is predicted to preserve food cultures by lowering the costs of local cultural food products.

Our paper contributes to the burgeoning literature on globalisation and health. Using a fixed-effect approach, Vogli, Kouvonen, Elovainio, and Marmot (2014), Goryakin, Lobstein, James, and Suhrcke (2015), and Miljkovic, Shaik, Miranda, Barabanov, and Liogier (2015) investigate the impact of globalisation on overweight and obesity. The economic and social aspects of globalisation are investigated using the KOF globalisation indices, which measure the economic, social, and political dimensions of globalisation for a large number of countries starting in 1970. Health and nutrition data are provided by international institutions.[6] Goryakin et al. (2015) highlight a positive effect of social globalisation and a small negative effect of economic globalisation on female overweight. Miljkovic et al. (2015) also find a positive impact of social globalisation on obesity. However, unlike Goryakin et al. (2015), they find that a subdimension of economic globalisation, trade openness, has a positive impact on country obesity, whereas FDI has no effect. One explanation for these contradictory results is that Miljkovic et al. (2015) do not control for rising incomes, which are likely to increase consumption (via the income effect).

We add to this literature by studying the effects of both social globalisation and trade openness—measured using the subcomponents of the KOF indices—on three key indicators of nutrition transition: the supplies of animal protein, free fat, and sugar available for human consumption. These nutrients exhibit the highest growth rates over the past 40 years. We also test how globalisation affects two main health outcomes associated with the nutrition transition: mean body mass index (BMI) and the prevalence of diabetes.[7]

All of our regressions control for the income effects of economic globalisation. In addition, we use the grouped fixed-effects (GFE) estimator of Bonhomme and Manresa (2015). First, we partition our sample of 70 countries into a number of distinct groups using an algorithm. Then, we group the time-varying component of unobserved heterogeneity by fully interacting group dummies with year dummies. Thereby, we can control for time-varying unobserved heterogeneity under the assumption that it follows a group pattern. In other words, we can account for trends in the potentially unobserved confounders of globalisation. This feature differentiates the GFE estimator from country fixed-effects models that only control for time-constant unobserved heterogeneity. This method thus greatly reduces any omitted-variable bias in the identification of the effect of social globalisation and trade openness. The GFE estimator hence allows for long-run analyses when additional control variables are not available over the longer time period.

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[5] While this paper focuses on inter-country heterogeneity in population-average diet, we do not forget that under- and over-nutrition coexist in many places: as for income distribution, a rise in the average food supply may be accompanied by increasing food inequality within countries.

[6] Vogli et al. (2014) use data from 128 countries, 1980–2008; Goryakin et al. (2015) pool Demographic Health Surveys (on women) from 56 countries, 1991–2009; the sample in Miljkovic et al. (2015) consists of 79 countries, 1986–2008. In addition, a study by Costa-Font and Mas (2016) uses an instrumental-variable approach (without controlling for country fixed-effects) to examine the link between globalisation and obesity. They find a positive effect of globalisation on obesity.

[7] A high intake of sugar increases the risk of overweight and type-2 diabetes (Te Morenga, Mallard, & Mann, 2013; Imamura et al., 2016). Free fats are associated with an increased risk of coronary heart disease mortality (Leren, 1968; de Souza et al., 2015) and animal proteins elevate the risk of type-2 diabetes (Malik, Li, Tobias, Pan, & Hu, 2016). However, diet is not the only channel through which globalisation affects health outcomes. For example, athletes and supermodels can motivate individuals to exercise more and thereby affect health outcomes. Due to the weaknesses of the diabetes data, we report the diabetes results in Section 10 of the online Appendix.

Our results suggest that social globalisation has a positive and significant effect on the supply of animal protein and sugar. This effect is small in size, as a one-unit increase in the index of social globalisation is associated with a 1.2% (0.9%) increase in the energy (kcal/capita/day) derived from animal proteins (sugar). On the contrary, social globalisation has no significant impact on the supply of free fats. Additional GFE regression results show that the effect of social globalisation comes from information flows (e.g., Internet, television, and newspapers). Social globalisation also has a positive effect on mean BMI. Trade openness has no impact on dietary outcomes or health.

The remainder of the paper proceeds as follows. Section 2 explains the theoretical background, and Section 3 describes the data used in the empirical analysis. Section 4 presents the estimation strategy, and the results appear in Section 5. Finally, Section 6 concludes.

2 | THEORETICAL BACKGROUND

In the theoretical model developed by Olivier et al. (2008), social globalisation and trade openness can have opposing effects on the intercountry heterogeneity in (food) cultures. In their model, consumers choose between a domestic cultural good X_i (e.g., national cuisine) and a foreign cultural good $X_{j \neq i}$. Consumption defines membership of a cultural group. Consumers derive utility not only from the consumption of the good but also from social interactions with other individuals consuming the same cultural good. This additional utility can be interpreted as the cultural externality $I_i(q_{i,t})$ at date t from the consumption of good X_i. $I_i(q_{i,t})$ increases in $q_{i,t}$, the fraction of individuals affiliated with culture i at date t, which is bounded below by 1. A larger group reinforces the sense of belonging and facilitates social exchange. The expected utility of a consumer in culture i, who consumes the cultural good X_i at date t is thus:

$$U_i(x_{i,t}) = (I_i(q_{i,t}))x_{i,t}. \tag{1}$$

An individual in culture i consuming a cultural good $X_{j \neq i}$ different from her own cultural good does not benefit from social interactions so that her expected utility at date t is given by

$$U_i(x_{j \neq i,t}) = x_{j,t}. \tag{2}$$

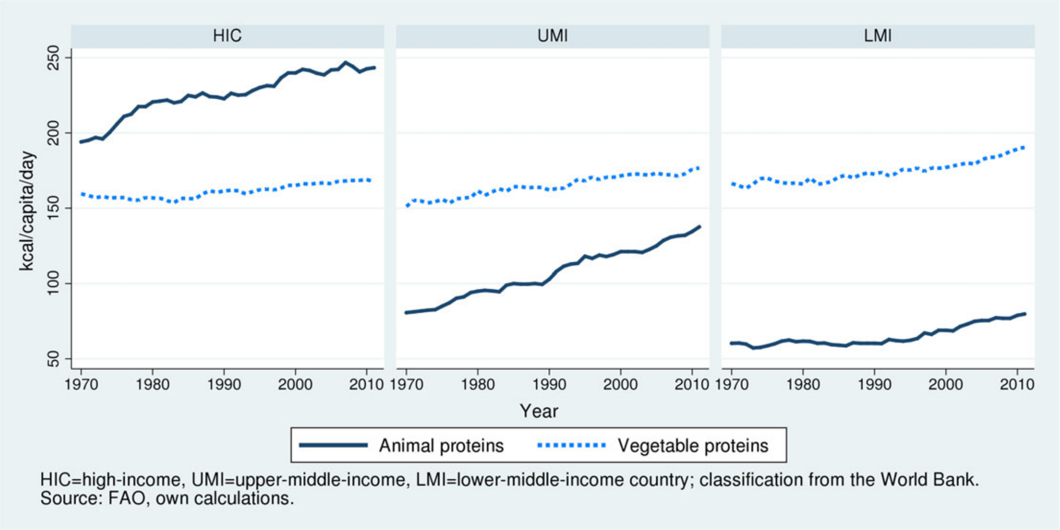
An overlapping generations model then describes the dynamic transmission of cultural preferences across generations. Parents value their children's consumption through the filter of their own consumption. It is thus costly for altruistic parents of type i to see their children make consumption choices of type j. Parents hence have an incentive to transmit their own culture. This incentive rises with the cultural externalities $I_i(q_{i,t})$ and falls with the market price of the domestic good X_i.

As country i becomes socially integrated, the share of the population $q_{i,t}$ consuming the good X_i, now measured at the world level, is smaller than the preintegration level. The cultural externalities $I_i(q_{i,t})$ consequently also fall, reducing the incentive of parents to transmit their own culture to their children. This triggers a reduction in domestic demand, which eventually weakens the dominance of the domestic culture. As the same process takes place simultaneously in all of the countries that globalise, the cultural homogeneity within countries is reduced. In Olivier et al. (2008), social globalisation therefore causes a convergence of (food) cultures across countries and consequently the convergence of nutrition patterns.

On the contrary, the model predicts that trade openness preserves (food) cultures across countries and even leads to cultural homogeneity within a country and cultural divergence across countries. If world integration produces a fall in the market price of the domestic good X_i, its consumption increases. This rise in consumption implies a rise in $q_{i,t}$, which strengthens the cultural externalities $I_i(q_{i,t})$. A higher level of $I_i(q_{i,t})$ increases parents' incentives to transmit their own culture to their children, and thus amplifies the initial effect of trade integration. Prices then affect cultural externalities through their effects on both consumption and $q_{i,t}$. In the long run, all individuals will consume the domestic good X_i. This prediction however relies on the model's assumption of perfect competition. Maystre, Olivier, Thoenig, and Verdier (2014) develop an alternative model based on monopolistic competition, which is empirically compared to that of perfect competition. The support for the model with imperfect competition is much stronger. As such, the predictions for trade openness have to be taken with caution.

3 | DATA

Our empirical analysis focuses on four key outcomes that, according to the literature, characterize the nutrition transition: the shares of animal protein, free fat and sugar in the total food supply available for human consumption, and the country-average BMI, whose trend may reflect changes in nutrition intake.



HIC=high-income, UMI=upper-middle-income, LMI=lower-middle-income country; classification from the World Bank.
Source: FAO, own calculations.

FIGURE 1 The composition of protein supply, 1970–2011. [Colour figure can be viewed at wileyonlinelibrary.com]

3.1 | Nutrition outcomes

The nutrition outcomes are calculated at the country-year level from the raw food supply data from the Food and Agriculture Organization (FAO).[8] The FAO in addition provides the amounts of fats and proteins for each food item in its nomenclature so that the raw data expressed in grams/capita/day can be converted into kcal/capita/day. We then determine the dominant type of fat, carbohydrate, and protein for each food item, using the distinctions below:[9]

- free fats (e.g., fats available from oil, butter, and cream) and animal and vegetable fats,
- sugar and other carbohydrates, and
- animal and vegetable proteins.

Figures 1–3, respectively, show the trends in the composition of the supplies of protein, fat, and carbohydrates between 1970 and 2011 by income group. The amount of energy (kcal/capita/day) derived from animal proteins rose by 70% in upper middle income countries, and 33% in lower middle-income countries, as compared to 25% in high-income countries (Figure 1). Similarly, the supply of free fat doubled in upper middle-income countries and rose by 78% in lower middle-income countries, but only 30% in high-income countries (Figure 2). Last, the supply of sugar grew by about 25% in middle-income countries but rose only little in high-income countries (Figure 3).

3.2 | Health outcomes

BMI is calculated as weight in kilograms divided by the square of height in meters (kg/m^2). This individual index is commonly used to classify underweight, normal weight, overweight, and obesity in adults, despite its well-known limitations (Burkhauser & Cawley, 2008). Country-average BMI data are obtained from NCD Risk Factor Collaboration, a global network of health scientists.[10] The dataset covers the 1975–2011 period and is constructed from population-based studies. The final data are age-standardised (NCD Risk Factor Collaboration, 2016), and we construct the mean BMI variable by averaging the female and male BMI values.

3.3 | Social globalisation and trade openness

To test the predictions of the model in Olivier et al. (2008), we account separately for social globalisation and trade openness. We construct both variables using data from the subcomponents of the KOF globalisation index developed by Dreher (2006). These data are available for a large sample of countries on a yearly basis since 1970.[11]

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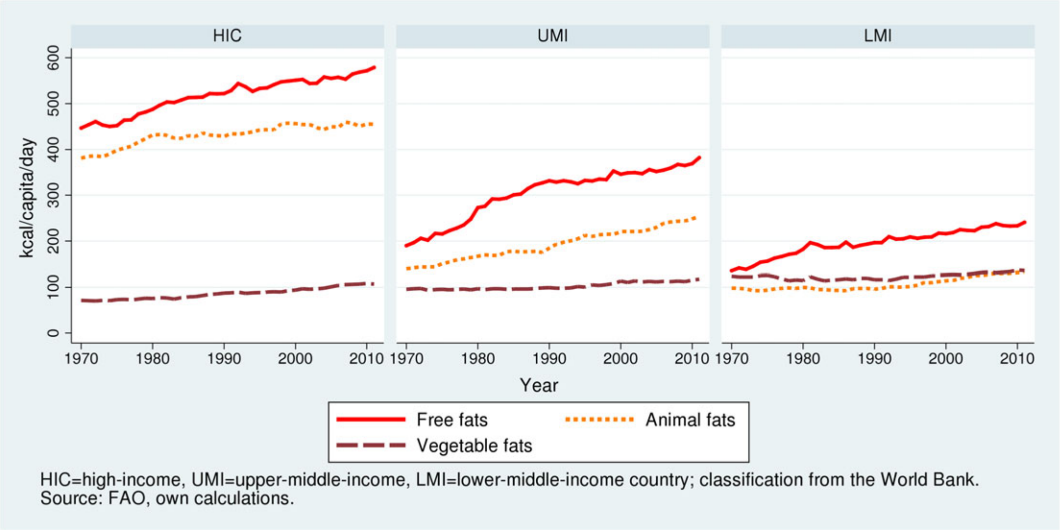
[8] The FAO data cover the 1961–2013 period. Because globalisation data are only available from 1970 and the FAO series contain many missing values for 2012 and 2013, we focus on the 1970–2011 period. The FAO balance-sheet data can be found at http://faostat3.fao.org/download/FB/FBS/E.

[9] The full classification is provided in Section 1 of the online Appendix.

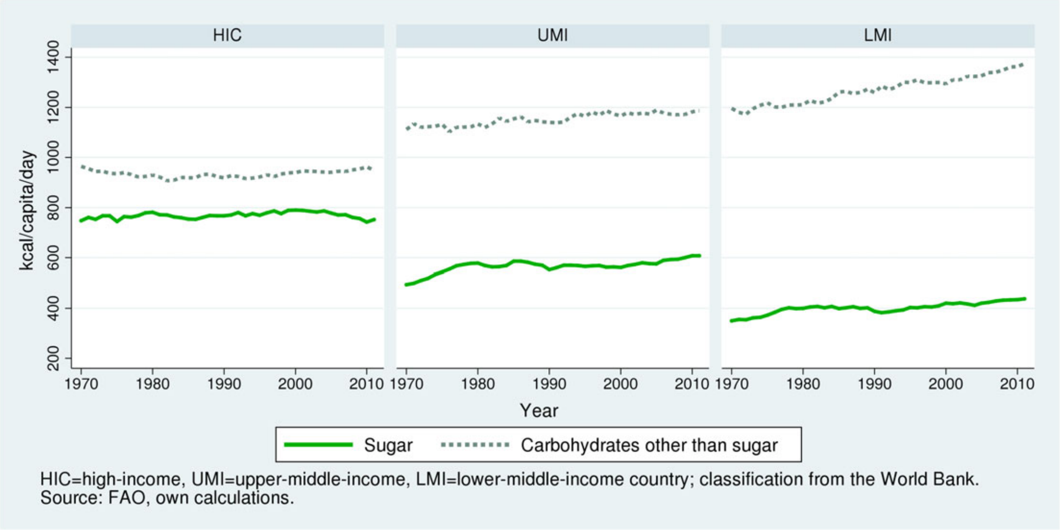
[10] We thank the research group for sharing their data. The data can be accessed at http://www.ncdrisc.org/index.html. We acknowledge that country averages do not reveal which parts of the distribution are responsible for the observed trends.

[11] See Section 2 in the online Appendix for a detailed presentation of the KOF globalisation index. We thank the KOF team for sharing their data. The data can be found at http://globalisation.kof.ethz.ch/.



HIC=high-income, UMI=upper-middle-income, LMI=lower-middle-income country; classification from the World Bank.
Source: FAO, own calculations.

FIGURE 2 The composition of fat supply, 1970–2011. [Colour figure can be viewed at wileyonlinelibrary.com]



HIC=high-income, UMI=upper-middle-income, LMI=lower-middle-income country; classification from the World Bank.
Source: FAO, own calculations.

FIGURE 3 The composition of carbohydrate supply, 1970–2011. [Colour figure can be viewed at wileyonlinelibrary.com]

Social globalisation is defined as a composite index with two subcomponents: (a) personal contacts (measured by telephone traffic, transfers, international tourism, the share of the population that is foreign, and international letters) and (b) information flows (Internet users, television users, and the size of the newspaper sector as a percentage of gross domestic product [GDP]). The trade-openness index combines trade flows and indicators for trade openness (e.g., hidden import barriers, tariffs and taxes on international trade, and all reverse coded). Both social and trade indices take values on a scale from 0 to 100, with higher values indicating higher levels of globalisation. The KOF data further provide two covariates for robustness checks: financial globalisation and stocks of FDI.

As shown in Figure 4, globalisation has intensified in recent decades. High- and middle-income countries experienced a sharp upward trend in both social globalisation and trade openness between the beginning of the 1990s and the 2008 crisis. In our sample, information flows are the main drivers of social globalisation. Social globalisation and trade openness are strongly correlated (0.81), as are the two subcomponents “personal contacts” and “information flows” of social globalisation (0.61).[12] In order to control for the income effect induced by globalisation, we include GDP per capita and its square in all the regressions.[13]

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[12] However, in simple Ordinary Least Squares (OLS) regressions, the variance inflation factor of all of the variables is substantially lower than the rule of thumb value of 10. Multicollinearity is thus not likely to bias the estimates.

[13] GDP per capita at constant 2005 prices in thousands of USD (at purchasing power parity). The data come from the World Development Indicators (World Bank).

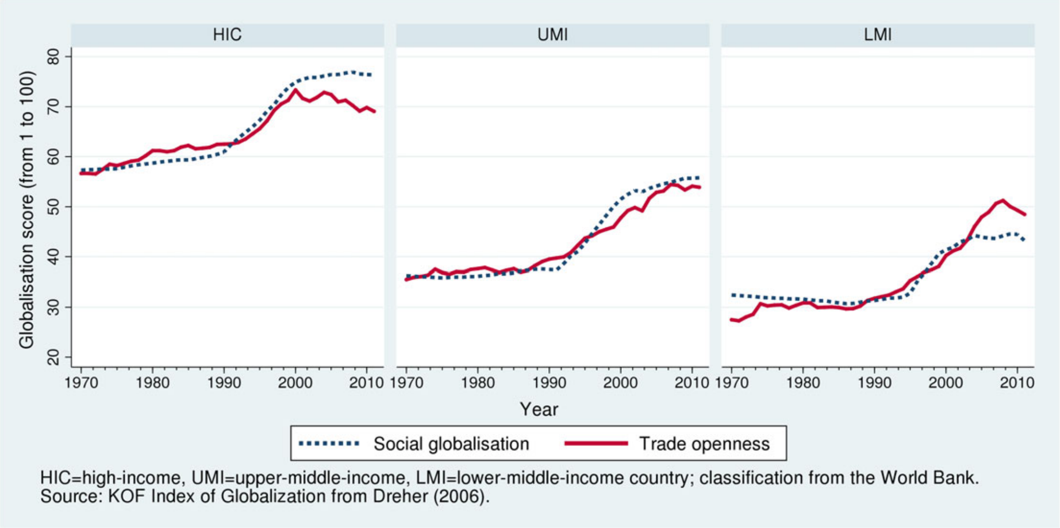

FIGURE 4 Social globalisation and trade openness, 1970–2011. [Colour figure can be viewed at wileyonlinelibrary.com]

We use a balanced estimation sample of 2,940 observations from 70 high- and middle-income countries over a 42-year (1970–2011) period, covering 76% of the world population.[14] Dropping all countries with missing values for any of the outcome variables or covariates produces an estimation sample that is very similar to the original sample (see Section 3 in the online Appendix). Our estimation results are thus not likely to be affected by selection bias. About 40% of the countries are high-income countries and 60% middle-income countries. Table 1 reports some summary statistics. On average, 143 kcal/capita/day come from animal protein, 360 kcal/capita/day from free fat, and about 600 kcal/capita/day from sugar. The mean scores of social globalisation and trade openness are both about 50 points on the 0–100 scale. Mean GDP per capita is about 10,500 U.S. dollars (USD). Due to data availability, the sample used for estimating the effects of globalisation on health outcomes is restricted to the 1975–2011 period and includes $N = 2,590$ observations. The mean BMI is 24.2, that is, slightly below the cutoff point of 25 for overweight defined by the World Health Organisation (WHO, 2015c).

4 | ESTIMATION STRATEGY

4.1 | The GFE estimator

A number of unobservable country characteristics may simultaneously affect a country's level of globalisation and its food supply. For example, cultural norms and unobserved trends in food innovation may both impact on a country's openness and its nutrition patterns. This will bias the estimated effect of globalisation on nutrition and health. A standard solution is to use fixed-effects estimators. However, including country fixed-effects will yield unbiased estimates only if the unobserved country characteristics are constant over time.

We relax this condition by using the GFE model developed by Bonhomme and Manresa (2015). The GFE model relies on the assumption that the number of distinct country-specific time patterns of unobserved heterogeneity is relatively small so that the sample of countries can be partitioned into distinct groups having the same patterns of time-invariant and time-varying unobserved heterogeneity. In practice, countries are endogenously grouped using an iterative algorithm, which alternates between a clustering procedure and regressions. Countries whose time profiles of the outcome variable—net of the effect of covariates—are the most similar are grouped together in order to minimize a least-squares criterion. We then fully interact group dummies with year dummies. Thereby, we allow each group to have a different time trend and the group-membership variables may be seen as an index of the time-varying paths of unobserved heterogeneity.

As the allocation process uses the time profile of the residuals, and not the time profile of the outcome variable, the identification of the effects of the covariates relies on within-group variations over time and across countries. The GFE estimator

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[14] We could have used an unbalanced panel, but our aim is to identify group patterns of heterogeneity that are comparable across countries, that is, identified over the same time period. The data are not weighted by population, as we are interested in predictions at the country level. Moreover, population size changes over time and is likely to be endogenous with respect to nutrition indicators.

TABLE 1 Summary statistics

	Mean	Standard deviation	Minimum	Maximum
Nutrition outcomes				
Animal proteins (kcal/capita/day)	143.03	85.26	22.00	422.72
Free fats (kcal/capita/day)	358.81	194.75	16.92	975.33
Sugar (kcal/capita/day)	598.14	211.65	71.49	1,077.74
Health outcomes				
Mean BMI	24.21	1.84	18.68	28.72
Covariates				
Social globalisation (0–100)	50.05	18.42	8.67	92.92
Personal contacts (0–100)	48.61	19.43	8.81	90.61
Information flows (0–100)	51.65	21.11	4.40	97.83
Trade openness (0–100)	49.57	19.83	5.48	96.58
GDP per capita (in 000's of 2005 PPP USD)	10.50	13.22	0.14	69.09
FDI (0-100)	55.93	23.83	1.00	100.00
Financial globalisation (0–100)	53.82	19.27	3.15	99.12
Urban population (% of population)	60.89	19.97	8.53	94.83
Female labour force participation (LFP; %)	52.91	16.50	10.50	83.30
Consumer price index (CPI)	67.79	26.73	0.00	114.02

Note. The sample used for health outcomes is slightly smaller ($N = 2,590$) than the sample used for nutrition outcomes ($N = 2,940$) due to missing data for the years 1970–1974. Reported values for the covariates are based on the nutrition sample (the values are very similar for the health sample). The sample for the urban population, female LFP, and CPI covers only 1990–2011 and 62 countries. BMI = body mass index; GDP = gross domestic product; PPP = purchasing power parity; USD = U.S. dollars; FDI = foreign direct investment.

assumes that there are at most as many time-varying paths of unobserved heterogeneity as there are groups. A key issue here is therefore the choice of the optimal number of groups (see below).[15]

In our setting, the assumption that countries cluster with respect to the unobserved determinants of nutrition profiles is very plausible. For example, urbanisation is often associated with the nutrition transition. Countries typically follow a S-shaped urbanisation process with moderate rates at the beginning and the end of the process and higher rates in the middle (Clark, 2000). Thus, countries which are at the same stage of the cycle probably encounter parallel urbanisation growth rates over time. Likewise, female labour force participation has also been found to follow an S shape over time (Fernández, 2013).

Our estimated equation is as follows:

$$y_{it} = \beta_1 \text{Social glob}_{it} + \beta_2 \text{Trade open}_{it} + \beta_3 GDPpc_{it} + \beta_4 (GDPpc_{it})^2 + \alpha_{g_i t} + v_{it}, \tag{3}$$

where y_{it} denotes the outcome variable for country i and year t, β_1 and β_2 measure the effect of social globalisation and trade openness respectively, GDP_{pc} is GDP per capita, g_i is country i's group membership, $\alpha_{g_i t}$ denotes the set of year dummies that are individually estimated within each group, and v_{it} is an i.i.d. error term. In some robustness checks, we additionally control for urbanisation, female labour supply and prices, although this forces us to restrict the time window. Note that we differentiate between two types of technological progress: the first is that produced by interactions with other countries and the country's endowments and resources (e.g., innovation capabilities and political reforms); the second is captured by the GFE estimator, which controls for country-specific factors. The social-globalisation variables thus pick up only the first type of technological progress.

4.2 | Detailed estimation procedure

We now present the main features of the estimation procedure (for a detailed description, see Bonhomme and Manresa, 2015). Group membership is estimated together with the model coefficients in order to minimize the following least-squares objective function:

$$F(\boldsymbol{\theta}, \boldsymbol{\alpha}, \boldsymbol{\gamma})_G = \sum_{i=1}^{N} \sum_{t=1}^{T} \left(y_{it} - x_{it}' \boldsymbol{\theta} - \alpha_{g_i t} \right)^2, \tag{4}$$

where $\boldsymbol{\theta}$ is the coefficient vector of the observed covariates x_{it}, $\alpha_{g_i t}$ are the group-specific time effects for all g_i taking on values in $\{1, ...G\}$ and all $t \in \{1, ...T\}$. We denote as $\boldsymbol{\alpha}$ the set of all the α_{gt}'s. Because the sum of squared residuals is minimised over

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[15] The GFE approach is related to finite mixture models (See Section 4 in the online Appendix).

the entire time period T, the algorithm takes into account any unobserved shocks that countries experience during T and groups together countries whose residuals exhibit a similar time profile. Consequently, group membership for each country is fixed over T and is denoted by the g_i. We define as $\boldsymbol{\gamma}$ the set of all g_i's. The estimation algorithm then alternates between an assignment step and an update step. Note that country grouping can vary with the outcome variables y_{it} and the vectors of observed covariates $\boldsymbol{\theta}$.

Step 1 - Assignment step. Given the parameter values at iteration s (e.g., $\boldsymbol{\theta}^s$ and $\boldsymbol{\alpha}^s$), the countries are sorted into groups by minimizing the sum of the squared residuals over all years and for each country i:

$$g_i = \underset{g\in\{1,\dots,G\}}{\operatorname{argmin}} \sum_{t=1}^{T} \left(y_{it} - x'_{it}\boldsymbol{\theta}^s - \alpha^s_{gt}\right)^2 \tag{5}$$

The assignment step results in a grouping $\boldsymbol{\gamma}^s = \left\{g_i^s; i = 1, \dots, N\right\}$.

Step 2 - Update step. The grouping $\boldsymbol{\gamma}^s$ is used to estimate by Ordinary Least Squares (OLS) a new set of coefficients $(\boldsymbol{\theta}^{s+1}, \boldsymbol{\alpha}^{s+1})$. The alternation between the assignment and update steps stops when the difference in coefficients between two iterations is smaller than some threshold (10^{-64} in our regressions).

One drawback of the procedure is that the algorithm may converge to a local minimum and not to the global minimum, depending on the choice of the initial starting values. To address this issue, Bonhomme and Manresa (2015) incorporate a variable neighbourhood-search method in the algorithm (see Section 5 in the online Appendix) and show that the modified algorithm reaches the global minimum. This is the algorithm that we use. Last, group membership having been estimated, the variance–covariance matrix is calculated by bootstrapping the entire estimation procedure (100 replications).[16]

4.3 | Optimal number of groups

The choice of the optimal number of groups is a balancing problem. On the one hand, if the chosen number exceeds the true number of groups, the GFE estimator remains consistent. In this case, the time profile of unobserved heterogeneity will simply be very similar across some groups. Increasing the number of groups reduces statistical efficiency but will not change the estimates too much. On the other hand, if the chosen number of groups is smaller than the true number of groups, and if the unobserved effects are correlated with the covariates, the GFE estimator becomes inconsistent (due to omitted-variable bias). Increasing the number of groups will then increase efficiency and affect the estimates.

To determine the optimal number of groups (separately for each outcome variable), we run GFE estimations with a number of groups G varying between 1 and 12. We first calculate the Bayesian information criterion (BIC) to assess the statistical benefit of having more groups.[17] According to Bonhomme and Manresa (2015), the BIC provides an upper bound on the true number of groups if T (years) exceeds N (countries), which is the case in our sample. Second, we test for coefficient stability with increasing G.

To illustrate the procedure, Table 2 shows the objective function, the BIC value and the GFE coefficient estimates for animal proteins (in logarithms).[18] It also shows the results for a benchmark specification that includes country and year fixed-effects, and a second specification where countries are grouped a priori according to their GDP (high, upper middle, and lower middle) and these group dummies are interacted with the year fixed-effects. The GFE regressions yield the lowest BIC value for $G = 8$, which is therefore an upper bound on the true number of groups. As depicted in Figure 5, the estimated coefficients on social globalisation and trade openness are fairly stable as we move from $G = 6$ to $G = 8$, indicating that the true G lies between 6 and 8 groups. The value of the GFE objective function with $G = 6$ groups is 85% lower than that with $G = 1$, that is, a simple OLS specification with year fixed-effects. A further increase in the number of groups does not produce a significant improvement in the objective function. From the above, we select $G = 6$ as the optimal number of groups for animal proteins.

Table 2 also shows two additional results. First, the GFE estimator with $G \geqslant 6$ groups yields a smaller value of the objective function than the fixed-effects estimator, showing the advantage of accounting for time-varying cross-country heterogeneity. Second, the value of the objective function when countries are simply classified according to their income group is substantially larger than that from the GFE estimator. This last result suggests that grouping by income does not capture much of the unobserved time-varying heterogeneity.

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[16] The code is available upon request from the authors.

[17] The BIC is a penalized measure of statistical fit, with the penalty depending on the number of parameters. $BIC(G) = \frac{1}{NT} * \hat{F}_G + \hat{\sigma}^2 \frac{GT+N+K}{NT} ln(NT)$, with Gbeing the number of groups, $N$the number of countries in the sample, $T$the number of years, and $K$the number of covariates. $\hat{F}_G$ is the sum of squared residuals of the regression with Ggroups and $\hat{\sigma}^2$ is an estimate of the variance of the error term v_{it}, which is calculated with $G_{max} = 12$. $\hat{\sigma}^2 = \frac{1}{NT-G_{max}T-N-K}\hat{F}_G$.

[18] Sections 6 and 9 in the online Appendix present the optimal number of groups for the two other nutrition outcomes (free fats and sugar), as well as for the health outcome (BMI).

TABLE 2 GFE estimates (outcome variable: animal proteins)

Number of groups	Objective function	BIC	Social globalisation	Trade openness	GDP per capita	Squared GDP per capita
1	315.30	0.1115	0.017[a]	0.001	0.045[a]	−0.001[a]
			(0.004)	(0.003)	(0.009)	(0.000)
2	162.95	0.0612	0.017[a]	−0.001	0.035[a]	−0.001[b]
			(0.005)	(0.004)	(0.013)	(0.000)
3	112.87	0.0457	0.019[a]	−0.001	0.045[b]	−0.001[a]
			(0.005)	(0.004)	(0.018)	(0.000)
4	88.12	0.0388	0.016[a]	−0.000	0.061[a]	−0.001[a]
			(0.004)	(0.004)	(0.015)	(0.000)
5	71.10	0.0346	0.015[a]	0.000	0.051[a]	−0.001[b]
			(0.004)	(0.003)	(0.016)	(0.000)
6	58.50	0.0318	0.012[a]	0.001	0.053[a]	−0.001[a]
			(0.004)	(0.003)	(0.015)	(0.000)
7	51.80	0.0311	0.015[a]	0.001	0.058[a]	−0.001[a]
			(0.004)	(0.003)	(0.014)	(0.000)
8[d]	46.99	0.0309	0.013[a]	0.001	0.051[a]	−0.001[b]
			(0.003)	(0.003)	(0.016)	(0.000)
9	43.01	0.0311	0.017[a]	−0.000	0.061[a]	−0.001[a]
			(0.003)	(0.003)	(0.014)	(0.000)
10	39.17	0.0314	0.013[a]	0.002	0.047[a]	−0.001[b]
			(0.004)	(0.003)	(0.016)	(0.000)
11	35.33	0.0316	0.012[a]	0.007[b]	0.038[b]	−0.001[c]
			(0.004)	(0.003)	(0.017)	(0.000)
12	31.74	0.0319	0.010[a]	0.007[b]	0.040[b]	−0.001[c]
			(0.004)	(0.003)	(0.016)	(0.000)
Alternative specifications						
Country & year	62.11		0.016[a]	0.002	0.005	−0.000
Fixed-effects			(0.004)	(0.002)	(0.012)	(0.000)
Income groups	248.60		0.014[a]	0.001	0.020[b]	−0.000[b]
x year fixed-effects			(0.004)	(0.003)	(0.010)	(0.000)

Note. This table reports the value of the objective function and the GFE estimated coefficients for $G = 1, \ldots, 12$. GFE standard errors are calculated with 100 bootstrap replications. The last two estimations provide the results from two alternative specifications: (a) with country and year fixed-effects and (b) with countries classified according to their income group (high, upper middle, and lower middle income). The income-group dummies are interacted with year fixed-effects. GFE = grouped fixed-effects; BIC = Bayesian information criterion; GDP = gross domestic product.

[a] Significance at the 1% level.

[b] Significance at the 5% level.

[c] Significance at the 10% level.

[d] The regression with the minimum BIC value.

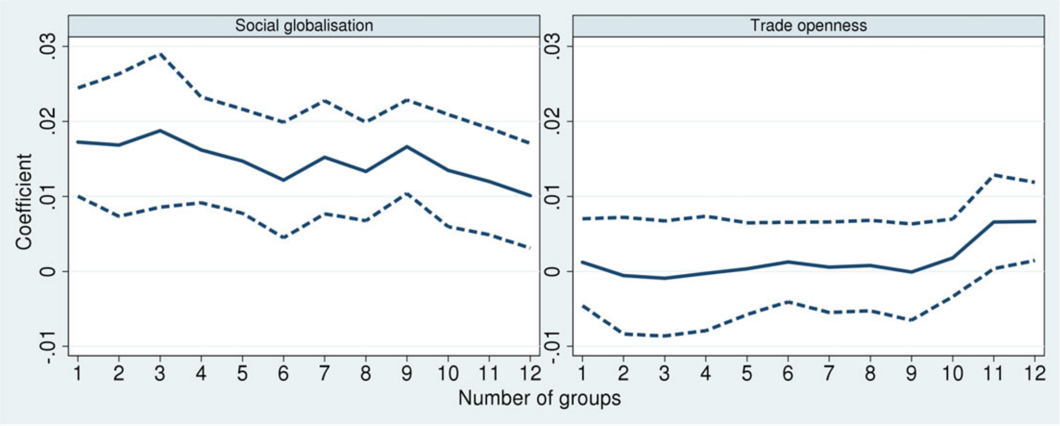

FIGURE 5 Supply of animal proteins (log): globalisation coefficients. [Colour figure can be viewed at wileyonlinelibrary.com]

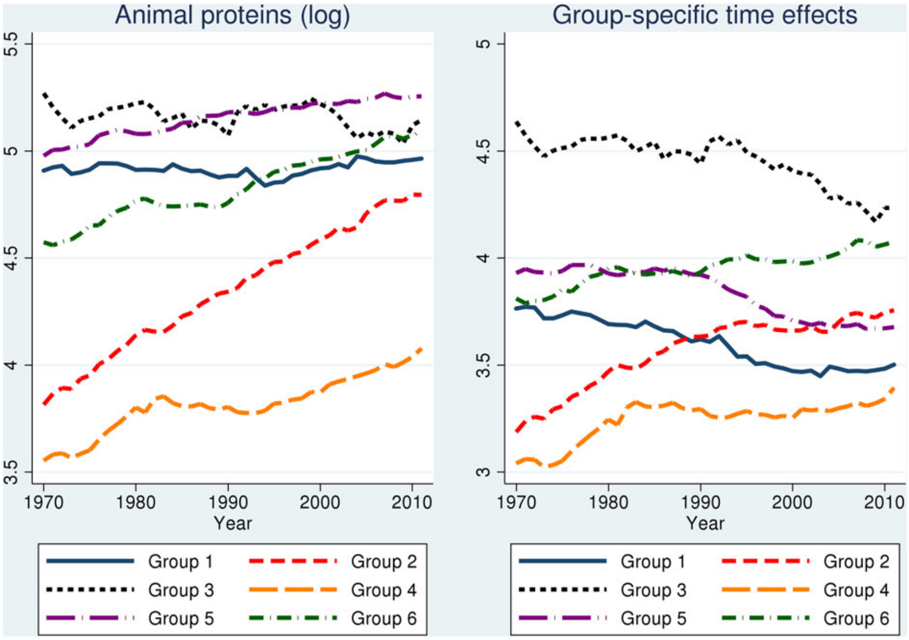

FIGURE 6 Supply of animal proteins (log) and group time effects, by group. [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 6 illustrates the usefulness of the GFE approach in controlling for the unobserved time-varying determinants of animal-protein supply. It presents the time trends in the supply of animal proteins (left) and the estimated grouped time effects α_{gt} (right) for the six groups of countries. In the left panel, some groups have rather flat trends in animal proteins whereas others experience significant growth rates over the period. Group 2, with a sharp upward trend, includes several countries not only in the Middle East and Central America but also in China and Korea. Groups 4 and 6 exhibit a parallel increase in animal proteins (with a much lower initial level for group 4). Group 4 includes countries not only in Sub-Saharan Africa but also in India and Indonesia, whereas group 6 consists mostly of Latin American countries. Groups 1, 3, and 5 remain at a constant high level of animal protein supply over the period. These groups include countries not only in Europe and North and Latin America but also Japan, Australia, and some countries in Sub-Saharan Africa.[19] The right panel of the figure clearly shows the importance of accounting for time-varying unobserved heterogeneity: the group-specific time effects are not flat and parallel over time and are thus not consistent with a fixed-effects model.

5 | RESULTS

This section presents and compares the estimation results from OLS, standard fixed-effect, and GFE models.

5.1 | Nutrition and health outcomes

Table 3 shows the OLS, fixed-effect, and GFE estimation results for the supplies of animal protein, free fat, and sugar, which are all expressed in logarithms (kcal/capita/day). Columns 1, 4, and 7 report the OLS estimates with year fixed-effects capturing yearly shocks that are common to all countries. Social globalisation is here significantly and positively associated with animal protein, free fat, and sugar supply (with $p < .01$ for animal proteins and sugar and $p < .1$ for free fats). The estimated coefficients on trade openness are insignificant. Columns 2, 5, and 8 show the results with country fixed-effects. Once we control for time-invariant unobservable characteristics, the coefficient on social globalisation becomes insignificant for free fats, suggesting that the previous OLS results were driven by some omitted fixed country characteristics. Columns 3, 6, and 9 present the GFE estimator results. Here, we control for the time-varying unobservable determinants of diet through the inclusion of group-specific time fixed-effects. The effect of social globalisation on the supply of animal proteins (resp. sugar) remains significant at the 1% (resp. 5%) level. Social globalisation again has no impact on free fats. One additional point in the social globalisation index is associated with a 1.2% rise in the supply of animal proteins (kcal/capita/day) and a 0.9% rise in the supply of sugar. This rise of 1.2% is equivalent to an additional 1.7 kcal/capita/day derived from animal proteins on average (with a minimum of 0.38

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[19] See Table S7 in the online Appendix for the detailed country grouping.

TABLE 3 Globalisation and nutrition outcomes

	Animal proteins (log)			Free fats (log)			Sugar (log)		
Outcome estimator	**OLS (1)**	**Fixed-effects (2)**	**GFE (3)**	**OLS (4)**	**Fixed-effects (5)**	**GFE (6)**	**OLS (7)**	**Fixed-effects (8)**	**GFE (9)**
Social globalisation	0.017[a]	0.016[a]	0.012[a]	0.009[c]	0.006	0.001	0.017[a]	0.008[b]	0.009[b]
	(0.004)	(0.004)	[0.004]	(0.005)	(0.004)	[0.007]	(0.004)	(0.004)	[0.004]
Trade openness	0.001	0.002	0.001	−0.003	0.001	0.004	−0.003	0.002	−0.001
	(0.003)	(0.002)	[0.003]	(0.004)	(0.002)	[0.004]	(0.002)	(0.002)	[0.002]
GDP per capita	0.045[a]	0.005	0.053[a]	0.060[a]	−0.004	0.039[c]	0.019[b]	−0.001	0.012
	(0.009)	(0.012)	[0.015]	(0.015)	(0.021)	[0.021]	(0.007)	(0.009)	[0.011]
Squared GDP per capita	−0.001[a]	−0.000	−0.001[a]	−0.001[a]	−0.000	−0.001[c]	−0.000[a]	−0.000	−0.000
	(0.000)	(0.000)	[0.000]	(0.000)	(0.000)	[0.000]	(0.000)	(0.000)	[0.000]
Fixed-effects									
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country		Yes			Yes			Yes	
Group			Yes			Yes			Yes
Group year			Yes			Yes			Yes
Observations	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940
Objective function	315.30	62.11	58.50	503.65	108.74	106.55	229.08	207.70	41.66

Note. This table shows the OLS, fixed-effects, and GFE results for the three nutrition outcomes: animal proteins, free fats, and sugar supply (in logarithms). Robust standard errors appear in parentheses. The bootstrapped standard errors are in square brackets (100 replications). The GFE results are obtained with $G = 6$ groups. GFE = grouped fixed-effects; GDP = gross domestic product.

[a] Significance at the 1% level.

[b] Significance at the 5% level.

[c] Significance at the 10% level.

TABLE 4 Globalisation and mean BMI

	Mean BMI		
Outcome estimator	**OLS (1)**	**Fixed-effects (2)**	**GFE (3)**
Social globalisation	0.067[a]	−0.004	0.026[c]
	(0.015)	(0.007)	(0.015)
Trade openness	0.007	0.009[b]	0.005
	(0.012)	(0.003)	(0.008)
GDP per capita	0.001	−0.043	0.067
	(0.037)	(0.027)	(0.055)
Squared GDP per capita	−0.001	0.000	−0.001
	(0.001)	(0.000)	(0.001)
Fixed-effects			
Year	Yes	Yes	Yes
Country		Yes	
Group			Yes
Group year			Yes
Observations	2,590	2,590	2,590
Objective function	3,922.94	169.42	156.68

Note. This table reports the OLS, fixed-effects, and GFE results for country-average BMI. Robust standard errors appear in parentheses. Bootstrapped standard errors are in square brackets (100 replications). The GFE results are obtained with $G = 11$ groups. BMI = body mass index; GFE = grouped fixed-effects; GDP = gross domestic product.

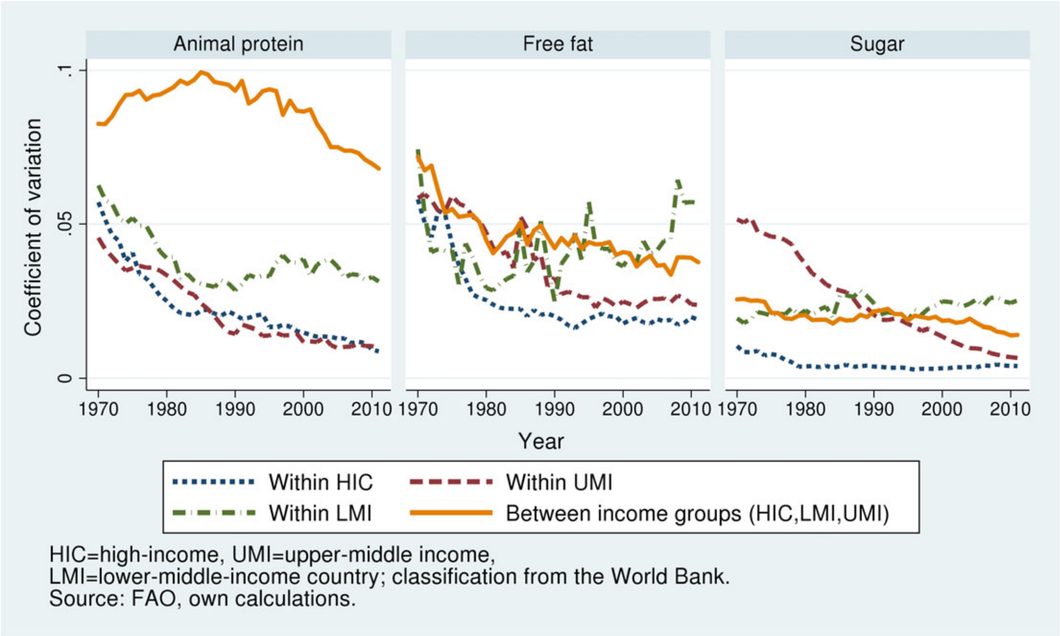
[a] Significance at the 1% level.

[b] Significance at the 5% level.

[c] Significance at the 10% level.

and a maximum of 4.3 additional kcal/capita/day). Last, the positive estimated coefficient on GDP per capita and the negative coefficient on its square suggest a hump-shaped relationship between GDP per capita and the outcome variables. The turning point for animal proteins is at 26,500 USD. This value is slightly over the mean GDP per capita of high-income countries in our sample over the 1970–2011 period (22,295 USD).

Table 4 presents the estimation results for mean BMI. The OLS estimates (columns 1) show that there is a positive and significant correlation between social globalisation and mean BMI ($p < .01$). Including country fixed-effects renders the coefficient on social globalisation insignificant. After controlling for group time-varying heterogeneity, the coefficient on social globalisation becomes positive and significant at the 10% level. A one-unit rise in the index of social globalisation is associated with an increase in the country-average mean BMI of 0.026 points. A one standard deviation (18.42) rise in the social globalisation index thus corresponds to an increase of about 2% in mean BMI. The coefficient on trade openness is insignificant.



HIC=high-income, UMI=upper-middle income,
LMI=lower-middle-income country; classification from the World Bank.
Source: FAO, own calculations.

FIGURE 7 The coefficient of variation for nutrition outcomes, 1970–2011. [Colour figure can be viewed at wileyonlinelibrary.com]

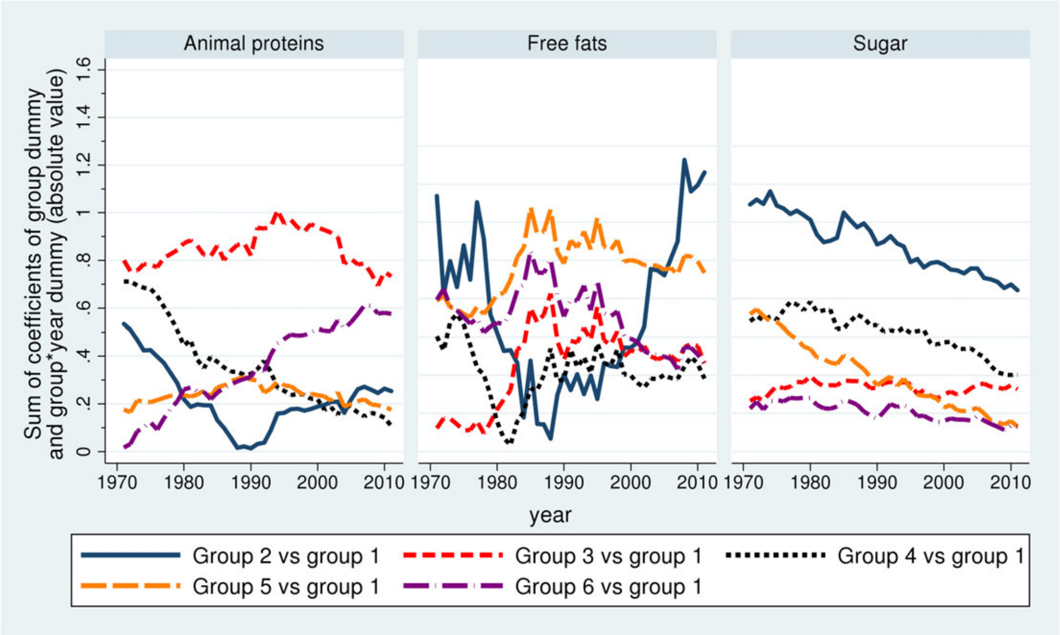


FIGURE 8 Convergence between groups for nutrition outcomes after controlling for social globalisation, trade openness, and gross domestic product per capita, 1970–2011 *Note*. The groupings may vary from one outcome to another. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 Robustness check: nutrition outcomes with additional covariates

Outcome estimator	**GFE**					
	Animal proteins (log)		**Free fats (log)**		**Sugar (log)**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Social globalisation	0.011[a]	0.010[a]	−0.004	0.006	0.009[b]	0.007[b]
	(0.004)	(0.003)	(0.006)	(0.004)	(0.004)	(0.003)
Trade openness	0.004	0.003	0.002	−0.000	−0.002	0.002
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
FDI		0.000		−0.001		0.001
		(0.001)		(0.001)		(0.001)
Financial globalisation		0.001		0.001		0.001
		(0.002)		(0.002)		(0.001)
GDP per capita	0.025[c]	0.018[c]	0.026[c]	0.020	0.011	0.011
	(0.014)	(0.010)	(0.014)	(0.014)	(0.011)	(0.010)
Squared GDP per capita	−0.000	−0.000	−0.000	−0.000	−40.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Urbanisation		0.011[a]		0.005		0.007[a]
		(0.003)		(0.004)		(0.003)
Female LFP		0.001		−0.004		−0.009[a]
		(0.003)		(0.004)		(0.003)
CPI		0.002[c]		0.001		−0.000
		(0.001)		(0.001)		(0.001)
Fixed-effects						
Year	Yes	Yes	Yes	Yes	Yes	Yes
Group	Yes	Yes	Yes	Yes	Yes	Yes
Group year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,364	1,364	1,364	1,364	1,364	1,364
Objective function	10.17	9.21	14.53	11.95	7.04	6.89

Note. This table shows the GFE estimation results for the supplies of animal proteins, free fats, and sugar (in logarithms). Due to the additional covariates, the sample covers only the 1990–2011 period and 62 countries. Columns 1, 3, and 5 show the main specification using this reduced sample. Bootstrapped standard errors (100 replications). The GFE results are obtained with $G = 8$ (except $G = 7$ for columns 2 and 6 and $G = 9$ for column 4). GFE = grouped fixed-effects; FDI = foreign direct investment; GDP = gross domestic product; LFP = labour force participation; CPI = consumer price index.

[a] Significance at the 1% level.

[b] Significance at the 5% level.

[c] Significance at the 10% level.

5.2 | Understanding the impact of social globalisation on the nutrition transition

Because the nutrition transition constitutes one important cause of subsequent health outcomes, we here further analyse the drivers of the nutrition transition. Our results suggest that globalisation is far from being the main direct driver of the moderate convergence of national nutrition patterns. Figure 7 shows the coefficient of variation for the nutrition outcomes (the ratio of the standard deviation to the mean) within and between country groups over time. The convergence between income groups is stronger for animal proteins and free fats than for sugar. Figure 8 plots the changes in the difference in the estimated time effects between groups over time.[20] After controlling for globalisation and GDP, the residual differences between groups attenuate over time for animal proteins (except in group 6) and sugar, but there is no clear downward trend is free fats. Overall, this suggests that other unobserved factors are likely to be at play.

Part of the time-varying unobserved heterogeneity in nutrition outcomes may indeed be related to other factors that are commonly associated with the nutrition transition, namely FDI, financial globalisation, urbanisation, female labour force participation and the consumer price index (Popkin, 1999; Datar, Nicosia, & Shier, 2014; Dubois, Griffith, & Nevo, 2014). We consider this possibility by running GFE regressions that include these factors (see Section 8 in the online Appendix for the detailed results). Due to data availability, the sample is reduced to the 1990–2011 period and eight countries are dropped. Table 5 reports the results. Social globalisation continues to have a positive and significant effect on animal proteins and sugar. Column 1 shows our main specification using the restricted sample, and column 2 the estimates with the additional control vari-

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[20] These differences are calculated as the sum of the group dummy and the grouped time effect, for example, for group 3 and year 1971 it is the sum of $group_3$ and $group_3 * year_{1971}$ relative to the base group (group 1).

TABLE 6 The subcomponents of social and economic globalisation and nutrition outcomes

	Animal proteins (log)			Free fats (log)			Sugar (log)		
Outcome estimator	**OLS (1)**	**Fixed-effects (2)**	**GFE (3)**	**OLS (4)**	**Fixed-effects (5)**	**GFE (6)**	**OLS (7)**	**Fixed-effects (8)**	**GFE (9)**
Personal contacts	0.005[b]	0.005[c]	0.004	0.003	0.000	0.002	0.004	0.000	−0.000
	(0.002)	(0.003)	[0.003]	(0.003)	(0.004)	[0.005]	(0.003)	(0.002)	[0.003]
Information flows	0.012[a]	0.010[a]	0.012[a]	0.005[c]	0.004[c]	0.004	0.013[a]	0.006[a]	0.007[a]
	(0.003)	(0.002)	[0.003]	(0.003)	(0.003)	[0.004]	(0.002)	(0.002)	[0.002]
Trade openness	0.002	0.002	0.003	−0.002	0.001	0.005	−0.002	0.002	−0.001
	(0.003)	(0.002)	[0.003]	(0.004)	(0.002)	[0.004]	(0.003)	(0.002)	[0.003]
GDP per capita	0.044[a]	0.006	0.059[a]	0.061[a]	−0.002	0.047[b]	0.017[b]	0.001	0.006
	(0.009)	(0.012)	[0.014]	(0.015)	(0.021)	[0.018]	(0.008)	(0.009)	[0.010]
Squared GDP per capita	−0.001[a]	−0.000	−0.001[a]	−0.001[a]	−0.000	−0.001[b]	−0.000[a]	−0.000	−0.000
	(0.000)	(0.000)	[0.000]	(0.000)	(0.000)	[0.000]	(0.000)	(0.000)	[0.000]
Fixed-effects									
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country		Yes			Yes			Yes	
Group			Yes			Yes			Yes
Group year			Yes			Yes			Yes
Observations	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940
Objective function	313.10	61.12	47.06	505.96	108.42	83.12	221.86	45.26	24.05

Note. This table reports the OLS, fixed-effects, and GFE results for the subcomponents of social and economic globalisation and the nutrition outcomes. Robust standard errors are in parentheses. Bootstrapped standard errors appear in square brackets (100 replications). The GFE results are obtained with $G = 8$ groups for animal proteins and free fats and $G = 10$ for sugar. GFE = grouped fixed-effects; GDP = gross domestic product.

[a] Significance at the 1% level.

[b] Significance at the 5% level.

[c] Significance at the 10% level.

ables. The coefficient estimates remain almost unchanged. We find again no significant effect of social globalisation or trade openness on free fats (columns 3 and 4).

This result contradicts the theoretical prediction of Olivier et al. (2008) that trade openness preserves food cultures, as otherwise we would have found a negative effect of trade openness on the supply of animal proteins, free fats, and sugar. However, as previously mentioned, this prediction relies on the strong assumption of perfect competition.[21] Moreover, countries may preserve their food culture with respect to spices and main ingredients even though the production process may change. Individuals may still eat traditional dishes but increase the size of the meat portions and rely more on processed food items, which contain more sugar and salt (Monteiro, 2009). Food culture may then be preserved but with the nutrition of ingredients becoming more similar to that in what is commonly understood as the "Western diet."

To better understand the drivers of the globalisation–nutrition link, we decompose the social-globalisation variable into its two main subcomponents (personal contacts and information flows). The OLS, country fixed-effects, and GFE estimation results appear in Table 6. The positive effect of social globalisation on animal proteins and sugar (in columns 3 and 9) is driven by information flows (e.g., Internet, television, and trade in newspapers). The subcomponents of social globalisation have no impact on free fats, which is consistent with our main results (see Table 3, column 6). One explanation of our results could be the role of food advertising in the media. A global review concluded that the most common food products promoted to children are items containing a lot of sugar, such as cereals, soft drinks, savoury snacks, and confectionery, as well as fast foods (Cairns, Angus, Hastings, & Caraher, 2013). Existing research documents a positive association between the food advertising of energy-dense nutrition-poor foods (including meat) and a greater desire for consumption among adults as well as a higher actual intake among children (Folkvord, Anschütz, Boyland, Kelly, & Buijzen, 2016). A positive effect of advertising on meat consumption has also been reported in work using demand models for the United States (Brester & Schroeder, 1995; Capps & Park, 2002).

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[21] The analysis in Hawkes (2005) suggests that (foreign) food companies dominate the industrial sector in many countries.

6 | CONCLUSION

Globalisation is often seen as the key driver of the nutrition transition and the "global epidemics" of obesity and diabetes. However, existing evidence concentrates on the economic aspects of globalisation and mostly consists of case studies of foreign investment and trade openness.

In this paper, we use a panel of 70 high- and middle-income countries observed between 1970 and 2011 to provide empirical evidence on the distinct effects of social globalisation and trade openness on the supply of animal protein, free fat, and sugar, as well as on BMI. We apply the standard fixed-effect estimator and the GFE estimator developed by Bonhomme and Manresa (2015). Although the former controls for country-specific time-invariant heterogeneity, the latter can be used with group patterns of unobserved time-varying heterogeneity.

Our results suggest that the social dimension of globalisation has a positive and significant effect on the supply of animal proteins and sugar, as well as on mean BMI. Controlling for income, trade openness has no direct impact on nutrition and health outcomes. These findings are relevant for economies and policy-makers, as meat-intensive diets have negative health and environmental consequences (e.g., health care costs and externalities). We further show that the effect of social globalisation on animal proteins and sugar is driven by information flows via television and the Internet. This highlights the importance of the cultural dynamics of preferences in consumption and health behaviours. Given that social globalisation seems to be a significant driver of changing diets, further research should focus on factors related to the social dimension of globalisation, such as food advertising on television and the Internet.

Last, from a methodological perspective, we show that the GFE estimator has the advantage of controlling for group patterns in unobserved time-varying heterogeneity. The GFE estimator should therefore be seen as an efficient alternative when modelling outcomes that are characterised by time-invariant and time-varying unobserved heterogeneity.

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Additional Supporting Information may be found online in the supporting information tab for this article.

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