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Assessment of Current Diets: Recent Trends by Income and Region

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WP4: Assessment of Current Diets: Recent Trends by Income and Region

Abstract
Dietary changes reflect a wide range of underlying conditions, many of which relate to a society's national income per capita and regional characteristics. This assessment uses a Preston Curve approach to trace systematic patterns associated with per-capita income in 1990 and 2013, so as to distinguish predictable trends from structural shifts driven by interventions and innovations in the food system. Our data combine dietary recall surveys with aggregate statistics to capture the multidimensional nature of nutritional changes and address the limitations of each individual type of data. Our central result is that, while overall nutritional status for the world's poorest people has improved sharply, several important aspects of dietary patterns in middle- and upper-income countries have worsened significantly. Increased intake of those relatively unhealthy foods in 2013 is primarily a continuation of the same systematic patterns observed in 1990. The principal structural change we observe is a sharp reduction in trans fat intake at each level of income, in all regions except South Asia. That improvement was driven by changes in both public policy and private-sector food production, revealing the potential and the need for further action on that and other risk factors for malnutrition and diet-related disease.

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Introduction and motivation

The dietary transition from undernutrition to obesity and diet-related disease is closely tied to many other aspects of economic development. Individual choices reflect local opportunities and constraints, which in turn are conditioned by national and regional conditions. In this paper, we focus on how countries' national-average intake of key foods and nutrients has shifted over time in every major region of the world.

To quantify trends and test for structural shifts in diet quality we provide some descriptive statistics by income and region, and then use a statistical data-visualization approach first introduced by Samuel Preston (1975). Preston Curves test whether observed changes over time and differences among countries are due to business-as-usual applications of existing technologies and institution, or whether technological change or institutional innovations have altered the outcomes observed at each income level. The method was first developed to identify the impact of technological change on life expectancy, and has since been widely used in public health research (Bloom and Canning 2007). The method is used here for nutrition outcomes, offering a novel approach to understanding the nutrition transition - a term coined in the early 1990s by Barry Popkin (1993, 1994) to describe changes in dietary intake and disease outcomes. Using the Preston Curve approach we can identify which aspects of nutrition transition in the 2000s follow the same income path as in the 1990s, and which are the genuinely new features of global diets seen so far in the 21st century.

For this paper we set the stage with changes in dietary intake and total food availability per capita across the major regions of the world, then introduce the Preston Curve approach regarding changes in energy balance and several specific dietary components associated with changes in diet-related disease. Our aim is to compare national average intake per capita across the largest possible number of countries around the world, asking whether the cross-country patterns observed in the 1990s have shifted in the 2000s, thereby measuring the accumulated effect of public-sector interventions as well as private-sector changes seen so far in the 21st century.

The Preston Curve approach to analyzing change compares the average observed in each year for every level of national income per capita, defined in real terms of real purchasing power over all kinds of goods and services. This allows us to test for statistically significant shifts in systemic conditions between 1990 and 2013, first for the world as a whole and then within each major region.

In each case our objective is to describe the patterns observed across countries, and test whether changes in dietary intake are due to countries' transitions along an established path of socioeconomic development associated with per-capita income and purchasing power, or instead might be caused by innovations in technology or social institutions that are new to a particular region and the world as a whole. The statistical method used here makes no assumptions about the shape of that path, applying nonparametric regression to test whether conditions have changed at each level of national income, defined as gross domestic product (GDP) per capita at purchasing-power parity (PPP) prices.

National purchasing power as measured here includes the sum of all household spending and also public expenditure on collective goods and services such as infrastructure, education or health care. These services may shift individuals' own income-consumption curves, and may affect entire communities in similar ways. Our Preston Curves are quite different from individuals' responses to changes in household income, first because they include the effects of collective actions and public-sector interventions, and also because they are estimated non-parametrically without the limitations imposed by individuals' budget constraints. To estimate individuals' elasticities of demand, these constraints have led to the development of specific functional forms such as the Nobel prize-winning work of Angus Deaton and others (Deaton and Muellbauer 1980). The phenomena explored in our Preston curves are not subject to these restrictions, so the dietary transitions explored here may take any form and differ by region as well as change over time. Using all available data to estimate Preston Curves allows us to test whether global changes, such as food policy reforms and private-sector innovations, have altered outcomes for the average country at each level of per-capita income. Our main results refer to specific food groups and nutrients, using data from dietary surveys in epidemiological models of diet-disease linkages. To set the stage for these changes in diet composition we turn first to more aggregate data on food availability and associated changes in heights, weights and energy balance.

A key feature of this paper is that, for each aspect of dietary transition we use *all* available data from the entire world. Our aim is to use the most widely available international source of data collected in a standardized way. Each observation is a national total or average per person in that country and year. These are based on household and individual surveys, converted into modeled estimates for comparability across countries and over time. Modeled estimates aim to overcome selection bias in the location and timing of surveys. For example, dietary recall data are collected primarily in richer countries where governments are concerned about diet quality, while child anthropometry is collected primarily in poorer countries using foreign assistance to improve maternal and child health. Modeled data also aim to overcome systematic biases associated with differences in data collection methods and survey quality. We cannot eliminate every kind of streetlight effect, but can limit the degree of cherry-picking by reporting all available data for each type of observation, helping readers see broad patterns quickly while also exploring the many exceptions and limitations of the available evidence.

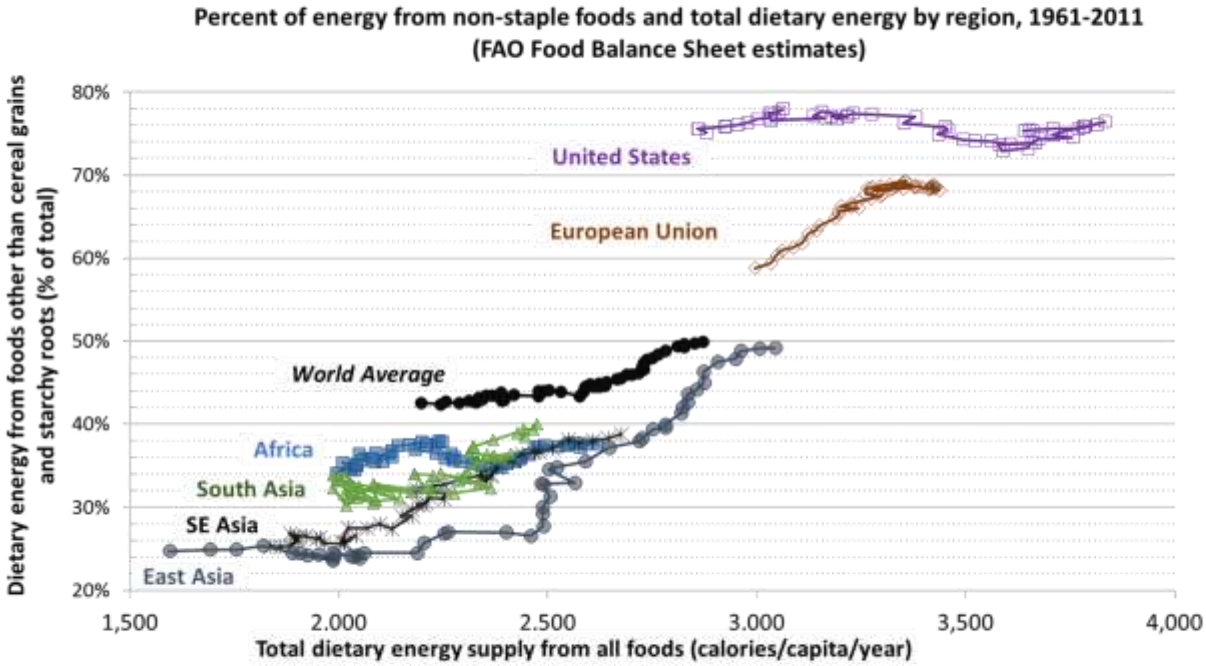
Background: From more food to different foods

The standard international source for availability of various foods are the Food Balance Sheets (FBS) assembled by the United Nations' Food and Agricultural Organization (FAO) from government sources around the world. The specific methods used are detailed at FAO (2015), and results are compared to dietary recall surveys in Del Gobbo et al. (2015). These FBS data originate with agricultural surveys for crop and livestock production, plus imports minus exports of each product, minus estimates of each crop's use as livestock feed, seed or waste. Results shown here are reported on a per-capita basis, converted to dietary energy using food composition tables. Countries differ in the quality of each underlying observation, but starting with production data and subtracting other uses provides the best available estimate of total food consumption per person computed in a consistent way for each country of the world since 1961.

Figure 1 uses regional aggregates to show long-term trends in the per-capita quantity of all foods, measured in calories, and fraction of those calories that come from foods other than starchy staples. This visualization of the entire collection of Food Balance Sheet data reveals that in the poorest regions at the bottom left of the chart, food systems grow mainly horizontally to produce *more food*, but that doing so leads quickly to a diagonal movement upwards towards *different foods.* Regions differ in their relative position at any one time, and vary greatly in speed and direction of change.

The changes shown in Figure 1 generally go from left to right (more food) and upwards (towards different foods), with important exceptions being shifts downward towards more starchy staples in Africa during the 1980s and then in the US during the 1990s, as well as the US and Europe's reductions in calorie use during the 2000s. For the world average, however, there is a clear pattern of horizontal increase during the first half of this period, followed by a trend upwards towards diet diversity in the 1990s and 2000s.

Figure 1. From more food to different foods: the dietary transition by region, 1961-2011



Source: Author's calculations from FAO Food Balance Sheets, faostat3.fao.org/download/FB/FBS/E (June 2015).

For public health, some of the most important aspects of dietary change involve the specific foods identified as having the clearest impact on disease risks by the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) managed by the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. Tables 1 and 2 below use the revised data known as GBD 2013, released in September 2015. The published description of these data is Forouzanfar et al. (2015), with detailed documentation available online at IHME (2015). These include four specific foods (red meat, processed meat, milk and sugar-sweetened beverages), four broad food groups (fruits, vegetables, nuts and seeds, and whole grains), and six specific food components (seafood omega-3 fatty acids, trans fatty acids, fibre, calcium and sodium). The GBD 2013 estimates of average intake in 1990 and 2013 presented here are based on diet recall surveys for various countries and years, extrapolated to fill missing data in ways designed to maintain comparability between them. This aspect of the GBD 2013 dataset is managed by the Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE), as documented for example in Singh et al. (2015). Our presentation of these data follows the classification into "healthy" and "unhealthy" items of Imamura et al. (2015), revealing clear patterns over time from 1990 to 2013 in each income quintile (Table 1) and each region (Table 2).

Table 1. Intake of selected dietary risk factors by national income, 1990 and 2013
(g/day, except PUFA and transfat which are percent of dietary energy)

		Quintile of GDP per capita in each year				
Healthy items		1st	2nd	3rd	4th	5th
Fruits	1990	91	95	121	114	160
	2013	95	115	140	146	168
Vegetables	1990	224	194	179	222	176
	2013	264	198	194	204	167
Whole grains	1990	37.6	27.2	21.3	25.7	43.6
	2013	35.9	22.6	20.5	19.1	40.8
Seafood n-3s	1990	0.15	0.09	0.08	0.11	0.23
	2013	0.11	0.10	0.09	0.15	0.24
Milk	1990	37	63	105	119	217
	2013	41	62	113	129	187
Nuts and seeds	1990	5.2	4.4	4.2	3.1	3.5
	2013	5.3	5.7	5.5	6.1	5.3
Fiber	1990	24.8	22.5	21.2	20.6	19.7
	2013	25.0	22.8	22.0	21.1	20.5
PUFA (% of energy)	1990	4.1%	4.9%	5.0%	5.4%	5.2%
	2013	4.2%	4.3%	5.9%	6.4%	5.4%
Unhealthy items						
Red meat	1990	25	35	48	55	78
	2013	24	39	49	61	68
Processed meat	1990	7.0	6.8	10.6	15.7	21.7
	2013	7.0	7.9	12.4	22.1	27.1
Sugar-Sw. beverages	1990	84	84	198	120	94
	2013	95	93	116	119	104
Sodium	1990	2.56	2.85	3.36	4.41	3.92
	2013	2.57	2.97	4.53	4.45	3.98
Transfat (% of energy)	1990	0.93%	0.94%	0.94%	0.96%	1.20%
	2013	0.82%	0.80%	0.73%	0.75%	0.84%

Note: Values shown are the mean intakes per capita, in the median country for each quintile of national income (5th = richest). Units are grams per day, except for PUFA (polyunsaturated fats) and transfats which are shown as percent of dietary energy. Sample size is 159 countries in 1990 (32 in each quintile except 5th), and 180 countries in 2013 (36 in each quintile).

Source: Intake data are Global Burden of Disease 2013 estimates from the Institute for Health Metrics and Evaluation, released in September 2015 (IHME 2015); quintiles of national income are based on GDP per capita at purchasing-power parity from the World Bank (2015), World Development Indicators.

Table 2. Intake of selected dietary risk factors by region, 1990 and 2013
(g/day, except PUFA and transfat which are percent of dietary energy)

		Regions of the world								
Healthy items		SSA	S.Asia	SE Asia	E.Asia	LAC	US-Can	EU15	RoW	World
Fruits	1990	93	60	112	57	136	115	152	112	111
	2013	96	76	131	65	154	131	180	123	125
Vegetables	1990	230	211	165	344	180	202	143	221	200
	2013	249	234	155	356	175	181	146	225	199
Whole grains	1990	58	37	4	21	29	44	47	19	28
	2013	56	35	6	18	25	45	46	18	25
Seafood n-3s	1990	0.14	0.07	0.51	0.04	0.08	0.11	0.27	0.11	0.13
	2013	0.13	0.07	0.74	0.05	0.09	0.10	0.25	0.11	0.12
Milk	1990	49	69	38	26	119	199	226	121	97
	2013	53	88	30	40	125	181	233	128	104
Nuts & seeds	1990	5.0	12.6	3.9	3.0	2.7	3.0	3.6	5.0	4.1
	2013	4.9	14.6	5.4	4.0	4.0	5.0	5.2	6.8	5.4
Fiber	1990	25	23	11	17	22	17	20	20	21
	2013	25	23	12	18	22	18	21	20	22
PUFA (%)	1990	3.9%	4.9%	2.6%	6.0%	5.1%	5.5%	5.3%	5.4%	4.9%
	2013	4.1%	5.0%	3.0%	6.6%	5.7%	6.2%	5.6%	5.9%	5.0%
Unhealthy items										
Red meat	1990	25	19	30	44	55	70	78	54	48
	2013	24	16	25	60	55	62	78	52	49
Proc. meat	1990	7.0	9.2	8.3	6.5	15.1	20.9	30.8	13.0	8.5
	2013	7.6	10.8	11.2	7.1	20.5	29.7	35.7	13.2	9.9
SSB	1990	86	105	67	35	405	195	94	64	88
	2013	97	100	73	34	416	297	90	64	97
Sodium	1990	2.6	4.5	5.4	5.4	3.2	4.1	3.9	4.6	3.7
	2013	2.6	4.5	5.4	5.4	3.3	4.1	3.9	4.6	3.7
Transfat (%)	1990	1.0%	2.5%	0.8%	1.0%	0.9%	2.3%	1.2%	1.0%	1.0%
	2013	0.8%	2.3%	0.8%	0.9%	0.7%	1.3%	0.8%	0.8%	0.8%

Note: Values shown are the mean intakes per capita, in the median country of each region. Units are grams per day, except for PUFA (polyunsaturated fats) and transfats which are shown as percent of dietary energy. Sample size is 159 countries in 1990, and 180 in 2013. Regions follow standard World Bank definitions except that the US and Canada are shown together and the EU-15 countries are shown separately. The Rest-of-World category includes Oceania, the Mideast and other areas outside the specified regions.

Source: Intake data are Global Burden of Disease 2013 estimates from the Institute for Health Metrics and Evaluation, released in September 2015 (IHME 2015). Regional medians are author's calculations.

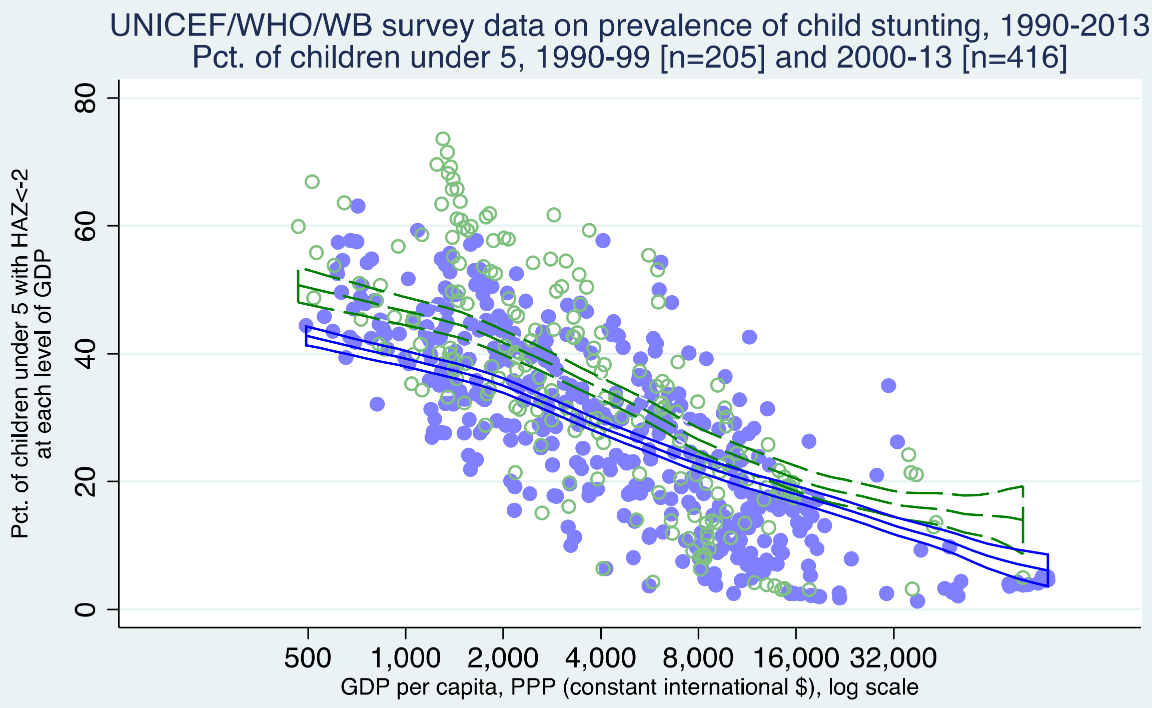
Preston curves for nutritional status: Child stunting, child overweight and adult BMI

To test for structural changes from decade to decade in the global pattern, we introduce the Preston Curve approach with the most readily observable external dimensions of nutritional status in terms of body size. As shown by Fogel (2004), Deaton (2007) and many others, differences in dietary intake as well as care practices and environmental conditions lead to wide variation in attained heights below each population's genetic potential, while variation in energy balance relative to physical activity levels leads to wide variation in average weights for each level of height. Here we focus on children under age 5, to capture recent changes in conditions experienced during gestation and infancy, and on adult women to capture energy balance over the life course. These choices are also driven by data availability, as the funders of nationally-representative anthropometric surveys are primarily concerned with maternal and child health. Figures 2, 3 and 4 provide the largest and most widely-used collections of such surveys. Each country's national average is shown individually, with a nonparametric regression used to compute the global average among countries at each level of national income. Confidence intervals around these local means permit statistical hypothesis testing, indicating the magnitude and variation of improvement at each income level.

International comparisons of children's growth over time in Figures 2 and 3 uses the prevalence of extreme values found in each survey, relative to the heights and weights of healthy children as recorded by the World Health Organization (WHO 2006). The units of measure are z scores, expressed in terms of standard deviations away from the median of a healthy population. The underlying data are surveys assembled by the UNICEF-WHO-World Bank joint database on child growth and malnutrition (WHO 205). In the database, each child's measured length or height and their weight is shown relative to the distribution observed in a healthy population at their age and sex. Figure 2 shows the prevalence of stunting, defined as having a height-for-age ratio more than 2 standard deviations below the median of a healthy population (HAZ < -2), while Figure 3 shows the prevalence of overweight, defined as a weight-for-height ratio more than 2 standard deviations above the corresponding median (WHZ > +2). In a population of healthy children, by definition only about 2.5 percent of children would have HAZ scores below -2, or WHZ scores above +2. The surveys collected by UNICEF, WHO and the World Bank reveal much larger fractions of children in these extreme conditions, especially for stunting.

Figure 2 reveals a sharp decline in stunting at each level of income, especially in the poorest countries. Surveys conducted during the 1990s found about 50% of children had heights below the HAZ<-2 threshold in the poorest countries, while surveys in countries at those income levels in the 2000s found only about 40% of children to be stunted. Countries that got richer also benefited from a strong income gradient, leading to a lower prevalence of stunting at higher levels of national income. To reach the WHO standard of only 2.5% of children stunted, countries would need per-capita incomes similar to the richest countries surveyed. That gradient is consistent with the definition of the WHO standard, which was constructed by surveying children living under the most favorable possible conditions. The purpose of Figure 2 is to identify the shift from the 1990s to the 2000s among poorer countries, who moved closer to those ideal conditions despite having much lower purchasing power of their own. In recent years, low-income countries have seen significantly greater improvements in child stunting than would have been predicted based on income growth alone, thanks to new programs, policy changes and food-system innovations of all kinds.

Figure 2. Child stunting has a strong income gradient and has shifted down at lower income levels

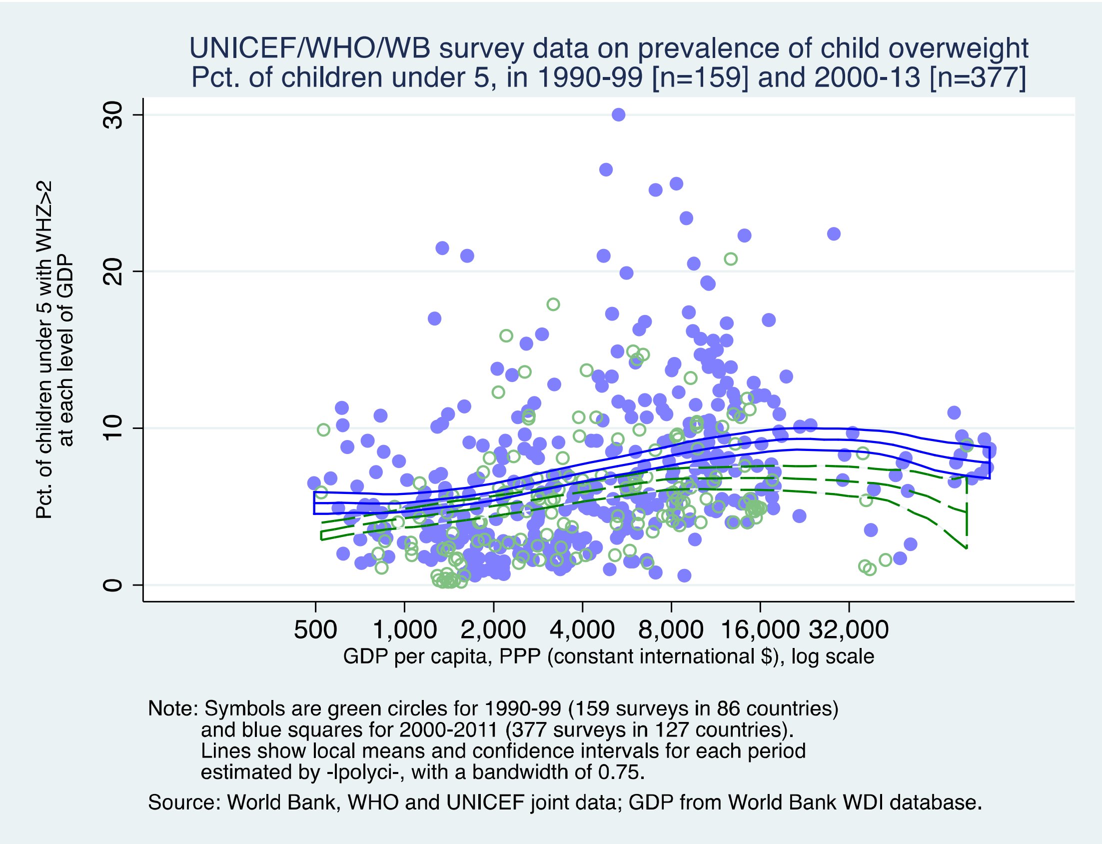


Note: Symbols are green circles for 1990-99 (205 surveys in 101 countries) and blue dots for 2000-2013 (416 surveys in 133 countries). Lines show local means and confidence intervals for each period estimated by -lpolyci-, with a bandwidth of 0.75.

Source: World Bank, WHO and UNICEF joint data; GDP from World Bank WDI database.

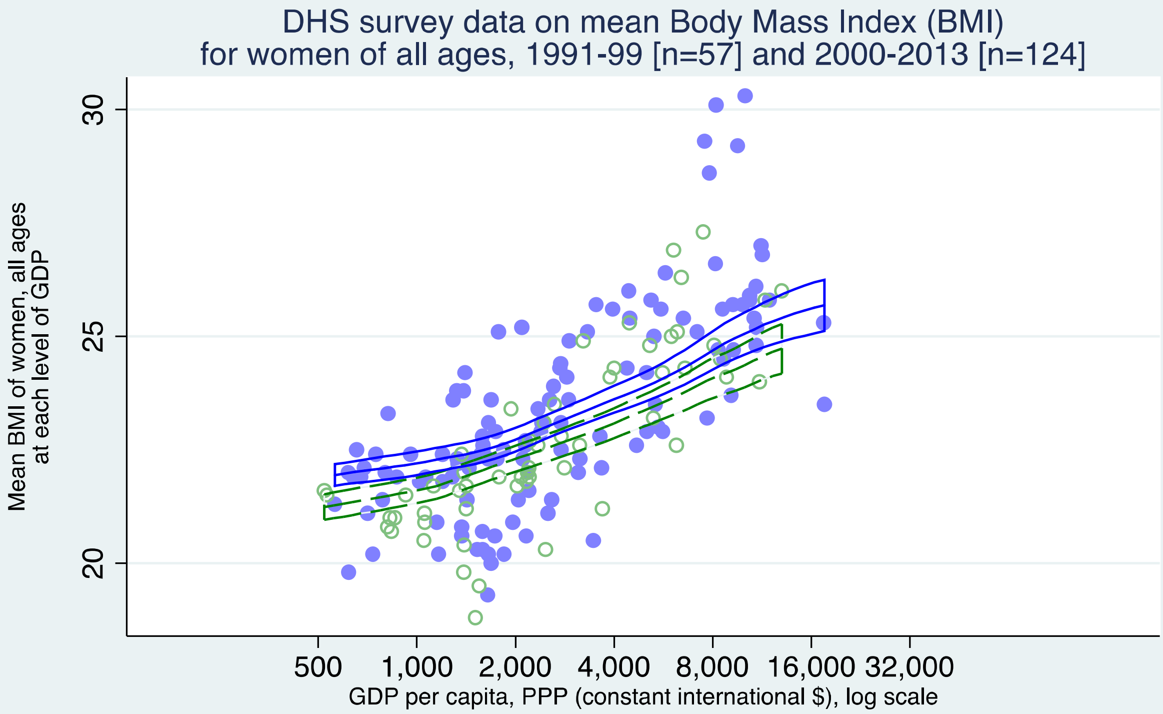
Increases in dietary energy and nutrient intake that are needed for linear growth also lead to weight gain, potentially to unhealthy levels. Figure 3 uses the same surveys as Figure 2 to show the fraction of measured children with weight-for-height z scores that are more than two standard deviations above the median of a health population. Here we note that a few countries at all income levels are near the WHO standard, with only about 2.5 percent of children above the threshold level of WHZ. In some countries more than 20 percent of children under five are classed as overweight, and the estimated mean for each income level range fall in the 5-10 percent range. There is much less of an income gradient than in the previous figure, but the Preston Curve approach does reveal a significant shift upwards over time among the higher-income countries in this sample. Like all such data these results are subject to selection bias regarding which countries were surveyed, and are influenced by methodological issues such as the bandwidth used to estimate the mean value among countries at each level of income. Our focus in this study is to ensure consistency across figures through uniformity of method, so that differences among the variables are readily visible.

Figure 3. Child overweight has a significant income gradient and shifted up at higher income levels



While stunting tends to occur very early in life and can readily be detected in children under five, weight gain occurs gradually and may begin only after adolescence. Figure 4 uses one of the most complete collections of nationally-representative surveys for adult heights and weights, namely the Demographic and Health Surveys (DHS) funded primarily by USAID. Unlike most of the child-focused surveys included in Figures 2 and 3, most DHS rounds include heights and weights of mothers. Here we show the mean value of their Body Mass Index (BMI), defined as weight for height squared (kg/m^2): this has a strong income gradient, but shifts in the mean at each income level do not exceed the confidence interval. A few lower- and middle-income countries have women's mean BMI levels around 20, whereas most middle- and higher-income countries have mean BMIs near 25. Standard clinical cutoffs for underweight, overweight and obesity are typically set at BMI levels of 18.5, 25 and 30 respectively. Figure 4 reveals the transition in average BMIs from low to high body weights relative to these benchmarks.

Figure 4. Women's BMI has a clear income gradient, and small shifts



Note: Symbols are green circles for 1991-99 (57 surveys in 42 countries) and blue squares for 2000-2013 (124 surveys in 62 countries). Lines show local means and confidence intervals for each period estimated by -lpolyci-, with a bandwidth of 0.75.

Source: Demographic and Health Surveys (Statcompiler); GDP is from World Bank.

Dietary intake by region: GBD estimates for major disease risk factors

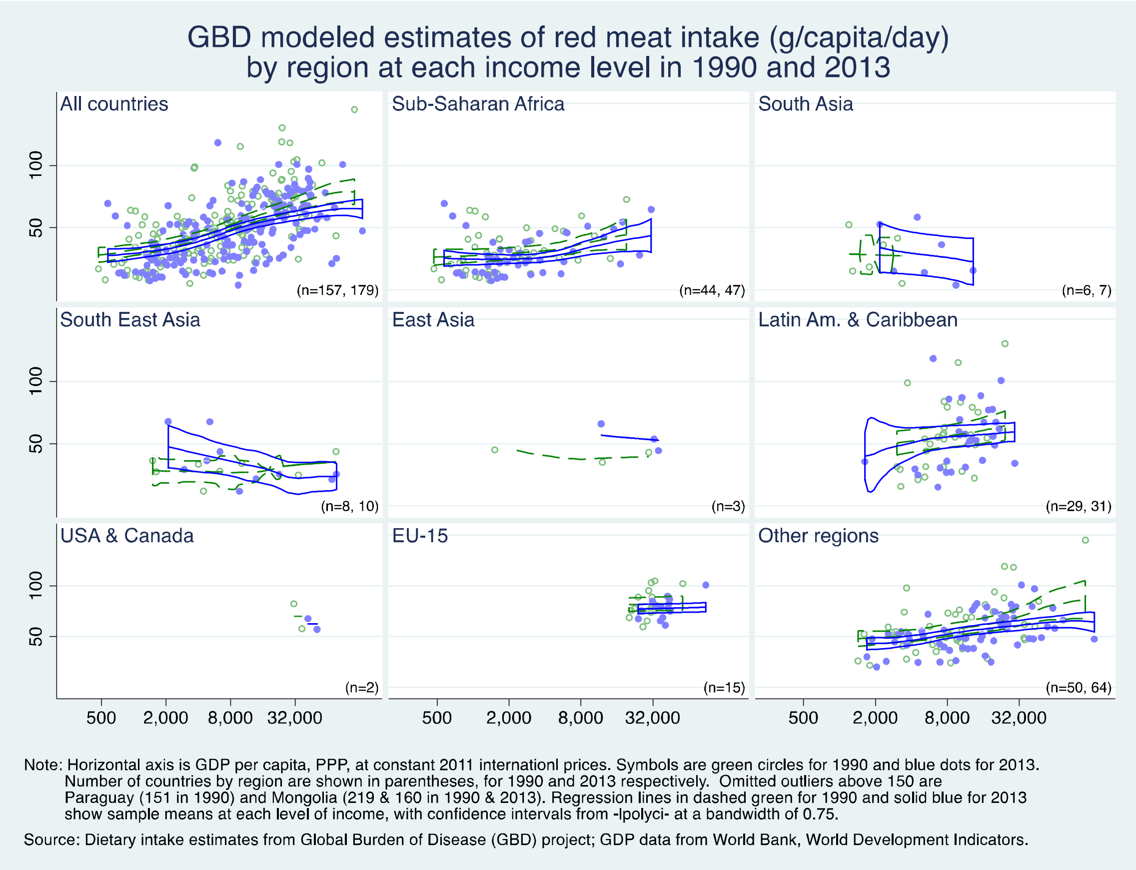
Results shown in Figures 2, 3 and 4 establish the Preston Curve technique regarding anthropometry and energy balance. To examine changes in dietary intake associated with specific diseases, we turn to the Global Burden of Disease 2013 data on dietary intake that was first introduced in Tables 1 and 2 above, looking specifically at intake of red meat, processed meat, milk and sugar-sweetened beverages, plus fruits and vegetables, seafood omega-3s and trans fats.

Compared to the anthropometric survey data in Figures 2, 3 and 4, the modeled data assembled for GBD 2013 offer unusually broad geographic coverage of both high- and low-income countries. This permits us to estimate Preston Curves within regions and for the world as a whole. Each of these figures begins with a global estimate, followed by regional Preston Curves for Africa, the three regions of Asia, two regions in the Americas, one for the EU-15 countries of Europe, and another for the rest of the world. For visual clarity, the countries in each regional chart are plotted using the same vertical axis. Outlier observations are listed separately in the note below each figure, with the number of remaining observations in each region for 1990 and 2013 listed inside each panel. The number of observations is lower in 1990 than in 2013 because of differences in availability of GDP, which exists only for countries that report their national accounts to the World Bank.

Our analysis of dietary transition begins with the four intake categories that show strong income gradients: red meat, processed meat, milk and fruit intake are all significantly greater in countries with higher national income. As emphasized earlier this is partly due to differences in individual purchasing power and income elasticities of demand, but is also due to other differences associated with per-capita income such as widespread refrigeration and consumption of more convenient packaged foods. Cultural preferences play an important role as well, as illustrated by the differences across major world regions between the patterns for meat (Figures 5 and 6) and the patterns for milk and fruit (Figures 7 and 8).

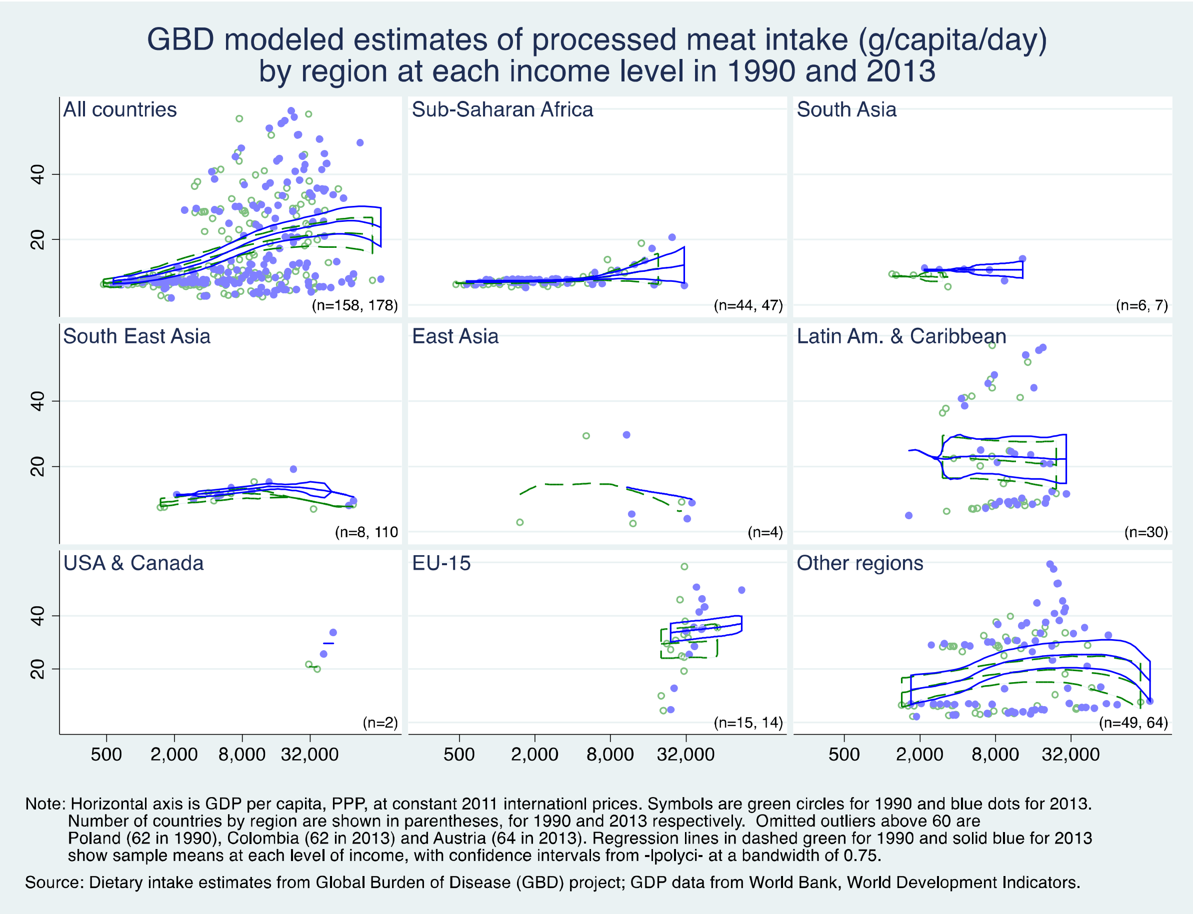
For red meat in Figure 5, there is a clear income gradient across the world as a whole, but that arises only because of differences between continents and within Africa and Latin America. There is no income gradient at all within the three regions of Asia where red meat plays a limited role, or within Europe and the US or Canada where it is widely consumed. Several regions and the world as a whole have a small downward shift in intake at the higher income levels, suggesting a move away from red meat towards other kinds of food. The outliers at very high consumption levels are Paraguay and Mongolia, omitted from this chart due to their estimated consumption levels above 150 g/day per capita as detailed in the note below the figure.

Figure 5. Red meat intake has a strong income gradient, but only outside of Asia



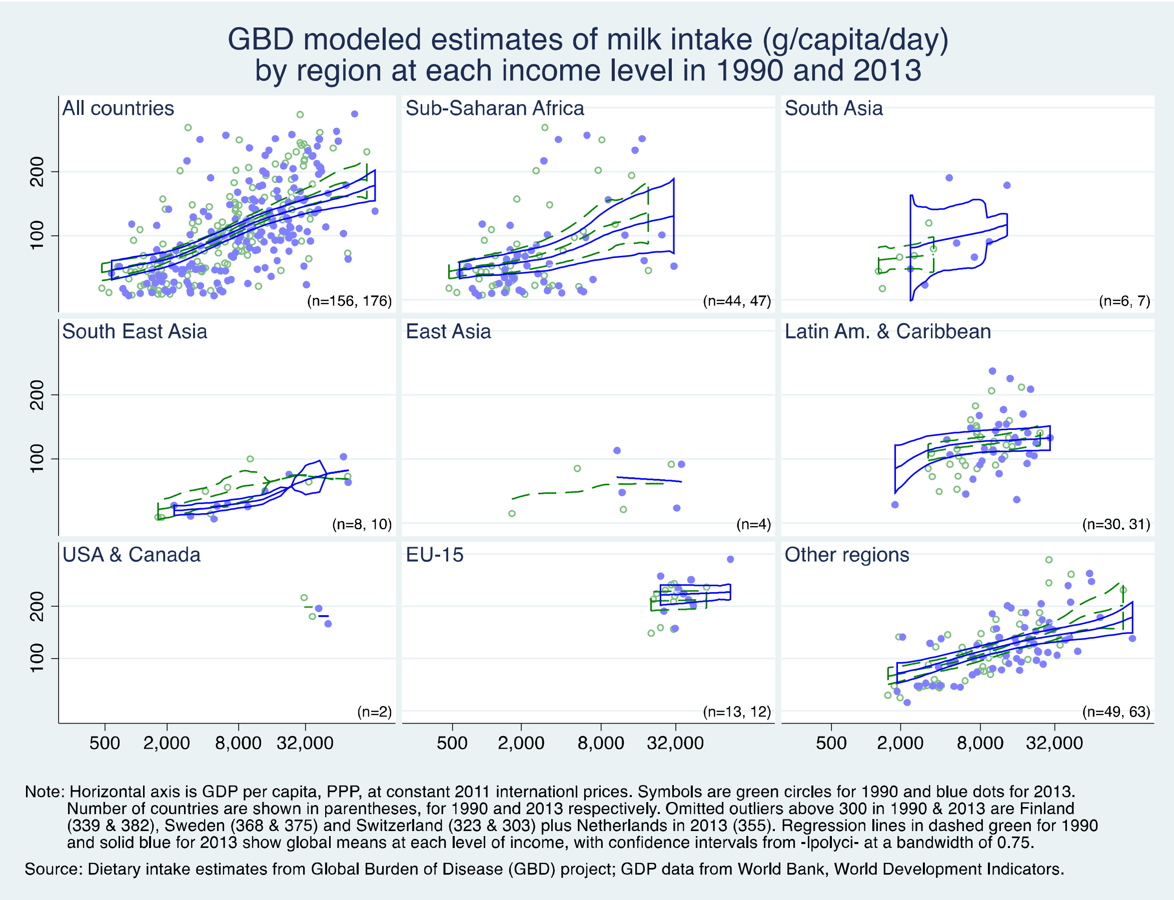
For processed meat in Figure 6, there are no significant shifts between 1990 and 2013, and again the income gradient arises mainly because of differences between regions rather than within them. Some regions such as Europe have exceptionally wide variation in intake at similar levels of income, including extreme outliers not shown on the chart such as Poland and Austria with intake levels above 60 g/day. In other cases there is a very strong correlation between estimated intake and national income that is almost certainly an artifact created by the imputation process as missing data was filled in. This is most noticeable examples of these artifacts are in Africa and Latin America, where strings of countries at increasing levels of GDP were judged to have increasing levels of processed meat intake.

Figure 6. Processed meat intake varies widely within each region and income level



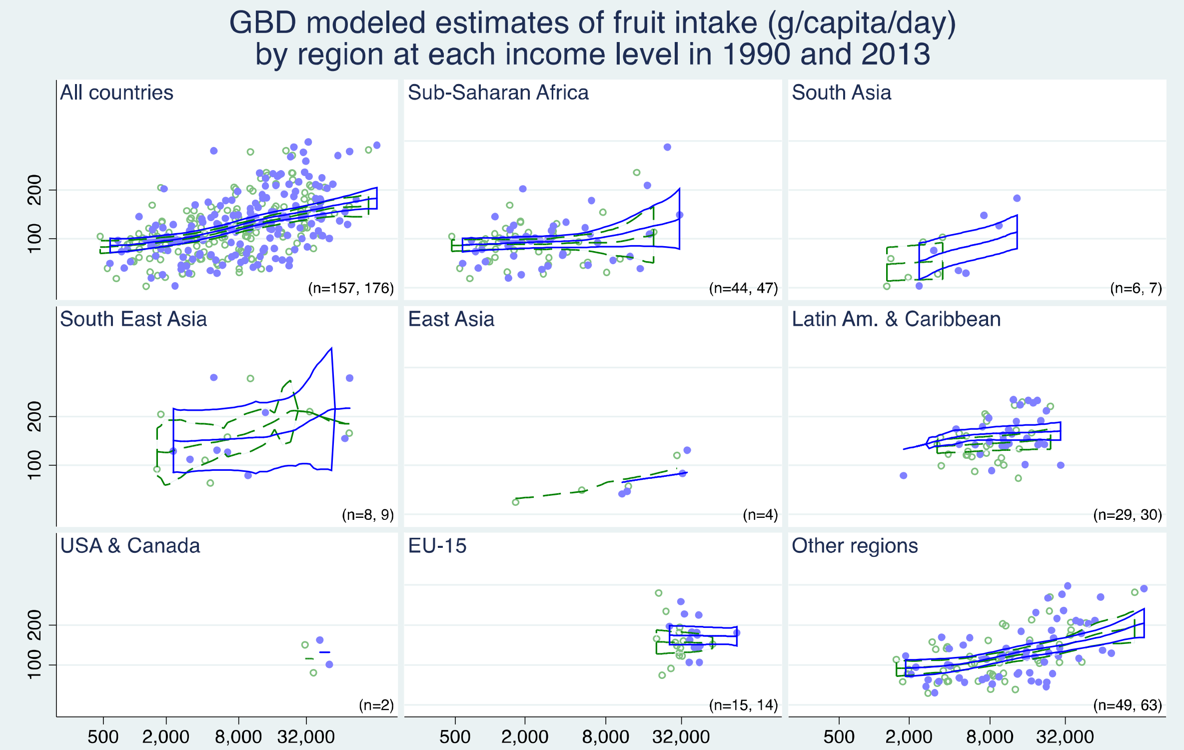
Unlike the meat examples above, milk intake in Figure 7 shows clear income gradients within regions as well as between them. There is a significant downward shift at income levels around $8,000 per capita, particularly in South East Asia, and steps down in both the United States and Canada while intake levels have remained high in Europe. Outliers with more than 300 g/day of milk intake who are omitted from these charts are Finland, Sweden, Switzerland and the Netherlands.

Figure 7. Milk intake has a strong income gradient that has shifted down over time



Fruit intake shown in Figure 8 has a flatter global income gradient than meat or milk, and no significant shifts up or down. Here, the omitted outliers above 300 g/day of fruit intake are Greece, Jamaica, Jordan and Malaysia. Comparing these data for fruit with the previous figures for meat and milk reveals much higher variation in South East Asia, and relatively little variation within East Asia and Latin America.

Figure 8. Fruit intake has a strong income gradient that has shifted little over time

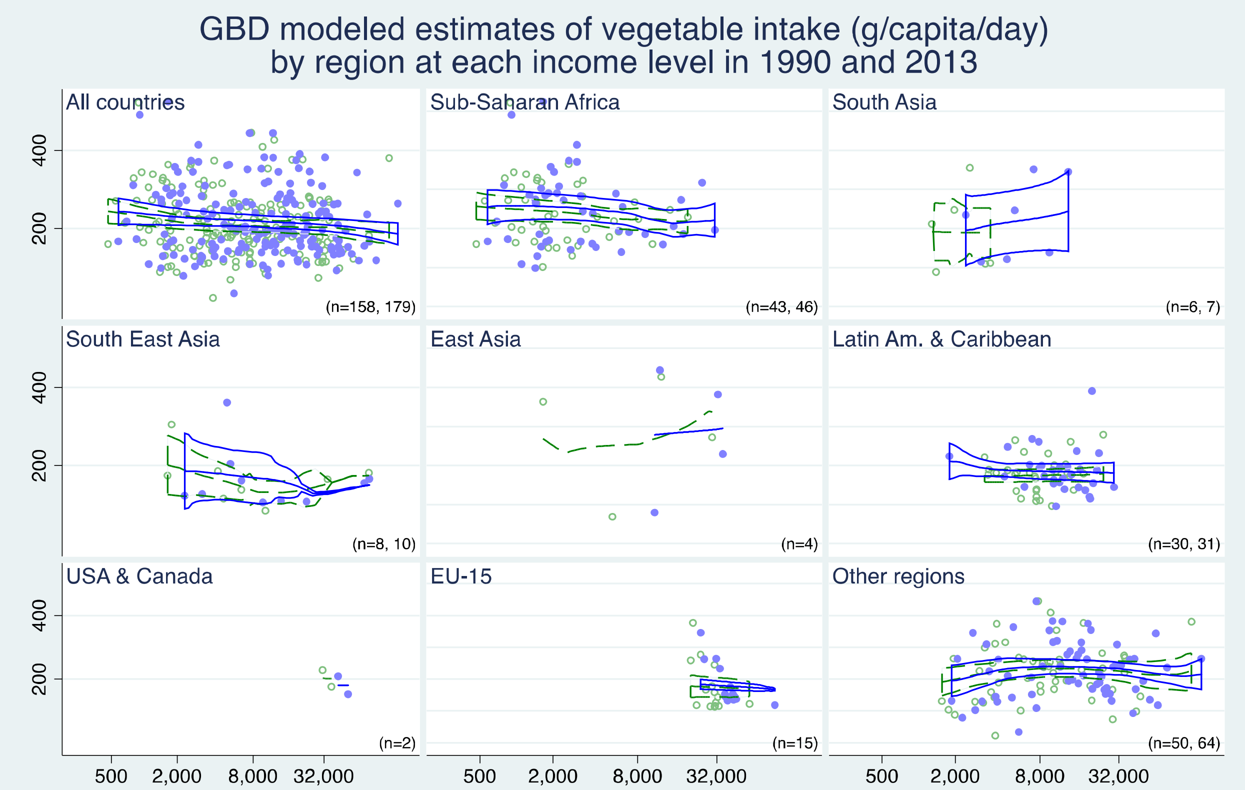


Note: Horizontal axis is GDP per capita, PPP, at constant 2011 internationl prices. Symbols are green circles for 1990 and blue dots for 2013. Number of countries are shown in parentheses, for 1990 and 2013 respectively. Omitted outliers above 300 in 1990 or 2013 are Jamaica (322 & 331) and Jordan (318 & 339), plus in 2013 also Greece (315) and Malaysia (339). Regression lines in dashed green for 1990 and solid blue for 2013 show global means at each level of income, with confidence intervals from -lpolyci- at a bandwidth of 0.75.

Source: Dietary intake estimates from Global Burden of Disease (GBD) project; GDP data from World Bank, World Development Indicators.

Having seen four types of food whose intake rises with national income, we now turn to three types of food with little income gradient. Figure 9 shows intake of vegetables, for which intake levels average around 200 g/day in all regions at all income levels. The one outlier with levels above 600 g/day is Burundi. Despite the clear association between vegetable consumption and health, there appears to be no systematic pattern associated with regional culture and preferences, and no systematic changes associated with income or time.

Figure 9. Vegetable intake has little income gradient and has shifted little over time

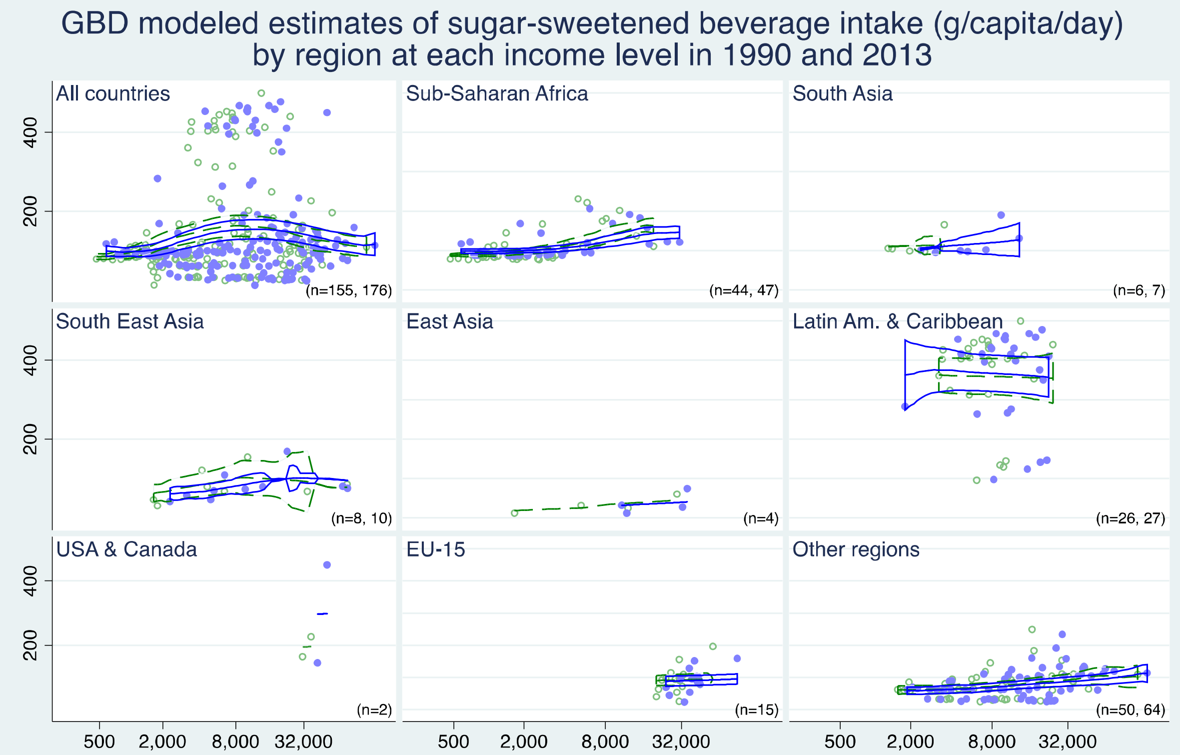


Note: Horizontal axis is GDP per capita, PPP, at constant 2011 internationl prices. Symbols are green circles for 1990 and blue dots for 2013. Number of countries are shown in parentheses, for 1990 and 2013 respectively. Omitted outlier above 600 is Burundi (774 in 1990, and 642 in 2013). Regression lines in dashed green for 1990 and solid blue for 2013 show sample means at each level of income, with confidence intervals from -lpolyci- at a bandwidth of 0.75.

Source: Dietary intake estimates from Global Burden of Disease (GBD) project; GDP data from World Bank, World Development Indicators.

Sugar-sweetened beverages are widely believed to be closely associated with industrialization and urbanization, but Figure 10 suggests that the highest levels of per-capita consumption are concentrated in Latin American countries at middle income levels. There is no income gradient for those countries, so as their incomes rose the global Preston Curve actually shifted down at the lower-middle income levels where Latin American countries had been in 1990 whereas by 2013 the countries at those income levels were predominantly Asian and African with lower sugar-sweetened beverage consumption. The high levels observed in Latin America would be even higher if the figures included the omitted outliers with consumption above 500 g/day, which are Barbados, Costa Rica, Cuba, Mexico and Trinidad & Tobago.

Figure 10. Sugar-sweetened beverage varies widely, especially in middle-income countries

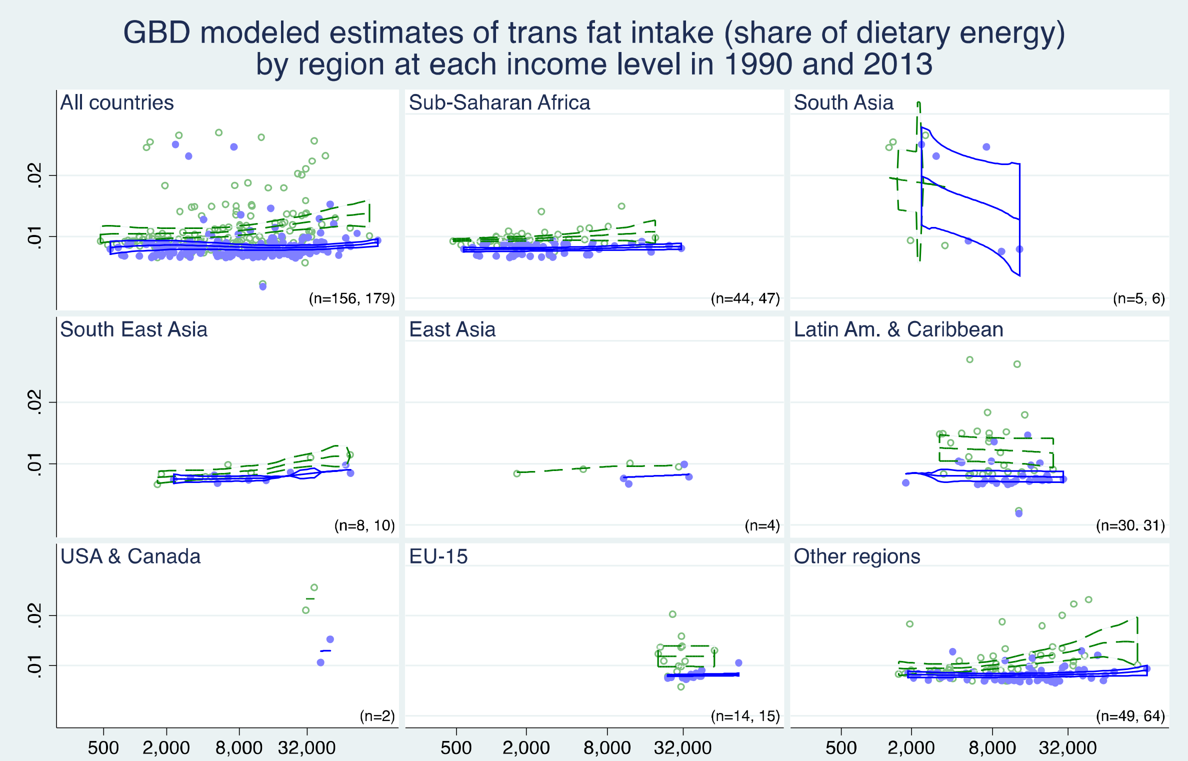


Note: Horizontal axis is GDP per capita, PPP, at constant 2011 internationl prices. Symbols are green circles for 1990 and blue dots for 2013. Number of countries are shown in parentheses, for 1990 and 2013 respectively. Omitted outliers above 500 in 1990 or 2013 are Barbados (515 & 542), Costa Rica (552 & 540), Mexico (518 & 561), Cuba (554 in 1990) and Trinidad & Tobago (552 in 2013). Regression lines in dashed green for 1990 and solid blue for 2013 show means at each income, with confidence intervals from -lpolyci- at a bandwidth of 0.75.

Source: Dietary intake estimates from Global Burden of Disease (GBD) project; GDP data from World Bank, World Development Indicators.

We conclude this section on dietary transition with trans fats, one of the most harmful components of many food systems. This is measured in GBD data as a fraction of dietary energy intake. In the 1990 data, trans fat consumption in this sense had a small upward gradient at higher income levels in the world as a whole, primarily due to that gradient within South East Asia and in other regions. The 2013 data show significant decreases at each income level, in all major regions except South Asia where a wide range of intake levels make trends difficult to discern. This result provides clear evidence that food policy reforms combined with private-sector innovation to change food formulation can achieve large-scale shifts in diet composition, particularly when an ingredient can be replaced with healthier alternatives at low financial cost.

Figure 11. Trans fat intake has shifted down at each income level, in all regions except South Asia



Note: Horizontal axis is GDP per capita, PPP, at constant 2011 internationl prices. Symbols are green circles for 1990 and blue dots for 2013. Number of countries are shown in parentheses, for 1990 and 2013 respectively. Omitted outliers above 3% are Pakistan (3.6% in 1990 and 2013), Egypt (3.5% in 1990) and Netherlands (3% in 1990). Regression lines in dashed green for 1990 and solid blue for 2013 show sample means at each level of income, with confidence intervals from -lpolyci- at a bandwidth of 0.75.

Source: Dietary intake estimates from Global Burden of Disease (GBD) project; GDP data from World Bank, World Development Indicators.

Conclusions

The assessment of dietary change presented here uses the approach introduced by Preston (1975) to distinguish predictable trends associated with national income from structural shifts caused by the introduction of new public policies and private-sector innovations. We begin with changes in total food availability and anthropometry, so as to establish the context for changes in diet composition between 1990 and 2013 as measured by the Global Burden of Disease Study (2015). This approach combines dietary recall surveys with aggregate statistics to use the strengths of each type of data while offsetting their limitations.

Our central result is that, while overall nutritional status for the world's poorest people has improved sharply, several important aspects of dietary patterns in middle- and upper-income countries have worsened significantly. Increased intake of those relatively unhealthy foods in 2013 is primarily a continuation of the same systematic patterns observed in 1990. The principal structural change we observe is a sharp reduction in trans fat intake at each level of income, in all regions except South Asia. That improvement was driven by changes in both public policy and private-sector food production, revealing the potential and the need for further action on that and other risk factors for malnutrition and diet-related disease.

Acknowledgements:

This paper draws on the author's work with numerous collaborators, including research assistance from Natalie Theys and Elena Martinez. Special thanks are due for Dariush Mozaffarian and Peilin Shi for guidance on use of the Global Burden of Disease dietary data; Patrick Webb for collaboration through the Global Panel on Agriculture and Food Systems for Nutrition as well as the Nutrition Innovation Lab; and Carl Pray, Anwar Naseem and colleagues for collaboration through the Feed the Future Policy Impact Study Consortium led by Rutgers University.

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ANNEX 1.

Table 3. GBD estimates of global death and disability attributable to selected dietary risk factors

	Deaths ('000s)		DALYs ('000s)	
	1990	**2013**	**1990**	**2013**
Healthy items: Diets too low in…				
Fruits	2,540	3,413	58,710	74,797
Vegetables	1,381	1,782	31,283	39,176
Seafood omega-3 fatty acids	712	1,031	16,285	22,448
Milk	66	105	1,515	2,218
Unhealthy items: Diets high in…				
Processed meat	457	644	11,745	17,380
Trans fatty acids	464	405	10,644	9,875
Sugar-sweetened beverages	60	126	2,712	6,190
Red meat	62	102	2,201	4,147

Notes: Risk factors listed here are those for which cross-country patterns are shown in Figures 5-11. Additional dietary risk factors used in the GBD but omitted from this report on dietary transition are consumption of whole grains, nuts and seeds, fibre, calcium, PUFAs and sodium. GBD estimates of total attributable deaths and disability-adjusted life years (DALYs) include confidence intervals not shown here.

Source: Excerpted from Forouzanfar, M.H., et al. (2015) "Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013." *The Lancet*, September 2015 (http://dx.doi.org/10.1016/S0140-6736(15)00128-2).

ANNEX 2.

Figure 1 details: Regional Food Balance Sheet data by food group and macronutrient, 1961-2011

Introductory note

This annex disaggregates the information provided in Figure 1 into components, by food group and macronutrient (protein and fats) to provide additional detail on this source of information about recent trends in diet composition.

Food Balance Sheets estimate each country's average per-capita consumption by subtraction, using the country governments' official statistics to estimate production of each food, plus imports minus exports and nonfood uses of that item, including stock changes, as well as an estimate of quantities lost to waste between harvest and final sale or on-farm consumption. This produces an estimate of how much of each food is consumed per person in each country in each calendar year. Regional food composition tables are then used to estimate total intake of protein and fats, which are presented here in total from all sources and from animal sources. As of March 2016 the last available year for all of the world's countries is 2011; for a selected set of high-malnutrition countries data are available through 2013 but those are not used here.

When interpreting FBS data, it is important to recognize that -- in principle, if there were no measurement errors -- the only difference between the FBS estimate of a country's food consumption and the mean of a nationally representative survey of individual intake would be kitchen and plate waste. In practice, there are many measurement errors in both FBS and survey data. As shown by Del Gobbo et al. 2015, these measurement errors have some systematic patterns. Most notably, countries report higher levels of total energy consumption in FBS data than individuals report in dietary surveys. It is not clear which food categories are most likely to be under- or over-reported in each source, but like Figure 1 the charts reported here focus on intake as a percent of total energy.

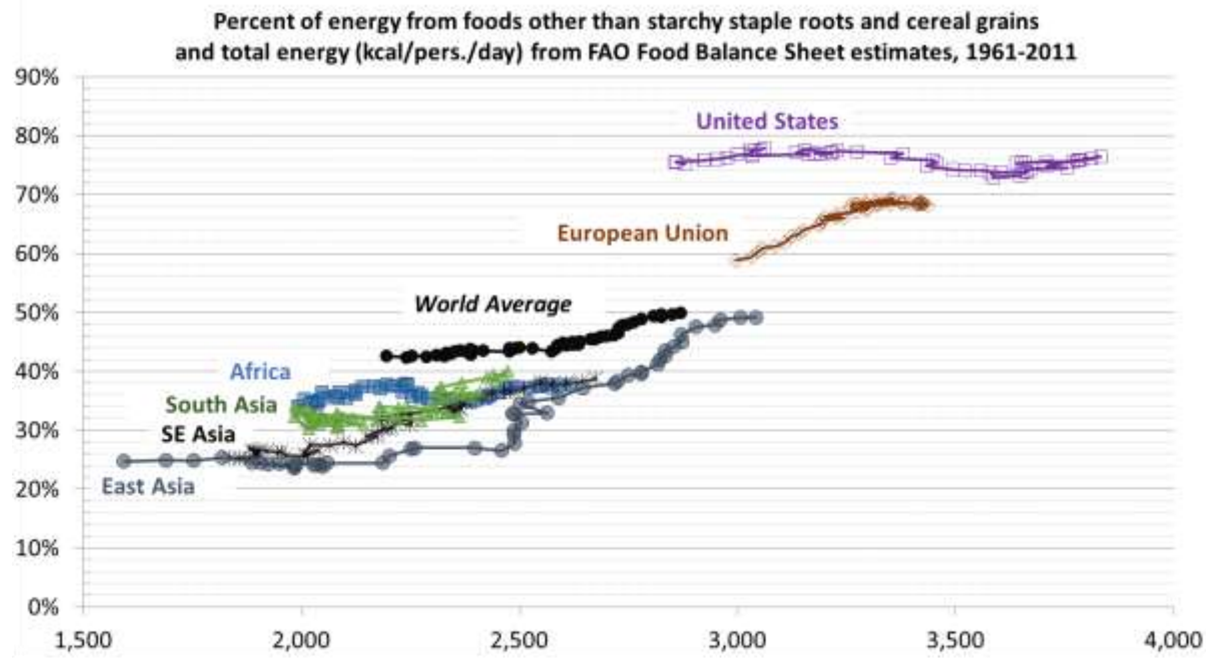
The FBS data shown here, like the results of dietary intake surveys, are subject to considerable measurement error so readers should focus only on the largest, most noticeable differences between regions. Cross-checking for plausibility is necessary, since any estimate of a confidence interval or standard error would itself depend on the estimation method. The figures provided here are accompanied by brief introductory comments regarding the context and interpretation of the major trends over time and regional differences. All data are shown first for the full 50-year period from 1961-2011, and then for the more recent period 1985-2011.

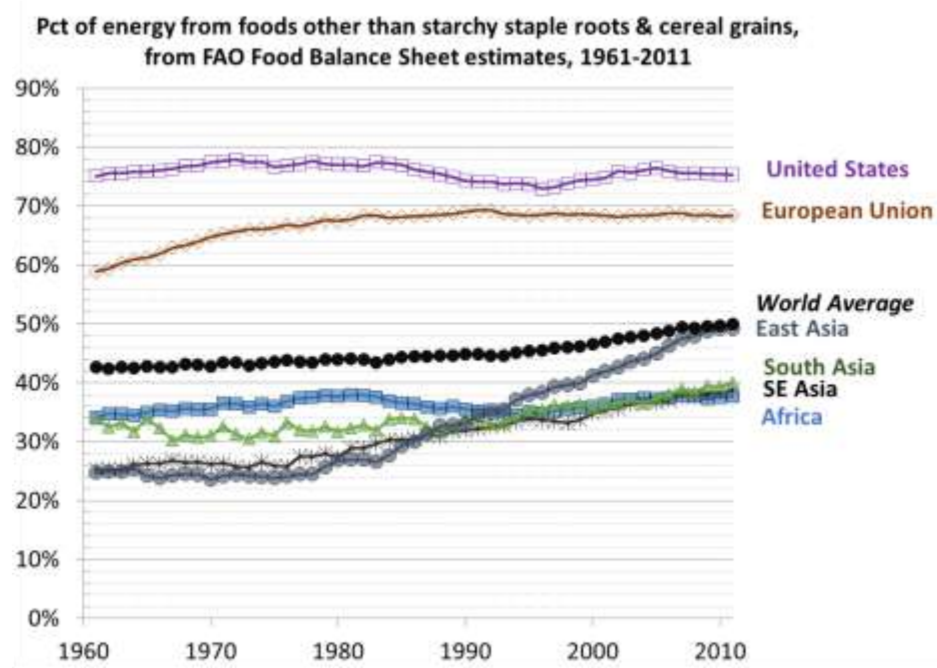
In this annex we start with intake for six broad food groups of nutritional importance: first the starchy staples, focusing on sum of all foods that are *not* starchy roots or cereal grains, then vegetable oils, meat, milk and eggs and the sum of all animal-sourced foods, fruits and vegetables, and sugar and sweeteners. Then we use the FAO's food composition data to report consumption over all foods of total protein, total fats, and then animal-sourced protein and fats.

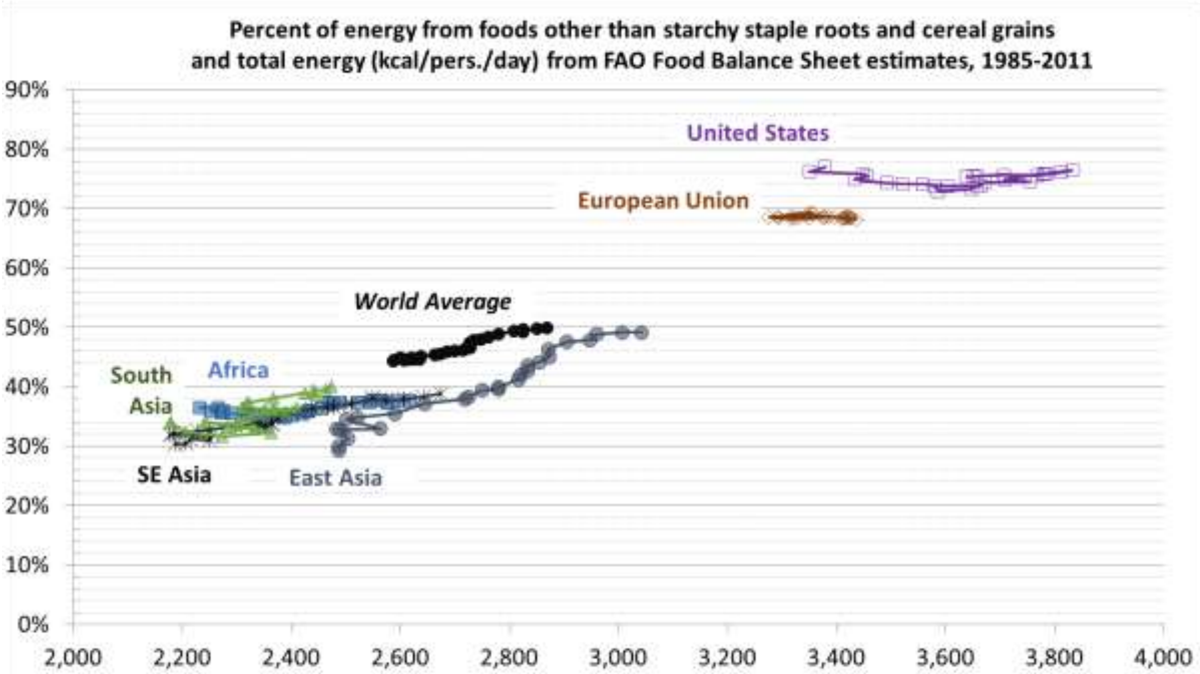
Source for all charts: Author's calculations from FAO Food Balance Sheets, March 2016

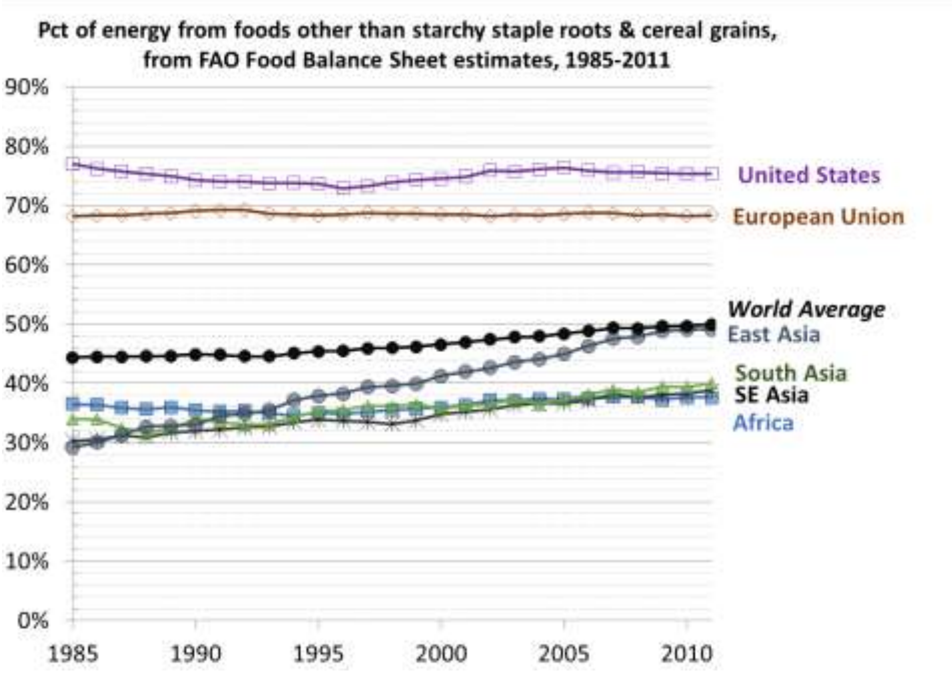
1. Non-staples: the simplest measure of diet quality

We begin by replicating Figure 1, which shows the global transition from starchy staples to more nutrient-dense foods. The only regions to experience a sustained return to starchy staples was Africa during its period of economic decline and impoverishment in the 1980s and early 1990s, and the US at that same time during its period of anti-fat messaging.



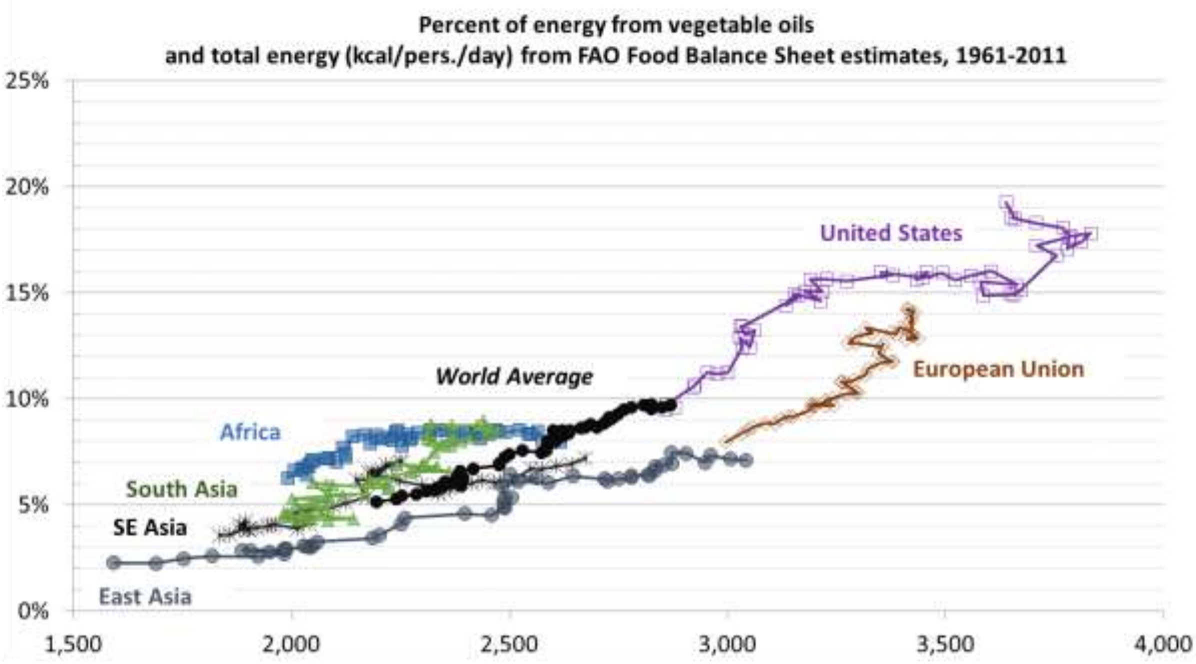


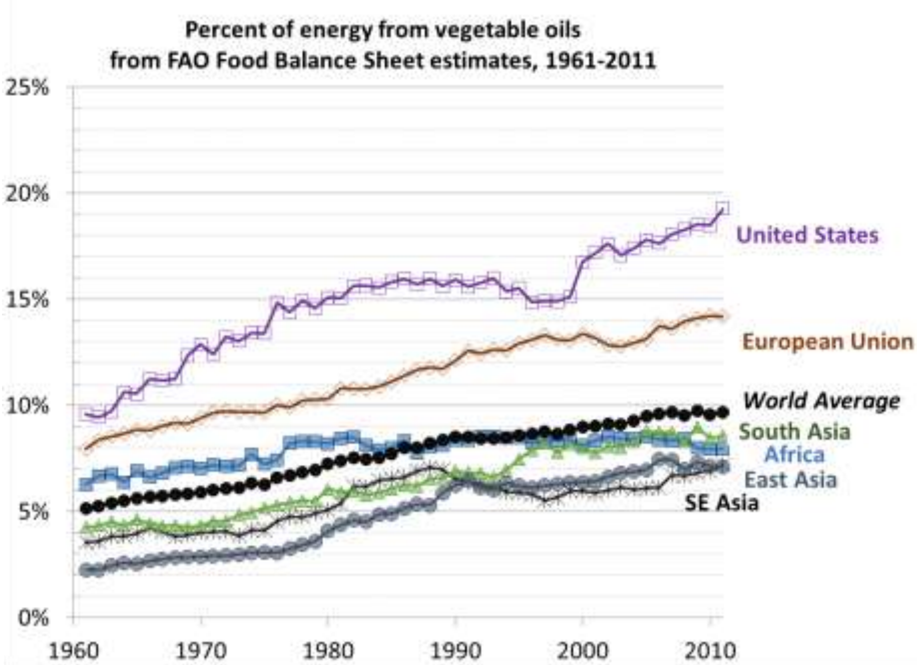

Percent of energy from foods other than starchy staple roots and cereal grains
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
United States
European Union
World Average
South Asia
Africa
SE Asia
East Asia


Pct of energy from foods other than starchy staple roots & cereal grains,
from FAO Food Balance Sheet estimates, 1985-2011
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1985
1990
1995
2000
2005
2010
United States
European Union
World Average
East Asia
South Asia
SE Asia
Africa

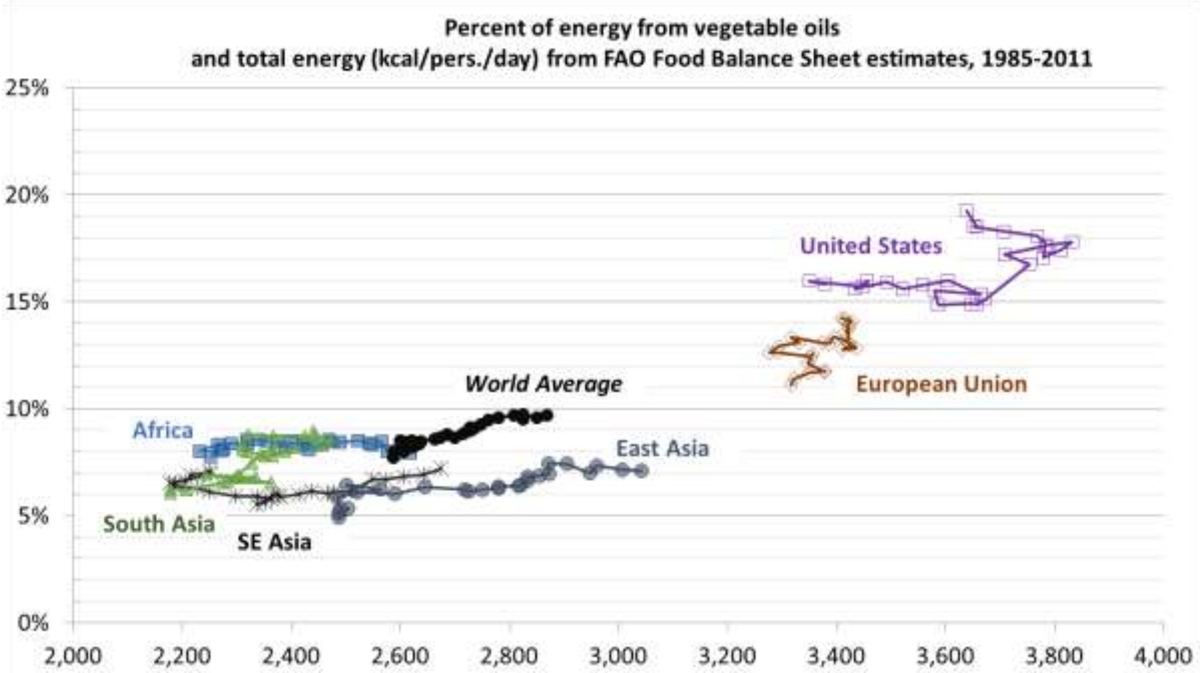
2. Vegetable oils: the soybean-industrial complex (also canola, palm etc.)

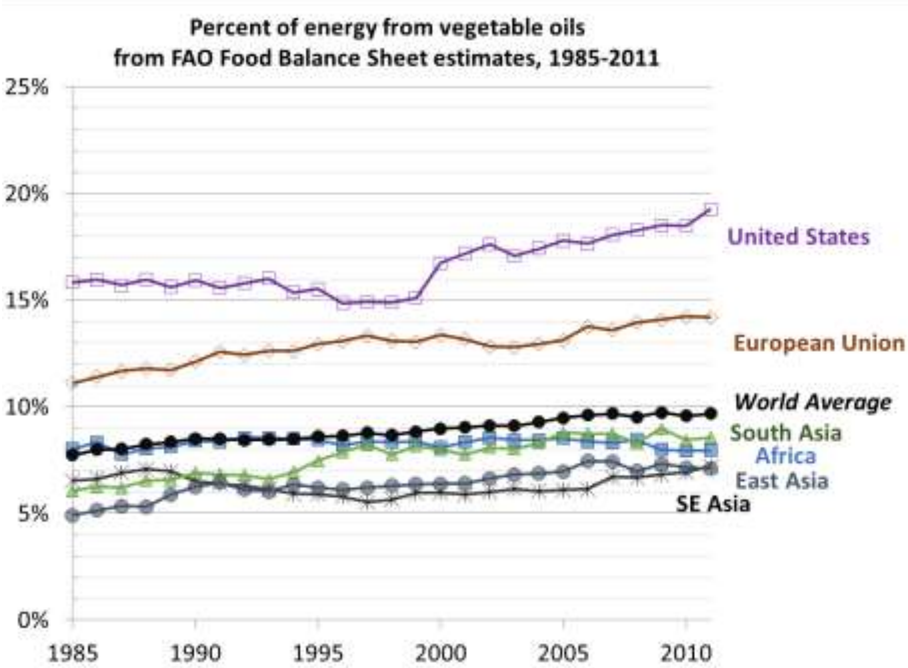
Consumption of vegetable oils rose very sharply in all regions during the 1970s and 1980s, then stopped increasing in Africa during its period of impoverishment, and declined in the US during its period of anti-fat messaging. Southeast Asia also saw a decline in vegetable oil's share of dietary energy from the late 1980s to the late 1990s, but that was in the context of a rapid rise in animal-sourced fat consumption. Vegetable oils are processed primarily from soybeans and other oilseeds but also oil palm, maize and many minor sources.





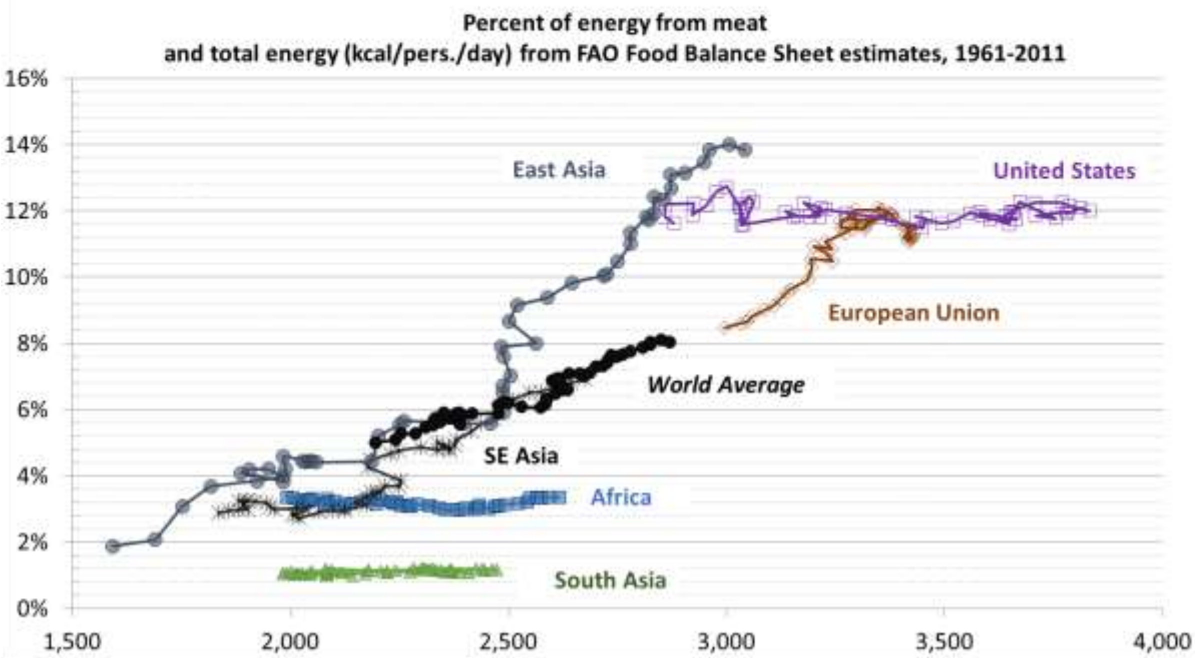
A notable feature of these charts is the different timing of changes in trends between the EU and US. Change in the EU could be due to shift in composition of countries included due to accession of Eastern Europe; change in US could involve a return to longer term trends after the anti-fat period.

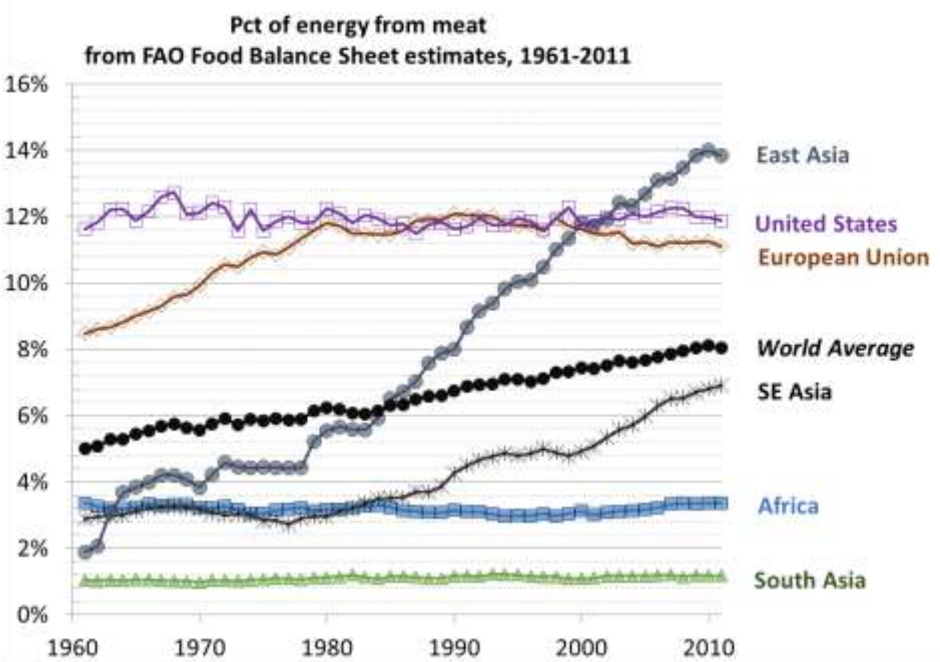


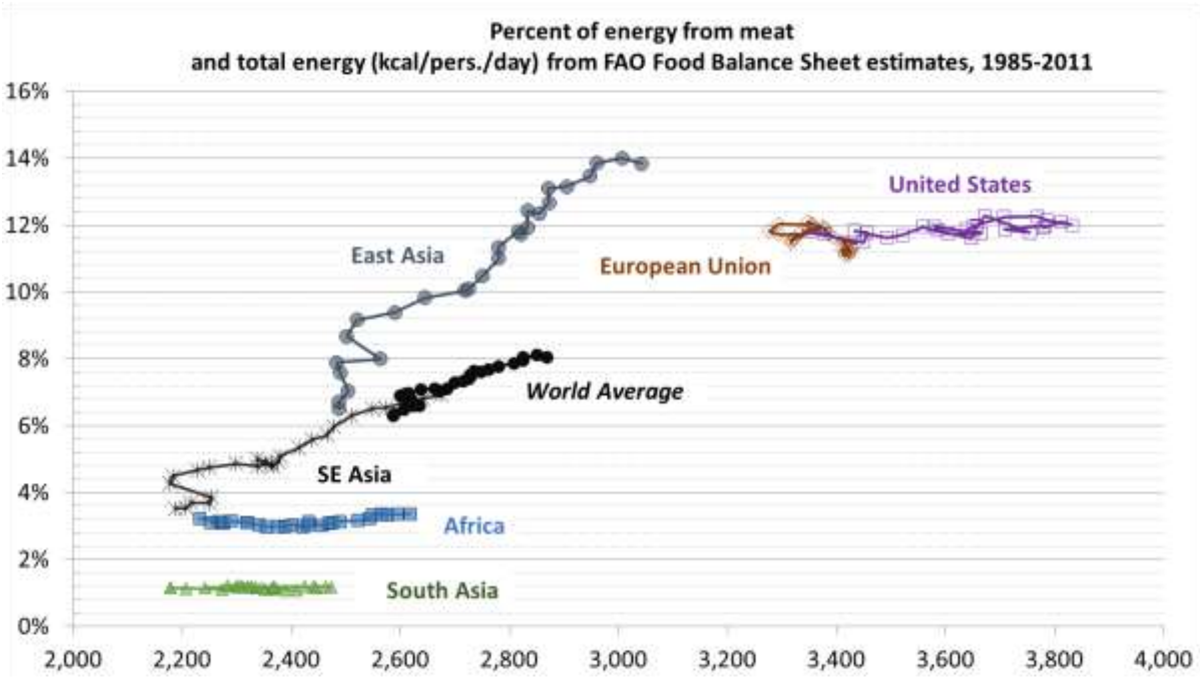


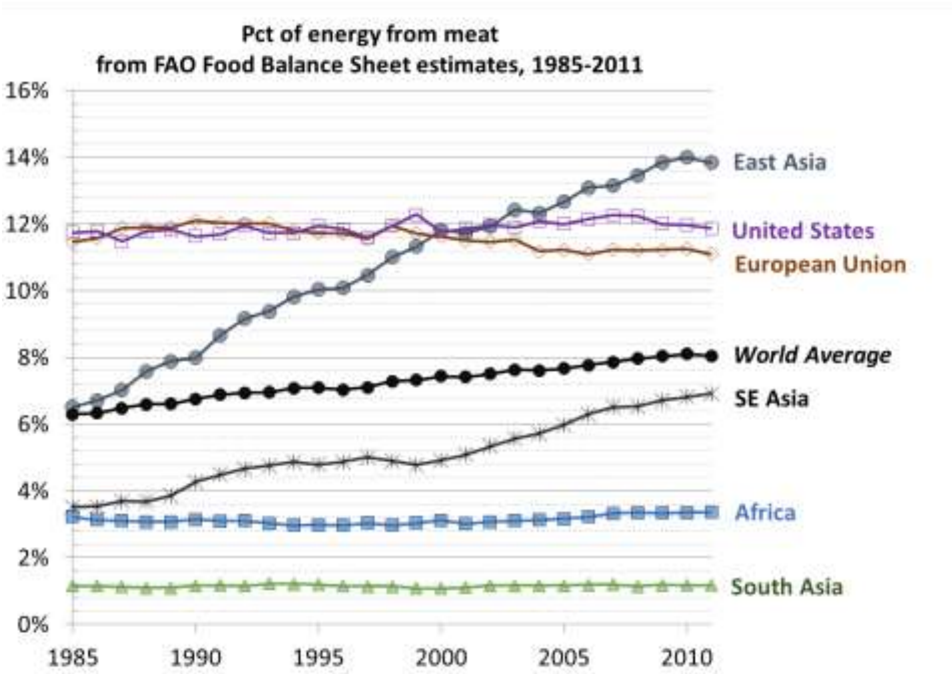
3. Meat: the world's luxury food (except in South Asia)

Rapid changes and big differences in meat consumption among regions reveal the effects of both relative scarcity and relative preferences. Two regions have experienced relatively little increase, Africa and South Asia, while the EU has cut back in recent years.

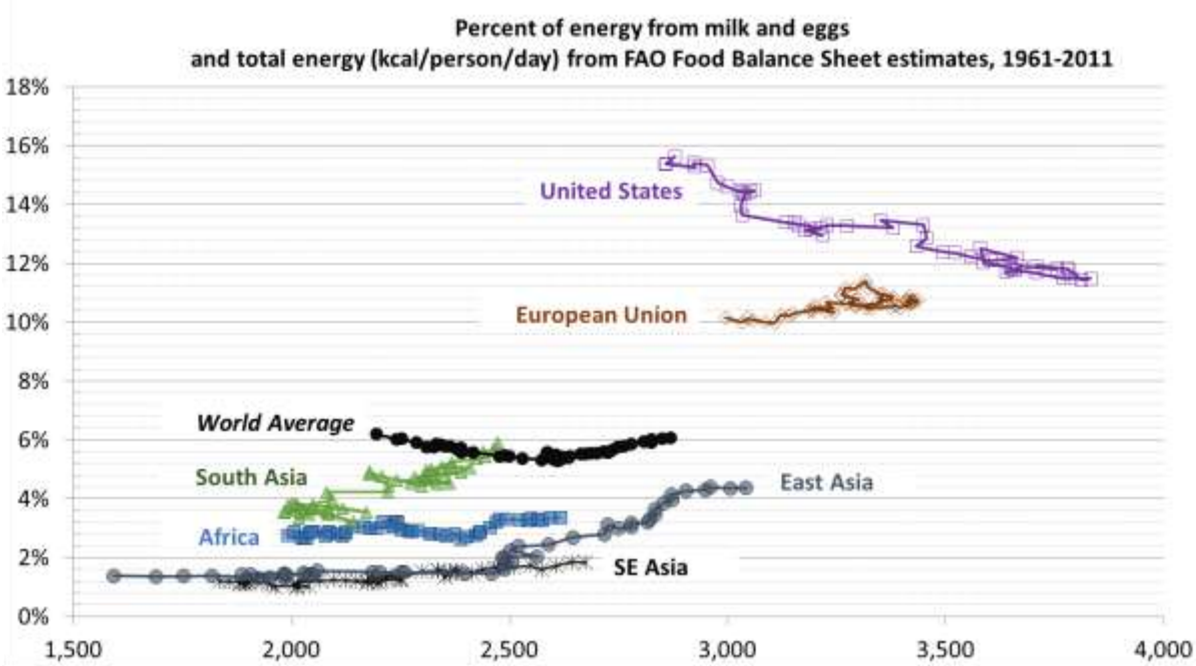


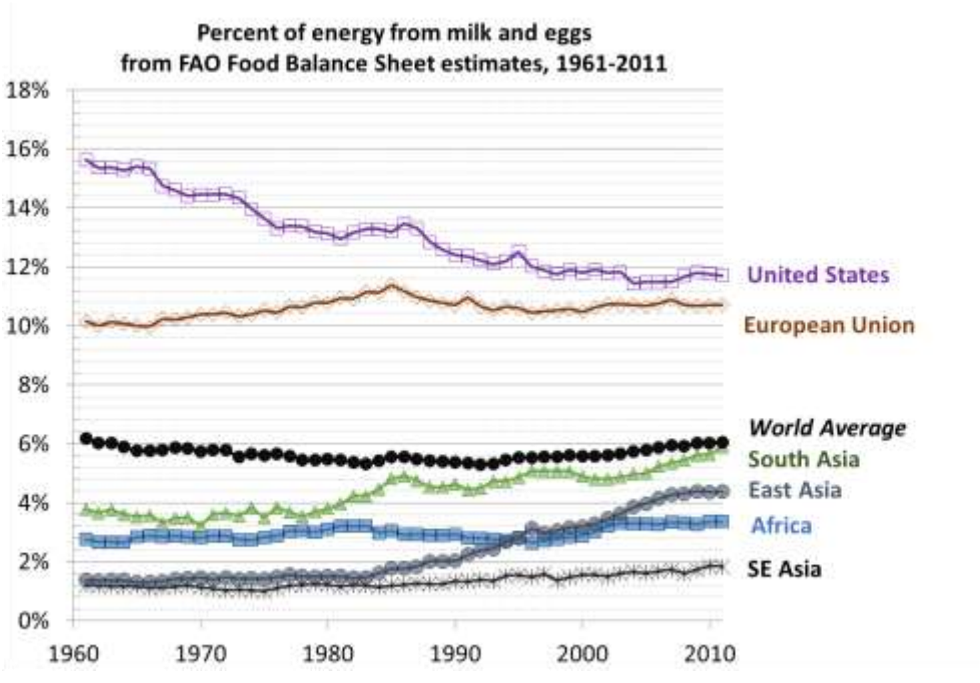


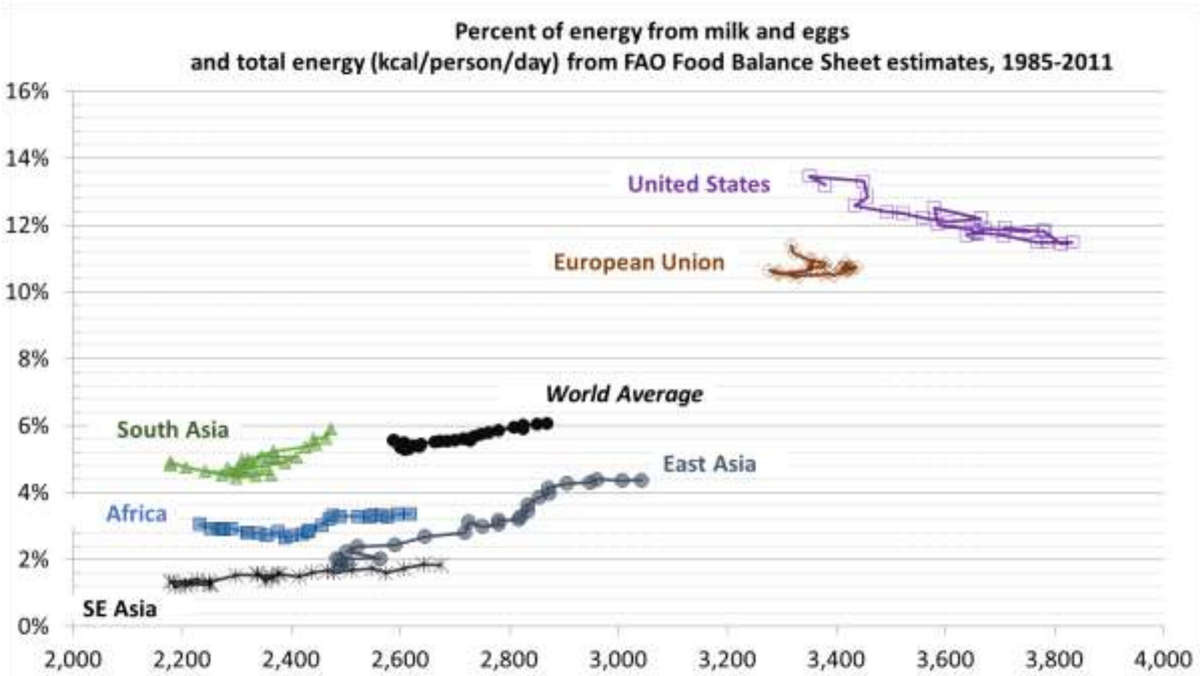

Percent of energy from meat
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
16%
14%
12%
10%
8%
6%
4%
2%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
East Asia
United States
European Union
World Average
SE Asia
Africa
South Asia

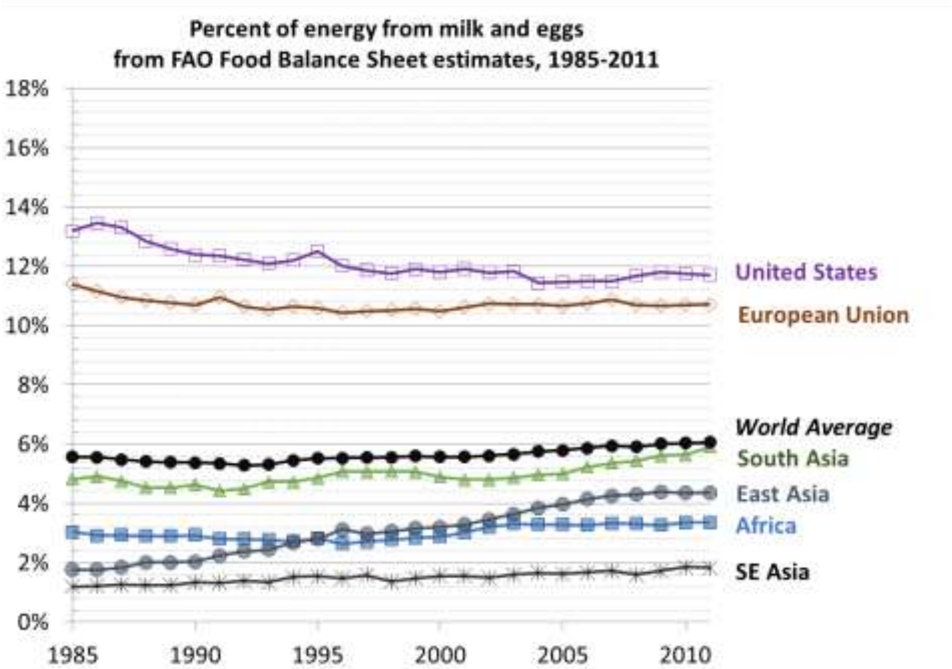

Pct of energy from meat
from FAO Food Balance Sheet estimates, 1985-2011
16%
14%
12%
10%
8%
6%
4%
2%
0%
1985
1990
1995
2000
2005
2010
East Asia
United States
European Union
World Average
SE Asia
Africa
South Asia

4. Milk and eggs: Consumption growth only in Asia, and in Africa since late 1990s

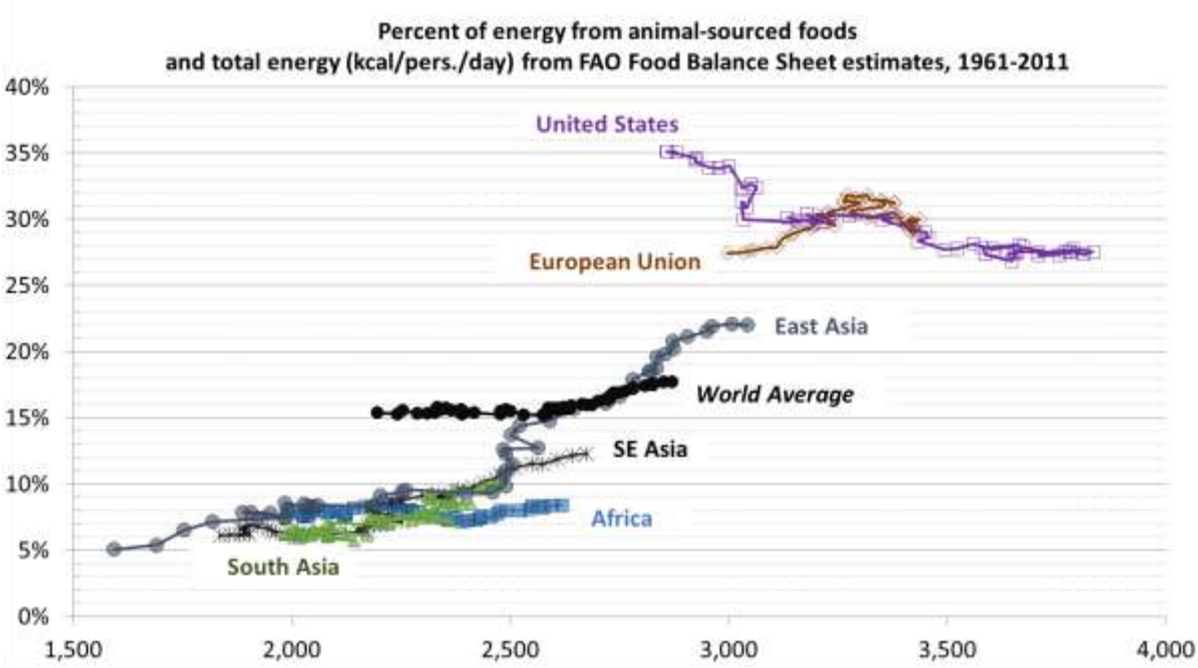


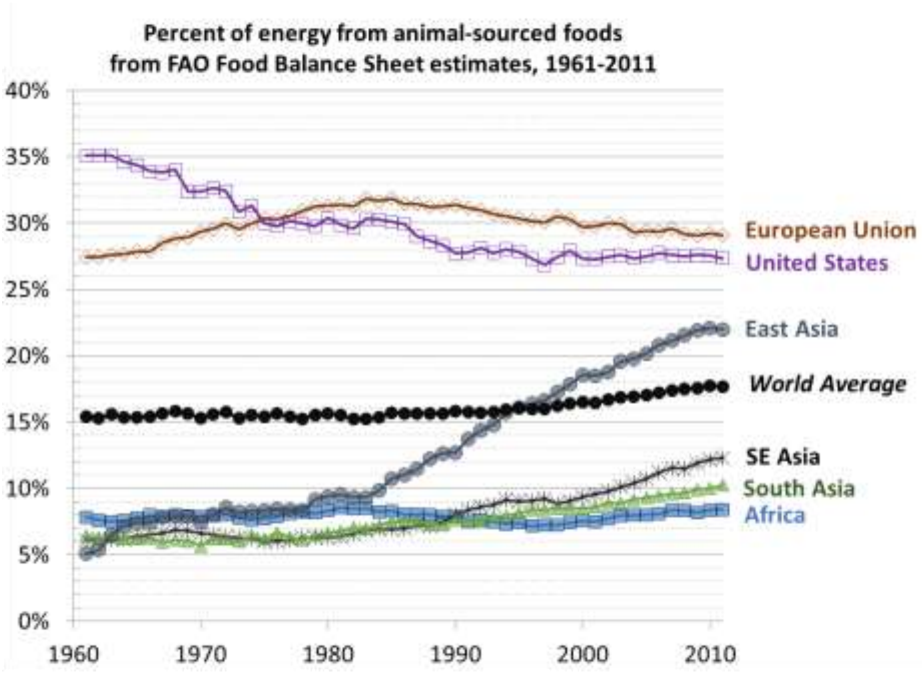


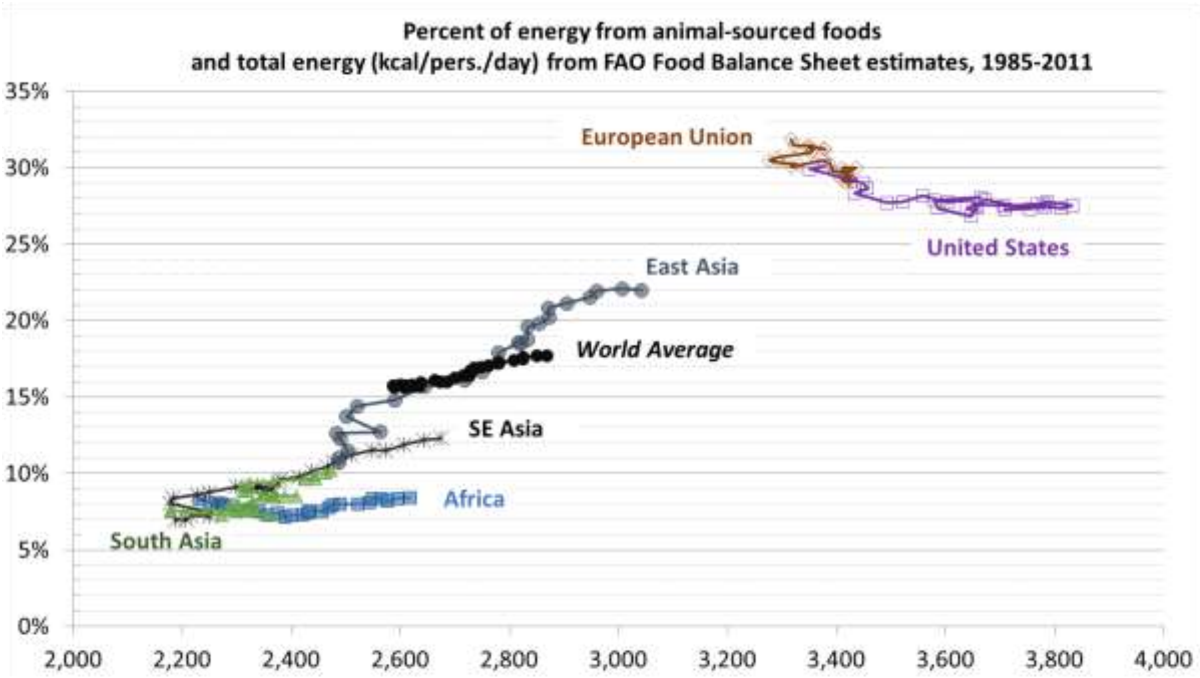

Percent of energy from milk and eggs
and total energy (kcal/person/day) from FAO Food Balance Sheet estimates, 1985-2011
16%
14%
12%
10%
8%
6%
4%
2%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
United States
European Union
World Average
South Asia
East Asia
Africa
SE Asia


Percent of energy from milk and eggs
from FAO Food Balance Sheet estimates, 1985-2011
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
1985
1990
1995
2000
2005
2010
United States
European Union
World Average
South Asia
East Asia
Africa
SE Asia

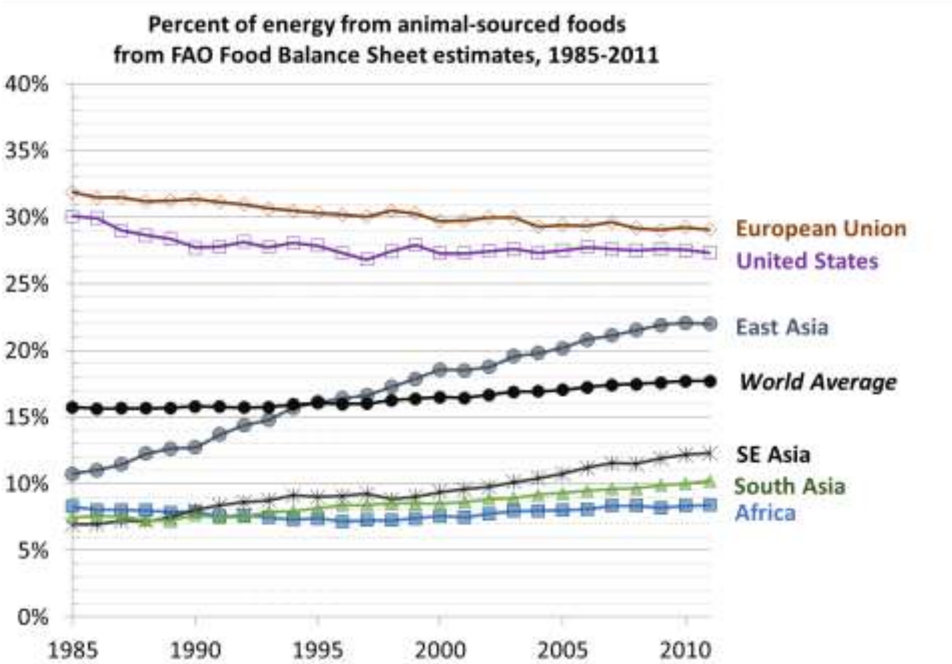
5. All ASFs (sum of milk, meat and eggs plus fish and offals, etc.)





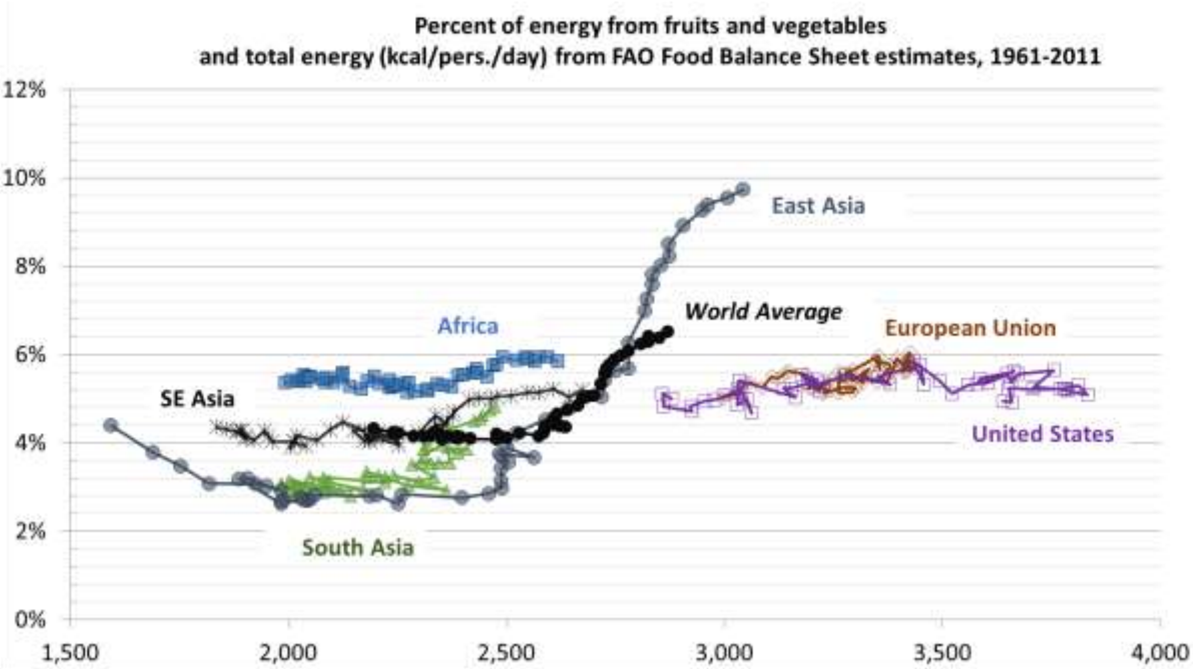


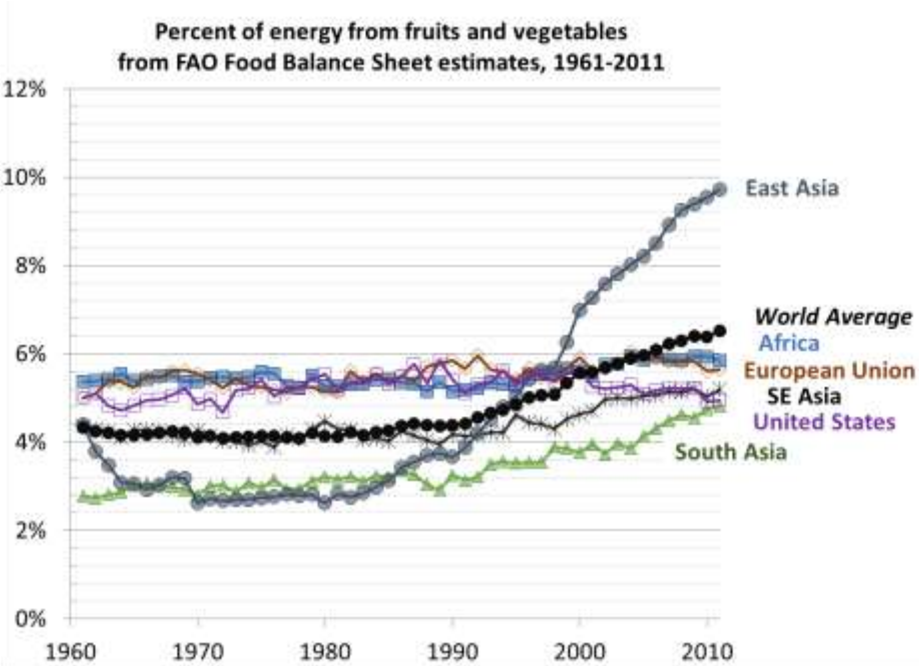
Percent of energy from animal-sourced foods
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
35%
30%
25%
20%
15%
10%
5%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
European Union
United States
East Asia
World Average
SE Asia
Africa
South Asia

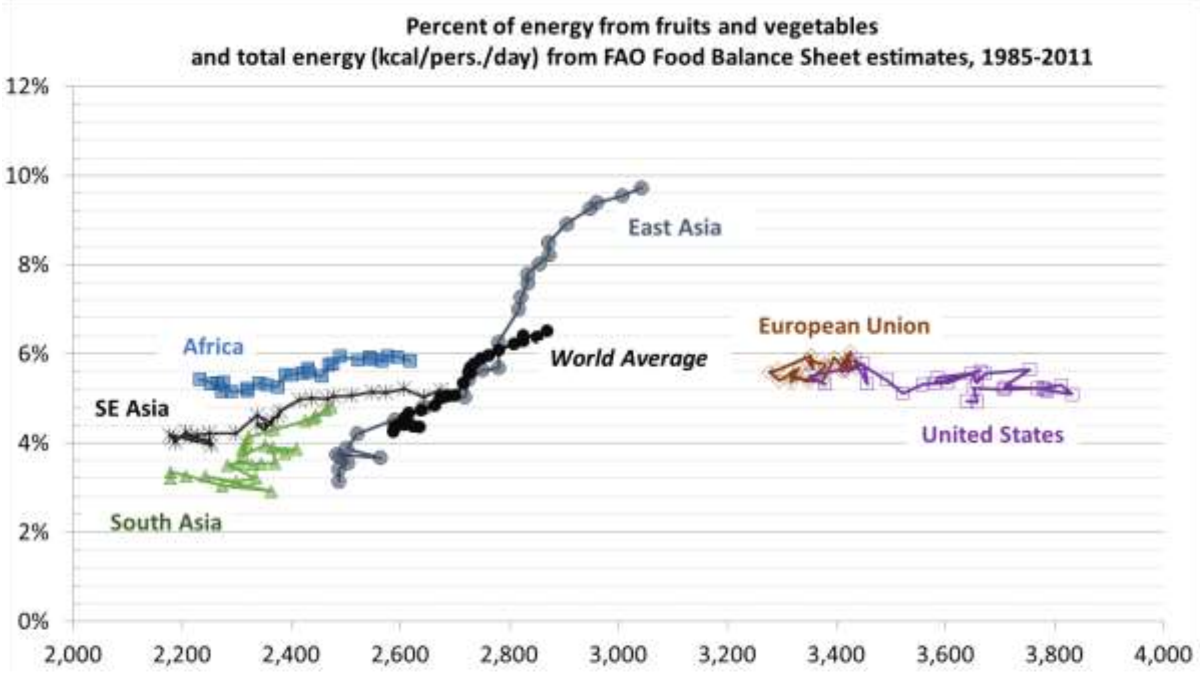


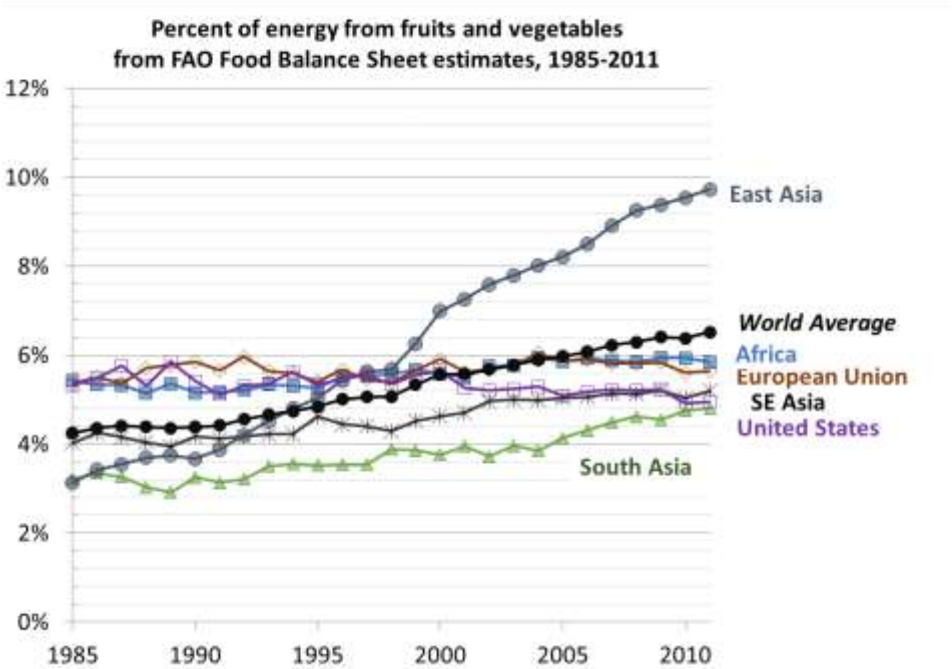
Percent of energy from animal-sourced foods
from FAO Food Balance Sheet estimates, 1985-2011
40%
35%
30%
25%
20%
15%
10%
5%
0%
1985
1990
1995
2000
2005
2010
European Union
United States
East Asia
World Average
SE Asia
South Asia
Africa

6. **Fruits and vegetables: Like milk and eggs, sharp rise in Asia but not elsewhere**

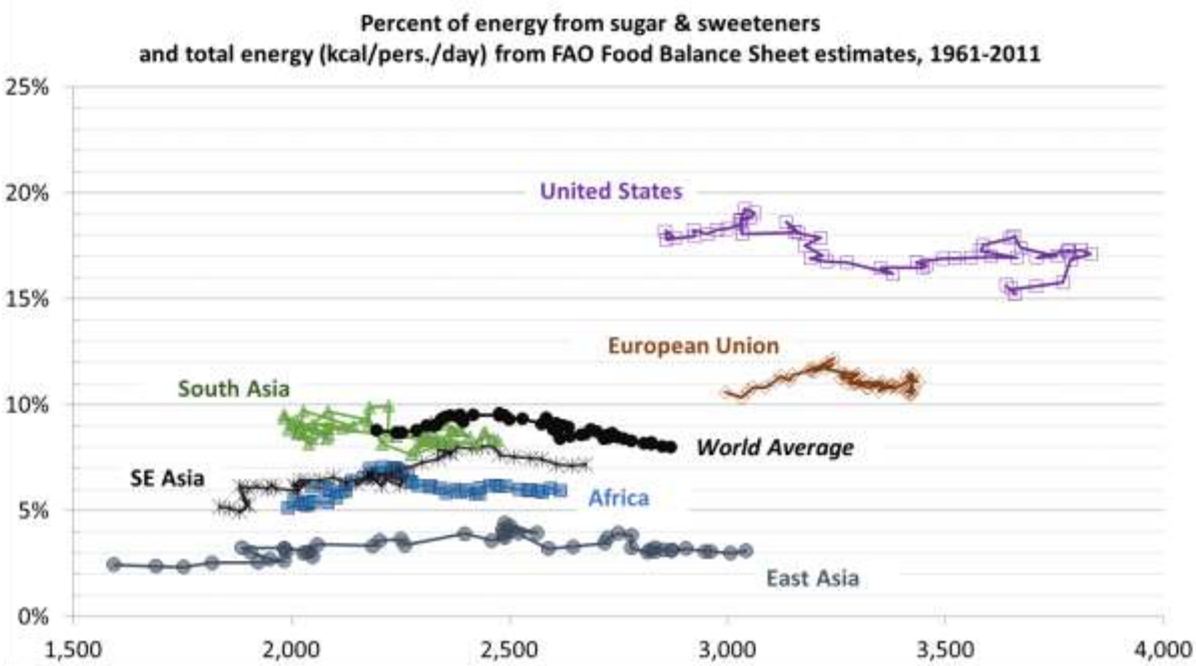


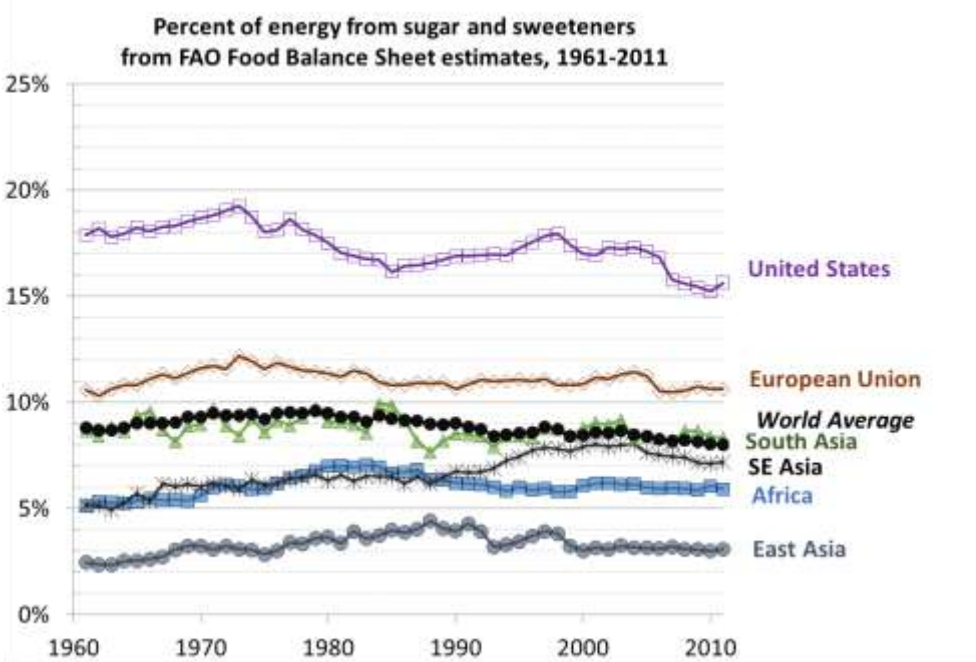


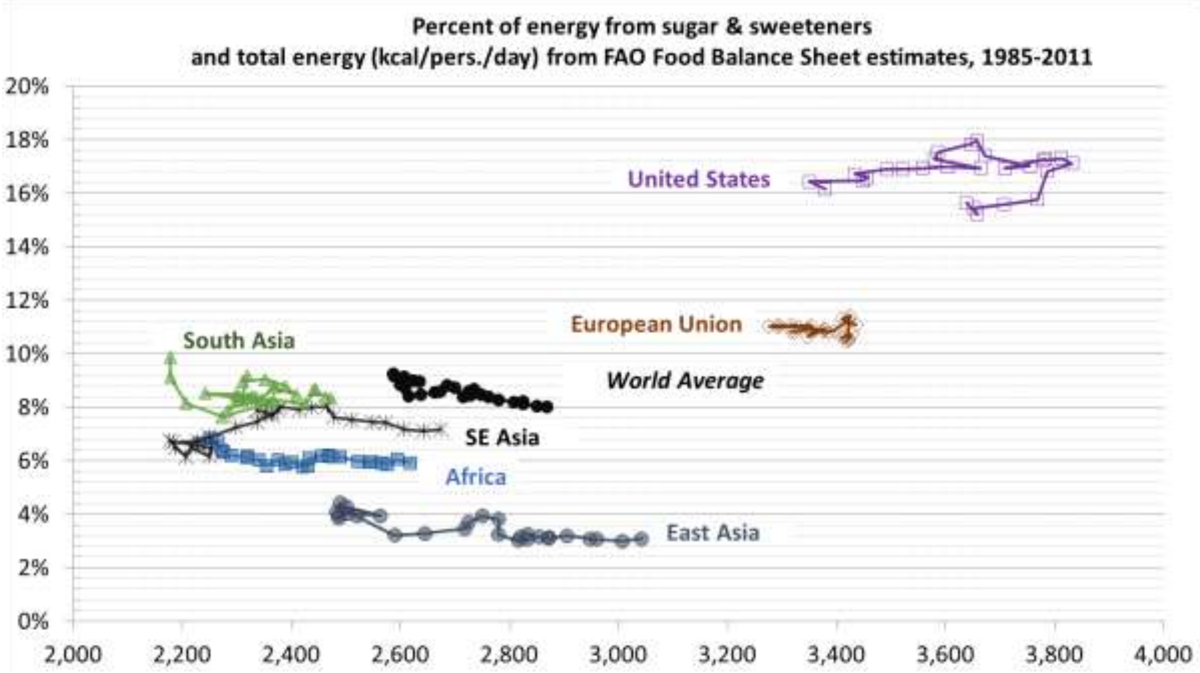

Percent of energy from fruits and vegetables
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
12%
10%
8%
6%
4%
2%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
East Asia
Africa
SE Asia
South Asia
World Average
European Union
United States


Percent of energy from fruits and vegetables
from FAO Food Balance Sheet estimates, 1985-2011
12%
10%
8%
6%
4%
2%
0%
1985
1990
1995
2000
2005
2010
East Asia
World Average
Africa
European Union
SE Asia
United States
South Asia

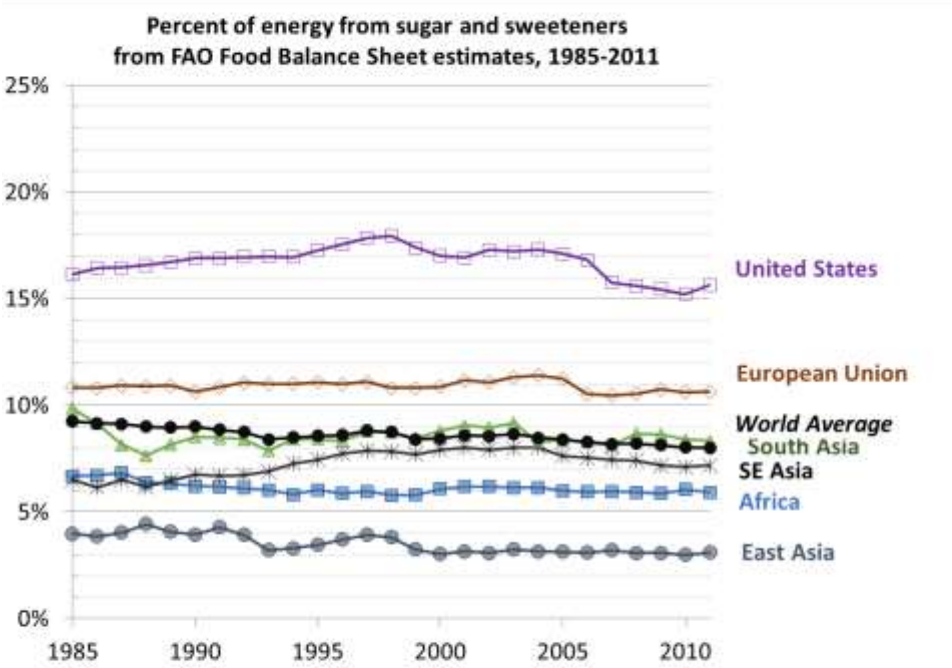
7. Sugar and sweeteners: Roughly flat or declining everywhere





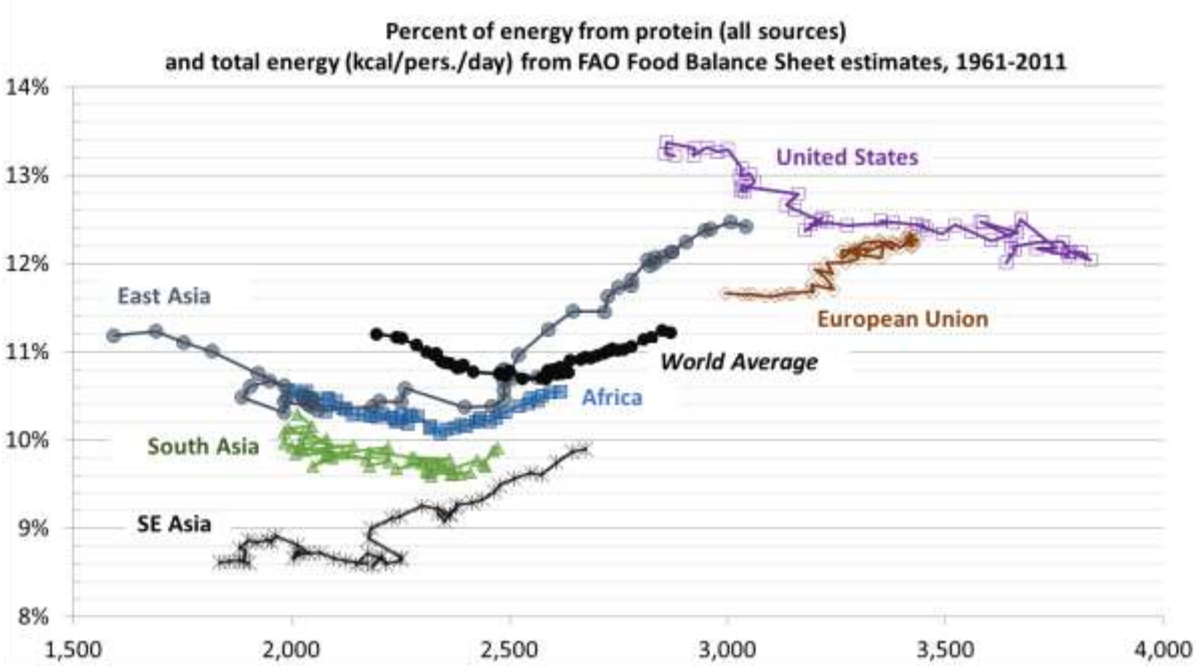


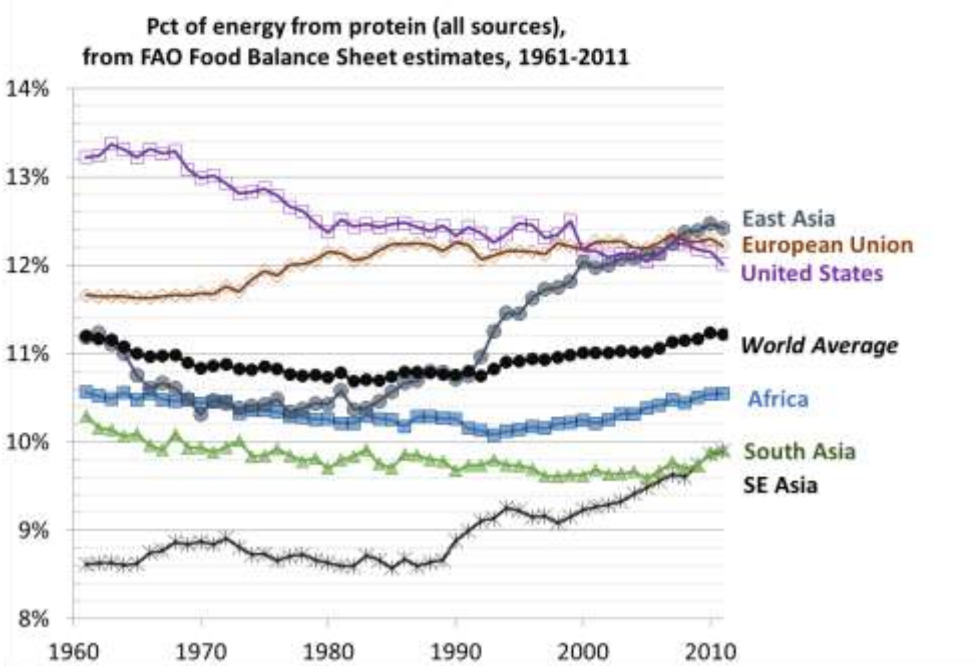
Percent of energy from sugar & sweeteners
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
United States
European Union
South Asia
World Average
SE Asia
Africa
East Asia

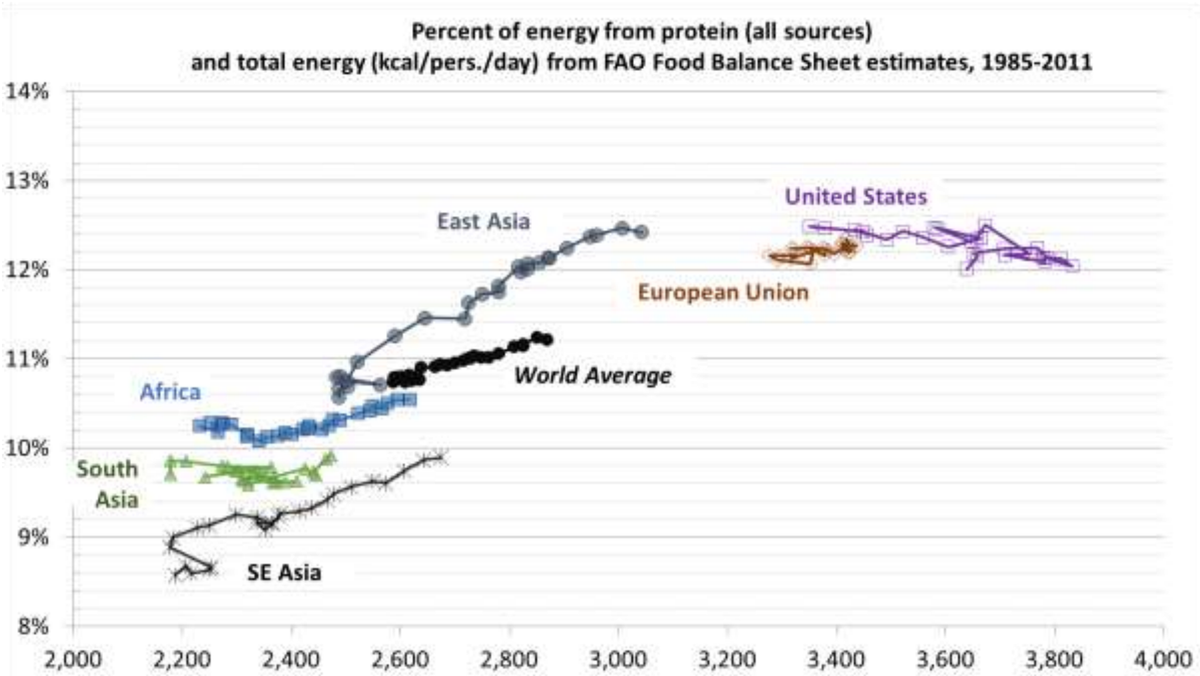


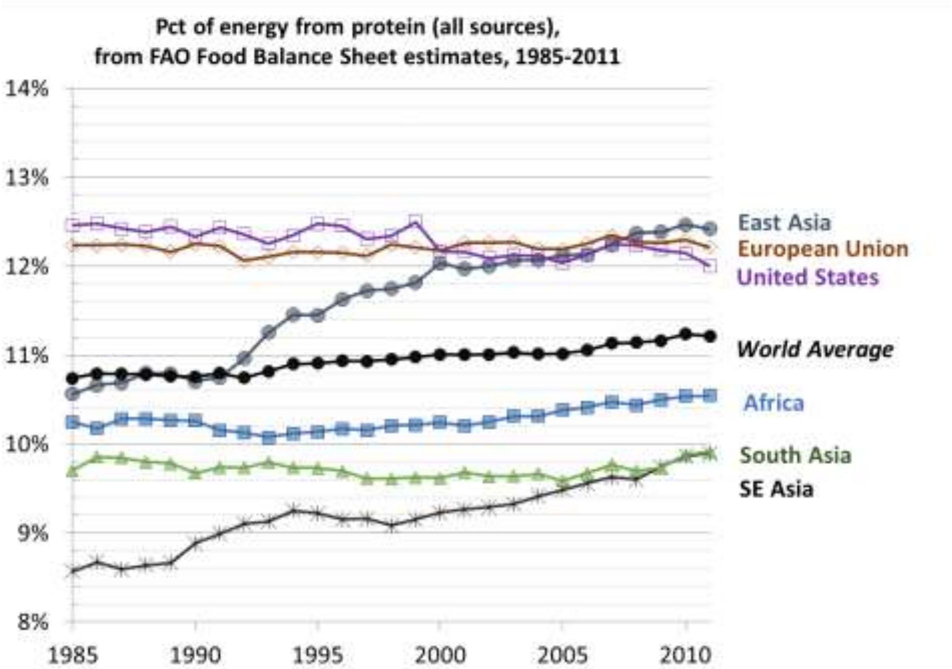
Percent of energy from sugar and sweeteners
from FAO Food Balance Sheet estimates, 1985-2011
25%
20%
15%
10%
5%
0%
1985
1990
1995
2000
2005
2010
United States
European Union
World Average
South Asia
SE Asia
Africa
East Asia

8. Protein (all sources): among other trends, a remarkable decline in South Asia until after 2005



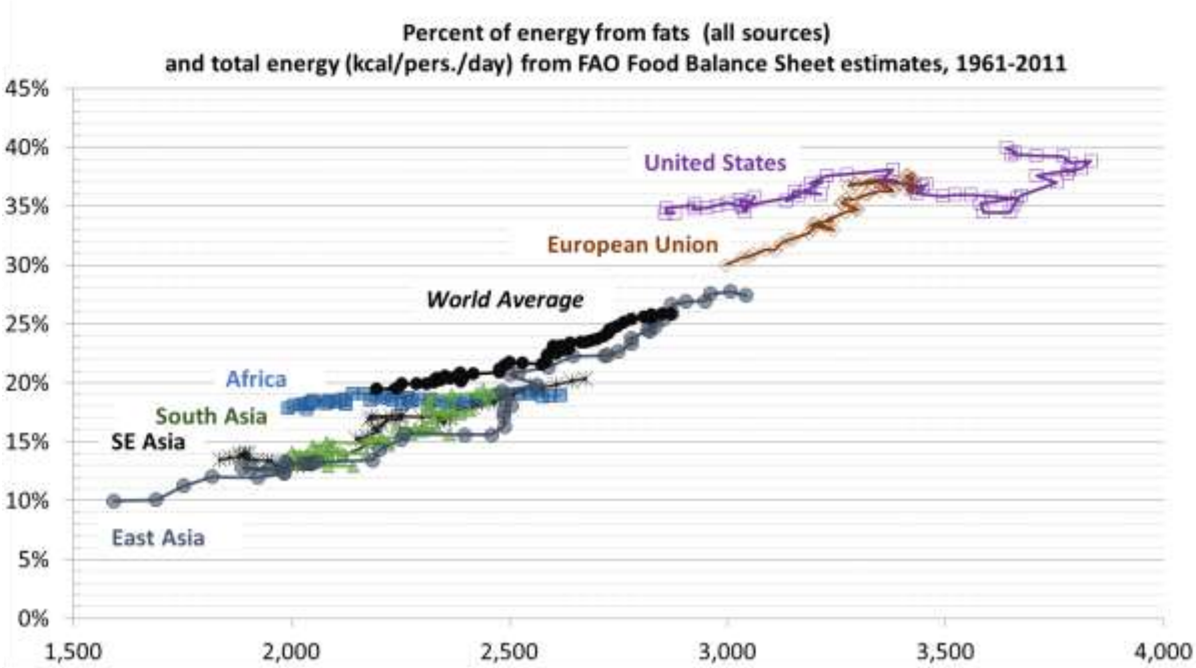


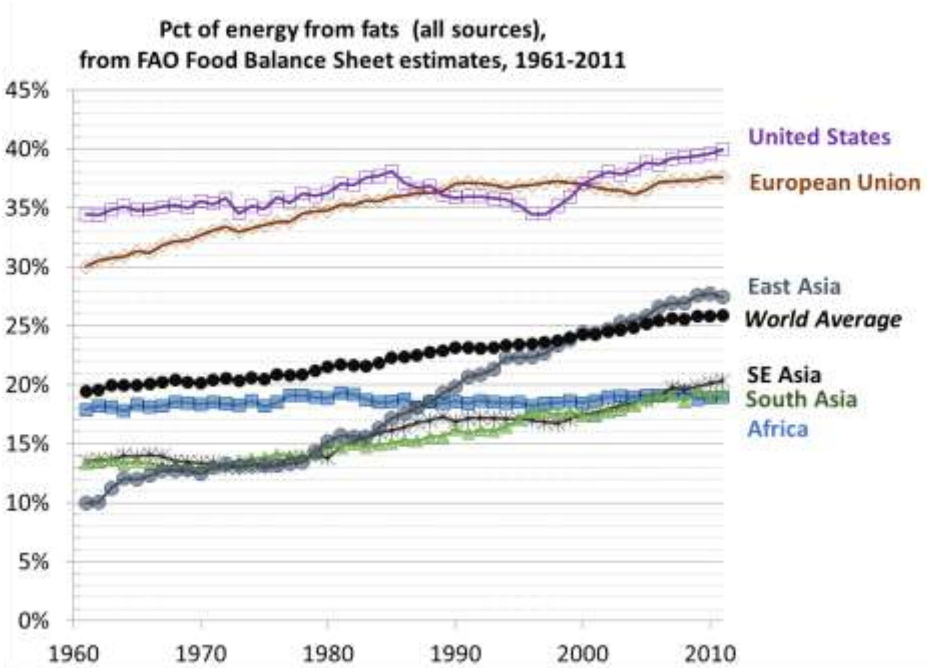

Percent of energy from protein (all sources)
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
14%
13%
12%
11%
10%
9%
8%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
United States
East Asia
European Union
World Average
Africa
South Asia
SE Asia

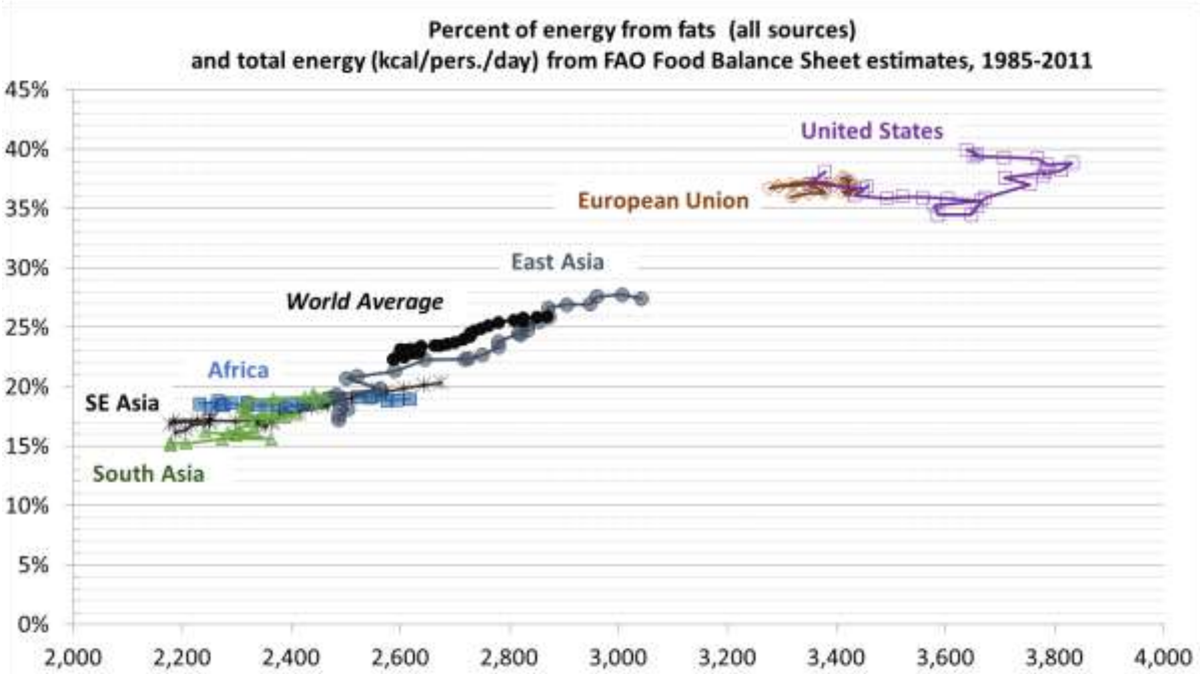

Pct of energy from protein (all sources),
from FAO Food Balance Sheet estimates, 1985-2011
14%
13%
12%
11%
10%
9%
8%
1985
1990
1995
2000
2005
2010
East Asia
European Union
United States
World Average
Africa
South Asia
SE Asia

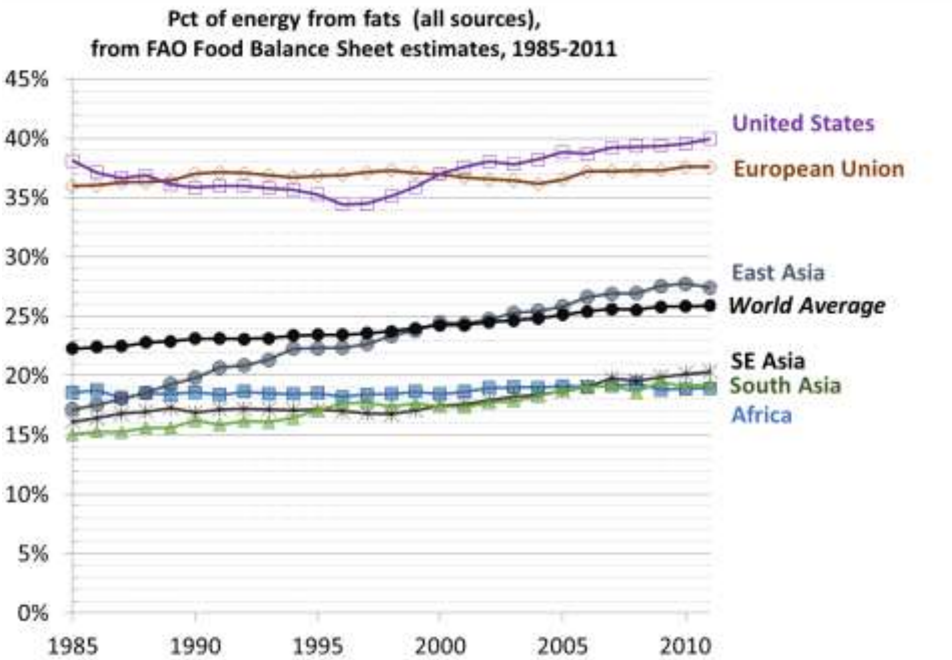
9. Fats (all sources)

Total fat consumption reveals several remarkable patterns. First, fat consumption is closely correlated with total calorie intake, with most regions moving along a common diagonal line in the first chart below. Key exceptions were Africa, which had been an outlier above the global pattern and moved towards the diagonal over time, and the US which experienced a remarkable reduction in fat consumption during its period of anti-fat messaging in the 1980s and early 1990s.

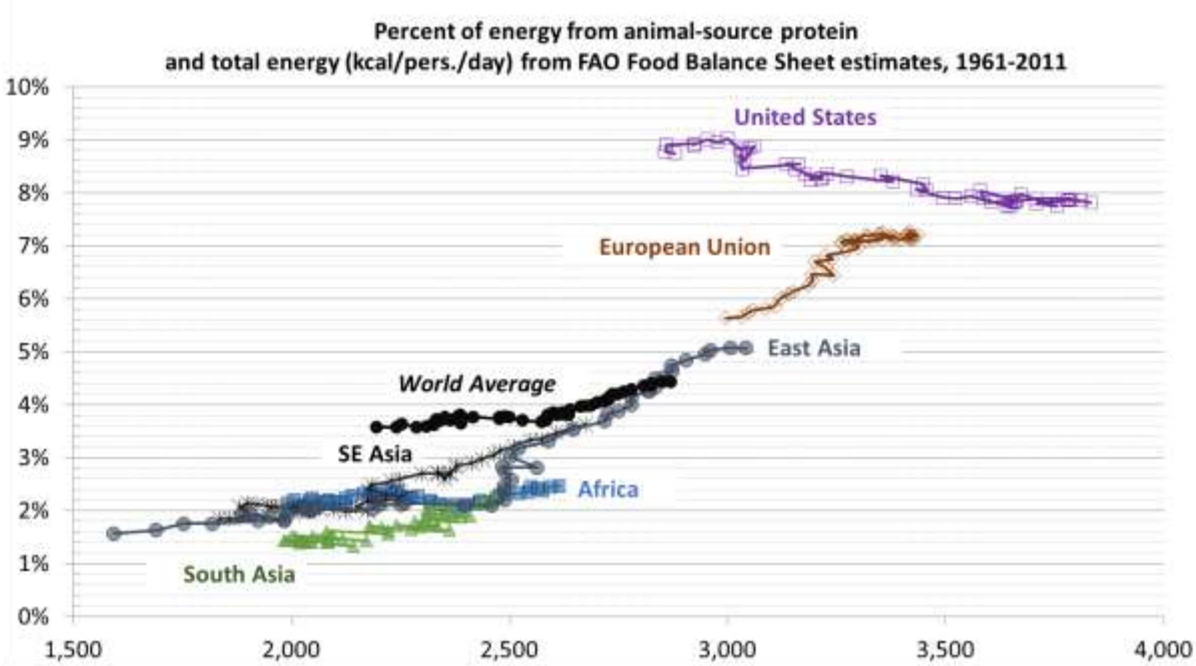


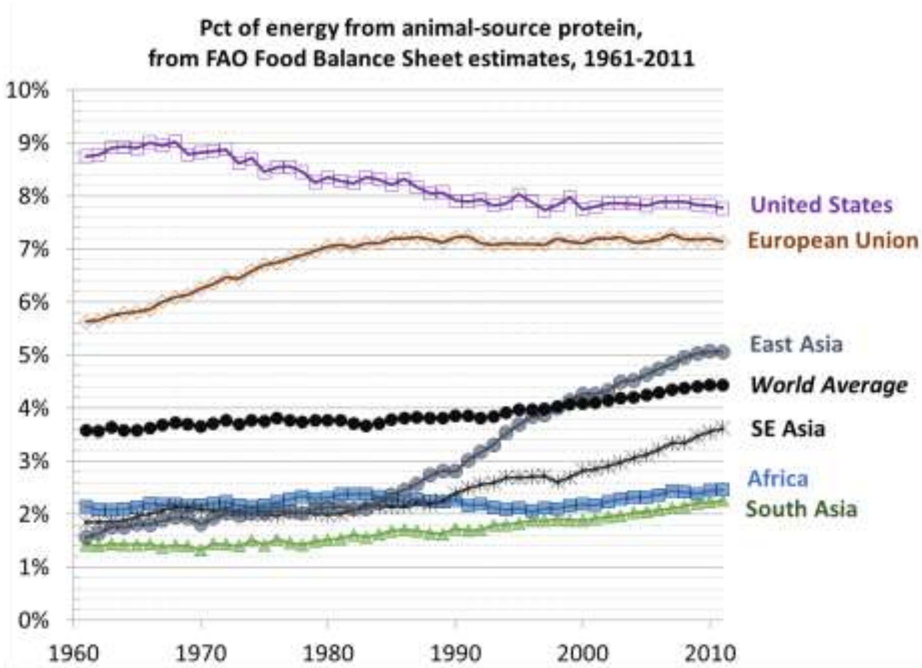


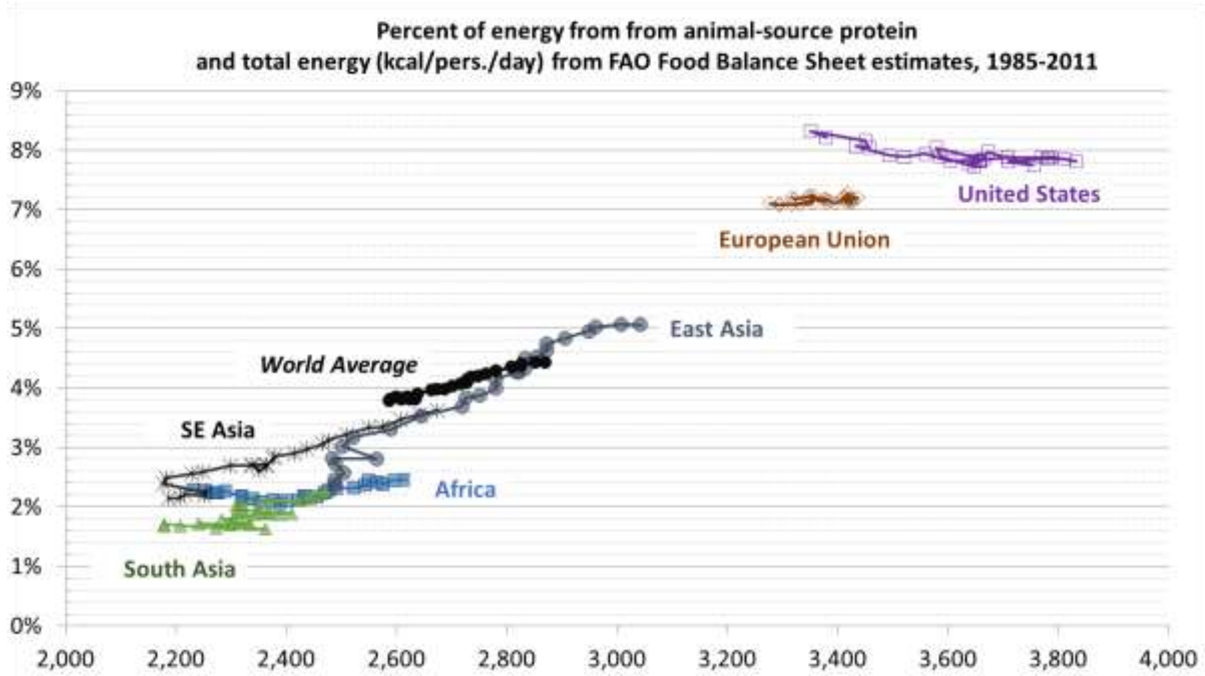

Percent of energy from fats (all sources)
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
United States
European Union
East Asia
World Average
Africa
SE Asia
South Asia
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000


Pct of energy from fats (all sources),
from FAO Food Balance Sheet estimates, 1985-2011
United States
European Union
East Asia
World Average
SE Asia
South Asia
Africa
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
1985
1990
1995
2000
2005
2010

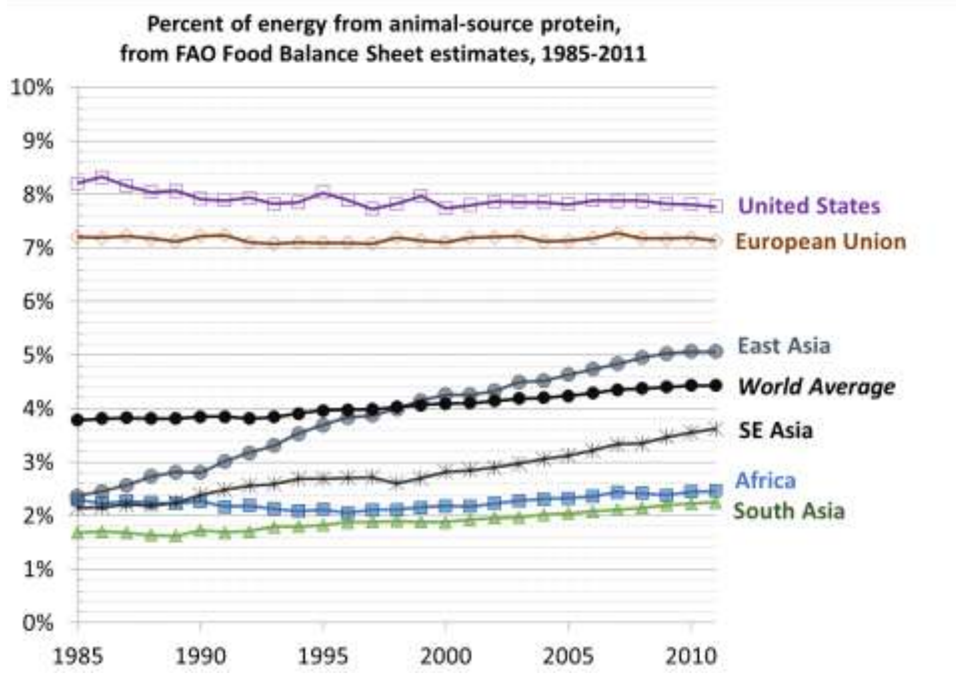
10. Animal-source protein





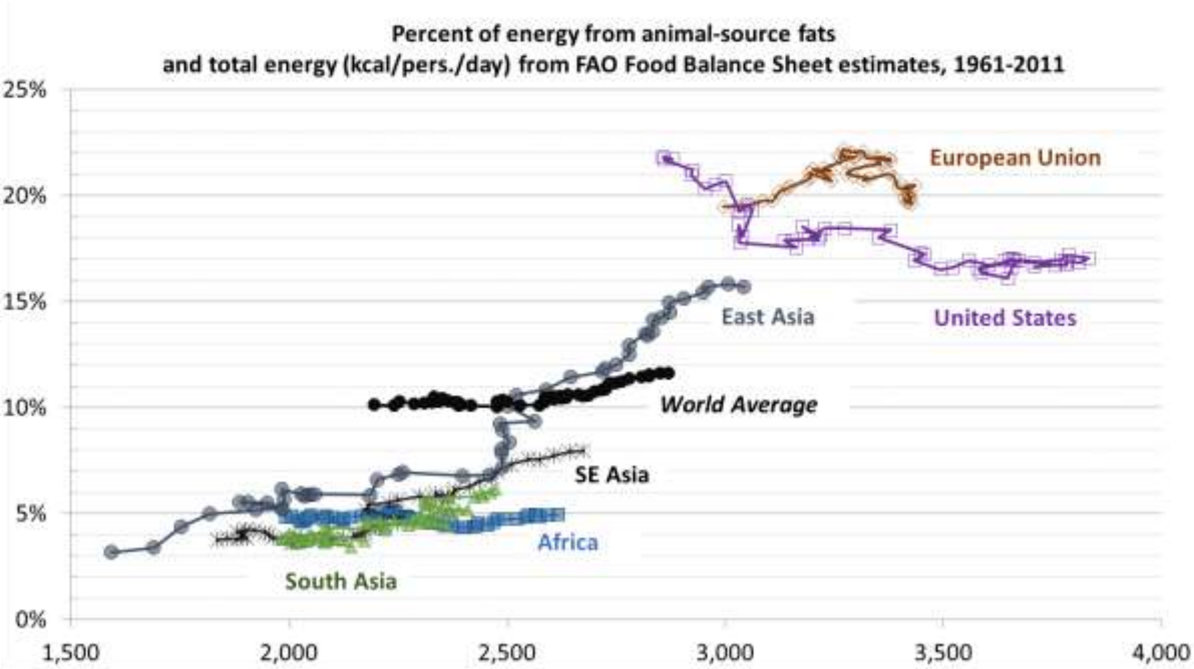


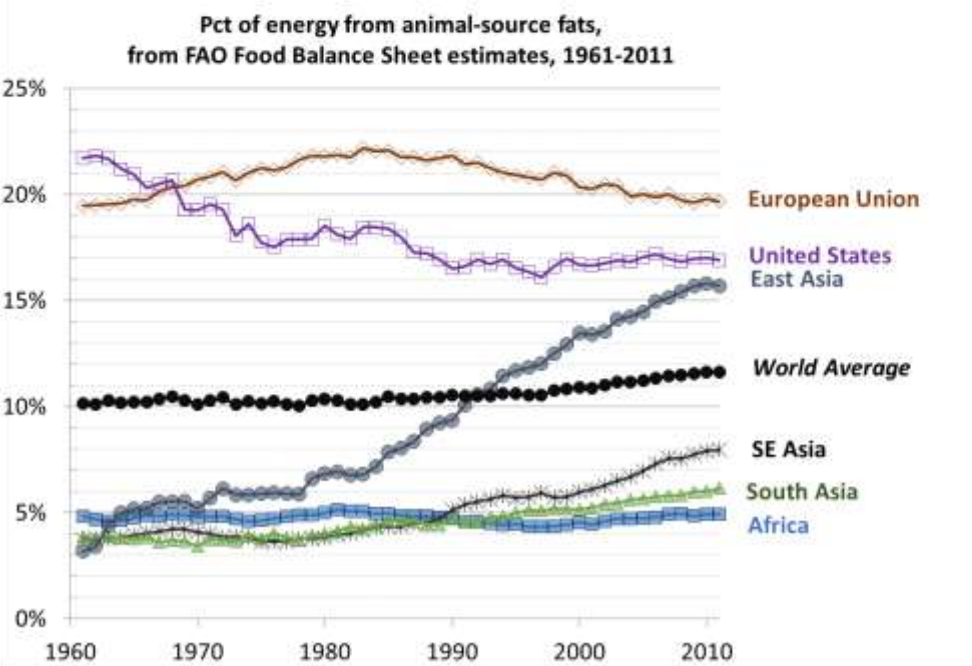
Percent of energy from from animal-source protein
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
United States
European Union
East Asia
World Average
SE Asia
Africa
South Asia

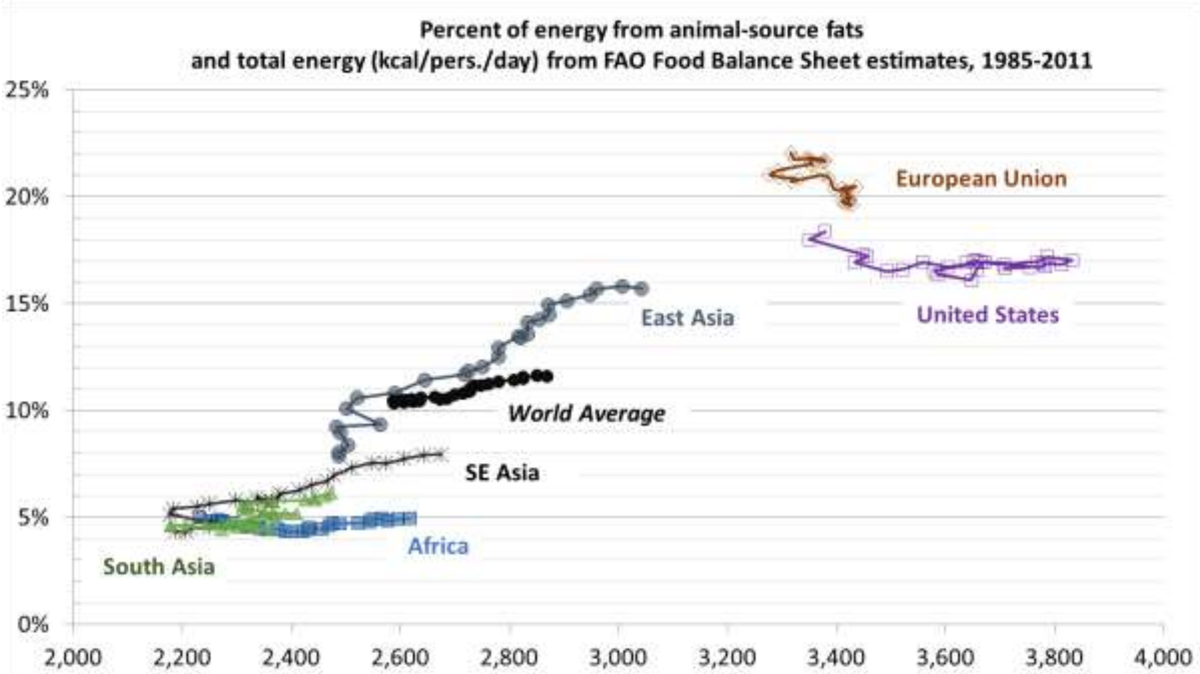


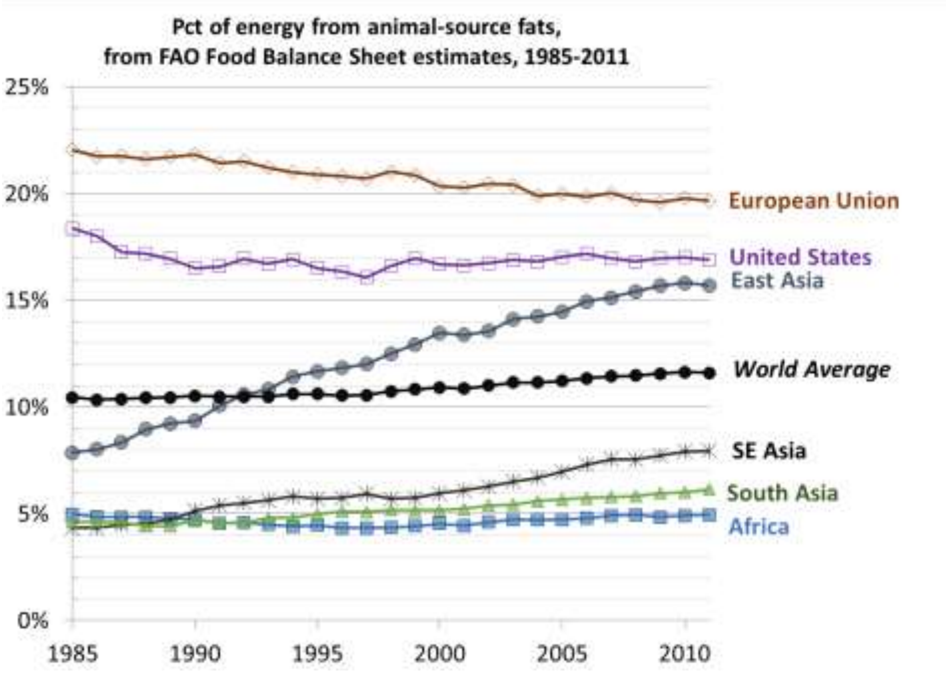
Percent of energy from animal-source protein,
from FAO Food Balance Sheet estimates, 1985-2011
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
1985
1990
1995
2000
2005
2010
United States
European Union
East Asia
World Average
SE Asia
Africa
South Asia

10. Animal-source fats






Percent of energy from animal-source fats
and total energy (kcal/pers./day) from FAO Food Balance Sheet estimates, 1985-2011
25%
20%
15%
10%
5%
0%
2,000
2,200
2,400
2,600
2,800
3,000
3,200
3,400
3,600
3,800
4,000
European Union
United States
East Asia
World Average
SE Asia
Africa
South Asia


Pct of energy from animal-source fats,
from FAO Food Balance Sheet estimates, 1985-2011
25%
20%
15%
10%
5%
0%
1985
1990
1995
2000
2005
2010
European Union
United States
East Asia
World Average
SE Asia
South Asia
Africa