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Processed foods and the nutrition transition: evidence from Asia

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Summary

This paper elucidates the role of processed foods and beverages in the 'nutrition transition' underway in Asia. Processed foods tend to be high in nutrients associated with obesity and diet-related non-communicable diseases: refined sugar, salt, saturated and trans-fats. This paper identifies the most significant 'product vectors' for these nutrients and describes changes in their consumption in a selection of Asian countries. Sugar, salt and fat consumption from processed foods has plateaued in high-income countries, but has rapidly increased in the lower–middle and upper–middle-income countries. Relative to sugar and salt, fat consumption in the upper–middle- and lower–middle-income countries is converging most rapidly with that of high-income countries. Carbonated soft drinks, baked goods, and oils and fats are the most significant vectors for sugar, salt and fat respectively. At the regional level there appears to be convergence in consumption patterns of processed foods, but country-level divergences including high levels of consumption of oils and fats in Malaysia, and soft drinks in the Philippines and Thailand. This analysis suggests that more action is needed by policy-makers to prevent or mitigate processed food consumption. Comprehensive policy and regulatory approaches are most likely to be effective in achieving these goals.

Keywords: Asia, non-communicable diseases, nutrition transition, processed foods.

obesity reviews (2014)

Introduction

Rapidly increasing consumption of processed foods is now likely to be a significant contributor to the current and future disease burden arising from non-communicable diseases (NCDs) in middle-income countries, home to the large bulk of the world's population (1–6). Such trends are predicted by nutrition transition theory. Within the context of the increasing globalization of food systems, this theory proposes that with economic development populations shift from minimally processed diets rich in staple foods of vegetable origin to diets high in meat, vegetable oils and processed foods (1,4,7,8). This theory is now well established empirically in several Asian countries (9–15), and recent predictions indicate that in the developing countries processed food consumption will continue to increase without policy intervention (5,6,16). From a public health perspective, the role of processed foods in nutrition transition is receiving greater scrutiny given that such foods tend to be high in refined sugars, sodium, and saturated and trans-fats (hereafter called: sugar, salt and fat) and the excessive consumption of these nutrients is associated with obesity and diet-related NCDs (17–19). Identifying which processed foods are the most significant 'vectors' for these nutrients can therefore identify targets for policy intervention. To date, however, few studies have analysed which processed food categories are the most significant 'product vectors' for these nutrients in Asian countries.

Processed foods are manufactured and distributed in ways that encourage consumption. Food science has been harnessed by transnational food and beverage corporations (TFBCs) so that products are manufactured using globally standardized recipes, but adapted and marketed to appeal to local tastes and consumer preferences (1,20). Added sugar, salt and fat are used along with other sophisticated ingredients and manufacturing technologies to produce 'hyper-palatable' products (3,21). These same processes increase product durability (shelf life) and transportability, allowing for long-distance and large-scale distribution. They are also prepared, branded, packaged and advertised in sophisticated ways that increase their desirability by consumers stratified by age, socio-economic and lifestyle status (2,21,22). Such foods are also associated with a different form of 'food culture'. While unprocessed and minimally processed foods are usually prepared and eaten at home and at regular times, processed foods are designed for consumption in any place at any time. They are designed to be 'ready-to-eat' or 'ready-to-heat' thereby requiring minimal preparation and offering convenience for time-pressured consumers (23–25). These characteristics not only make processed foods highly amenable to consumption, but also profitable for the corporations that produce them (3,6,23).

The role of processed foods in the nutrition transition in Asia is worthy of investigation for several reasons. First, Asia is home to nearly half the world's population and better nutrition there can improve the lives of billions (26). It is a region undergoing rapid economic development and the accompanying increases in household incomes are likely to have generated demand for processed foods (6,27,28); as per capita income increases the proportion of total food expenditure spent on processed foods increases from less than one-third in lower–middle-income countries (L-MIC) to approximately one-half in upper–middle-income countries (U-MIC) and high-income countries (HIC) (29). Urbanization also increases access to processed foods (7,12), and the region has some of the highest rates of rural–urban migration globally with China and Vietnam expected to urbanize most rapidly in the coming decades (30). Workforce trends and changing family structures, including the growing economic participation of women, are likely to be expanding time-pressures and demand for convenience foods (7,29). Increasing consumption of non-food items including refrigerators, microwaves and motorized transport may further expand access to a wider diversity of foods (29).

Second, since 1980 Asia has been the recipient of more foreign direct investment (FDI) than any other developing region; nearly a quarter of the world's total in 2011 (31,32). It is likely that the associated increasing presence of TFBCs has significantly expanded processed food consumption (6,20,33). Although recent analyses have demonstrated that ultra-processed food products now dominate the food supplies of HICs and consumption is rapidly increasing in middle-income countries (5,6,16), little is known about consumption patterns within countries of the Asia region.

Third, although Asian populations are on average leaner than their Western counterparts, the rising prevalence of overweight and obesity across the region is of particular concern given their greater susceptibility to diet-related NCDs (34–37). This susceptibility stems from several characteristics. Undernutrition in early life may exacerbate NCD risk under conditions of nutritional abundance in later-life and underweight and obesity often coexist within the same households in Asia (27,38,39). Relative to European populations, some Asian populations demonstrate a higher percentage of central adiposity and total body fat relative to body mass as well as a higher risk of type-2 diabetes (T-2D) and cardiovascular disease (CVD) at lower levels of adiposity (4,37,40,41). This has led to the consideration (but not the adoption) of lower World Health Organization body mass index cut-off points for some Asian populations (42).

Finally, the globalization of diets is experienced differently with no single nutrition transition across populations. Dietary convergence–divergence theory posits that while globally there is increasing convergence of consumption of a small number of food commodities (in particular vegetable oils, meats, some grains and processed foods), there is widening divergence in local consumption resulting from demographic, cultural and socio-economic factors that shape dietary preferences and consumer demand (1,43). A regional focus therefore may not only demonstrate historic trends in processed food consumption across the region, but also differences in the likely future trends in consumption and associated health risk.

The aim of this paper is to identify the processed food categories that are the most significant product vectors for sugar, salt and fat in a selection of Asian countries, and identify in which countries the levels and rates of consumption of these product categories are changing most rapidly.

Methods

Setting and subjects

Countries within South, East and South-east Asia (henceforth 'Asia') were chosen as an analytical unit. Processed food consumption data were available for 12 countries, which were classified according to World Bank income bracket. L-MIC (2012 gross national income [GNI] per capita US$1,036–4,085; combined population of 1,863,325,000) included India, the Philippines, Vietnam, Indonesia and Pakistan; U-MIC (GNI US$4,086–12,615; combined population of 1,443,857,000) included China,

Malaysia, and Thailand; and HIC (GNI > US$12,616; combined population of 206,115,300) included Singapore, South Korea, Taiwan and Japan. Country population estimates (total population, all ages) were sourced from the World Bank World Development Indicators (44).

Data sources, product and ingredients categorization

Market sales (consumption) data for processed food products and ingredients were sourced from Euromonitor International (Euromonitor) Passport Global Market Information Database, 2013 Edition. Euromonitor has adopted the terminology 'packaged food', but noted this is synonymous with 'processed food' in their categorization schema (45). For the purposes of this paper, we adopted a definition of processed foods as substances extracted and purified from unprocessed or minimally processed foods (e.g. vegetable oils) and industrially produced ready-to-eat or ready-to-heat food products resulting from the processing of several food substances (e.g. snack bars). This is a deliberately broader definition than the 'ultra-processed food' category proposed by others (3), because we intended to capture edible oil, identified as a significant source of recent dietary change in Asia (1,4).

First, data on per capita sales volumes (kg per capita) of processed food products through retail and food service channels, from 1998 to 2012 with projections to 2017, were obtained for the categories outlined in Table 1. These are market categories defined by Euromonitor (45). Various combinations of these categories have been used in analyses of processed food consumption by others (5,6,29,46). Because the Euromonitor categories aggregate ultra-processed foods with non-ultra-processed foods it was not possible to categorize products by their level of processing as proposed elsewhere (3,23). Euromonitor collects this data from a number of sources including trade associations, industry bodies, business press, company financial reports, company filings and official government statistics. Consumption volume estimates are validated by people working within the food industry. Projections are calculated by establishing a historic market trend and then factoring in likely future industry-specific (e.g. regulation) or market-specific (e.g. likelihood of recession) changes, and should be interpreted with caution (45).

Second, to determine which food categories were the most significant sugar, fat and salt vectors, the volume (tonnes) of each ingredient consumed through (linked to) each category were obtained. For the purposes of this paper, we defined ingredients as substances extracted and

Table 1 Processed food product categories and descriptions used in the analysis

Product category	Description
Total processed foods	Aggregation of all processed food categories
Baked goods	Bread, pastries and cakes
Biscuits	Sweet biscuits, savoury biscuits and crackers, and bread substitutes
Breakfast cereals	Ready-to-eat and hot cereals
Canned food	Canned/preserved meat and meat products, fish/seafood, vegetables, tomatoes, beans, fruit, ready meals, soup, pasta
Confectionary	Chocolate confectionary, chewing gum and bubble gum, sugar confectionary
Dairy	Cheese (processed/unprocessed), drinking milk products (fresh/pasteurized, long-life, goat, flavoured milk drinks, soy beverages, milk powder), yoghurt/sour milk
Chilled processed food	Chilled processed meats, processed fish/seafood products, lunch kits, fresh cut fruits, ready meals, pizza, prepared salads, soup, fresh pasta and noodles
Dried processed food	Rice, dessert mixes, dried ready meals, dehydrated soup, instant soup, dried pasta, plain noodles and instant noodles
Frozen processed food	Processed red meat, poultry, fish/seafood, vegetables, meat substitutes, potatoes, bakery products, desserts, ready meals, pizza, soup, noodles and other frozen food
Ice cream	Impulse ice cream, take-home ice cream, frozen yoghurt and artisanal ice cream
Noodles	Plain, instant, chilled, frozen and snack noodles
Oils and fats	Olive oil, vegetable/seed oil, cooking fats, butter, margarine, spreadable oils/fats
Pasta	Canned, dried and chilled/fresh pasta
Ready meals	Canned/preserved, frozen, dried, chilled ready meals, dinner mixes, pizza, salads
Snack bars	Granola/muesli bars, breakfast bars, energy and nutrition bars, fruit bars
Sweet and savoury snacks	Fruit snacks, chips/crisps, extruded snacks, corn chips, popcorn, pretzels, nuts
Total beverages	Aggregation of all beverage categories
Carbonated soft drinks	Non-alcoholic drinks containing dissolved carbon dioxide, regular & low calorie
Concentrates	Liquid concentrates and powder concentrates
RTD coffee	Packaged RTD coffee, excluding coffee flavoured milk drinks
RTD tea	Still RTD tea and carbonated RTD tea
Fruit/vegetable juice	100% juice, nectars (25–99% juice), juice drinks (<24% juice), flavoured drinks
Sports and energy drinks	Sports and energy drinks

RTD, ready-to-drink.

Table 2 Ingredients categories used in the analysis

	Categories	Description
Sugars	Total sugar	Aggregation of all sugar subcategories
	Sucrose	Sucrose, molasses, isomaltulose, brown sugar
	Lactose	Lactose
	High fructose	Glucose/fructose syrup, glucose/corn syrup, fructose, high-fructose corn syrup, invert sugar
	Glucose	Glucose
	Other sugars*	Malitol, erythritol, isomalt, lactitol
Fats	Total fat	Aggregation of all fat subcategories
	Animal fat	Pork lard, beef tallow, milk fat (butterfat)
	Vegetable fats	Vegetable fat, cocoa butter, hydrogenated vegetable fat, hydrogenated vegetable oil
	Vegetable oil	Vegetable oils
	Other fats*	Long and short chain omega-3 fatty acids, animal oils, powdered fats, stanols/stanol esters, waxes, other
Salt	Total salt	Sodium chloride, sodium bicarbonate, monosodium glutamate, disodium diphosphate, sodium metabisulphite

*Included in total.

purified from unprocessed or minimally processed foods used in the manufacture of processed foods (3). Ingredients data for each product category was calculated by Euromonitor using the following steps: (i) recipes for each of the leading two to five branded products and a generic recipe for the remainder of the market were sourced from patent literature, trade interviews and specialist knowledge; (ii) the ingredients content for the same leading two to five brands were sourced from nutrition information panels, and for the remainder of the market were estimated from the generic recipe. The percentage of each ingredient as a proportion of the total branded and generic recipes was then estimated; (iii) these percentages were multiplied by sales volumes of the respective brands and generic brand to generate total ingredients volumes; and (iv) the data were then subjected to validation by industry experts at ingredients companies and brand manufacturers (45,47). Because critical assumptions are made regarding the recipes of leading brands and the ingredients and recipes used in other brands, these data should be interpreted with caution. Using population size estimates we converted volumes to kg per capita for the ingredients categories in Table 2. Values were not adjusted for energy intake. Lack of data availability prevented further disaggregation of ingredients categories (e.g. into different vegetable oils).

To determine the nutritional content of the food categories we grouped the associated ingredients data into sugar, fats and salts. Sugars were grouped into glucose and high-fructose (monosaccharide sugars), and sucrose and lactose (disaccharide sugars) categories based on a standard classification (48). These groupings are important because high-fructose sweetener consumption, including high-fructose corn syrup, has been hypothesized as a nutrition risk for obesity and diet-related NCDs (49–51). Lower-calorie artificial sugar substitutes, which had negligible values were excluded from these categories, but were included in the 'total' sugar value. Fats were grouped into animal fats (fats of animal origin), vegetable fats (solid at room temperature) and vegetable oil (liquid at room temperature). Given the nature of the ingredients data, we were not able to estimate saturated and trans-fat consumption; instead, we characterized fats by their source (vegetable versus animal) and state (solid versus liquid). However, the differentiation between solid vegetable fats and liquid vegetable oils was justified given the higher saturated and trans-fatty acid (TFAs) content of the former category, in particular hydrogenated vegetable oils and evidence demonstrating an association with cardiovascular risk (52). Other fats and oils ingredients that were consumed in negligible amounts were excluded from these categories, but included in the 'total' values. Salt included all sources of industrially added dietary salt.

Analysis

Using the product and ingredient categorizations described earlier, we estimated the per capita consumption of salt, fats and sugars from processed foods in each country for the years 1999–2012 and projections to 2017. Product categories were then ranked according to their per capita contribution to total sugar, salt and fat consumption. The most significant product vectors were selected as those ranked in the top five for their contribution to either sugar, salt and fat consumption, respectively. This generated 12 product categories for HICs, 10 for U-MICs and 9 for L-MICs. The remaining categories were aggregated as 'other processed foods' and included in figures to demonstrate total processed food consumption volumes. Trends in consumption of sugar, salt and fat and the top five product vectors were identified by plotting time series data for each country since 1999. Annual average per capita consumption growth rates were also calculated for the time period 1999–2012.

Results

As a first step we determined which processed food categories were the most significant 'product vectors' for sugar, salt and fat in the region and how consumption of these nutrients differed between countries at varying stages of economic development.

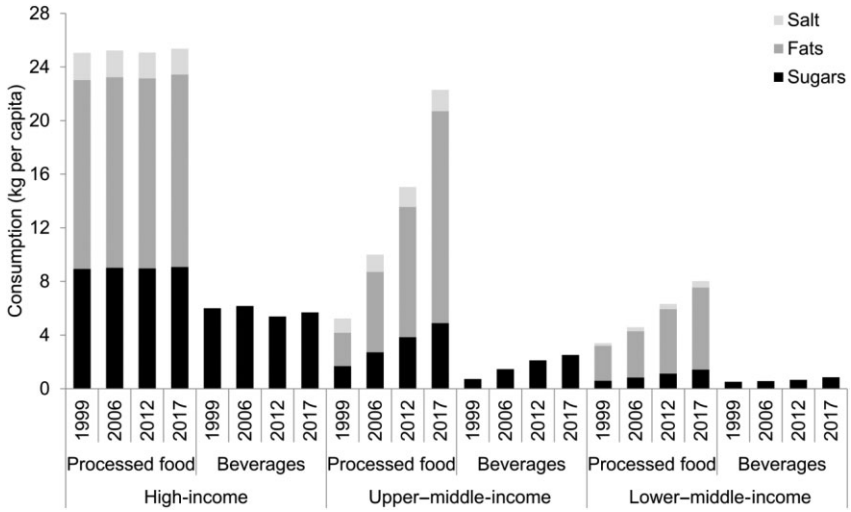

Figure 1 Total sugar, fat and salt consumption (kg per capita) from processed foods and beverages in select high-income, upper–middle income and lower–middle-income countries in Asia, 1999–2012 with projections to 2017. Lower–middle-income countries (2012 gross national income [GNI] per capita US$1,036–4,085) included: India, Philippines, Vietnam, Indonesia, and Pakistan; upper–middle-income countries (US$4,086–12,615): China, Malaysia, and Thailand; high-income countries (>US$12,616): Singapore, South Korea, Taiwan, and Japan.

Observation 1: total sugar, fat and salt consumption from processed foods and beverages has plateaued in high-income countries, but has increased rapidly in upper–middle-income countries and lower–middle-income countries

Consumption has increased most rapidly in U-MICs (Fig. 1), particularly in China and Thailand. Relative to sugar and salt, per capita fat consumption from processed foods in U-MICs and L-MICs has moved towards consumption levels in HICs most rapidly; in 2012 there was an approximately threefold difference between L-MICs and HICs (totals of 4.8 kg and 14.2 kg, respectively). This compared with an approximately fivefold difference in salt consumption (0.4 kg and 1.96 kg) and an eightfold difference in sugar consumption (1.8 kg and 14.5). Euromonitor projections indicate that per capita fat consumption from processed foods in U-MICs will exceed consumption in HICs in 2017 (15.8 kg and 14.4 kg, respectively), whereas salt consumption is projected to be 83% of HIC levels (1.6 kg and 1.95 kg) and sugar consumption 50% (7.4 kg and 14.8 kg). Processed foods may have therefore driven, and may continue to drive fat consumption more rapidly than salt and sugar consumption during the nutrition transition in the countries included in this analysis.

Observation 2: carbonated soft drinks were the most significant sugar vector irrespective of country income bracket

Per capita sugar consumption from carbonated soft drinks was fivefold higher in HICs than in L-MICs (2.02 kg and 0.4 kg respectively) (Table 3). Other top five sugar vectors present in all countries include baked goods, confectionary and dairy foods. Fruit and vegetable juice was ranked second as a sugar vector in U-MICs, most likely reflecting agricultural policy adjustments that led to large-scale investments in Chinese apple production and apple juice concentrate processing in the early 2000s and a rapid increase in both domestic and global supply (53). Sucrose was the most added sugar ingredient irrespective of country income, comprising 74% of total sugar in L-MICs, 72% in U-MICs and 70% in HICs. High-fructose sugar was the second most added sugar ingredient, comprising 16% of added sugar in L-MICs, 21% in U-MICs and 24% in HICs (Supporting Information Tables S1–S3).

Interestingly, the contribution of the top five product vectors to total sugar consumption from processed foods differed from 72.6% in L-MICs to 63.6% in U-MICs and 53.2% in HICs, possibly reflecting a greater diversity in the availability of processed foods containing added sugar in later stages of economic development. In all country income brackets beverages contributed between 36% and 38% of total sugar consumption but negligible contributions to total fat (0.0%) and salt consumption (<0.7%).

Observation 3: oils and fats were the most significant fat vector irrespective of country income bracket

In 2012, per capita oils and fats consumption was 4.2 kg in L-MICs, 8 kg in U-MICs and 8.2 kg in HICs (Table 3). However, the contribution of oils and fats to total fat consumption from processed foods differed from 87.7% in L-MICs to 81.7% in U-MICs and 57.6% in HICs, possibly reflecting a greater diversity in the availability of processed foods containing added fats in later stages of economic development. Malaysia, an U-MIC, had the highest per capita oils and fats volume of 37 kg, more than twice that of the next highest countries Thailand and Taiwan (16.2 kg and 13.3 kg, respectively). Baked goods were the second

Table 3 Top five product vector categories for sugar, fat and salt consumption (kg per capita), 2012

Sugars	High-income countries			Upper–middle-income countries			Lower–middle-income countries		
Rank	Product category	Total	%	Product category	Total	%	Product category	Total	%
1	Carbonated soft drinks	2.022	14.0	Carbonated soft drinks	0.868	14.4	Carbonated soft drinks	0.397	21.8
2	Baked goods	1.840	12.7	Fruit/veg juice	0.821	13.7	Confectionary	0.270	14.8
3	Confectionary	1.481	10.2	Dairy	0.758	12.6	Biscuits	0.267	14.7
4	Dairy	1.295	8.9	Baked goods	0.699	11.6	Dairy	0.228	12.5
5	Ice cream	1.061	7.3	Confectionary	0.676	11.2	Baked goods	0.160	8.8
	Total top five	7.699	53.2	Total top five	3.822	63.6	Total top five	1.322	72.6
	Total processed foods	8.962	61.9	Total processed foods	3.836	63.8	Total processed foods	1.126	61.9
	Total beverages	5.512	38.1	Total beverages	2.175	36.2	Total beverages	0.694	38.1
	Total	14.474	100.0	Total	6.011	100.0	Total	1.82	100.0
Fats	High-income countries			Upper–middle-income countries			Lower–middle-income countries		
Rank	Product category	Total	%	Product category	Total	%	Product category	Total	%
1	Oils and fats	8.168	57.6	Oils and fats	7.981	81.7	Oils and fats	4.206	87.7
2	Baked goods	1.422	10.0	Baked goods	0.563	5.8	Biscuits	0.185	3.9
3	Sweet/savoury snacks	0.816	5.8	Dairy	0.303	3.1	Baked goods	0.104	2.2
4	Noodles	0.412	2.9	Biscuits	0.282	2.9	Dried processed food	0.045	0.9
5	Dried processed food	0.408	2.9	Frozen processed food	0.206	2.1	Dairy	0.040	0.8
	Total top five	11.226	79.2	Total top five	9.335	95.5	Total top five	4.580	95.5
	Total processed foods	14.182	100.0	Total processed foods	9.771	100.0	Total processed foods	4.797	100.0
	Total beverages	–	–	Total beverages	–	–	Total beverages	–	–
	Total	14.182	100.0	Total	9.771	100.0	Total	4.797	100.0
Salt	High-income countries			Upper–middle-income countries			Lower–middle-income countries		
Rank	Product category	Total	%	Product category	Total	%	Product category	Total	%
1	Chilled processed food	0.347	17.7	Baked goods	0.062	4.1	Baked goods	0.032	8.1
2	Baked goods	0.17	8.7	Biscuits	0.026	1.7	Biscuits	0.012	3.0
3	Ready meals	0.133	6.8	Chilled processed food	0.025	1.7	Sweet/savoury snacks	0.010	2.5
4	Sweet/savoury snacks	0.089	4.6	Dried processed food	0.019	1.3	Dried processed food	0.005	1.3
5	Frozen processed food	0.065	3.3	Frozen processed food	0.019	1.3	Noodles	0.005	1.3
	Total top five	0.804	41.1	Total top five	0.151	10.1	Total top five	0.064	16.1
	Total processed foods	1.942	99.3	Total processed foods	1.492	99.7	Total processed foods	0.397	100.0
	Total beverages	0.013	0.7	Total beverages	0.004	0.3	Total beverages	–	–
	Total	1.955	100.0	Total	1.496	100.0	Total	0.397	100.0

–, indicates <0.0005 kg per capita; lower–middle-income countries (2012 gross national income per capita US$1,036–4,085) included: India, Philippines, Vietnam, Indonesia, and Pakistan; upper–middle-income countries (US$4,086–12,615): China, Malaysia, and Thailand; high-income countries (>US$12,616): Singapore, South Korea, Taiwan, and Japan.

most significant fat vector in U-MICs and HICs, whereas biscuits were in L-MICs. Vegetable oil was responsible for the bulk of fat consumption comprising 83% of total oils and fats consumption in L-MICs, 88% in U-MICs and 78% in HICs. Vegetable fats (our proxy measure for trans-fat) followed, comprising 14.1% of total oils and fats consumption in L-MICs, 7% in U-MICs and 13.7% in HICs (Supporting Information Tables S1–S3). In all U-MICs and L-MICs with the exception of Thailand, vegetable fat consumption rose rapidly between 1999 and 2013 (Supporting Information Fig. S1).

Observation 4: baked goods and biscuits were the most significant salt vectors in upper–middle-income countries and lower–middle-income countries. Chilled processed foods and baked goods were the most significant salt vectors in high-income countries

Per capita salt consumption from processed foods was approximately fivefold higher in HIC relative to L-MICs (1.9 kg and 0.4 kg, respectively; Table 3). The high salt contribution from chilled processed foods in HICs may have

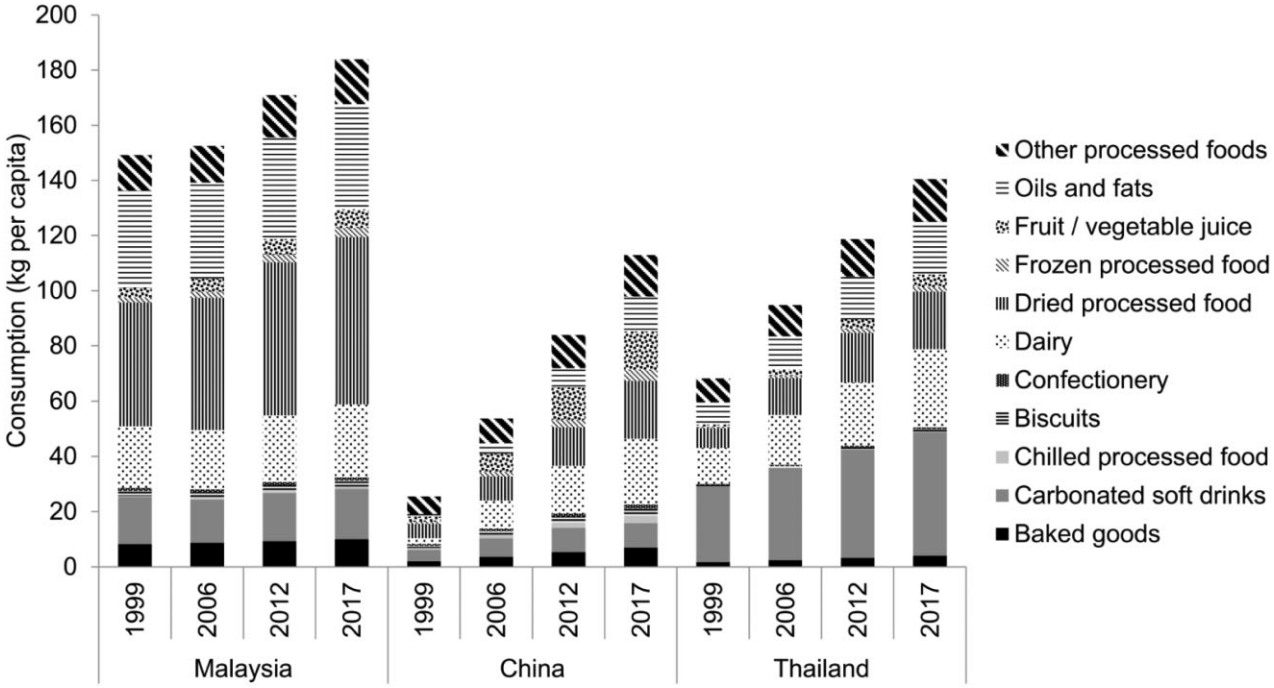

Figure 2 Consumption (kg per capita) of processed food product vectors highest in sugar, salt and fat, in select upper–middle-income countries in Asia, 1999–2012 with projections to 2017. Countries ranked by gross national income (GNI) per capita from left (highest) to right (lowest).

been attributed to high consumption volumes of chilled seafood/fish and noodles in Japan (54). Although chilled processed foods and frozen processed foods were top five salt vectors in HICs and U-MICs they were not significant in L-MICs, possibly reflecting population differences in refrigerator ownership. Baked goods were the only product vector to rank in the top five for each nutrient category across all country income brackets, a concerning finding given the high trans-fat content of some baked goods (19,55).

As a second step we plotted trends in consumption of the product vectors identified in Table 3 to illuminate in which countries the levels and rates of processed food consumption are changing most rapidly.

Observation 5: processed food consumption has increased rapidly in lower–middle-income countries and in most upper–middle-income countries, but has slowed or declined in high-income countries. Beverage consumption has increased most rapidly

Average annual growth rates for total per capita processed food consumption for the period 1999–2012 were 5.4% for L-MICs, 5.1% for U-MICs and 0.2% for HICs (Supporting Information Table S4). China, Thailand, India, Indonesia and Vietnam have undergone the most rapid changes in consumption over this period. In China for example, consumption increased 3.2-fold from 19.6 kg per capita in 1999 to 63.4 kg in 2012 (Fig. 2). In Vietnam, it increased 3.6-fold from 10.7 kg per capita to 38.7 kg (Fig. 3). Although markedly higher in HICs the consumption of baked goods, a top five sugar, salt and fat vector, has increased most rapidly in U-MICs, in particular China at an average growth rate of 7.7% per year. The consumption of oils and fats, the most significant fat vector has increased most rapidly in U-MICs, in particular China at an average rate of 16.5% annually. Among the L-MICs, it has increased at variable rates from an average of 0.6% annually in Pakistan to 7.5% in Indonesia and 10.9% in Vietnam (Supporting Information Table S4). Although South Korea has been noted for achieving a nutrition transition less deleterious to health than Western countries (retaining over the course of its economic development a low fat diet rich in vegetables) (7,13), these data demonstrate that Singapore may have also, at least in terms of processed food consumption, undergone an attenuated transition. Consumption in Taiwan was still increasing in 2012 (Fig. 4)

Relative to processed foods, beverage consumption has increased even more rapidly (Supporting Information Table S5). The average annual growth rate for total per capita beverage consumption for the period 1999–2012 were 11.5% for L-MICs, 7.2% for U-MICs and 2.6% for HICs. In U-MICs and L-MICs, the bottled water, ready-to-drink tea, and sports and energy drinks categories have grown most rapidly. The average growth rate of the most

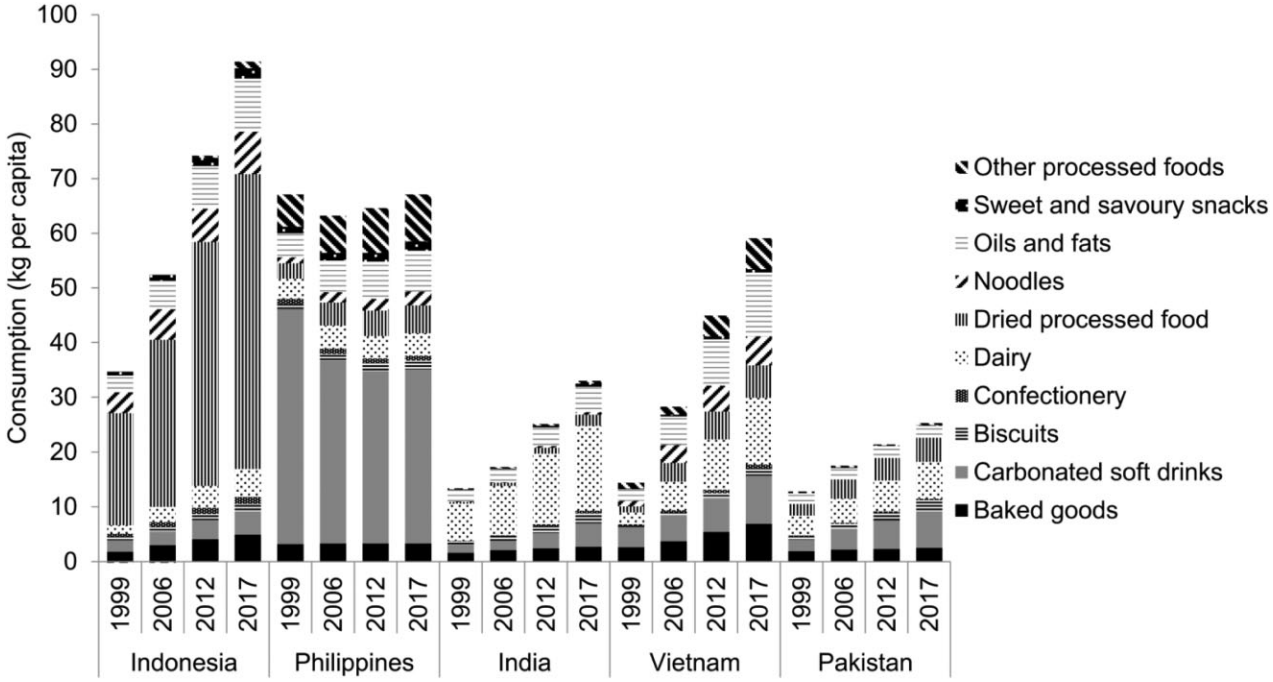

Figure 3 Consumption (kg per capita) of processed food product vectors highest in sugar, salt and fat, in select lower–middle-income countries in Asia, 1999–2012 with projections to 2017. Countries ranked by gross national income (GNI) per capita from left (highest) to right (lowest).

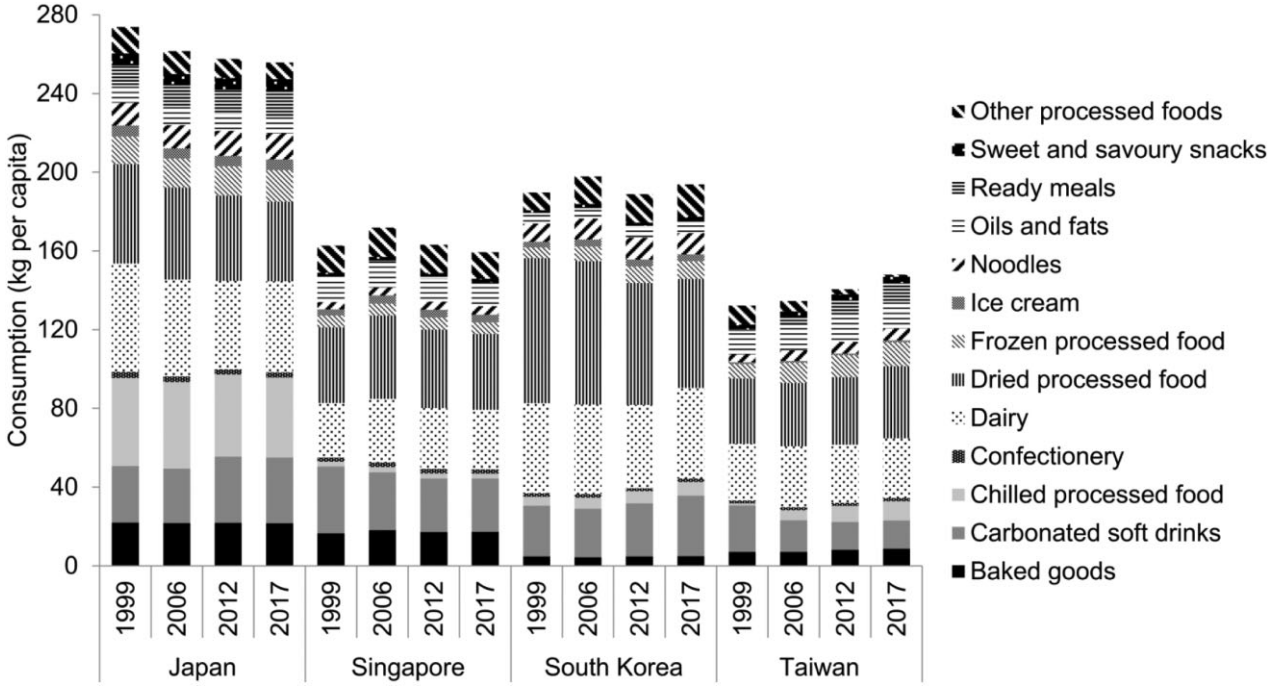

Figure 4 Consumption (kg per capita) of processed food product vectors highest in sugar, salt and fat, in select high-income countries in Asia, 1999–2012 with projections to 2017. Countries ranked by GNI per capita from left (highest) to right (lowest).

significant sugar vector, carbonated soft drinks, was negative in HICs (–0.4%) in contrast to the higher rates in U-MIC and L-MICs (3.1% and 5.2%, respectively), with Chinese and Vietnamese markets changing most rapidly (6% and 10.5%, respectively). The Philippines was the only U-MIC or L-MIC with a negative average growth rate for carbonated soft drinks of –1.7%, although consumption volumes were considerably higher relative to other L-MICs (Fig. 3). In 2012, Thailand, Japan and the Philippines had the highest carbonated soft drinks consumption volumes of 39.2, 33.6 and 31.5 L per capita, respectively (Figs 2–4).

Observation 6: there was regional level convergence in processed food consumption, but with notable country-level divergences

All HICs demonstrated similar processed food consumption patterns with the exception of greater consumption of chilled processed foods in Japan and dried processed foods in Korea (Fig. 4). Among the U-MICs, Thailand had a disproportionately high consumption of carbonated soft drinks. Another U-MIC, Malaysia, had a disproportionately high consumption of dried processed foods, and oils and fats, and total processed food consumption volumes in excess of the HICs Taiwan and Singapore. By 2017 Malaysia is likely to achieve a total consumption value approaching that of South Korea (Figs 2 and 3). Among the L-MICs, Indonesia had a disproportionately high consumption of dried processed foods, and the Philippines a disproportionately high consumption of carbonated soft drinks (Fig. 2).

As a further step, we determined production patterns for all countries (imports vs. domestic production) using available trade and consumption value data for beverages, and oils and fats, which were identified as significant vectors for sugar and fat, respectively.

Observation 7: production to consumption pathways (foreign imports vs. domestic production) appears to be vector dependent

Low trade balances and high domestic consumption values indicated that the production of beverages (a significant sugar vector) was primarily domestic (Supporting Information Fig. S2). Production of oils and fats (the most significant fat vector) was different, with large trade balance surpluses in the exporting nations Indonesia and Malaysia, and large trade balance deficits in the importing nations India and China (Supporting Information Fig. S3). This indicated that oils and fats were produced largely in the former countries, but are consumed (along with oils and fats produced domestically or imported from other countries) largely in the latter. Overall, this indicates different production to consumption pathways by which these product categories have acted as vectors for sugar and fat consumption in the region.

Discussion

This analysis demonstrates that processed foods are significant sugar, salt and fat vectors in the nutrition transition underway in the developing countries of Asia. Although consumption has plateaued or declined in HICs, it is rapidly increasing in the L-MICs and U-MICs. Relative to sugar and salt, per capita fat consumption is increasing and approaching levels in HICs most rapidly. Others made similar observations over a decade ago, finding that among Asian nations the proportion of energy derived from complex carbohydrates decreased and the proportion from fats and sugars increased with rising national income levels (15,56). Several processed food categories, in particular carbonated soft drinks, baked goods, and oils and fats appear to be the most significant vectors irrespective of country income bracket. These findings support nutrition transition theory, demonstrating higher processed food consumption in countries at later stages of economic development (7,57). The findings also demonstrate that sugar and fat is consumed from a greater diversity of product categories at higher levels of per capita income; the five most significant product vectors for sugar, for example, accounted for 72.6% of total sugar consumption in L-MICs, 63.6% in U-MICs and 53.2% in HICs.

What are the likely health implications?

Increased consumption of sugar, salt and fat from processed foods is a threat to public health for several reasons. Total processed food consumption has been positively associated with obesity prevalence across countries after controlling for income levels, indicating the contribution of such foods to excessive energy intake (6,17,19). Sugar consumption and not just total dietary joules, has been associated with rising rates of diabetes in L-MIC and U-MIC even after controlling for overweight and sedentary lifestyle (58). High levels of dietary saturated and trans-fats (52), and sodium (59), are established risk factors for CVD. Strong evidence supports sugar-sweetened beverage consumption as an established risk factor for obesity, T-2D and CVD (49,50,60). Mechanistic evidence from human and animal studies has linked systemic low-grade inflammation, the metabolic syndrome and associated NCDs with diets high in saturated fats, trans-fats, elevated ω-6/3 fat ratios, salt and glycaemic load (61–63).

There are also likely health impacts specific to the region. Overweight status is increasing rapidly in several countries across Asia (34–36). This is a real concern given that Asian populations have a greater susceptibility to diet-related NCDs. They are more likely to develop T-2D at lower levels of adiposity, at younger ages, have more complications and die at younger ages (37,40,64). Among the countries for

which we had data, of particular concern are India, China, Malaysia and Thailand where the prevalence of T-2D has increased in the urban centres (40,65,66). Nutrition transition theory predicts that in the HICs, demand for healthier food products will grow in response to the needs of more affluent, health conscious and ageing consumers. In Malaysia, a U-MIC with the highest obesity and diabetes rates in the region (15.2% and 11.5% in 2012 respectively), health concerns appear to be driving such demand (67).

These data provide support for convergence–divergence theory, demonstrating similarities in processed food consumption across the region but with country-level differences. Convergence likely reflects the integration of domestic Asian food markets into the global food economy and the resulting adoption of globally ubiquitous processed food brands (the 'Coca-colanization' theory), while divergence is likely to result from local adaptations of products targeting niche markets and cultural dietary preferences (1,20,43). A convergence of concern is the rapidly increasing levels of vegetable fat (our proxy for trans-fat) consumption observed in all U-MICs and L-MICs except Thailand. In Indonesia alone annual consumption doubled from 0.65 kg per capita in 1999 to 1.36 kg in 2013. There are also notable country-level divergences. With regards to soft drinks, Thailand and the Philippines have consumption volumes comparable with HICs at much lower levels of economic development. In terms of oils and fats, the U-MIC Malaysia has the highest consumption volume of any country, more than twice that of the second highest Thailand. Both of these countries consume more oils and fats than any HIC. As in China, it is probable that a significant proportion of this consumption constitutes edible oil used for frying rather than baking, boiling or steaming foods in the home (68). These consumption patterns are likely endpoints of historical developments in global edible oil markets that have markedly increased the availability of soybean, canola and palm oil in Asia since the 1980s, especially in China and India (1,4). Palm oil may be particularly relevant to regional health given its high saturated fat content (69), and as we have demonstrated, the large production volumes exported intra-regionally from Malaysia and Indonesia. Data from the Food and Agricultural Organization demonstrates that Indonesian palm oil production alone increased 33-fold from 721,172 tonnes in 1980 to 23,672,000 in 2012 (70).

We know that the rate of increase in obesity and diet-related NCDs is highest in rapidly developing L-MIC and U-MIC. In many countries there is also a shift in the burden of obesity from high to low socio-economic groups during the middle and later stages of economic development (4,71,72). The health consequences resulting from the dietary divergences described earlier may therefore exacerbate existing inequalities in health between countries across Asia (43,73).

What factors are driving a processed food nutrition transition in Asia?

Several factors are likely driving the increased consumption of processed foods in Asia. As noted earlier, on the demand-side rising household incomes, rapid urbanization and the increasing female economic participation are likely to be driving demand for convenience foods. However, others have recently demonstrated that market penetration by transnational corporations, as indicated by FDI inflows, correlates strongly with processed food and beverage consumption (6,46), and with associated NCDs (33,58). This suggests a significant role for supply-side factors, and three most likely explain recent increases in processed food consumption.

First, integration into the global economy has resulted in large inflows of FDI by TFBCs into the region (31,32,74). The increased penetration of foreign firms in previously unexposed developing markets is likely to trigger increased market competition, market concentration, changes in product pricing, expanded product distribution and marketing intensity. TFBCs bring with them new and more efficient technologies and organizational practices that are adopted by domestic firms. They also establish global and vertically integrated supply chains and distribution systems that achieve economies of scale (1,20,74). Regional integration is also likely to drive expansion of processed food consumption from manufacturing epicentres. Thailand and Malaysia, for example, have been among the leading four developing countries for processed foods exports (75). With the advent of the ASEAN Economic Community in 2015, manufacturers in Thailand are gearing up for regional expansion (76). Mass media food advertising to children has been reported as extensive in some countries including India, Malaysia and the Philippines (77). Other technologies including television ownership, Internet and mobile technologies have provided more advertising channels for TFBCs (1), in particular the use of social media websites in Thailand and China (76,78). The net effect of these changes are likely to increase the availability, affordability and desirability of processed foods (1,20).

Second, has been the supermarketization of the region in a series of 'waves'. In the first-wave countries Japan, Taiwan, South Korea, Philippines and Thailand 50–60% of food retail sales were through supermarkets by the mid-2000s. A second wave included Indonesia with 30% of food retail by the early 2000s. In a third wave, supermarkets are spreading throughout urban centres in Vietnam, China and India (79–81). Although introducing improved food safety standards, supermarkets act predominantly as distribution channels for processed foods in the early stages

of market growth, before offering a wider diversity including fresh foods (and out-competing wet markets) in later stages (1,4,80). Supermarkets may also drive market segmentation of processed food sales, initially targeting high-income consumers in large urban centres with an increasing diversity of products, before expanding product offerings and distributions channels to target low-income and rural consumers (1,80). Market segmentation likely explains our observations that sugar and fat are consumed from a wider diversity of processed foods at later stages of economic development. In China and India, TFBCs are also attempting to 'jump' the urban–rural distribution gap by penetrating rural markets through offering smaller package sizes and more affordable pricing points (78,82).

Third, although unlikely to be significant to population nutrition outside of the dense urban centres, fast food companies have also rapidly expanded throughout the region since the 1990s (a process of 'McDonaldization') when many companies underwent aggressive international expansion. McDonalds, for example, expanded its number of outlets in the Asia-Pacific region from 1,458 (11.7% of total) in 1991 to 6,775 (23.3%) in 2001 (22). In China, the number of sales transactions per capita at fast food outlets increased more than threefold from 18.3 in 1999 to 60 in 2012 (83). Yum! brands (Pizza Hut, KFC) and McDonalds are market leaders in most countries, ranging from a combined 3% market share in India to 73.4% in Malaysia (84,85). These global companies have undertaken aggressive marketing campaigns and have localized their products to meet the taste preferences of Asian consumers; McDonalds, for example, offers rice porridge with chicken and pork in Thailand, and a diversity of vegetarian options in India (22,84,86).

Study limitations

There are several limitations of this analysis. As noted earlier, the methods adopted by Euromonitor to calculate ingredients' volumes introduces potential inaccuracies and the results should be interpreted with caution. The market data used captures sales volumes only; this is an imperfect measure of consumption because it does not capture other sources of processed food including those manufactured at home or those prepared through informal (non-market) food systems. Additionally, these data do not account for food wastage. However, the abundance of this industry data has allowed for comparisons between countries and over multiple time-periods (6). This analysis also relies on processed food categories that are aggregates of subcategories. This has not allowed for a more specific determination of which categories are acting as sugar, salt and fat vectors nor has it allowed for a brand-specific analysis, which has been proposed as 'best practice' in terms of food monitoring (16). Nor has it allowed for categorization of products based on the extent of processing as proposed elsewhere (3). Further, because of lack of data, this analysis has not included low-income countries for example Myanmar, Cambodia and Laos. We also note that although there is consensus on the adverse health effects of TFAs, there is some debate concerning the adverse effects of total dietary fat and saturated fats (87). Further, although this analysis identifies oils and fats as the most significant fat vector, we have not been able to differentiate between amounts used in cooking and in processed food manufacturing. It is likely that edible oils used for frying foods at home comprises a significant proportion of this consumption (68). The interpretation of the results pertaining to fat therefore warrants caution. Further, our analysis determines average nutrient intakes associated with each respective product category, whereas there can be significant variations in the nutrient content of individual products within each category. For example, one analysis demonstrated that for most processed food categories the highest sodium brand had a sodium concentration at least one-half greater than the lowest sodium brand (18). Despite these limitations, this analysis provides insights into the role of processed foods in the nutrition transition underway in Asia.

Conclusions

We have adopted a novel approach for estimating levels of sugar, salt and fat consumed from processed food categories in countries at varying stages of economic development across the region. Consumption of these nutrients has stabilized in the rich countries, but is increasing rapidly in the U-MICs and L-MICs, trends that are likely to continue without policy intervention. We identified the most significant product vectors for sugar, salt and fat, in particular carbonated soft drinks, baked goods, and oils and fats. We have also identified country-specific potential health impacts, in particular, the high soft drink consumption volumes in the Philippines and Thailand, and high oil and fat consumption in Malaysia.

Diet-related NCDs are the leading cause of death and disability in the Asian region and in the world today. Mitigating and preventing a processed food-driven nutrition transition is likely to yield significant public health benefits for billions of Asian citizens. For L-MICs and U-MICs the key question is: With ongoing economic development how can governments avoid a nutrition transition where processed foods are a significant and unhealthy part of the typical diet? For the HICs: How can current levels of processed food consumption be attenuated? For all countries: How can their contribution to sugar, salt and fat consumption be reduced?

This analysis suggests that policy-makers should take action to prevent or mitigate processed food consumption. Comprehensive policy and regulatory approaches are most

likely to be effective in achieving these goals (53,88–90). The different production to consumption pathways demonstrated for beverages (domestic production), and oils and fats (regional production) in this analysis suggests that policy-makers should strive for domestic as well as regional (and multilateral) approaches to policy intervention.

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Conflicts of interest statement

The authors declare that they have no competing interests.

Supporting information

Additional Supporting Information may be found in the online version of this article, http://dx.doi.org/10.1111/obr.12174

Figure S1. Vegetable fat consumption (kg per capita), select countries in Asia, 1999–2012 with projections to 2017.
Figure S2. Values (billions of US$) of domestic consumptions and trade balances (exports minus imports) for beverages, in select countries in Asia, 2012.
Figure S3. Values (billions of US$) of domestic consumptions and trade balances (exports minus imports) for fats and oils, in select countries in Asia, 2012.
Table S1. Contributions of processed food and beverage product categories to sugar, fat and salt consumption (kg per capita), in high-income countries, 2012.
Table S2. Contributions of processed food and beverage product categories to sugar, fat and salt consumption (kg per capita), in upper–middle-income countries, 2012.
Table S3. Contributions of processed food and beverage product categories to sugar, fat and salt consumption (kg per capita), lower–middle-income countries, 2012.
Table S4. Average annual growth rates (% change) in per capita processed food consumption for the period 1999–2012.
Table S5. Average annual growth rates (% change) in per capita beverage consumption for the period 1999–2012.

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