

Ultra-processed foods and the nutrition transition: global, regional and national trends, food systems transformations and political economy drivers

Phillip Baker^{1,2}, Priscila Machado^{1,2}, Thiago Santos³, Katherine Sievert², Kathryn Backholer⁴, Michalis Hadjikakou⁵, Cherie Russell², Oliver Huse⁴, Colin Bell⁴, Gyorgy Scrinis⁶, Anthony Worsley^{1,2}, Sharon Friel⁷, Mark Lawrence^{1,2}

1. Institute for Physical Activity and Nutrition, Deakin University, Geelong, Australia
2. School of Exercise and Nutrition Science, Deakin University, Geelong, Australia
3. Federal University of Pelotas, Pelotas, Brazil
4. Global Obesity Centre, Deakin University, Geelong, Australia
5. School of Life and Environmental Sciences, Deakin University, Geelong, Australia
6. School of Agriculture and Food, University of Melbourne, Melbourne, Australia
7. School of Regulation and Global Governance, Australian National University, Canberra, Australia

Corresponding author details: Phillip Baker, Institute for Physical Activity and Nutrition, Deakin University, Geelong, Australia; phil.baker@deakin.edu.au

Key words: ultra-processed foods, sugar sweetened beverages, nutrition transition, palm oil, food systems, political economy

Running title: Ultra-processed foods and the nutrition transition

Conflicts of interest: The authors declare no conflicts of interest.

Acknowledgements: Phillip Baker received income through an Alfred Deakin Postdoctoral Research Fellowship provided by Deakin University.

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: [10.1111/obr.13126](https://doi.org/10.1111/obr.13126)

Abstract

Understanding the drivers and dynamics of global ultra-processed food (UPF) consumption is essential, given the evidence linking these foods with adverse health outcomes. In this synthesis review we take two steps. First, we quantify per capita volumes and trends in UPF sales, and ingredients (sweeteners, fats, sodium, cosmetic additives) supplied by these foods, in countries classified by income and region. Second, we review the literature on food systems and political economy factors that likely explain the observed changes. We find evidence for a substantial expansion in the types and quantities of UPFs sold worldwide, representing a transition towards a more processed global diet, but with wide variations between regions and countries. As countries grow richer, higher volumes and a wider variety of UPFs are sold. Sales are highest in Australasia, North America, Europe and Latin America, but growing rapidly in Asia, the Middle East and Africa. These developments are closely linked with the industrialisation of food systems, technological change and globalisation, including growth in the market and political activities of transnational food corporations, and inadequate policies to protect nutrition in these new contexts. The scale of dietary change underway, especially in highly-populated middle-income countries, raises serious concern for global health.

Introduction

In this paper, our starting premise is that human diets are becoming more highly processed, with important consequences for global nutrition, public health and the environment. Although several schemas for categorising foods according to their degree of processing have been proposed ¹, the NOVA system developed by Monteiro and colleagues has become the most widely used in research and policy ¹⁻³. This distinguishes between four categories of food: *unprocessed and minimally processed foods* as edible parts of whole foods, modified without adding new substances to extend shelf-life, safety or palatability e.g. milled cereals, meats, eggs, milk, vegetables, nuts and seeds; *processed culinary ingredients* as extracted substances, or substances collected from nature, for use in food preparation e.g. vegetable oils, vinegar, butter, sugar, salt; *processed foods* as combinations of culinary ingredients, unprocessed or minimally processed foods e.g. canned fish, cheese, artisanal breads, cured meats; and *ultra-processed foods* as ready-to-consume and ready-to-heat formulations, made by combining substances derived from foods with cosmetic additives, typically through a series of industrial processes e.g. soft drinks, confectionary, savoury snacks, many packaged breads and sweet biscuits ⁴.

Foods in the first three NOVA categories have long been dietary staples. Basic food processing has played an important role in human nutrition and evolution ever since the use of fire began between 1.5

and 2 million years ago⁵⁻⁸. The conversion of foraged and cultivated foods into more palatable, safe, nutritious and durable forms – e.g. through heating, cutting, grinding, drying, salting, fermenting and smoking – enabled hunter-gatherers and pastoral groups to thrive across many ecological zones, and later in the agrarian era (beginning ~12,000 years ago) the growth of cities and entire civilizations^{5, 7, 8}. This continues today in the production of artisanal foods and in the preparation of a wide variety of traditional and modern cuisines using combinations of culinary ingredients, unprocessed and minimally processed foods^{6, 8}. The mass-production and global trade in non-perishable processed food commodities (e.g. sugar, tea, coffee and cocoa) accelerated during the colonial and mercantile-industrial eras (circa. 1870s onwards), alongside the invention of canning, refrigeration and steam-powered transport (e.g. frozen meat, butter, and canned meats, vegetables and fruits)^{8,9}.

More recently (circa. 1950s onwards), ultra-processed foods (UPFs) have become a significant, and in some cases the main, source of dietary energy in high-income countries including the United States, Canada, the United Kingdom and Australia^{3,4}. Such foods have only become available on a truly global-scale during the current era, characterised by the globalisation of food systems (i.e. post-1970s)¹. They now play a key role in the ‘nutrition transition’ underway in low- and middle-income countries, involving a shift away from traditional diets towards those linked with obesity and diet-related non-communicable diseases¹⁰⁻¹⁴. Because such countries – for example Brazil, China, Indonesia, India and South Africa – are home to more than two-thirds of the world’s population, the dietary changes that are occurring have major implications for global health^{13, 14}. These developments also affect nutrition equity¹⁵. In high-income countries, UPF consumption is inversely associated with socioeconomic position¹⁶⁻¹⁸, whereas the reverse is observed in middle-income countries^{19, 20}. This indicates a ‘social transition’ in consumption, from higher to lower socioeconomic groups, as country income increases²¹. Although the adverse health outcomes associated with some forms of basic food processing are well known (e.g. removing rice husks and resulting thiamin deficiency and beriberi in populations with staple white rice diets)⁸, the adverse outcomes associated with more intensive forms of food processing, and in particular ultra-processing, have more recently come under scrutiny¹.

Evidence for the health implications of food processing is rapidly building²². Population-based cross-sectional and cohort studies applying the NOVA classification system in high and middle-income countries find that a greater contribution of UPFs to total energy intake results in poorer dietary quality²³⁻²⁸, and also higher risks of all-cause mortality^{18, 29-31}, obesity³²⁻³⁶, cardio-metabolic diseases³⁷⁻⁴¹, cancer⁴², gastrointestinal disorders⁴³, asthma⁴⁴, frailty⁴⁵, and depression^{46, 47}. Ecological studies and systematic reviews find that regular consumption of certain types of UPFs associates with adverse outcomes, including sugar sweetened beverages with obesity and type-2 diabetes⁴⁸⁻⁵³, fast food with poor diet

quality and obesity^{54, 55}, and processed meat with colorectal cancer⁵⁶. The level of processing *per se* as an independent risk factor, comes from a randomised controlled trial finding that an ultra-processed diet relative to an unprocessed one causes excessive calorie intake and weight gain⁵⁷, and three cohort studies showing an association between UPF consumption and weight gain, obesity, type-2 diabetes or hypertension risk, which remains significant after controlling for nutrient composition and overall diet quality^{34, 37, 40}.

Evidence for the mechanisms linking UPFs with adverse health outcomes is emerging²². This includes poor nutritional profile (e.g. as vectors for added sugars, sodium and trans-fats) and displacement of unprocessed or minimally-processed foods, and associated fibre and beneficial nutrients in the diet⁵⁸⁻⁶¹, higher glycaemic load and reduced gut-brain satiety signalling resulting from alterations in the physical properties of foods (e.g. degradation of the food matrix by processing)⁶²⁻⁶⁵, contamination with carcinogens formed during high-temperature cooking (e.g. carbohydrate-rich foods with acrylamide, and meats with hetero-cyclic amines)^{66, 67}, links between certain industrial food additives (or clusters of additives) and gut microflora dysbiosis, increased intestinal permeability and inflammation⁶⁸⁻⁷⁰, and endocrine disruption from chemical plasticizers (e.g. bisphenols, phthalates) used in food packaging⁷¹⁻⁷⁴. Certain properties of UPFs may also promote overconsumption, including their convenience⁷⁵⁻⁷⁷, hyper-palatability and quasi-addictiveness for susceptible individuals^{78, 79}, and the use of sophisticated and intensive marketing practices, often targeting children⁸⁰⁻⁸². High consumption of added sugars in early childhood is associated with *inter alia* increased preferences for sweet food⁸³, and dental caries⁸⁴. Food processing also uses significant environmental resources in the form of energy, water and packaging materials, and generates much of the plastic waste stream entering marine ecosystems⁸⁵⁻⁸⁷.

Recent studies also demonstrate the links between the nutrition transition and food systems dynamics – changes in the inputs, actors and activities relating to the production, processing, distribution, preparation, consumption and disposal of food^{13, 88}. Nutrition transition studies show that alongside changes in factors generally associated with economic development and food systems change – including income, urbanisation, technology and labour markets – there is a shift away from traditional diets to those higher in animal-sourced foods, vegetable oils, refined carbohydrates and caloric sweeteners^{11, 89, 90}. Comprehensive empirical studies now also implicate increasing processed and ultra-processed food consumption as a central feature of the nutrition transition^{14, 91-94}. A growing number of studies further demonstrate the importance of the underlying technological and political economy drivers of food systems. These include trade and investment liberalisation, the global expansion of transnational food and beverage corporations and their market and political activities, alongside changes in food production, processing and marketing technologies, and the failure of policies and regulations designed to protect and

promote healthy diets in these new contexts^{90, 91, 95, 96}. As markets for UPFs stagnate in high-income countries, food and beverage corporations, mostly headquartered in the United States and Europe, are vigorously pursuing new growth opportunities throughout the Global South⁹⁵⁻⁹⁷.

Despite the importance for global nutrition and public health, few systematic analyses of global trends, patterns and drivers of UPF markets exist. In this analysis, we build on earlier work^{14, 98-100}, but also draw from a wider literature and more comprehensive data set to address several key questions. First, to what extent has growth in UPF markets continued, accelerated or abated in recent decades globally, across regions and countries, and in which product categories? Second, what are the contributions of UPFs as ‘vectors’ for ingredients linked with obesity and diet-related NCDs, including sweeteners, oils and fats, sodium, and cosmetic additives? Third, have all regions and countries undergone a similar transition to more highly-processed diets, or are there *transitions* with substantial differences between them? If there are differences among otherwise similar countries, what food systems and political economy factors may explain the observed trends and variations? Although defined as a ‘processed culinary ingredient’ by NOVA, we also include vegetable oils in our analysis, given the importance of this category in the nutrition transition, and as an ingredient and cooking medium used in UPF manufacturing¹⁰¹.

Methods

Given the complexity of the research topic and the diversity of quantitative and qualitative data sources required to address the aim, we adopted a mixed methods synthesis review method^{102, 103}. This combined a) a quantitative analysis of worldwide trends and patterns in the apparent consumption of UPFs, including ‘risk ingredients’ linked to various categories of foods, using per capita market sales data; with, b) a qualitative semi-structured review of relevant literature on the drivers of food systems change, including political economy factors, to understand the results found in (a). Although the UPF concept, as defined by NOVA, includes both food and beverage categories, from hereon we differentiate between ultra-processed foods (UPF) and ultra-processed beverages (UPB) for analytical purposes.

Countries: Data on UPF and UPB sales volumes were available for 80 countries. For comparability we followed Vandevijvere *et al.*⁹⁹ by classifying these countries by World Bank income category and Global Burden of Disease Study regions (Table S1). These included 38 high-income countries (HICs), 26 upper-middle income countries (UMICs), and 16 lower-middle income countries (LMICs), making-up 47.5%, 32.5% and 20% of the total number of countries respectively. The eight regions used were Africa, Central and East Asia, Central and Eastern Europe, Latin America and Caribbean, North Africa and Middle East, North America and Australasia, South and Southeast Asia and Western Europe.

Data sources: Globally comparable, nationally representative longitudinal household expenditure or individual food intake survey data for UPFs and UPBs was unavailable. This at least partly reflects inadequate provision for these products in standard instruments for measuring dietary change in transitioning countries¹⁰⁴. Consistent with similar analyses^{48, 100, 105}, we instead adopted country-level sales volume data (kilograms sold through combined retail and food service channels) from the Euromonitor Passport database for the years 2006-2019, with projections to 2024¹⁰⁶. Guided by the NOVA classification system, three of us (PB, PM and TM) agreed on grouping these into the UPF and UPB categories provided in Table 1. All non-UPF categories were excluded with the exception of vegetable oils, which we analysed separately as an important standalone ingredient used in cooking and UPF manufacturing. We further grouped the vegetable oils and sauces, dressings and condiments categories together, because these are typically used as ingredients in food preparation, whereas other categories are typically consumed as ready-to-eat or ready-to-heat foods.

[Insert Table 1 about here]

Euromonitor collects sales data from trade associations, industry bodies, business press, company financial reports, company filings, and official government statistics. People working within the food industry then validate the estimates¹⁰⁶. The Euromonitor database has similar limitations to official government statistics and is not a scholarly database¹⁰⁰. Sales data do not capture products sold through informal channels or wastage (i.e. the proportion of food sold but not consumed). From a nutritional standpoint the data has not been validated, for example by comparison to expenditure or survey data. However, it has some advantages. Unlike survey data it is not subject to recall bias and data is consistently reported across all countries over time using standardised measures¹⁰⁰. The database also offers a disaggregated food and beverage classification, which allowed for reclassification into UPF and UPB categories.

To understand the role of UPFs and UPBs as ‘vectors’ for risk ingredients, we obtained volume (kg) data for the ingredients listed in Table 2 for each of the categories listed in Table 1. We included ingredient sources of added sugars, fat and sodium, as well as additives with cosmetic functions (e.g. artificial sweeteners, colorants, flavourings, emulsifiers, thickeners, bulking and gelling agents) which are a characteristic group of ingredients used in UPFs¹⁰⁷. Artificial sweeteners were included in a separate category (low-calorie & non-caloric sweeteners). Euromonitor calculates this ingredients data as follows: i) recipes for the leading 2-5 branded products within each category and a generic recipe for the remainder of the market are sourced from patent literature, trade interviews and specialist knowledge; ii) ingredients for the same leading 2-5 brands are sourced from nutrition information panels and for the remainder of the market from the generic recipe. The percentage of each ingredient in the total branded

and generic recipes are then estimated; iii) these percentages are multiplied by sales volumes to generate total ingredients volumes; iv) the data is then validated by industry experts at ingredient companies and brand manufacturers¹⁰⁶. Because assumptions are made regarding the recipes of leading and other brands, and also in relation to the sales volumes of the associated product categories, this data should be interpreted with caution. Using country population size estimates sourced from the World Bank's World Development Indicators database¹⁰⁸, we converted the UPF and UPB category sales volumes, and the ingredients volumes supplied by these categories, to kg per capita. This data was not adjusted for energy intake.

[Insert Table 2 about here]

Sweeteners were grouped into caloric (mono-, di- and poly-saccharide sugars), and low-calorie (sugar alcohols) and non-caloric (non-nutritive) sweeteners¹⁰⁹. The inclusion of added caloric sweeteners is important given the WHO recommendation to limit 'free sugars' intake to less than 10% of total energy intake, and to less than 5% or ~25g/day for further health benefits¹¹⁰. Fruit juice was included as an important ingredient and source of added sugars in UPFs, calculated as 90g of sugar / kg as the average sugar content per unit volume of apple and orange juice¹¹¹. We characterised fats by their source (vegetable vs. animal) and state (solid vs. liquid at room temperature). The differentiation between solid vegetable fats and liquid vegetable oils was justified, given the higher industrial trans-fatty acid content of the former category, and the association of partially-hydrogenated vegetable fats with cardiovascular risk¹¹². Sodium included all sources of added dietary sodium. Cosmetic additives included ingredients added to disguise undesirable sensory properties of the final product, or to provide sensory properties especially attractive to sight, taste, smell and/or touch¹⁰⁷.

Analysis: We first estimated per capita sales volumes of the UPF and UPB categories for each country, and country income and region category for all available years. Next, we estimated per capita volumes of sweeteners, fats, sodium and cosmetic additives supplied from these categories. Artificial sweeteners and monosodium glutamate, despite being cosmetic additives, were included in the categories of low-calorie & non-caloric sweeteners and sodium, respectively. Growth in UPF and UPB sales, and of ingredients, were estimated by calculating the compounding annual growth rate (CAGR) for the period 2009-19, representing the mean annual growth rate over a one decade period. The analyses and graphical outputs were generated using R version 3.6.2 (Foundation for Statistical Computing).

Semi-structured literature search and review: Given the broad and multi-faceted nature of the topic, we used a combination of structured and branching searches to source literature on UPFs, the nutrition transition and related food systems and political economy drivers. Scholarly databases (Medline, Scopus,

Google Scholar) were searched using the search string: ‘*processed food*’ AND ‘nutrition’. To identify drivers, these terms were used in combination with key words derived from food systems conceptual frameworks^{113, 114}. We further searched the websites of key international organisations for relevant grey literature including the WHO, Food and Agricultural Organization, Global Panel on Agriculture and Food Systems for Nutrition, Global Nutrition Report and the International Panel of Experts on Sustainable Food Systems. We did not set any date limits on these searches. We included studies in English, published in peer-reviewed journals or scholarly books and reports. Study quality was appraised by relevance to the aim of the review and whether it had clearly described aims, study design and methodology including data sources, a coherent statement of findings and justifiable conclusions. All documents were uploaded to the qualitative analysis software NVivo (QSR International) and coded using the food system frameworks as an initial guide. This allowed for the identification and development of themes. The thematic results were then synthesised and interpreted in relation to the results of the quantitative component of the analysis.

Results

As a first step we described trends and patterns in per capita sales of UPFs and beverages by country, income-level and region.

Global trends and patterns in ultra-processed food and beverage sales

Figure 1 and Figure 2 show changes in per capita sales volumes by region for UPFs and beverages respectively. Figures S1 and S2, and Tables S2 and S3, provide category-specific sales data for country income categories and highly-populated countries. All regions except Western Europe demonstrated strong UPF sales growth. Sales were markedly higher in Australasia & North America and Western Europe than in other regions. UPB sales growth was strong in all regions except Australasia & North America, Western Europe and Latin America & Caribbean, where it was stagnant or declining. UPB sales were also markedly higher in Australasia & North America, Western Europe and Latin America & Caribbean than in other regions.

[Insert Figure 1 about here]

[Insert Figure 2 about here]

Total per capita UPF sales in HICs were 3.4- and 11.3-fold higher than in UMICs and LMICs, reaching 109.3, 32.3 and 9.7 kg/capita respectively in 2019. UPB sales were 2.4- and 8.9-fold higher reaching 161.6, 68.5 and 18.1 L/capita respectively. UPF sales were increasing across all country income groups,

with compounding annual growth rates (CAGR) of 0.4%, 2.8% and 4.4% respectively in HICs, UMICs and LMICs during the 2009-19 period. UPB sales in HICs were 2.4- and 8.9-fold higher than in UMICs and LMICs, at 161.6, 68.5 and 18.1 L/capita respectively. In HICs, UPB sales grew at a CAGR of 0.1% compared with 2.2% and 6.6% in UMICs and LMICs respectively. Total UPB sales growth was projected to stagnate in HICs, but continue strongly in UMICs and LMICs.

Figure 3 shows combined per capita UPF and beverage sales volumes versus the CAGR for each country, differentiated by income level and population size. Figures S3 and S4 show this data for UPF and UPB separately. There is wide variation between countries at the same income level. Among HICs, the United States and Germany have remarkably high sales whereas South Korea and Singapore have comparatively low sales. Among UMICs, Mexico stands out with high sales, largely attributable to UPBs, whereas China has comparatively low sales. South Africa stands out as an African country with high sales and growth in UPFs, and even more so in UPBs. Several countries in Africa, South Asia and South East Asia had remarkably high sales growth in both UPFs and beverages, including Cameroon, India and Vietnam, although from a low per capita baseline.

[Insert Figure 3 about here]

There were notable differences in the types and volumes of categories sold. A wider variety of UPFs were sold in HICs, including higher volumes of animal-sourced foods (e.g. dairy foods, processed meat and seafood), convenience foods (e.g. ready meals, snack foods and confectionary), and those requiring refrigeration (e.g. frozen desserts, processed frozen potatoes, dairy foods). In HICs, the ready meals, savoury snacks, sweet biscuits & fruits snacks, meat substitutes and instant noodles categories had the strongest sales growth, which offset near zero or declining growth in all other categories. In UMICs and LMICs nearly all categories had moderate to strong growth, although the baked goods, and sauces, dressings and condiments categories were dominant by volume.

Carbonated beverages comprised the majority of UPB sales globally, with volumes growing in most regions, except Australasia & North America, Western Europe and Latin America & Caribbean with small declines or stagnant growth. In Africa, carbonated beverages comprised the large majority of beverage sales. In several regions declines in carbonated beverages have been offset by significant growth in other beverage categories. East & South East Asia, for example, showed remarkable growth in ready-to-drink (RTD) coffee, tea & Asian speciality drinks; Australasia & North America, and Western Europe in sports & energy drinks; and Latin America & Caribbean in juice drinks & nectars.

Although not an UPF, we also examined changes in vegetable oil sales. Figure 4 shows changes in per capita vegetable oil sales volumes by region. Figure S5 shows the same data by country income level.

There were marked differences between the types and volumes sold. Sunflower oil dominated sales in North Africa & the Middle East and in Central & Eastern Europe, soy oil in Latin America & Caribbean, Australasia & North America and Central & East Asia, palm oil in South & South East Asia, and olive oil in Western Europe. Palm oil is by far the highest volume oil type sold in LMICs. Total vegetable oil sales in UMICs and LMICs exceeded those in HICs at 10.6, 8.7 and 7.8 kg/capita respectively in 2019. Vegetable oil sales increased by just 0.6% CAGR in HICs but grew markedly at 4.1% and 11.6% in UMICs and LMICs respectively during the 2009-19 period. The two food categories mainly used in meal preparation – vegetable oils, and sauces, dressings and condiments together comprised 46% and 57% of total sales in UMICs and LMICs respectively, compared with 21% in HICs.

[Insert Figure 4 about here]

Global trends and patterns in ingredients supplied from ultra-processed foods and beverages

In a second step, we determined volumes of ‘risk ingredients’ supplied from UPFs and beverages, including sweeteners, fats, sodium and cosmetic additives.

Figure 5 shows changes in per capita volumes of sweeteners, fats, sodium, and cosmetic additives from UPFs and beverages by region. Figure S8 shows these same volumes by country income. Tables S4 and S5 provide further ingredients sales volume and growth rate data by country income and region respectively. Irrespective of country income level, caloric sweeteners comprised the dominant share of ingredients from UPFs and nearly the entire share of ingredients from UPBs. Caloric sweeteners made up approximately two thirds of all ingredients supplied from UPFs and beverages combined, with volumes of 25.8, 9.2 and 2.2 kg/capita in HICs, UMICs and LMICs respectively in 2019. Total caloric sweeteners declined in HICs with a CAGR of -0.3% over the 2009-19 period, but increased by 1.6% and 3.9% in UMICs and LMICs respectively. However, the decline in HICs was mainly attributable to a -1.2% CAGR in caloric sweeteners from UPBs, while caloric sweeteners from UPFs increased by 0.4%. Caloric sweeteners from UPFs and beverages increased in all regions, with the exception of small declines from UPBs in Australasia & North America, Latin America & Caribbean and Western Europe. Total low calorie and non-caloric sweeteners (LCNCS) volumes were 0.4, <0.1 and <0.1 kg/capita in HICs, UMICs and LMICs respectively in 2019, and had CAGRs of 0.4%, 2.3% and 4.2% for the 2009-19 period. In HICs, UPFs were the primary source of LCNCS at 0.4 kg/capita versus <0.1 kg from UPBs, although the latter category grew much more with CAGRs of 0.2% and 4% respectively. Volumes of LCNCS supplied in Australasian & North America and Western Europe were between 2- to 40-fold higher than in other regions.

[Insert Figure 5 about here]

Vegetable oils made up a large share of the ingredients supplied exclusively from UPFs, at 6.3, 1.5, and 0.5 kg/capita in HICs, UMICs and LMICs respectively in 2019, with CAGRs of 2.0%, 3.8% and 8.0%. Vegetable oils from UPFs increased in all regions. Solid vegetable fats, which we used as a proxy for trans-fats, were supplied almost exclusively from UPFs, and were markedly higher in HICs at 2.6 kg/capita compared with 0.7 and 0.2 kg/capita in UMICs and LMICs respectively. Vegetable fat volumes declined in all country income groups, with CAGRs of -2.3%, -0.8% and -1.3% in HICs, UMICs and LMICs respectively. Vegetable fats declined in all regions except North Africa & the Middle East. Reductions were most prominent in Australasia & North America, and Western Europe.

Sodium was supplied from salt or salted ingredients added to UPF, at 1.2, 1.1 and 0.3 kg/capita in HICs, UMICs and LMICs respectively in 2019, and increased with CAGRs of 0.4%, 1.7% and 1.8%. Sodium volumes increased in all regions. Australasia & North America, Central & East Asia and Western Europe had markedly higher sodium volumes of 1.3, 1.4 and 0.9 kg/capita in 2019. The supply of cosmetic additives increased everywhere, mostly from UPFs. Total cosmetic additives supplied from UPFs and UPBs combined was 3.3- and 11.5-fold higher in HICs than in UMICs and LMICs at 2.3, 0.7 and 0.2 kg/capita respectively. Volumes were markedly higher in Australasia & North America and Western Europe than in other regions, with volumes of 3.1 and 1.8 kg/capita respectively in 2019. Furthermore, cosmetic additives increased with CAGRs of 0.7%, 2.9% and 4.8% in HICs, UMICs and LMICs, exceeding growth in total UPF and beverage sales.

Food systems transformations linked with changing ultra-processed food and beverage markets

Our results so far indicate that UPF and beverage markets are growing nearly everywhere, indicating a global convergence towards a more highly-processed diet. However, there are also important divergences in the volumes and types of products sold and ingredients supplied at regional and country levels^{14, 92}. In the following sections our objective is to understand how contemporary transformations in food systems might explain this convergent-divergent pattern. This considers food supply chains, food environments and consumer behaviour as core food system elements, but also a range of external food system drivers (social, economic, technological, institutional, and political) and knowledge systems, policies and regulatory frameworks shaping those systems^{113, 115}. We adopt a combined food systems and political economy approach, acknowledging in particular the power of transnational food and beverage corporations (TFBCs) – including producers, processors, manufacturers, fast food chains and retailers – to shape food systems in ways that alter the availability, price, nutritional quality, desirability and ultimately consumption of UPFs and beverages^{95, 96, 100, 115, 116}.

From the literature we identified strong incentives for TFBCs to expand transnationally, including market saturation in their home countries, their large market capitalisations and profits (providing finance to grow), global brand recognition, knowledge capital (intellectual property, organisational practices, manufacturing and logistical technologies), and their capacity to adapt global brands to local cultures and regulatory contexts^{96, 117, 118}. Since the establishment of the World Trade Organization in the mid-1990s, the number and depth of trade and investment agreements has increased substantially. Many countries have also unilaterally liberalized their economics, becoming more integrated into the global economy and deregulating markets^{119, 120}. This has accelerated the globalisation of food systems by reducing barriers to the movement of finance, technologies, production capacity, raw materials and final products across borders, enabling TFBCs to more easily enter and drive consumption in emerging markets, and connect these markets to their global sourcing and production networks^{91, 92, 119, 121}. Through greater investments, more intensive marketing and the introduction of new technologies and business practices, such companies have also spurred competition and bolstered the development of domestic (or home-grown) UPF and beverage industries^{91, 96}.

Basic economic, demographic and socio-cultural drivers: At the most basic level, TFBCs have pursued growth opportunities in emerging markets in response to factors that drive demand for UPFs and beverages, including those generally associated with economic development. These include income growth, urbanisation, changing workforce structures and demographics. Total UPF and beverage sales have increased rapidly in Central & East Asia, North Africa & the Middle East and South & South East Asia, where per capita *income* has grown rapidly in recent decades^{14, 119}. As economies grow consumer incomes rise, resulting in higher household expenditure on food alongside a decline in the proportion of total expenditure on food relative to non-food items. This tends to result in increased diversification of the diet, and expenditure on more expensive products, including animal-sourced and highly-processed foods^{88, 94, 100, 122}, and purchasing of non-food items that facilitate greater access and utilisation of these foods, such as cars, microwave ovens, and refrigerators^{11, 123}. Our results reflect this, showing higher volumes of a wider variety of UPFs and beverages, and a greater share of animal-sourced foods at higher country incomes. This is also reflected in, for example, the higher volumes of refrigerated products (e.g. ice-cream and frozen desserts) in HICs, and less perishable ones in UMICs and LMICs (e.g. vegetable oils, baked goods, sauces).

Within countries, the above processes appears to play out in socially-stratified and dynamic ways, whereby UPF consumption increases first among higher-income groups^{19, 20}, and then shifts to lower socioeconomic groups as countries grow richer¹⁶⁻¹⁸. This same pattern is observed with the ‘social transition’ in obesity prevalence^{21, 124}. There are however, significant variations in UPF and beverage

sales between countries at the same level of per capita income. Income appears to be more strongly associated with UPF sales in countries that are more integrated into the global economy, and hence more highly penetrated by TFBCs^{97, 100}. Food *prices* are also a key determinant of affordability and consumption. Price per calorie of different types of ultra-processed and ready-to-eat foods vary markedly across country incomes and regions, as do prices relative to less processed foods^{125, 126}. In 2011, for example, vegetable oils and sugar were relatively cheap almost everywhere; soft drinks relatively inexpensive in HICs and very cheap in North America and Australasia, moderately so in UMICs, and expensive in LMICs; and, potato chips very inexpensive in HICs, moderately so in UMICs and LMICs, and inexpensive in India, China and elsewhere in East Asia¹²⁵.

Urbanisation is also a key driver. This facilitates greater physical proximity to more diverse and cheaper foods, including UPFs and beverages, exposure to commercial marketing and ready-to-eat foods, and occupations and lifestyles less conducive to home food preparation¹²⁷⁻¹²⁹. This may partly explain differences in sales and growth rates between the highly urbanised regions of Western Europe, Australasia & North America and rapidly urbanising Asia, North Africa & the Middle-East, Latin America and Africa. However, with the increased penetration of UPF and beverage supply chains into rural areas, the importance of urbanisation may be diminishing^{94, 100}. In 2010, Reardon *et al.*, for example, found highly-processed foods comprised between 13% and 22% of total food expenditure in rural households of four low- and middle-income Asian countries, comparable to (although still lower than) urban households with between 17.7% and 36.7%⁹⁴.

Another key factor is the growing number of women participating in formal work and the associated shift to dual worker households, without an equitable re-distribution of household work between women and men. In the United States this has meant an approximate halving of the time women spend preparing food and a small increase for men¹³⁰. This increases the *time opportunity cost* of sourcing and preparing food, and consequently the demand for semi-prepared and ready-to-heat convenience foods, and for food eaten outside the home^{88, 127, 131}. This may explain the higher proportions of convenient ready meals and snack foods in the HICs of Australasia & North America, and Western Europe relative to the higher proportions of categories used in meal preparation, such as vegetable oils, sauces, dressings and condiments sold in UMICs and LMICs. Such demand may also closely link with a *culinary skills transition* involving significant changes in the patterns and kind of skills required, and the time spent procuring, preparing and consuming food¹³²⁻¹³⁴. This can involve the adoption of ‘technological skills’ required to prepare convenience foods, as in using a microwave oven, opening cereal boxes or assembling processed ingredients (e.g. making sandwiches)¹³². *Population age structure* is another relevant demographic

factor. The younger populations of middle-income countries may be more likely than their elders to forego traditional foods for newer ones ¹².

Supply chain transformations: Growing but highly variable worldwide UPF and beverage sales are not only driven by changing demand alone. Changes in global, regional and national supply chains are also important, involving the actors and processes that take products from the production of raw ingredients through to manufacturing, marketing, retail and consumption.

This begins with market consolidation, technological change and growth in the *production, processing and global trade* in basic agricultural commodities and additives used as ingredients in manufacturing ^{92, 114, 119}. A small number of corporations control this sector. These include the four so-called 'ABCD' agribusinesses Archer Daniels Midland (USA), Bunge (USA), Cargill (USA) and Louis Dreyfus (France), who together controlled an estimated 70-90% of global grain trade by the mid-2000s ^{114, 135}. Others include Dow Dupont (US), Associated British Foods (UK), Royal DSM (Netherlands), Bunge (US), China National Cereals, Oils and Foodstuffs (China) and Wilmar (Singapore), and a number of specialised ingredients suppliers spanning the food, pharmaceutical and nutraceutical sectors ^{135, 136}. As shown in Figure 6, world production of the four major processed vegetable oil crops expanded 19-fold from 7.5 to 144.8 million tonnes between 1961 and 2014, mainly from government-supported expansion of palm oil production in Indonesia and Malaysia, soybean oil in China, US, Brazil and Argentina, and canola/rapeseed in Canada and China ^{92, 119, 137}. Palm oil is now the world's most significant vegetable oil ¹³⁸, with food manufacturing using an estimated ~70% of production, and half of all packaged and processed foods containing this oil or its derivatives ¹³⁵.

World raw sugar production expanded 3.3-fold from 53.2 to 176.9 million tonnes over the same period, mainly from sugar cane in Brazil, India and China, and beet sugar in the European Union and United States. In the United States, the production of high-fructose corn syrup (HFCS) also increased, with a subsequent 10-fold rise in consumption between 1970 and 1990 to represent >40% and ~100% of caloric sweeteners added to foods and beverages respectively ¹³⁹. In 1994, tariff reductions mandated under the North American Free Trade Agreement then led to increasing volumes of HFCS in the food supplies of Mexico and Canada ^{140, 141}. Relative to rice, wheat production has also increased given its use in producing noodles, baked goods and similar products, for example in Asia and West Africa ^{128, 142}. Increased production of oil and cereal crops has also provided cheap inputs for expanded livestock production, and hence the supply of meat and other animal sourced foods used in UPF manufacturing ¹⁴³.

[Insert Figure 6 about here]

In the food *manufacturing sector*, companies have utilised these low-cost and readily-available ingredients to develop diverse product portfolios, often using variations of the same ingredients for multiple branded products in the same market ¹¹⁴. In 2019, ten companies controlled 47.5% of the market share of the world's top-100 food manufacturers, with sales ranging from US\$61.5 to US\$17.6 billion ¹⁰⁶. These included Nestle (Switzerland), PepsiCo (US), Coca Cola (US), Mondelez (US), Danone (France), Kraft Heinz (US), Unilever (UK/Netherlands), Mars (US), Kelloggs (US) and Ferrero (Italy) ¹¹⁴. However, when considering the market in its entirety, the top-ten controlled just 14.7% of world market share in 2019 ¹⁰⁶, indicating the importance of other large, as well as small- and medium-sized companies, in this sector ¹⁴⁴. Market concentration is much higher at the product category level, including beverages, snack foods and biscuits. For example, Coca Cola and PepsiCo alone controlled 19.3 and 8.3% of the world's beverage market in 2018, with 37 and 19 brands respectively. The carbonated beverages category is even more concentrated, with these two companies controlling 45.6% and 17.5% of world market share ¹⁰⁶.

Many of these manufacturers have been at the vanguard of economic globalisation ⁹⁶. However, they have expanded with renewed vigour from the 1980s onwards. This is evident in the rapid growth in foreign direct investment in this sector throughout the Global South, with manufacturers establishing new (often 'mega') manufacturing plants and distribution centres through 'greenfield investments' ^{91, 119, 120}. This has led to the establishment of vast manufacturing capabilities serving domestic and regional markets. For example, Nestle reported having 403 factories spanning 84 countries in 2019, with 16 in Brazil, 13 in Mexico and 31 in the Greater China Region ¹⁴⁵. Growth has also been achieved through the acquisition of domestic competitors. For example, in 1993 Coca Cola became the market leader in India by acquiring the domestic Parle Products company and its cola brand Thums Up, and in 1999 became the market leader in Peru by acquiring the Lindley Corporation and its Inca Kola brand ^{119, 120}. Some countries have seen the emergence of large domestic companies prior to transnational market entry, for example IndoFoods in Indonesia, and in China the state-owned China National Cereals, Oils and Foodstuffs ^{96, 142}. Japan's market is dominated by domestic manufacturers, with foreign companies having limited market share ^{96, 146}.

New *production and processing technologies* have increased production efficiencies, lengthened shelf-life, enabled long-distance transportability, and enhanced the hedonistic properties of UPFs. This includes the development of new varieties of high-yielding oilseed crops and processing techniques (e.g. extraction, refining and hydrogenation) that have enabled the development of novel ingredients and reduced the costs of baking and frying fats, margarines and cooking oils ¹⁴⁷. New processing techniques of automation, extrusion and frozen dough production, and additives such as new yeast varieties, enzymes

and emulsifiers have enabled the mass production of breads, noodles and other baked goods^{88, 148}. Other manufacturing techniques and technologies have included high temperature processing, extraction, fractionation and hydrogenation¹⁴⁹. New packaging technologies have enabled entirely new product categories, for example microwaveable popcorn¹⁵⁰. Manufacturers have invested heavily in their technological capabilities to enhance the organoleptic properties of their products including structure, mouth feel, taste, aroma and flavour. Fortification, functionalisation and reformulation techniques have been used to alter the nutritional properties of products¹⁵¹. They have also adapted (or ‘glocalised’) global brands and menu offerings to meet local tastes, cultural preferences and regulatory environments^{149, 152}. This is enabled through the establishment of food and nutrition science research capabilities, coordinated on a global scale. Nestle, for example, has "the world’s largest private nutrition research capability" spanning a Research Centre for basic research, seven research and development centres, and nine product technology centres, with nutritional expertise in every market¹⁵³.

Developments in the *retail sector* have also contributed in important ways to growing and diversifying UPF and beverage markets, especially the growth of modern food retail throughout the Global South. This sector is highly concentrated (and moderately to strongly oligopolistic) in many countries, often dominated by transnational grocery retailers including Walmart (US), Aldi (Germany), Carrefour (France), Tesco (UK) and 7-Eleven (Japan), or other regional and national players^{96, 114, 154}. Figure 7 presents data on processed food distribution channels by country income level. Distribution occurs predominately through ‘modern grocery retailers’ in HICs (supermarkets, hypermarkets and convenience stores), in LMICs through ‘traditional grocery retailers’ (mostly small, independent, owner-operated stores and wet markets), and in UMICs through a mix of modern and traditional channels. Modern grocery retailers originated in the US and other HICs in the mid-1950s, with several companies achieving considerable market power in some countries. Supermarkets then spread into South America, East Asia (excluding China) and South Africa in the 1990s, followed by Mexico, Central America and most of South-East Asia in the mid- to late-1990s, and then China, India and Vietnam in the early 2000s^{155, 156}. This expansion has closely followed the timing of countries accession to the World Trade Organization and its General Agreement on Trade in Services, which liberalised foreign investment in the food retail sector^{92, 123}. Within countries, supermarkets tend to spread from major cities to intermediate and smaller localities, reflecting an initial targeting of wealthier middle-class consumer segments before targeting poorer urban and rural segments^{157, 158}.

[Insert Figure 7 about here]

In contrast to traditional grocery retailers, supermarkets shape UPF and beverage sales in a powerful way by facilitating market segmentation through the development of new products, or the re-development of

existing ones, to target consumer groups differentiated by income, age, gender, geography and lifestyle-status or other. Supermarkets also provide a platform for facilitating market segmentation by stocking a wide variety of foods and accepting the risk of introducing new foods, as well as regularly updating their stock in response to demand. Because consumer purchasing behaviour shapes their procurement activities, supermarkets also send market signals to manufacturers about what and what not to produce¹⁵⁴. This may explain the greater variety of UPFs and beverages sold in HICs relative to UMIC and LMICs, because as this analysis has demonstrated, a greater proportion of such foods are distributed through supermarket channels in the former.

Supermarkets act predominantly as new distribution channels for durable processed foods in the early stages of market growth, before offering a wider variety including fresh foods (and out-competing traditional wet markets) in later stages^{12, 157, 159, 160}. As a result, supermarket distribution shares in categories such as grains, noodles and dairy products have increased more rapidly than in fresh food categories¹⁶¹. This reflects not only the greater economies of scale in sourcing processed foods^{159, 162}, but also because ‘cultures of consumption’ change over time, from the daily purchasing of fresh foods in traditional markets to less frequent purchasing from modern retailers and refrigerator storage^{163, 164}. Supermarkets often use price discounting, prominent displays at the end of aisles, and place snack food lines close to cash registers to stimulate impulsive purchasing^{165, 166}. By leveraging their market power to negotiate large-scale acquisition contracts, supermarket chains can drive down sourcing costs to supply customers with prices well below those charged by traditional retailers^{166, 167}. For example, a Brazilian study found that the share of UPFs as a proportion of total food purchased was 25% higher at supermarkets, and supermarket prices were 37% lower for these products, compared with other food retail stores¹⁶⁵.

In the absence of modern retail formats in emerging markets, UPF and beverage manufacturers have also developed novel strategies to target poorer and rural consumers. In China and India, for example, companies have offered smaller package sizes and affordable pricing points more appealing to low-income and rural consumers^{168, 169}. Others have developed ‘last mile’ strategies to reach the ‘base’ of the consumer pyramid. In Mexico, for example, Coca Cola developed an extensive distribution network of tiendas (small stores), providing free incentives such as refrigerators and point-of-sale advertising materials in return for exclusivity agreements⁹². In Brazil, Nestle has used ‘floating supermarkets’ to sell more than 300 products to small towns throughout the Amazon basin, and through its door-to-door’ salesforce reaches more than 250,000 households with more than 800 products every fortnight, in the country’s favelas^{95, 170}.

In LMICs and UMICs, the consumer food service sector tends to be dominated by thousands of small, independent restaurants or street food operators, often selling local dishes at very low prices, and operating entirely in the informal sector^{96, 128}. However, growth in transnational fast food chains has been rapid, presenting more outlets for UPF and beverage distribution^{88, 128}. Five ‘fast food’ corporations have led this transnational expansion: Seven & I Holdings (Japan/South Korea; 7-Eleven), Yum! Brands (US; KFC, Pizza Hut, Taco Bell), McDonalds (US), Doctor’s Associates (US; Subway) and Starbucks (US). In China alone, the number of fast food chain outlets expanded 6.4-fold from 25,984 in 2004 to 167,560 in 2018, beginning in major cities before spreading to smaller cities and towns. Yum! Brands has been at the forefront of this expansion, given the preference of Chinese consumers for chicken over beef⁹⁶. Franchising has been a key growth strategy, allowing firms to acquire local knowledge about consumer preferences and business practices, and to ‘glocalise’ their menu offerings. For example, McDonalds offered vegetarian options in India, rice porridge with chicken and pork in Thailand, and rice-based wraps, bowls and ‘bubble tea’ in China⁹⁶. Local restaurants and street food vendors often develop similar products, mimicking the fast food brands¹²⁸. The rapid uptake of online food delivery platforms such as Uber Eats in many countries has provided a new distribution channel, reducing the time-cost of sourcing fast food for consumption at work or home^{171, 172}.

Growing but highly variable UPF and beverage markets also reflects more intensive food *marketing*, enabled by the globalisation of marketing agencies and new media technologies⁹². Food companies and the marketing agencies that work for them, have used increasingly sophisticated techniques to reach consumers segmented by age, income, location, lifestyle and cultural preference. Extensive mass media advertising targeting children and adolescents via television, film and media franchising has been reported in many countries¹⁵². The globalisation of digital technologies including social media, mobile phones, gaming platforms and others, has enabled new ways to reach younger audiences, including gamification, peer-to-peer and user-generated messaging, cross-device tracking, in-store surveillance and prompting, and demographic- and location based targeting^{88, 173, 174}. These technologies are harnessed in powerful ways by using ‘Big Data’ processing and analytics platforms to collate, analyse and use data, including the profiling and predictive targeting of individual consumers¹⁷³. Sophisticated packaged-based marketing techniques are also used to promote purchasing. This includes making health and nutritional claims to imbue products with ‘health halos’, and packaging designs (e.g. shapes, cues and sizes) that skew perceptions of quantity and increase preferences for supersized portions and packages¹⁷⁵. Some have suggested that the net effect of these changes is the increased desirability of ultra-processed relative to unprocessed and minimally processed foods^{176, 177}, the decline of traditional food cultures (e.g. commensal eating) and a shift towards those more conducive to UPF and beverage consumption (e.g. snacking)^{95, 178, 179}.

Policy, regulatory and political economy drivers: Finally, growing but variable worldwide UPF and beverage markets also reflect differences in the strength of policy and regulatory frameworks targeting unhealthy diets, and the power of different actors and interests to enable or hinder policy action.

As our findings so-far demonstrate, the drivers of UPF and beverage markets are multi-factorial and dynamic, reflecting transformational changes in food systems underway. Therefore, an ecological approach to policy intervention, targeting multiple components of food systems simultaneously, is needed to drawdown consumption and minimise harm^{113, 115, 180}. Various frameworks exist for guiding such action^{113, 180, 181}, requiring a strong role for government legislation and regulation^{182, 183}. These include actions targeting food supplies (e.g. removing sugar subsidies, reformulation, public procurement standards), food environments (e.g. restrictions on advertising and promotion, taxes and import tariffs, food and menu labelling, school food standards), and communications to encourage behaviour change (e.g. food-based dietary guidelines, mass-media campaigns, nutrition education in school curricula, counselling in health care settings)^{180, 182}. It also requires cross-cutting actions. These include bottom-up civil society mobilization, top-down political commitment, protections against conflicts of interest in policy development, and well-resourced monitoring, accountability and enforcement mechanisms¹⁸⁴⁻¹⁸⁶.

However, worldwide policy responses are currently inadequate in both scope and strength¹⁸⁷⁻¹⁸⁹. According to the latest WHO monitoring reports, the large majority of reporting governments have implemented education and counselling (75%) and media campaigns (61%) targeting lifestyle-behavioural change. Far fewer have implemented more upstream actions targeting food supplies and food environments including, among others, taxes on sugar-sweetened beverages (38%) and unhealthy foods (6%), front-of-pack labelling schemes (25%; with just over half being mandatory), elimination of industrially produced trans-fats (37%), portion-size controls (16%), and school food standards (43%)^{190, 191}. The majority of these actions have been taken in HICs in Europe¹⁸⁹, although UMICs with high obesity and diet-related NCD burdens in Latin America and the Pacific Islands are world leaders^{88, 192, 193}. Weak worldwide policy responses and the skew towards lifestyle-behavioural interventions, at least partly reflects the nature of food regulatory paradigms in many countries. For example, ‘cutting red-tape’ agendas have emerged in many high-income countries, with potential to impede new UPF regulations¹⁹⁴. Drawing from behavioural economics, ‘nudge’ approaches to policy intervention, involving minor modifications to consumer environments, have also come into vogue. This approach shows mixed results, small at best, for modifying consumer choices^{195, 196}. It focuses on the ‘immediate choice architecture’ of consumers, but fails to address many of the structural and commercial determinants of consumption we describe¹⁹⁷.

Policy actions in many countries are informed by reductionist approaches, including nutrient-profiling models, to assess the healthiness of foods^{198, 199}. Such models have an important role to play. However, in focussing on the amount of certain nutrients in foods, this approach does not address other harms associated with food processing, or how foods fit within an overall healthy diet. It has led to an over-reliance on ‘nutrients-to-limit’ reformulation initiatives in some countries^{200, 201}, with potentially counter-productive outcomes. This includes the replacement of certain highly processed ingredients with other such ingredients, for example unhealthy fats with added sugars, or with additives, for example added sugars with artificial sweeteners, rather than whole or minimally processed foods. Nutrient-centric approaches, can also stimulate the production and promotion of UPFs. For example, between 2014 and 2019, the Australian nutrient-based Health Star Rating (HSR) system approved between 73-77% of UPFs using the system to display a ‘pass mark’ of 2.5 stars or more (out of a possible 5) on labels^{202, 203}. Food-based dietary guidelines (FBDGs) adopted in most countries are a foundation for nutrition policy and guidance^{199, 204}. Yet a large majority of FBDGs adopt a nutrient-centric approach, recommending to limit foods high in certain risk nutrients or ‘energy-dense and nutrient-poor’ foods. The term ‘discretionary foods’ is also used, a framing that implies consumer rather than producer responsibility⁸⁵. Only Brazil, Peru, Uruguay, Ecuador and Canada have dietary guidelines that differentiate foods by the degree of processing, recommending to favour unprocessed and minimally processed foods, limit processed foods, and avoid UPFs altogether^{4, 85, 201}.

Weak worldwide responses also reflects the power of the food industry to undermine political commitment for action^{205, 206}. The food industry, including predominantly transnational food corporations and the peak industry groups that represent them, have strongly resisted policy responses using standard ‘playbook’ tactics^{97, 205}. These have included *inter alia* lobbying policy-makers, making political donations, framing policy debates, adopting self-regulation to pre-empt and delay government action (policy substitution), public relations campaigns portraying business as ‘part of the solution’, and partnerships with community and sporting associations^{151, 205, 207, 208}. This has occurred at multiple-levels, often focusing in battleground jurisdictions, as shown in the intensive lobbying, media campaigns and establishment of front groups to resist the adoption of SSB taxes in US counties and throughout Latin America²⁰⁹⁻²¹¹. At the international level, the Codex Alimentarius Commission, the UN food standard-setting body, has faced intensive lobbying as it often functions as the de-facto benchmark for food regulatory agencies in low and middle-income countries, as well as the reference standard used in WTO trade disputes²¹². Companies and industry groups have skewed the production of knowledge and evidence informing policy and regulatory debates. This includes financing academic research, sponsoring scientific organisations to produce favourable messaging (e.g. International Life Sciences Institute), and

producing in-house research that minimises the harms, and supports the health benefits of their products^{213, 214}.

More broadly, food industry power has been enhanced in the context of growing preferences for hybrid governance arrangements, including public-private partnerships (PPPs), that expand corporate influence in policy decision-making^{97, 116, 151}. At both national and international levels this includes a variety of PPP types involving various combinations of government, industry and civil society actors, and activities spanning food reformulation and fortification, consumer education, labelling, direct food provision and research^{215, 216}. By procuring in-house nutritional expertise, food companies have expanded their capacity to engage in these activities, and thereby influence food policy and regulation-setting processes¹⁵¹. As a result, PPPs involving food manufacturers have focused more on nutrient-based responses, such as reformulation. This depoliticises food environments by deflecting attention away from the structural determinants of unhealthy diets, including the wide availability and intensive marketing of UPFs¹⁵¹. Trade liberalisation further enhances food industry power by restricting the ‘policy space’ of governments through limiting the scope of regulatory actions allowed under trade rules, and by imposing ‘regulatory chill’ or a reluctance to adopt regulations through the fear of a trade dispute^{119, 217}. This chilling effect is enhanced when HIC governments representing the interests of TFBCs (mainly the US and EU) have used WTO trade dispute mechanisms to challenge food regulations adopted by other countries^{119, 218}. Furthermore, as suppliers of jobs and tax revenue, the food industry has gained ‘productivist power’ through its importance in national economies, and greater international capital mobility as trade liberalisation enables TFBCs to punish or reward governments for their policy decisions, by shifting or threatening to re-locate jobs and investments^{14, 92, 205}.

Market concentration is another key mechanism enabling the food industry’s power across all sectors, whereby increasing market share, and hence market power, is held by a declining number of firms^{157, 219, 220}. This increases the buying and selling power of corporations, allowing them to dictate terms of trade, set prices, control consumer product offerings and cut costs^{118, 219, 221}. Market power reinforces political power as accumulating financial resources and economic importance in national economies can be used for greater political influence^{114, 116}. Mergers and acquisitions have become the main mechanism by which this concentration occurs and through which corporations grow^{157, 219}. The home markets of the US and European food and beverage corporations are now highly concentrated, especially in the processing and retail sectors^{146, 221-223}. Markets are also concentrating regionally as in the Asia-Pacific and Latin America, as well as globally^{96, 146, 221}. In the manufacturing sector, concentration is highest in ultra-processed segments such as soft drinks, biscuits, and snack foods^{224, 225}.

Through establishing transnational networks of affiliated firms and contractual suppliers, this market power can be coordinated across global value chains (GVC) incorporating multiple supply chain components including research & development, production, processing, manufacturing and distribution^{96, 114}. This enables the sourcing of raw ingredients, labour and other production inputs from wherever costs are lowest and regulatory environments most favourable, distancing consumers and regulators from the harms associated with production (e.g. deforestation associated with palm oil production)^{117, 226}. Financialisation of the global economy, involving the emergence of a liberal financial regime characterised by rapid growth in marketised securities and monetary exchange freedoms, has facilitated GVC integration. This enables food and beverage corporations to use financial derivatives to offset risks associated with sourcing large volumes of agricultural commodities from volatile global markets¹¹⁷. Processes of transnationalisation and market concentration are also closely linked with the financialisation of food systems. A small number of private equity firms – mainly Blackrock, Vanguard, State Street, Capital Group and Fidelity – have funnelled vast amounts of equity into publicly listed food and beverage corporations, providing them with access to finance for accelerated global expansion²²⁷.

Discussion

Our findings have important implications for global public health and policy responses targeting unhealthy diets, obesity and diet-related NCDs.

First, UPF and beverage sales are growing in all regions and in the large majority of countries, but most rapidly in UMICs and LMICs, although with wide variations in the volumes and types of products sold. Given the well-established evidence linking UPFs with adverse health outcomes, and because growth is most apparent in highly-populated regions and countries, the consequences for global health are likely to be substantial. We also find important changes in the nature of the transition to diets higher in UPFs and beverages. A wider variety of products are sold in richer countries. Cosmetic additives are supplied from UPFs in markedly higher volumes in HICs, but are increasing almost everywhere, and have approximately doubled in UMICs and LMICs. The vegetable oils, and sauces, dressings and condiments categories used in food preparation, make up a greater share of total food sales in UMICs and LMICs relative to HICs. Together, these results indicate a shift in the global diet towards higher consumption of UPFs and beverages, and that populations purchase a wider variety of products, and more higher-value and convenience products, as countries grow richer. Although UPFs appear to contribute more to the ‘sweetening’ of the global diet, vegetable oil as a stand-alone product and as an ingredient used in UPFs has grown rapidly, especially in the UMICs and LMICs of Central & East Asia, and South & South East Asia. This is consistent with previous studies showing vegetable oils have contributed more than any other food category to the expanding world calorie supply – the ‘fattening’ of the global diet⁹². The rise

of palm oil as a cooking oil in many transitioning countries, and as an ingredient or medium used in UPF manufacturing, raises concern, given the high-levels of ‘probable carcinogens’ (certain fatty acid esters and glycidol), generated during the palm oil refining process ²²⁸.

Second, important changes are underway in the beverage sector. Declines in carbonated beverages in high-income countries and certain regions have been offset by growth in sports, energy, ready-to-drink teas, and juice drinks. This diversification may represent several dynamics underway in beverage markets. This includes rising health consciousness among consumers, substitution effects resulting from policy actions targeting sugar-sweetened beverages (SSBs) ¹⁸⁸, and more intensive marketing of these categories as beverage companies diversify product portfolios to offset declines in revenue from carbonated beverages. Our results show that beverages contribute nearly as much caloric sweeteners as UPFs across all income levels, suggesting the continuing importance of policy actions to reduce SSB consumption. This may be particularly important in HICs and UMICs where SSBs are a relatively inexpensive source of calories ¹²⁵. The growth in energy drinks in particular presents an important challenge for food regulators, given the intensive marketing of these products to youth and the harms associated with excessive consumption ²²⁹.

Third, our findings on ingredients raise several policy challenges. Caloric sweeteners from beverages are declining in HICs, suggesting that policy actions including SSB taxation, labelling and reformulation, are having some effect ¹⁸⁸. However, caloric sweetener volumes from UPFs have increased or barely changed in HICs, indicating a need to broaden these policy actions beyond SSBs. Furthermore, volumes of caloric sweeteners from UPFs and beverages are growing rapidly in UMICs and LMICs. Policy actions to reduce added sugars from UPFs and beverages therefore remain crucial, given the well-established adverse health outcomes associated with high sugar intake ^{110, 230}. Significant growth in cosmetic additives, and non-caloric and low-calorie sweeteners, raises further questions for public health, given the emerging evidence on the health effects of these ingredients. Hydrogenated vegetable fat, which was our proxy for industrial trans-fat in this analysis, is steadily declining across all country income levels. This possibly reflects successful policy actions to eliminate these fats from the food supply in many countries. Sodium levels are increasing nearly everywhere, and are markedly higher in North America, East & South East Asia and Western Europe. The world’s highest sodium levels, reported in Central & East Asia, may reflect the use of sodium-rich sauces, dressings and condiments used in food preparation, given home-cooked foods are the main dietary source of sodium in China ²³¹.

Fourth, we have shown how changing global markets for UPF and beverages reflect transformations underway in all food systems sectors, including those linked with the expansion and growing market and political power of transnational food and beverage corporations. Variations in sales across countries are

likely to reflect differences in these food systems factors and dynamics, and supports the importance of adopting a combined food systems and political economy approach to understanding global dietary change^{115, 116}. A recent review on the political economy of nutrition reported industry interference as the most important barrier to achieving strong regulatory actions on unhealthy diets, obesity and diet-related NCDs in HICs and UMICs²⁰⁵. This emphasises the importance of further understanding, monitoring and acting on the commercial determinants of health⁹⁷. A growing literature on this topic is emerging, including monitoring food industry corporate political activity in multiple countries^{232, 233}. Scholars are also paying increasing attention to the political economy of food systems, placing actors and their relations of power at the centre of analysis^{116, 234}. This includes emerging research on the financialisation of food systems, and the way new investment patterns by private equity firms and food corporations, are transforming market and political relations in their favour^{117, 227}.

Finally, reducing UPF and beverage consumption and associated harms, involves implementing synergistic policy actions targeting multiple food system sectors simultaneously. Several factors have enabled policy progress in some jurisdictions, especially the accelerated adoption of SSB taxes. These include the mobilisation of broad-based civil society coalitions, the strategic development and use of evidence, and concerted advocacy during key policy windows, for example during fiscal reform^{184, 193, 210}. Expanding financial support for mobilizing civil society coalitions and ‘social lobbying’, as provided by Bloomberg Philanthropies in Mexico²¹⁰, presents an important opportunity for accelerating worldwide policy change. Some of the key challenges to sustaining policy actions in the long-term include maintaining political commitment, countering ongoing industry resistance, and ensuring adequate capacity to design, implement and monitor policy actions^{205, 207, 235}. This highlights the importance of continuing technical guidance and country-level support provided by WHO, FAO, UNICEF, the World Bank and others. Classifying foods and beverages by degree of processing (as in the NOVA classification) in dietary guidelines, and not just nutrient content alone, can help policy-makers and the public to better identify foods associated with adverse health outcomes²³⁶. Such ‘food-based profiling’ is now guiding policy action. For example, the Brazilian Government recently included limits on UPFs in new school food programme legislation²³⁷. Developing guidance on food-based profiling, in combination with existing nutrient profiling work, may present an important new technical activity for WHO in particular. There are also potential strategies to develop less-processed packaged foods (whole-food reformulation), and to promote the consumption of home- and hand- prepared foods²⁰¹.

There are several limitations of our analysis. We have not reported actual consumption and have instead used retail sales data. Our reliance on using Euromonitor sales and ingredients data reflects the absence of these food types in nationally-comparable standardised dietary survey instruments, presenting an

important data gap for the global nutrition community. We have not considered trends or patterns in the social stratification of UPF and UPB sales within countries. Although urban consumers tend to be more affluent than rural, some studies reveal the urban poor purchase higher levels of UPFs¹²⁹. We have also reported only formal UPF and UPB sales. This may therefore under-represent true volumes as it does not capture sales via informal channels, which are more important in lower-income countries. We have not included commercial breastmilk substitutes or commercial complementary foods, which are often the first types of UPFs consumed by children, although we have reported on these elsewhere⁹⁸. We have considered the health impacts of UPFs, but have largely ignored the environmental implications. Our understanding of the links between the degree of food processing and environmental degradation (or benefit) is emerging, and presents an important topic of investigation as evident in recent studies focused on greenhouse gas emissions^{238, 239}. Although the large variety of UPF products on supermarkets shelves may be manufactured from a small number of primary agricultural commodities, the links between these products and agricultural biodiversity has barely been explored.

Conclusion

The findings of this review supports our initial premise that there has been a substantial expansion in the types and quantities of ultra-processed foods and beverages available in the world's food supply, occurring first in high-income countries and increasingly in middle-income ones. This provides evidence that a transition towards a more highly-processed global diet is not only underway, but also continues apace. As countries grow richer, their populations appear to purchase a wider variety of higher value and convenience ultra-processed products, with the share of foods used mainly in food preparation declining. There are however wide variations at regional and country levels, suggesting that although there may be a singular global transition to a more highly-processed diet, *transitions* are also playing out across regions and countries at different stages of economic and social development. This at least partly reflects differences in the underlying drivers, core elements and dynamics of food systems that influence purchasing behaviours and dietary change. Causes for concern include the failure to reduce caloric sweeteners from UPFs in HICs, the rising supply of caloric sweeteners from both UPFs and beverages in UMICs and LMICs, and the rising supply of cosmetic additives and low-calorie and non-caloric sweeteners nearly everywhere.

We have also shown that these transitions are closely linked with the industrialisation of food systems, technological change and globalisation, including growth in the commercial and political practices of transnational food and beverage corporations, and the power these corporations have to shape food

systems on a global scale. Growing UPF and beverage markets are closely linked with the mass production of primary agricultural commodities, and the conversion of these commodities into a diverse range of cheap ingredients available for use in manufacturing. In the current era of trade and investment liberalization, these ingredients flow through globally integrated sourcing, production and distribution networks of corporations, making ultra-processed foods available on a truly global scale. These food processing transitions are also closely linked with transformative changes underway in food retailing, especially the growth of modern grocery retailers, as well as the intensive use of sophisticated marketing techniques. The rise of new digital marketing technologies, enabled by big data platforms, is a crucial topic for ongoing investigation.

Our results also suggest that these food processing transitions reflect variations in the strength of policy and regulatory frameworks targeting unhealthy diets and the power of different actors and interests to help or hinder policy action. Although there has been some recent progress, policy and regulatory actions in many countries are weak, with a skew towards lifestyle-behavioural interventions targeting individuals rather than more upstream ones targeting the commercial practices of the UPF industry. Substantial evidence now shows this industry has impeded political commitment for strong regulatory action. This power has been expanded by favourable governance arrangements, nutrient-based approaches to profiling the healthiness of foods, and processes linked with trade and investment liberalisation, market concentration, and the financialisation of food systems. This brings into question the role of the UPF industry in current food governance arrangements, and ‘as part of the solution’ in policy responses to attenuate unhealthy diets.

Overall, these findings suggest that adopting an approach that combines food systems and political economy thinking is vital for understanding the determinants of global dietary change, and to informing future nutrition policy responses. Given the rapidly emerging evidence on the adverse health outcomes associated with dietary exposure to UPFs, and the scale of change underway, the implications for global nutrition and public health are crucial to consider.

References

- 1 Moubarac J-C, Parra DC, Cannon G, Monteiro CA. Food classification systems based on food processing: significance and implications for policies and actions: a systematic literature review and assessment. *Curr Obes Report*. 2014; 3: 256-72.
- 2 Monteiro CA, Cannon G, Moubarac JC, *et al*. Ultra-processing. An odd 'appraisal'. *Public Health Nutr*. 2018; 21: 497-501.
- 3 Monteiro CA, Cannon G, Moubarac JC, *et al*. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr*. 2018; 21: 5-17.

- 4 Monteiro CA, Cannon G, Lawrence M, da Costa Louzada ML, Machado PP. Ultra-processed foods, diet quality, and health using the NOVA classification system. Rome: Food and Agricultural Organization of the United Nations 2019.
- 5 Cordain L, Eaton SB, Sebastian A, *et al.* Origins and evolution of the Western diet: Health implications for the 21st century. *Am J Clin Nutr.* 2005; 81: 341-54.
- 6 Pollan M. Cooked: a natural history of transformation: Penguin 2014.
- 7 Uliaszek SJ, Mann N, Elton S. Evolving human nutrition: implications for public health: Cambridge University Press 2012.
- 8 Kiple KF, Ornelas KC. Cambridge world history of food. United Kingdom: Cambridge University Press 2000.
- 9 McMichael P. A food regime genealogy. *J Peasant Stud.* 2009; 36: 139-69.
- 10 Monteiro CA, Levy RB, Claro RM, De Castro IRR, Cannon G. Increasing consumption of ultra-processed foods and likely impact on human health: Evidence from Brazil. *Public Health Nutr.* 2011; 14: 5-13.
- 11 Popkin BM. Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am J Clin Nutr.* 2006; 84: 289-98.
- 12 Popkin BM, Adair LS, Ng SW. Global nutrition transition: the pandemic of obesity in developing countries. *Nutr Rev.* 2012; 70: 3-21.
- 13 Food systems and diets: Facing the challenges of the 21st Century. London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2016.
- 14 Baker P, Friel S. Processed foods and the nutrition transition: Evidence from Asia. *Obes Rev.* 2014; 15: 564-77.
- 15 2020 Global Nutrition Report: Action on equity to end malnutrition. Bristol: Development Initiatives 2020.
- 16 Djupegot IL, Nenseth CB, Bere E, *et al.* The association between time scarcity, sociodemographic correlates and consumption of ultra-processed foods among parents in Norway: a cross-sectional study. *BMC Public Health.* 2017; 17: 447.
- 17 Moubarac J-C, Martins APB, Claro RM, *et al.* Consumption of ultra-processed foods and likely impact on human health. Evidence from Canada. *Public Health Nutr.* 2013; 16: 2240-48.
- 18 Schnabel L, Kesse-Guyot E, Allès B, *et al.* Association Between Ultraprocessed Food Consumption and Risk of Mortality Among Middle-aged Adults in France. *JAMA Intern Med.* 2019.
- 19 Simões BdS, Barreto SM, Molina MdCB, *et al.* Consumption of ultra-processed foods and socioeconomic position: a cross-sectional analysis of the Brazilian Longitudinal Study of Adult Health. *Cad Saude Publica.* 2018; 34: e00019717.
- 20 Khandpur N, Cediel G, Obando DA, Jaime PC, Parra DC. Sociodemographic factors associated with the consumption of ultra-processed foods in Colombia. *Rev Saude Publica.* 2020; 54: 19.
- 21 Monteiro CA, Moura EC, Conde WL, Popkin BM. Socioeconomic status and obesity in adult populations of developing countries: a review. *Bull World Health Organ.* 2004; 82: 940-46.
- 22 Elizabeth L, Machado P, Zinocker M, Baker P, Lawrence M. Ultra-Processed Foods and Health Outcomes: A Narrative Review. *Nutrients.* 2020; 12: 1955.
- 23 Louzada MLDC, Ricardo CZ, Steele EM, *et al.* The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. *Public Health Nutr.* 2018; 21: 94-102.
- 24 Cediel G, Reyes M, da Costa Louzada ML, *et al.* Ultra-processed foods and added sugars in the Chilean diet (2010). *Public Health Nutr.* 2018; 21: 125-33.
- 25 Martínez Steele E, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a nationally representative cross-sectional study. *Popul Health Metr.* 2017; 15: 6.
- 26 Rauber F, da Costa Louzada ML, Steele EM, *et al.* Ultra-Processed Food Consumption and Chronic Non-Communicable Diseases-Related Dietary Nutrient Profile in the UK (2008-2014). *Nutrients.* 2018; 10.

- 27 Moubarac JC, Batal M, Louzada ML, Martinez Steele E, Monteiro CA. Consumption of ultra-processed foods predicts diet quality in Canada. *Appetite*. 2017; 108: 512-20.
- 28 Machado PP, Steele EM, Levy RB, *et al*. Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study. *BMJ Open*. 2019; 9: e029544.
- 29 Kim H HE, Rebholz CM. Ultra-processed food intake and mortality in the USA: results from the Third National Health and Nutrition Examination Survey (NHANES III, 1988-1994). *Public Health Nutr*. 2019; 1-9.
- 30 Rico-Campà A, Martínez-González M, Alvarez-Alvarez I, *et al*. Association between consumption of ultra-processed foods and all cause mortality: SUN prospective cohort study. *BMJ*. 2019; 365:.
- 31 Blanco-Rojo R, Sandoval-Insausti H, Lopez-Garcia E, *et al*. Consumption of Ultra-Processed Foods and Mortality: A National Prospective Cohort in Spain. *Mayo Clin Proc*. 2019; 94: 2178-88.
- 32 Juul F, Martinez-Steele E, Parekh N, Monteiro CA, Chang VW. Ultra-processed food consumption and excess weight among US adults. *Br J Nutr*. 2018; 120: 90-100.
- 33 Louzada ML, Baraldi LG, Steele EM, *et al*. Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. *Prev Med*. 2015; 81: 9-15.
- 34 Mendonça RD, Pimenta AM, Gea A, *et al*. Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *Am J Clin Nutr*. 2016; 104: 1433-40.
- 35 Nardocci M, Leclerc BS, Louzada ML, *et al*. Consumption of ultra-processed foods and obesity in Canada. *Can J Public Health*. 2018.
- 36 Canhada SL, Luft VC, Giatti L, *et al*. Ultra-processed foods, incident overweight and obesity, and longitudinal changes in weight and waist circumference: the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). *Public Health Nutr*. 2019: 1-11.
- 37 Mendonça RD, Lopes AC, Pimenta AM, *et al*. Ultra-Processed Food Consumption and the Incidence of Hypertension in a Mediterranean Cohort: The Seguimiento Universidad de Navarra Project. *Am J Hypertens*. 2017; 30: 358-66.
- 38 Rauber F, Campagnolo PD, Hoffman DJ, Vitolo MR. Consumption of ultra-processed food products and its effects on children's lipid profiles: a longitudinal study. *Nutr Metab Cardiovasc Dis*. 2015; 25: 116-22.
- 39 Srouf B, Fezeu LK, Kesse-Guyot E, *et al*. Ultra-processed food intake and risk of cardiovascular disease: prospective cohort study (NutriNet-Sante). *BMJ*. 2019; 365: 11451.
- 40 Srouf B, Fezeu LK, Kesse-Guyot E, *et al*. Ultraprocessed Food Consumption and Risk of Type 2 Diabetes Among Participants of the NutriNet-Sante Prospective Cohort. *JAMA Intern Med*. 2019.
- 41 Martínez Steele E, Juul F, Neri D, Rauber F, Monteiro CA. Dietary share of ultra-processed foods and metabolic syndrome in the US adult population. *Prev Med*. 2019; 125: 40-48.
- 42 Fiolet T, Srouf B, Sellem L, *et al*. Consumption of ultra-processed foods and cancer risk: results from NutriNet-Santé prospective cohort. *BMJ*. 2018; 360: k322.
- 43 Schnabel L, Buscail C, Sabate JM, *et al*. Association Between Ultra-Processed Food Consumption and Functional Gastrointestinal Disorders: Results From the French NutriNet-Santé Cohort. *Am J Gastroenterol*. 2018.
- 44 Melo B, Rezende L, Machado P, Gouveia N, Levy R. Associations of ultra-processed food and drink products with asthma and wheezing among Brazilian adolescents. *Pediatr Allergy Immunol*. 2018.
- 45 Sandoval-Insausti H, Blanco-Rojo R, Graciani A, *et al*. Ultra-processed Food Consumption and Incident Frailty: A prospective Cohort Study of Older Adults. *J Gerontol A Biol Sci Med Sci*. 2019.
- 46 Adijbade M, Julia C, Alles B, *et al*. Prospective association between ultra-processed food consumption and incident depressive symptoms in the French NutriNet-Sante cohort. *BMC Med*. 2019; 17: 78.

- 47 Gomez-Donoso C, Sanchez-Villegas A, Martinez-Gonzalez MA, *et al.* Ultra-processed food consumption and the incidence of depression in a Mediterranean cohort: the SUN Project. *Eur J Nutr.* 2019.
- 48 Basu S, McKee M, Galea G, Stuckler D. Relationship of Soft Drink Consumption to Global Overweight, Obesity, and Diabetes: A Cross-National Analysis of 75 Countries. *Am J Public Health.* 2013; March: e1-e7.
- 49 Bray GA, Nielsen SJ, Popkin BM. Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. *Am J Clin Nutr.* 2004; 79: 537-43.
- 50 Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev.* 2013; 14: 606-19.
- 51 Malik VS, Popkin BM, Bray GA, Després J-P, Hu FB. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation.* 2010; 121: 1356-64.
- 52 Pereira MA, Kartashov AI, Ebbeling CB, *et al.* Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet.* 2005; 365: 36-42.
- 53 Imamura F, O'Connor L, Ye Z, *et al.* Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. *BMJ.* 2015; 351: h3576.
- 54 Duffey KJ, Gordon-Larsen P, Steffen LM, Jacobs Jr DR, Popkin BM. Regular consumption from fast food establishments relative to other restaurants is differentially associated with metabolic outcomes in young adults. *J Nutr.* 2009; 139: 2113-18.
- 55 Smith KJ, McNaughton SA, Gall SL, *et al.* Takeaway food consumption and its associations with diet quality and abdominal obesity: a cross-sectional study of young adults. *Int J Behav Nutr Phys Act.* 2009; 6: 29.
- 56 Chan DSM, Lau R, Aune D, *et al.* Red and Processed Meat and Colorectal Cancer Incidence: Meta-Analysis of Prospective Studies. *PLOS ONE.* 2011; 6: e20456.
- 57 Hall KD AA, Brychta R, *et al* Ultra-Processed Diets Cause Excess Calorie Intake and Weight Gain: An Inpatient Randomized Controlled Trial of Ad Libitum Food Intake. *Cell Metab.* 2019; 10.1016/j.cmet.2019.05.008. 31105044.
- 58 Luiten CM, Steenhuis IH, Eyles H, Ni Mhurchu C, Waterlander WE. Ultra-processed foods have the worst nutrient profile, yet they are the most available packaged products in a sample of New Zealand supermarkets. *Public Health Nutr.* 2016; 19: 530-8.
- 59 Ni Mhurchu C, Brown R, Jiang Y, *et al.* Nutrient profile of 23 596 packaged supermarket foods and non-alcoholic beverages in Australia and New Zealand. *Public Health Nutr.* 2016; 19: 401-8.
- 60 Poti JM, Mendez MA, Ng SW, Popkin BM. Is the degree of food processing and convenience linked with the nutritional quality of foods purchased by US households? *Am J Clin Nutr.* 2015; 101: 1251-62.
- 61 Martínez Steele E, Monteiro CA. Association between dietary share of ultra-processed foods and urinary concentrations of phytoestrogens in the US. *Nutrients.* 2017; 9: 209.
- 62 Fardet A. Minimally processed foods are more satiating and less hyperglycemic than ultra-processed foods: a preliminary study with 98 ready-to-eat foods. *Food Funct.* 2016; 7: 2338-46.
- 63 Fardet A, Méjean C, Labouré H, Andreeva VA, Feron G. The degree of processing of foods which are most widely consumed by the French elderly population is associated with satiety and glycemic potentials and nutrient profiles. *Food Funct.* 2017; 8: 651-58.
- 64 de Graaf C, Kok F. Slow food, fast food and the control of food intake. *Nat Rev Endocrinol* 2010; 6, .
- 65 Small DM, DiFeliceantonio AG. Processed foods and food reward. *Science.* 2019; 363: 346-47.
- 66 Panel on Contaminants in the Food Chain. Acrylamide in food. European Food Safety Authority: 2015.
- 67 Gibis M. Heterocyclic aromatic amines in cooked meat products: causes, formation, occurrence, and risk assessment. *Compr Rev Food Sci Food Saf.* 2016; 15: 269-302.

- 68 Zinöcker M, Lindseth I. The Western Diet–Microbiome–Host Interaction and Its Role in Metabolic Disease. *Nutrients*. 2018; 10: 365.
- 69 Miclotte L VdWT. Food processing, gut microbiota and the globesity problem. *Crit Rev Food Sci Nutr*. 2019; 1-14.
- 70 Chazelas E, Deschasaux M, Srouf B, *et al.* Food additives: distribution and co-occurrence in 126,000 food products of the French market. *Sci Rep*. 2020; 10: 1-15.
- 71 Halden RU. Plastics and health risks. *Annu Rev Public Health*. 2010; 31: 179-94.
- 72 Thompson RC, Moore CJ, Vom Saal FS, Swan SH. Plastics, the environment and human health: current consensus and future trends. *Phil Trans R Soc B*. 2009; 364: 2153-66.
- 73 Heindel JJ, Newbold, R., & Schug, T. T. . Endocrine disruptors and obesity. *Nat Rev Endocrinol*. 2015; 11.
- 74 Buckley JP, Kim H, Wong E, Rebholz CM. Ultra-processed food consumption and exposure to phthalates and bisphenols in the US National Health and Nutrition Examination Survey, 2013–2014. *Environ Int*. 2019; 131: 105057.
- 75 Alexy U, Sichert-Hellert W, Rode T, Kersting M. Convenience food in the diet of children and adolescents: consumption and composition. *Br J Nutr*. 2008; 99: 345-51.
- 76 Peltner J, Thiele S. Convenience-based food purchase patterns: identification and associations with dietary quality, sociodemographic factors and attitudes. *Public Health Nutr*. 2018; 21: 558-70.
- 77 Bellisle F. Meals and snacking, diet quality and energy balance. *Physiol Behav*. 2014; 134: 38-43.
- 78 Gordon EL, Ariel-Donges AH, Bauman V, Merlo LJ. What is the evidence for “food addiction?” A systematic review. *Nutrients*. 2018; 10: 477.
- 79 Filgueiras AR, Pires de Almeida VB, Koch Nogueira PC, *et al.* Exploring the consumption of ultra-processed foods and its association with food addiction in overweight children. *Appetite*. 2019; 135: 137-45.
- 80 Lobstein T, Dobb S. Evidence of a possible link between obesogenic food advertising and child overweight. *Obesity Rev*. 2005; 6: 203-08.
- 81 Pulker CE, Scott JA, Pollard CM. Ultra-processed family foods in Australia: nutrition claims, health claims and marketing techniques. *Public Health Nutr*. 2018; 21: 38-48.
- 82 Mallarino C, Gómez LF, González-Zapata L, Cadena Y, Parra DC. Advertising of ultra-processed foods and beverages: children as a vulnerable population. *Rev Saude Publica*. 2013; 47: 1006-10.
- 83 Bleich SN, Vercammen KA. The negative impact of sugar-sweetened beverages on children’s health: an update of the literature. *BMC obesity*. 2018; 5: 6.
- 84 Moynihán P, Kelly S. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. *J Dent Res*. 2014; 93: 8-18.
- 85 Hadjidakou M, Baker P. The untenable role of “junk food” in a healthy and sustainable food system. In: Lawrence M, Friel S (eds.). *Healthy and Sustainable Food Systems*. Routledge: London 2019; 158-69.
- 86 Kroyer GT. Impact of food processing on the environment—an overview. *LWT - Food Sci Technol*. 1995; 28: 547-52.
- 87 Koutsodendris A, Papatheodorou G, Kougiourouki O, Georgiadis M. Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification. *Estuar Coast Shelf Sci*. 2008; 77: 501-12.
- 88 Popkin BM, Reardon T. Obesity and the food system transformation in Latin America. *Obesity Rev*. 2018; 19: 1028-64.
- 89 Popkin BM. Nutritional patterns and transitions. *Popul Dev Rev*. 1993: 138-57.
- 90 Kearney J. Food consumption trends and drivers. *Philos Trans R Soc B*. 2010; 365: 2793-807.
- 91 Hawkes C. The role of foreign direct investment in the nutrition transition. *Public Health Nutr*. 2005; 8: 357-65.
- 92 Hawkes C. Uneven dietary development: Linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Global Health*. 2006; 2.

- 93 Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra- processed products are becoming dominant in the global food system. *Obesity Rev.* 2013; 14: 21-28.
- 94 Reardon T, Tschirley D, Dolislager M, *et al.* Urbanization, diet change, and transformation of food supply chains in Asia. *Michigan: Global Center for Food Systems Innovation.* 2014.
- 95 Monteiro CA, Cannon G. The impact of transnational "big food" companies on the south: A view from Brazil. *PLoS Med.* 2012; 9.
- 96 Baker P, Friel S. Food systems transformations, ultra-processed food markets and the nutrition transition in Asia. *Global Health.* 2016; 12.
- 97 Moodie R, Stuckler D, Monteiro C, *et al.* Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet.* 2013; 381: 670-79.
- 98 Baker P, Smith J, Salmon L, *et al.* Global trends and patterns of commercial milk-based formula sales: is an unprecedented infant and young child feeding transition underway? *Public Health Nutr.* 2016; 19: 2540-50.
- 99 Vandevijvere S, Jaacks LM, Monteiro CA, *et al.* Global trends in ultraprocessed food and drink product sales and their association with adult body mass index trajectories. *Obesity Rev.* 2019; 20: 10-19.
- 100 Stuckler D, McKee M, Ebrahim S, Basu S. Manufacturing epidemics: the role of global producers in increased consumption of unhealthy commodities including processed foods, alcohol, and tobacco. *PLoS Med.* 2012; 9: e1001235.
- 101 Hawkes C, Friel S, Lobstein T, Lang T. Linking agricultural policies with obesity and noncommunicable diseases: a new perspective for a globalising world. *Food Policy.* 2012; 37: 343-53.
- 102 Pluye P, Hong QN. Combining the power of stories and the power of numbers: mixed methods research and mixed studies reviews. *Annu Rev Public Health.* 2014; 35: 29-45.
- 103 Heyvaert M, Maes B, Onghena P. Mixed methods research synthesis: definition, framework, and potential. *Qual Quant.* 2013; 47: 659-76.
- 104 Walls HL, Johnston D, Mazalale J, Chirwa EW. Why we are still failing to measure the nutrition transition. *BMJ Glob Health.* 2018; 3: e000657.
- 105 Baker P, Friel S. Processed foods and the nutrition transition: Evidence from Asia. *Obesity Reviews.* 2014; 15: 564-77.
- 106 Passport Global Market Information Database. London: Euromonitor International 2019.
- 107 Monteiro C, Cannon G, Levy R, *et al.* Ultra-processed foods: what they are and how to identify them. *Public Health Nutr.* 2019.
- 108 World Development Indicators: Population Estimates and Projections. Washington, D.C.: World Bank 2019.
- 109 Cummings J, Roberfroid M, Andersson H, *et al.* A new look at dietary carbohydrate: chemistry, physiology and health. *Eur J Clin Nutr.* 1997; 51: 417.
- 110 Guideline: sugars intake for adults and children. Geneva: World Health Organization 2015.
- 111 McCance and Widdowson's composition of foods integrated dataset. London: Public Health England 2019.
- 112 Mozaffarian D, Katan MB, Ascherio A, Stampfer MJ, Willett WC. Trans fatty acids and cardiovascular disease. *New Engl J Med.* 2006; 354: 1601-13.
- 113 Nutrition and food systems: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: Committee on World Food Security 2017.
- 114 Too big to feed: Exploring the impacts of mega-mergers, consolidation and concentration of power in the agri-food sector. London: International Panel of Experts on Sustainable Food Systems 2017.
- 115 The new science of sustainable food systems: overcoming barriers to food systems reform. London: International Panel of Experts on Sustainable Food Systems 2015.
- 116 Baker P, Demaio A. The political economy of healthy and sustainable food systems. In: Lawrence M, Friel S (eds.). *Healthy and Sustainable Food Systems.* Routledge 2019.
- 117 Clapp J. Financialization, distance and global food politics. *J Peasant Stud.* 2014; 41: 797-814.
- 118 Fuchs D, Kalfagianni A. The causes and consequences of private food governance. *Bus Polit.* 2010; 12: 1469-3569.

- 119 Baker P, Kay A, Walls H. Trade and investment liberalization and Asia's noncommunicable disease epidemic: a synthesis of data and existing literature. *Global Health*. 2014; 10: 66.
- 120 Baker P, Friel S, Schram A, Labonte R. Trade and investment liberalization, food systems change and highly processed food consumption: A natural experiment contrasting the soft-drink markets of Peru and Bolivia. *Global Health*. 2016; 12.
- 121 Thow AM, Hawkes C. The implications of trade liberalization for diet and health: a case study from Central America. *Global Health*. 2009; 5: 5.
- 122 Grigg D. The changing geography of world food consumption in the second half of the twentieth century. *Geogr J*. 1999: 1-11.
- 123 Reardon T, Timmer CP, Berdegue JA. The rapid rise of supermarkets in developing countries: induced organizational, institutional, and technological change in agrifood systems. *J Dev Agric Econ*. 2004; 1: 168-83.
- 124 Monteiro CA, Conde WL, Popkin BM. Income-specific trends in obesity in Brazil: 1975–2003. *Am J Public Health*. 2007; 97: 1808-12.
- 125 Headey DD, Alderman HH. The relative caloric prices of healthy and unhealthy foods differ systematically across income levels and continents. *Nutr J*. 2019; 149: 2020-33.
- 126 Moubarac J-C, Claro RM, Baraldi LG, *et al*. International differences in cost and consumption of ready-to-consume food and drink products: United Kingdom and Brazil, 2008–2009. *Glob Public Health*. 2013; 8: 845-56.
- 127 Popkin BM. Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am J Clin Nutr*. 2006; 84: 289-98.
- 128 Pingali P. Westernization of Asian diets and the transformation of food systems: Implications for research and policy. *Food Policy*. 2007; 32: 281-98.
- 129 Hawkes C, Harris J, Gillespie S. Changing diets: Urbanization and the nutrition transition. *Global Food Policy Report*. International Food Policy Research Institute (IFPRI): Washington, DC 2017; 34-41.
- 130 Smith LP, Ng SW, Popkin BM. Trends in US home food preparation and consumption: analysis of national nutrition surveys and time use studies from 1965–1966 to 2007–2008. *Nutr J*. 2013; 12: 45.
- 131 Gehlhar M, Regmi A. Factors shaping global food markets. Washington, DC: US Department of Agriculture 2005.
- 132 Lang T, Caraher M. Is there a culinary skills transition? Data and debate from the UK about changes in cooking culture. *Journal of the HEIA*. 2001; 8: 2-14.
- 133 Warde A, Cheng S-L, Olsen W, Southerton D. Changes in the practice of eating: a comparative analysis of time-use. *Acta Sociol*. 2007; 50: 363-85.
- 134 Brunner TA, Van der Horst K, Siegrist M. Convenience food products. Drivers for consumption. *Appetite*. 2010; 55: 498-506.
- 135 Murphy S, Burch D, Clapp J. Cereal secrets: The world's largest grain traders and global agriculture. Oxford: Oxfam 2012.
- 136 Food Ingredients Sector. Dublin: Global M&A Partners 2018.
- 137 Briones R, Rakotoarisoa M. Investigating the structures of agricultural trade industry in developing countries. FAO Commodity and Trade Policy Research Working Paper, 38. Rome: Food and Agricultural Organization of the United Nations 2013.
- 138 Fry J, Fitton C. The Importance of the Global Oils and Fats Supply and the Role that Palm Oil Plays in Meeting the Demand for Oils and Fats Worldwide. *J Am Coll Nutr*. 2010; 29: 245S-52S.
- 139 Bray GA, Nielsen SJ, Popkin BM. Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. *The American Journal of Clinical Nutrition*. 2004; 79: 537-43.
- 140 Barlow P, McKee M, Basu S, Stuckler D. Impact of the North American Free Trade Agreement on high-fructose corn syrup supply in Canada: a natural experiment using synthetic control methods. *CMAJ*. 2017; 189: E881-E87.
- 141 Unar-Munguía M, Monterubio Flores E, Colchero MA. Apparent consumption of caloric sweeteners increased after the implementation of NAFTA in Mexico. *Food Policy*. 2019; 84: 103-10.

- 142 Reardon T, Echeverria R, Berdegue J, *et al.* Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations. *Agric Syst.* 2019; 172: 47-59.
- 143 Delgado C, Rosegrant M, Steinfeld H, Ehui S, Courbois C. Livestock to 2020: The next food revolution. *Outlook Agric.* 2001; 30: 27-29.
- 144 Alexander E, Yach D, Mensah GA. Major multinational food and beverage companies and informal sector contributions to global food consumption: implications for nutrition policy. *Global Health.* 2011; 7: 26.
- 145 Annual Review 2019. Vevey Nestlé S.A 2019.
- 146 Wilkinson J. The globalization of agribusiness and developing world food systems. *Mon Rev.* 2009; 61.
- 147 Popkin B. Technology, transport, globalization and the nutrition transition food policy. *Food Policy.* 2006; 31: 554-69.
- 148 Kamel B, Stauffer C. *Advances in Baking Technology.* Amsterdam: Springer 1993.
- 149 Scrinis G. *Nutritionism: The science and politics of dietary advice.* New York: Columbia University Press 2013.
- 150 Risch SJ. Food packaging history and innovations. *J Agric Food Chem.* 2009; 57: 8089-92.
- 151 Clapp J, Scrinis G. Big food, nutritionism, and corporate power. *Globalizations.* 2017; 14: 578-95.
- 152 Hawkes C. Marketing activities of global soft drink and fast food companies in emerging markets: a review. *Globalization, diets and noncommunicable diseases.* World Health Organization: Geneva 2002; 1-78.
- 153 Green H. Global obesity: Nestlé initiatives in nutrition, health, and wellness. *Nutr Rev.* 2006; 64: S62-S64.
- 154 Hawkes C. Dietary implications of supermarket development: A global perspective. *Development Policy Review.* 2008; 26: 657-92.
- 155 Reardon T, Henson S, Gulati A. Links Between Supermarkets and Food Prices, Diet Diversity and Food Safety in Developing Countries. In: Hawkes C, Blouin C, Henson S, Drager N, Dube L (eds.). *Trade, Food, Diet and Health: Perspectives and Policy Options.* John Wiley & Sons Ltd: Chichester, West Sussex 2010; 111-30.
- 156 Reardon T, Hopkins R. The supermarket revolution in developing countries: Policies to address emerging tensions among supermarkets, suppliers and traditional retailers. *Eur J Dev Res.* 2006; 18: 522-45.
- 157 Reardon T, Timmer C. Transformation of Markets for Agricultural Output in Developing Countries Since 1950: How Has Thinking Changed? In: Evenson RE, Pingali P, Schultz TP (eds.). *Volume 3: Handbook of Agricultural Economics: Agricultural Development: Farmers, Farm Production and Farm Markets.* Elsevier: Burlington 2005.
- 158 Reardon T, Timmer CP, Minten B. Supermarket revolution in Asia and emerging development strategies to include small farmers. *Proc Natl Acad Sci.* 2012; 109: 12332-37.
- 159 Hawkes C. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Globalisation and Health.* 2006; 2: 4.
- 160 Reardon T, Berdegue J, Timmer CP. Supermarketization of the "Emerging Markets" of the Pacific Rim: Development and Trade Implications. *J Food Distrib Res.* 2005; 36.
- 161 Reardon T, Timmer C, Barrett C, Berdegue J. The rise of supermarkets in Africa, Asia and Latin America. *Am J Agric Econ.* 2003; 85: 1140 - 46.
- 162 Hawkes C. The role of foreign direct investment in the nutrition transition. *Public Health Nutrition.* 2005; 8: 357-65.
- 163 Reardon T, Hopkins R. The supermarket revolution in developing countries: Policies to address emerging tensions among supermarkets, suppliers and traditional retailers. *Europ J Devel Res.* 2006; 18: 522-45.
- 164 Coe NM, Wrigley N. Host economy impacts of transnational retail: The research agenda. *J Econ Geogr.* 2007; 7: 341-71.

- 165 Machado P, Claro R, Canella D, Sarti F, Levy R. Price and convenience: The influence of supermarkets on consumption of ultra-processed foods and beverages in Brazil. *Appetite*. 2017; 116: 381-8.
- 166 Stanton R. Food retailers and obesity. *Curr Obes Rep*. 2015; 4: 54-9.
- 167 Taillie L, Ng SW, Popkin BM. Global growth of "big box" stores and the potential impact on human health and nutrition. *Nutr Rev*. 2016; 74: 83-97.
- 168 Packaged Food in China. London: Euromonitor International 2013.
- 169 Packaged Food in India. London: Euromonitor International 2013.
- 170 Barki E, Parente J. Challenges and opportunities of the last mile for the base of the pyramid: the case of Brazil. *FACTS*. 2014: 1-4.
- 171 Maimaiti M, Zhao X, Jia M, Ru Y, Zhu S. How we eat determines what we become: opportunities and challenges brought by food delivery industry in a changing world in China. *Eur J Clin Nutr*. 2018; 72: 1282-86.
- 172 Bates S, Reeve B, Trevena H. A narrative review of online food delivery in Australia: challenges and opportunities for public health nutrition policy. *Public Health Nutr*. 2020: 1-11.
- 173 Montgomery K, Chester J, Nixon L, Levy L, Dorfman L. Big Data and the transformation of food and beverage marketing: undermining efforts to reduce obesity? *Crit Public Health*. 2019; 29: 110-17.
- 174 Freeman B, Kelly B, Baur L, *et al*. Digital junk: food and beverage marketing on Facebook. *Am J Public Health*. 2014; 104: e56-e64.
- 175 Chandon P. How package design and packaged-based marketing claims lead to overeating. *Appl Econ Perspect Policy*. 2013; 35: 7-31.
- 176 Hawkes C. The role of foreign direct investment in the nutrition transition. *Public Health Nutr*. 2005; 8: 357-65.
- 177 Hawkes C. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Global Health*. 2006; 2: 4.
- 178 Lang T, Rayner G. Overcoming policy cacophony on obesity: An ecological public health framework for policymakers. *Obes Rev*. 2007.
- 179 Kennedy G, Nantel G, Shetty P. Globalization of food systems in developing countries: impact on food security and nutrition. Rome: Food and Agricultural Organization of the United Nations 2004.
- 180 Hawkes C, Jewell J, Allen K. A food policy package for healthy diets and the prevention of obesity and diet-related non-communicable diseases: the NOURISHING framework. *Obesity Rev*. 2013; 14: 159-68.
- 181 Global action plan for the prevention and control of NCDs 2013-2020. Geneva: World Health Organization 2013.
- 182 Magnusson R. Advancing the right to health: the vital role of law. Geneva: World Health Organization 2017.
- 183 Swinburn BA. Obesity prevention: the role of policies, laws and regulations. *Aust NZ J Publ Heal*. 2008; 5.
- 184 Baker P, Brown AD, Wingrove K, *et al*. Generating political commitment for ending malnutrition in all its forms: A system dynamics approach for strengthening nutrition actor networks. *Obes Rev*. 2019; 20: 30-44.
- 185 Gortmaker SL, Swinburn BA, Levy D, *et al*. Changing the future of obesity: science, policy, and action. *Lancet*. 2011; 378: 838-47.
- 186 Report of the commission on ending childhood obesity. Geneva: World Health Organization 2016.
- 187 Roberto CA, Swinburn B, Hawkes C, *et al*. Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *Lancet*. 2015; 385: 2400-09.
- 188 Popkin BM, Hawkes C. Sweetening of the global diet, particularly beverages: patterns, trends, and policy responses. *Lancet Diabetes Endocrinol* 2016; 4: 174-86.
- 189 Haddad LJ, Hawkes C, Achadi E, *et al*. Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development: International Food Policy Research Institute 2015.

- 190 Global nutrition policy review 2016-2017. Geneva: World Health Organization 2018.
- 191 Assessing national capacity for the prevention and control of noncommunicable diseases: report of the 2017 global survey. Geneva: World Health Organization 2018.
- 192 Dodd R, Reeve E, Sparks E, *et al.* The politics of food in the Pacific: coherence and tension in regional policies on nutrition, the food environment and non-communicable diseases. *Public Health Nutr.* 2019; 1-13.
- 193 Pérez- Escamilla R, Lutter C, Rabadan- Diehl C, *et al.* Prevention of childhood obesity and food policies in Latin America: from research to practice. *Obes Rev.* 2017; 18: 28-38.
- 194 Crammond B, Van C, Allender S, *et al.* The possibility of regulating for obesity prevention—understanding regulation in the Commonwealth Government. *Obes Rev.* 2013; 14: 213-21.
- 195 Bucher T, Collins C, Rollo ME, *et al.* Nudging consumers towards healthier choices: a systematic review of positional influences on food choice. *Br J Nutr.* 2016; 115: 2252-63.
- 196 Wilson AL, Buckley E, Buckley JD, Bogomolova S. Nudging healthier food and beverage choices through salience and priming. Evidence from a systematic review. *Food Qual Prefer.* 2016; 51: 47-64.
- 197 Smith M, Toprakiran N. Behavioural insights, nudge and the choice environment in obesity policy. *Policy Stud J.* 2018.
- 198 Mozaffarian D, Rosenberg I, Uauy R. History of modern nutrition science—implications for current research, dietary guidelines, and food policy. *BMJ.* 2018; 361: k2392.
- 199 Ridgway E, Baker P, Woods J, Lawrence M. Historical developments and paradigm shifts in Public Health Nutrition Science, guidance and policy actions: a narrative review. *Nutrients.* 2019; 11: 531.
- 200 Scrinis G, Monteiro CA. Ultra-processed foods and the limits of product reformulation. *Public Health Nutr.* 2018; 21: 247-52.
- 201 Adams J, Hofman K, Moubarac J-C, Thow AM. Public health response to ultra-processed food and drinks. *BMJ.* 2020; 369: m2391.
- 202 Dickie S, Woods JL, Lawrence M. Analysing the use of the Australian Health Star Rating system by level of food processing. *Int J Behav Nutr Phys Act.* 2018; 15: 1-9.
- 203 Dickie S, Woods JL, Baker P, Elizabeth L, Lawrence MA. Evaluating Nutrient-Based Indices against Food- and Diet-Based Indices to Assess the Health Potential of Foods: How Does the Australian Health Star Rating System Perform after Five Years? *Nutrients.* 2020; 12: 1463.
- 204 Monteiro CA, Cannon G, Moubarac J-C, *et al.* Dietary guidelines to nourish humanity and the planet in the twenty-first century. A blueprint from Brazil. *Public Health Nutr.* 2015; 18: 2311-22.
- 205 Baker P, Hawkes C, Wingrove K, *et al.* What drives political commitment for nutrition? A review and framework synthesis to inform the United Nations Decade of Action on Nutrition. *BMJ Global Health.* 2018; 3: e000485.
- 206 Swinburn BA, Kraak VI, Allender S, *et al.* The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *Lancet.* 2019; 393: 791-846.
- 207 Cullerton K, Donnet T, Lee A, Gallegos D. Playing the policy game: a review of the barriers to and enablers of nutrition policy change. *Public Health Nutr.* 2016; 19: 2643-53.
- 208 Nestle M. Food politics: How the food industry influences nutrition and health. California: University of California Press 2013.
- 209 Gostin LO, Roache SA. The untapped power of soda taxes: incentivizing consumers, generating revenue, and altering corporate behavior. *Int J Health Policy Manag.* 2017; 6: 489-93.
- 210 James E, Lajous M, Reich MR. The politics of taxes for health: an analysis of the passage of the sugar-sweetened beverage tax in Mexico. *Health Systems & Reform.* 2020; 6: e1669122.
- 211 Carriedo A, Koon A, Encarnación LM, *et al.* The Political Economy of Sugar-Sweetened Beverages Taxation in Latin America: Lessons from Mexico, Chile and Colombia. *Global Health.* 2020.
- 212 Thow AM, Jones A, Hawkes C, Ali I, Labonté R. Nutrition labelling is a trade policy issue: lessons from an analysis of specific trade concerns at the World Trade Organization. *Health Promot Int.* 2017; 33: 561-71.

- 213 Nestle M. Unsavory truth: how food companies skew the science of what we eat. New York: Basic Books 2018.
- 214 Steele S, Ruskin G, Stuckler D. Pushing partnerships: corporate influence on research and policy via the International Life Sciences Institute. *Public Health Nutr.* 2020; 1-9.
- 215 Kraak VI, Harrigan PB, Lawrence M, *et al.* Balancing the benefits and risks of public-private partnerships to address the global double burden of malnutrition. *Public Health Nutr.* 2012; 15: 503-17.
- 216 Hawkes C, Buse K. Public health sector and food industry interaction: it's time to clarify the term 'partnership' and be honest about underlying interests. *Eur J Public Health.* 2011; 21: 400-01.
- 217 Friel S, Gleeson D, Thow A-M, *et al.* A new generation of trade policy: potential risks to diet-related health from the trans pacific partnership agreement. *Global Health.* 2013; 9: 46.
- 218 Barlow P, Labonte R, McKee M, Stuckler D. Trade challenges at the World Trade Organization to national noncommunicable disease prevention policies: A thematic document analysis of trade and health policy space. *PLoS Med.* 2018; 15: e1002590.
- 219 Hawkes C. The role of foreign direct investment in the nutrition transition. *Public Health Nutr.* 2005; 8: 357 - 65.
- 220 Chopra M. Globalization and Food: Implications for the Promotion of "Healthy" Diets. *Globalization, Diets and Noncommunicable Diseases.* World Health Organization: Geneva 2002.
- 221 Lang T. Food Industrialisation and Food Power: Implications for Food Governance. *Dev Policy Rev.* 2003; 21: 555-68.
- 222 Hawkes C. Dietary implications of supermarket development: a global perspective. *Dev Policy Rev.* 2008; 26: 657-92.
- 223 Chopra M, Darnton-Hill I. Tobacco and obesity epidemics: not so different after all? *BMJ.* 2004; 328: 1558-60.
- 224 Hawkes C. The influence of trade liberalization and global dietary change: The case of vegetable oils, meat and highly processed foods. In: Hawkes C, Blouin C, Henson S, Drager N, Dube L (eds.). *Trade, Food, Diet and Health: Perspectives and Policy Options.* John Wiley & Sons Ltd: Chichester, West Sussex 2010; 35-59.
- 225 Wei A, Cacho J. Competition among foreign and Chinese agro-food enterprises in the process of globalization. *Int Food Agribus Man.* 2000; 2: 437-51.
- 226 Clapp J. Distant agricultural landscapes. *Sustain Sci.* 2015; 10: 305-16.
- 227 Clapp J. The rise of financial investment and common ownership in global agrifood firms. *Rev Int Political Econ.* 2019: 1-26.
- 228 Wallace H, Jan A, Barregård L, *et al.* Risks for human health related to the presence of 3-and 2-monochloropropanediol (MCPD), and their fatty acid esters, and glycidyl fatty acid esters in food. *EFSA Journal.* 2016.
- 229 Reissig CJ, Strain EC, Griffiths RR. Caffeinated energy drinks—a growing problem. *Drug Alcohol Depend.* 2009; 99: 1-10.
- 230 Steele EM, Baraldi LG, da Costa Louzada ML, *et al.* Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open.* 2016; 6.
- 231 Tan M, He FJ, Wang C, MacGregor GA. Twenty- Four- Hour Urinary Sodium and Potassium Excretion in China: A Systematic Review and Meta- Analysis. *J Am Heart Assoc.* 2019; 8: e012923.
- 232 Mialon M, Swinburn B, Sacks G. A proposed approach to systematically identify and monitor the corporate political activity of the food industry with respect to public health using publicly available information. *Obesity Rev.* 2015; 16: 519-30.
- 233 McKee M, Stuckler D. Revisiting the corporate and commercial determinants of health. *Am J Public Health.* 2018; 108: 1167-70.
- 234 Harris J, Molly A, Clément C, Nisbett N. The Political Economy of Food. Brighton: Institute of Development Studies 2019.
- 235 Baker P, Jones A, Thow AM. Accelerating the Worldwide Adoption of Sugar-Sweetened Beverage Taxes: Strengthening Commitment and Capacity: Comment on" The Untapped Power of Soda

Taxes: Incentivizing Consumers, Generating Revenue, and Altering Corporate Behavior". *Int J Health Policy Manag.* 2018; 7: 474.

236 Preparation and use of food-based dietary guidelines: report of a joint FAO/WHO consultation. Geneva: World Health Organization 1998.

237 RESOLUÇÃO Nº 6, DE 8 DE MAIO DE 2020: Dispõe sobre o atendimento da alimentação escolar aos alunos da educação básica no âmbito do Programa Nacional de Alimentação Escolar - PNAE. Brasília: Órgão: Ministério da Educação/Fundo Nacional de Desenvolvimento da Educação, República Federativa do Brasil 2020.

238 Hadjikakou M. Trimming the excess: environmental impacts of discretionary food consumption in Australia. *Ecol Econ.* 2017; 131: 119-28.

239 Hendrie G, Baird D, Ridoutt B, Hadjikakou M, Noakes M. Overconsumption of energy and excessive discretionary food intake inflates dietary greenhouse gas emissions in Australia. *Nutrients.* 2016; 8: 690.

Table and figure legends

Table 1

*vegetable oil is classified as a culinary food ingredient in the NOVA food classification

Table 2

Notes: *calculated as 90g sugar / kg as the average sugar content per unit volume of apple and orange juice

Figure 6

Notes: Data from FAOSTAT database

Figure 7

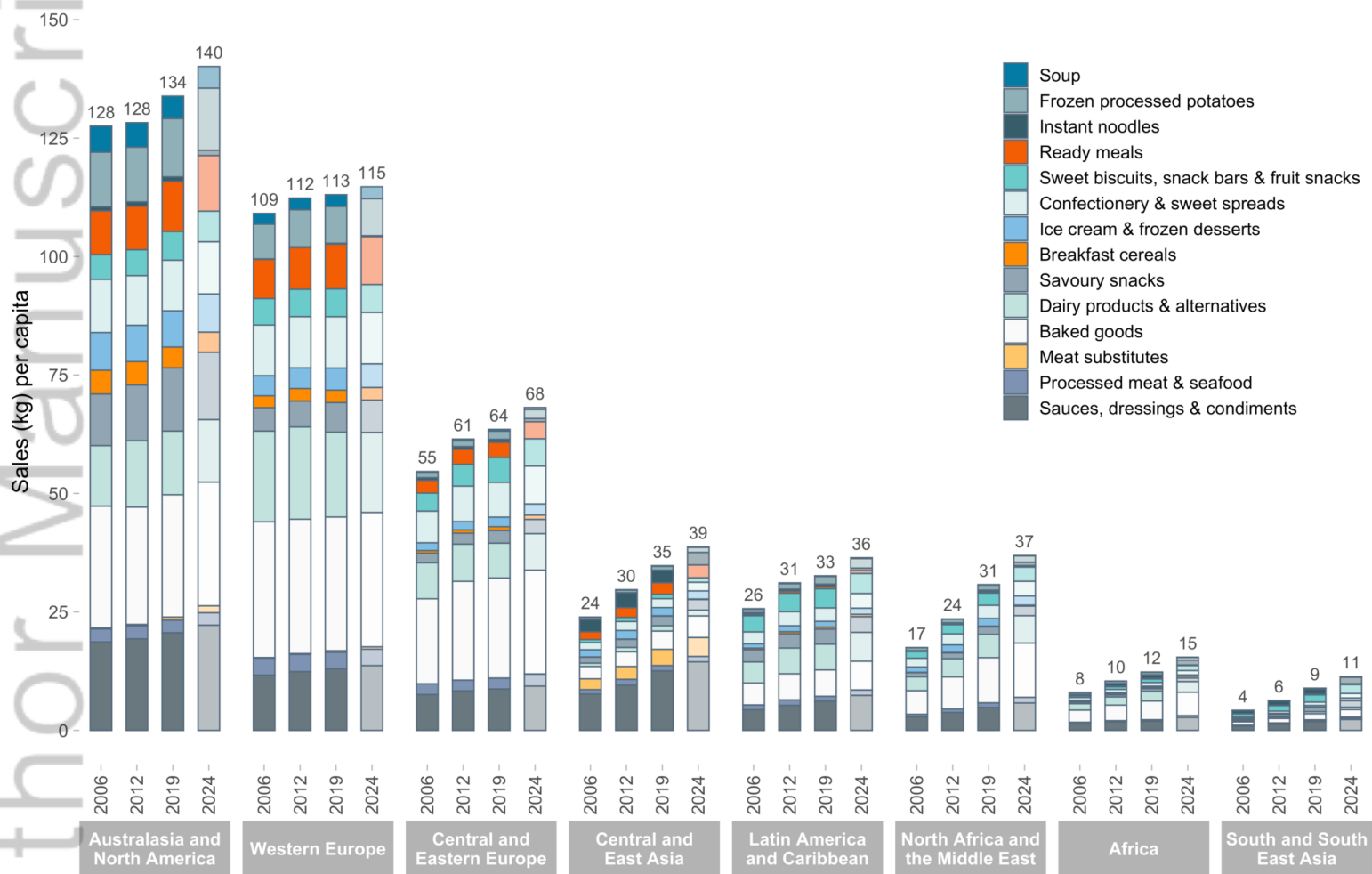
Notes: Data from Euromonitor International Passport database
Table 1. Ultra-processed food and beverage product categories used in the analysis, and sub-categories as defined by Euromonitor

Product categories	Sub-categories
Total ultra-processed foods	Aggregation of all ultra-processed food categories
Baked goods	Dessert mixes, frozen baked goods, packaged cakes, packaged flat bread, packaged leavened bread, packaged pastries
Breakfast cereals	Ready-to-eat cereals
Confectionery & sweet spreads	Chocolate spreads, confectionery, jams and preserves, nut and seed based spreads
Dairy products & alternatives	Chilled and shelf stable desserts, chilled snacks, coffee whiteners, flavoured condensed milk, flavoured fromage frais and quark,

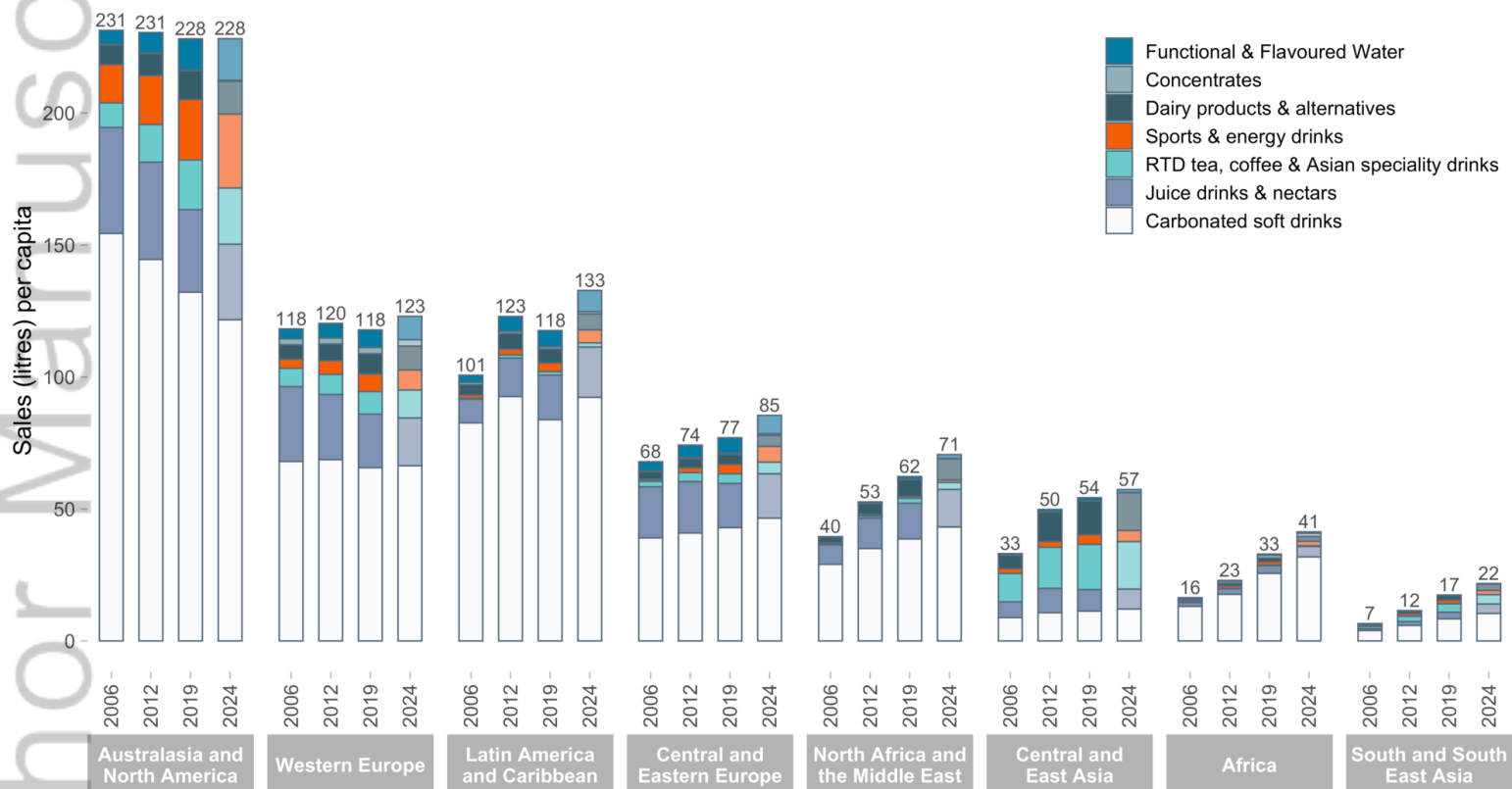
	flavoured yoghurt, margarine and spreads, processed cheese
Frozen processed potatoes	Frozen processed potatoes
Ice cream & frozen desserts	Frozen desserts, frozen yoghurt, impulse ice cream, take-home ice cream
Instant noodles	Instant noodles
Meat substitutes	Meat substitutes
Processed meat & seafood	Shelf stable meat, shelf stable seafood
Ready meals	Chilled lunch kits, chilled pizza, chilled ready meals, dinner mixes, dried ready meals, frozen pizza, frozen ready meals, shelf stable ready meals
Sauces, dressings & condiments	Sauces, dressings and condiments
Savoury snacks	Other savoury snacks, popcorn, pretzels, salty snacks, savoury biscuits soup
Sweet biscuits, snack bars & fruit snacks	Processed fruit snacks, snack bars, sweet biscuits
Vegetable oils*	Corn oil, olive oil, palm oil, rapeseed oil, soy oil, sunflower oil, other edible oil
Total ultra-processed beverages	Sub-categories
Carbonated soft drinks	Carbonates
Concentrates	Concentrates
Dairy products & alternatives	Drinking yoghurt, flavoured milk drinks, milk alternatives
Functional & flavoured water	Flavoured bottled water, functional bottled water
Juice drinks & nectars	Coconut and other plant waters, juice drinks (up to 24% juice), nectars, reconstituted 100% juice
RTD tea, coffee & Asian speciality drinks	Asian speciality drinks, ready-to-drink coffee, ready-to-drink tea
Sports & energy drinks	Energy drinks, sports drinks

Table 2. Ingredients categories used in the analysis

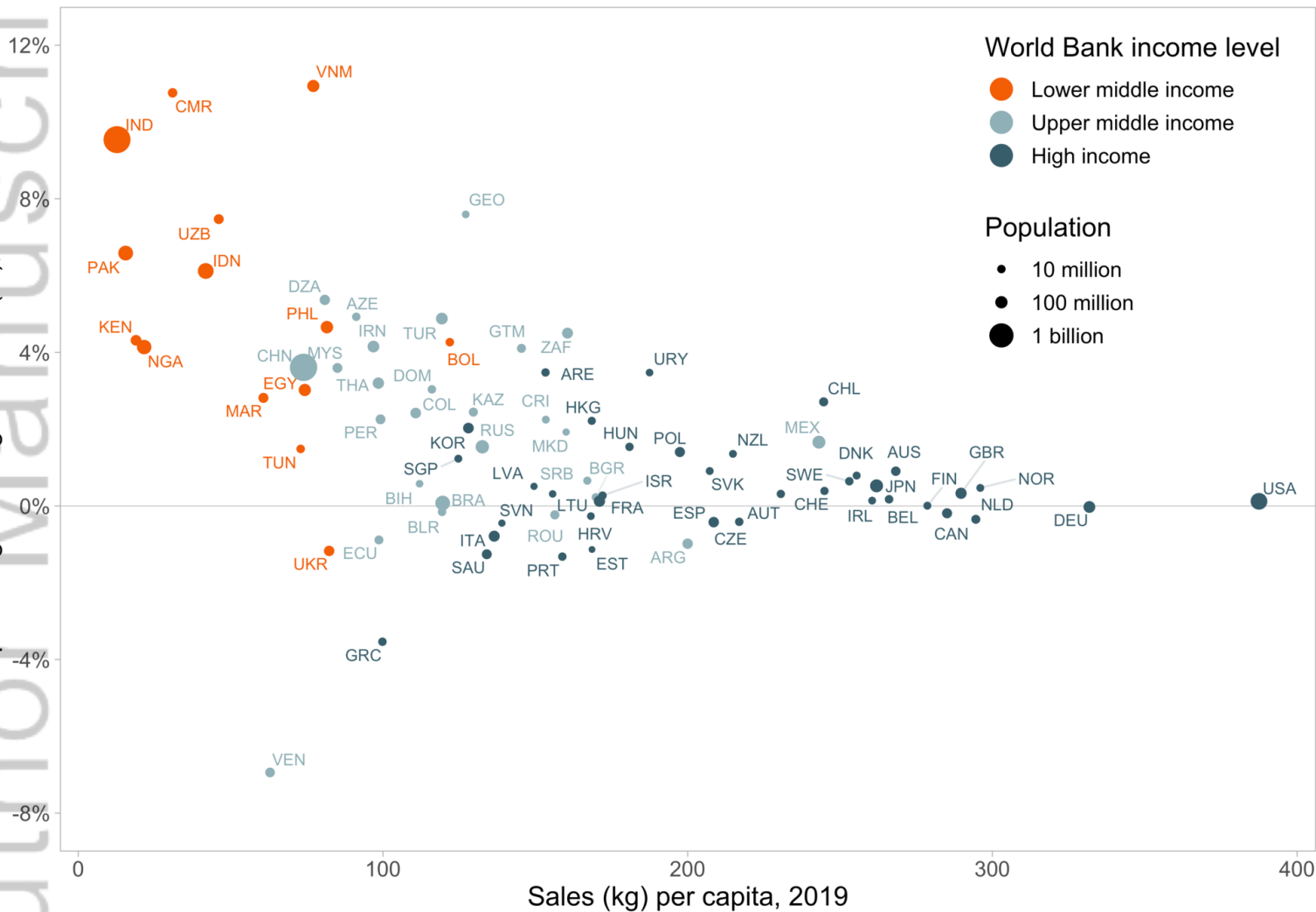
Category	Sub-category	Ingredients
Sweeteners	Caloric sweeteners	Monosaccharides (dextrose, glucose/corn syrup, fructose, high fructose corn syrup, honey, invert sugar, glucose/fructose syrup, fruit juice*), disaccharides (lactose, sucrose, brown sugar, molasses, treacle, isomaltulose, maltose syrup), polysaccharides (maltodextrin)
	Low-calorie & non-caloric sweeteners	Sugar alcohols (Sorbitol, isomalt, mannitol, maltitol, maltitol syrup, lactitol, inositol, erythritol, xylitol), non-nutritive sweeteners (Acesulfame k, aspartame, saccharin, stevia, sucralose, cyclamate)
Fats	Vegetable fats (solid at room temperature)	Hydrogenated vegetable fat, hydrogenated vegetable oil, vegetable fat, cocoa butter
	Vegetable oils (liquid at room temperature)	Vegetable oils
	Animal fats	Animal fat (e.g. beef tallow, pork lard), milk fat (e.g. butter)
	Other fats	Long chain omega-3 fatty acids, short chain omega-3 fatty acids, powdered fats, stanol/sterol esters, waxes, other fats and oils
Sodium	Sodium	Monosodium glutamate, potassium chloride, sodium acetate, sodium chloride, disodium diphosphate, sodium bicarbonate, sodium metabisulphite, sodium sulphite, sodium sulphate, sodium triphosphate, sodium carbonate
Cosmetic additives	Cosmetic additives	Colours, flavours, flavour enhancers, thickeners and other structurants, emulsifiers, bulking and gelling agents



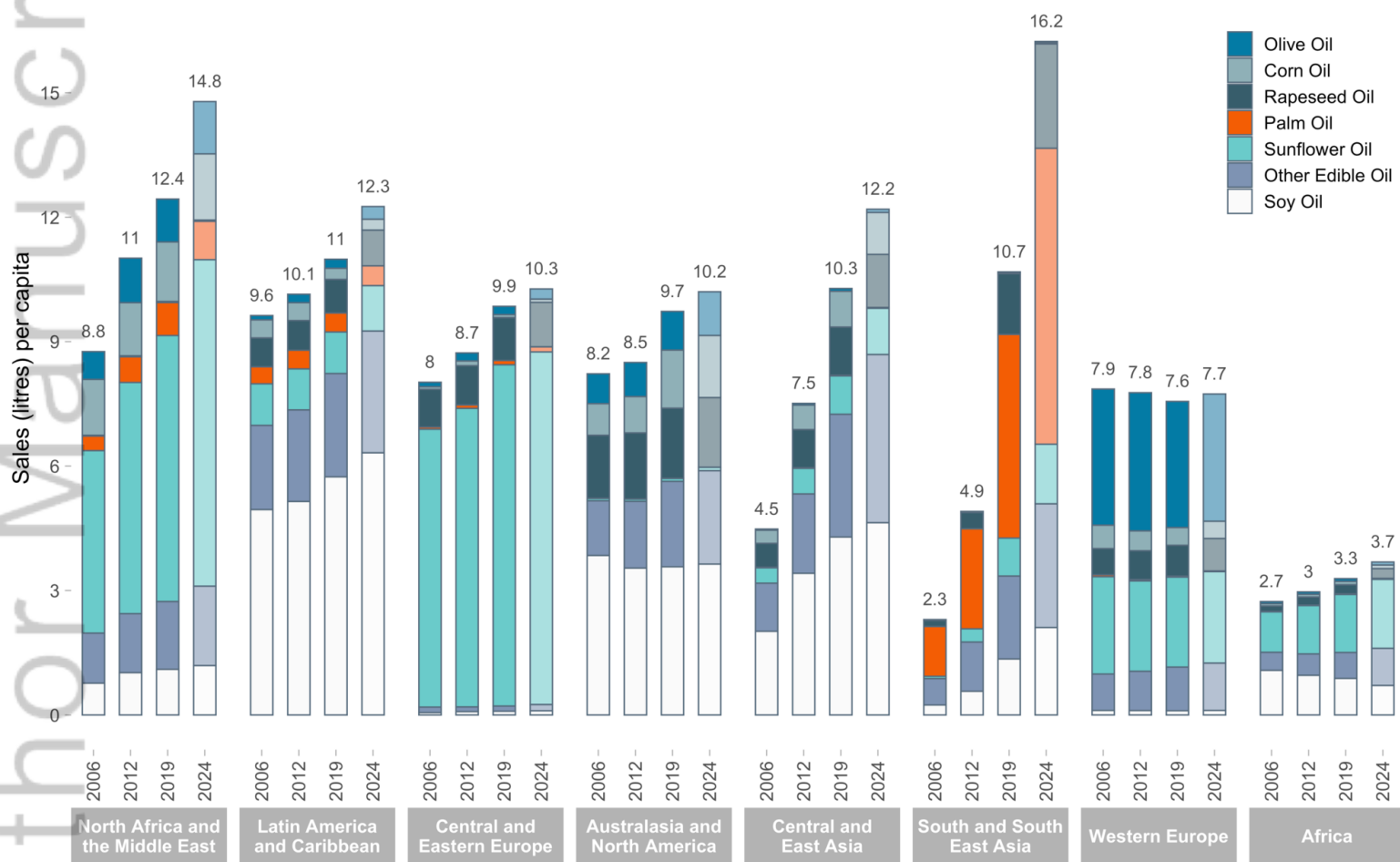
OBR_13126_Figure_1.tif



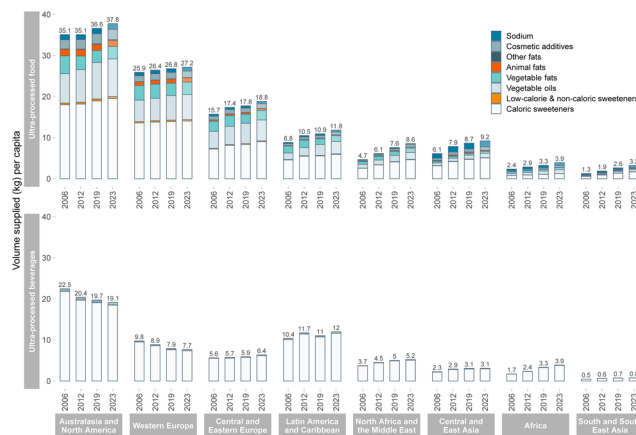
OBR_13126_Figure_2.tif



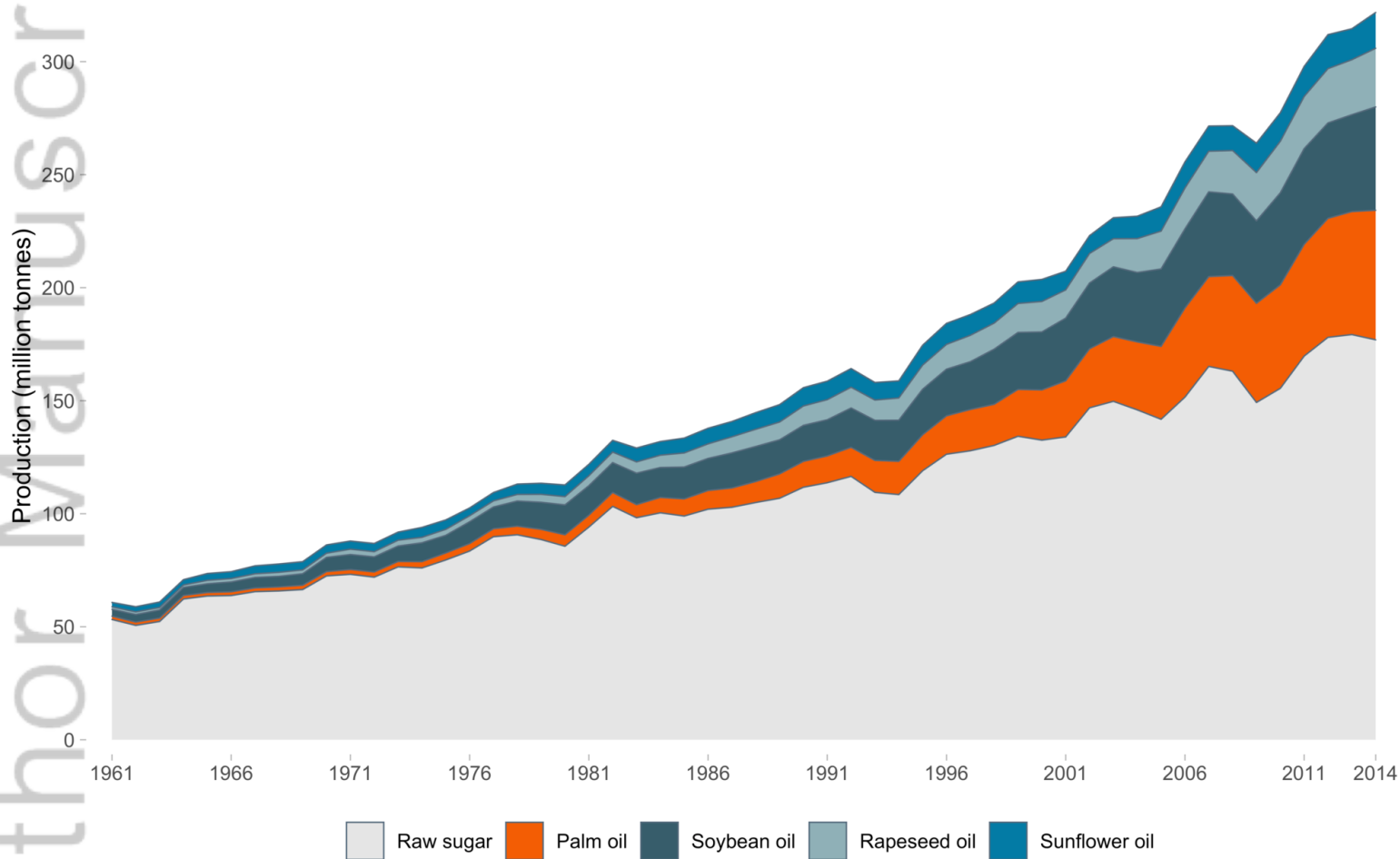
OBR_13126_Figure_3.tif



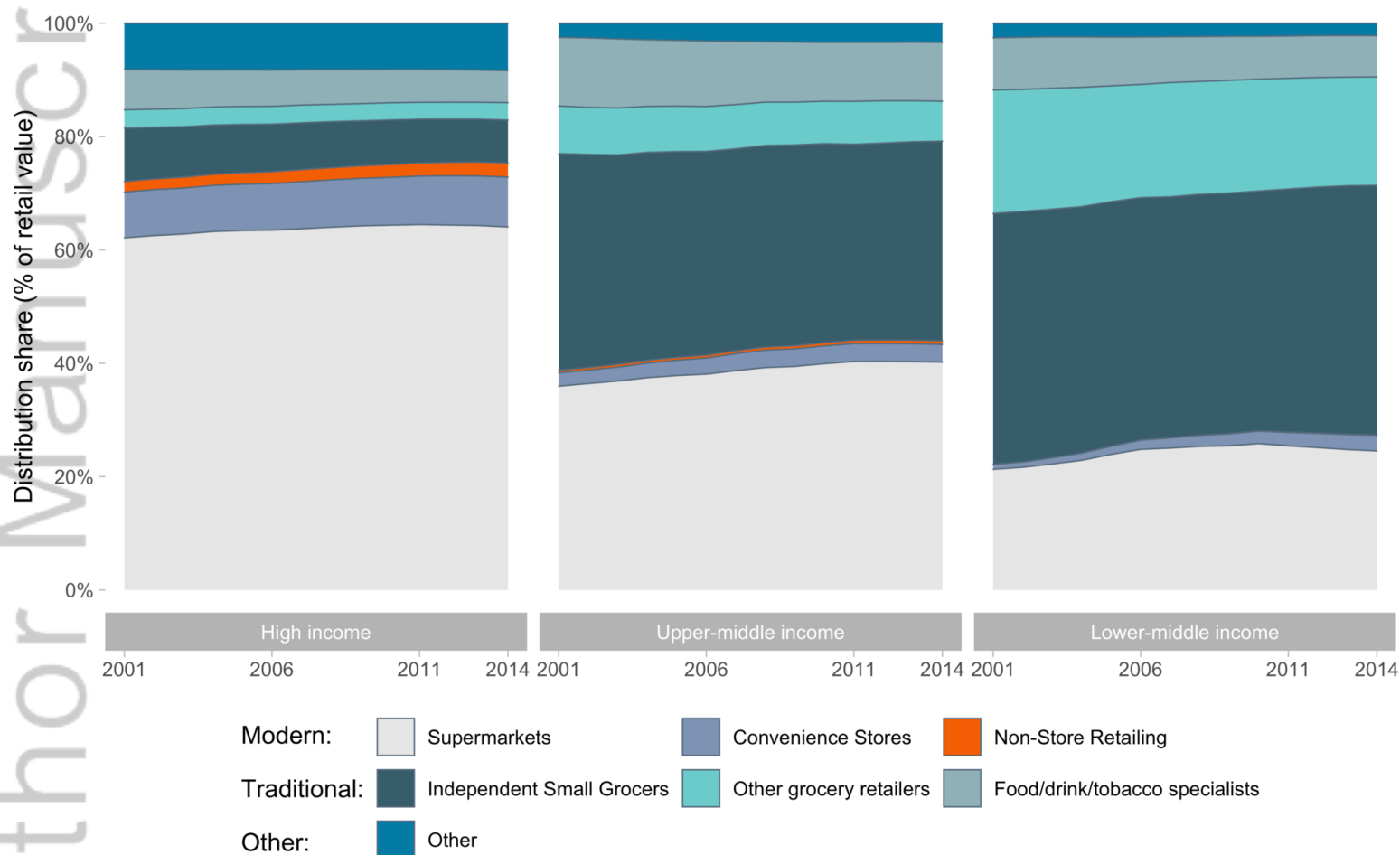
OBR_13126_Figure_4.tif



OBR_13126_Figure_5.tif



OBR_13126_Figure_6.tif



OBR_13126_Figure_7.tif