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ABSTRACT

Are Vegetable Seed Oils Fueling the Obesity Epidemic?*

I argue that increased consumption of vegetable seed oils high in omega-6 polyunsaturated fats has driven obesity in the United States, a link overlooked in the economics literature. Obesity rates have closely tracked the level of seed oils in the food supply since 1960, while diverging from calorie intake and exercise trends post-2000. I present evidence from biochemistry supporting this hypothesis, demonstrating how seed oils disrupt metabolism, fat storage, and other biochemical processes. I document supporting evidence of these mechanisms in economics research and population health trends. I then develop a conceptual theory of imperfect information to explain consumer overconsumption of these oils, considering the interactions among food and drug companies, scientists, government regulators, and medical providers in shaping dietary information and the overall food supply. Finally, I discuss policy implications, emphasizing the need for a coordinated approach.

JEL Classification: I12, Q18, L66, I18, D72

Keywords: obesity, vegetable oils, seed oils, food policy, nutritional biochemistry, polyunsaturated fatty acids, political economy

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1 Introduction

Obesity rates continue to climb worldwide, to the seeming bewilderment of scientists, medical providers, and policymakers (Mozaffarian, 2022). In the US, the adult obesity rate now stands at 40.3%, up from 30.5% in 2000 (Fryar, Carroll, and Afful, 2020; Emmerich et al., 2024). The prior economics literature on obesity has tended to focus on technological change—resulting in reduced physical activity and increased caloric intake—as a primary explanation for increased obesity prevalence (Cutler, Glaeser, and Shapiro, 2003; Philipson and Posner, 2003; Lakdawalla, Philipson, and Bhattacharya, 2005; Rosin, 2008; Lakdawalla and Philipson, 2009). However, economics alone has been unable to fully explain the continued rise in obesity (Cawley, 2015).

Why has obesity continued to rise, despite increased public health awareness of its deleterious effects for at least the past 25 years? Calorie levels in the food supply have not changed much since 2000, while rates of physical exercise and gym memberships have actually increased. Over the same time period, however, the supply of industrially processed vegetable seed oils has increased by 33% while the supply of caloric sweeteners has *declined* by 17%.[1] Seed oils are high in omega-6 polyunsaturated fats (PUFAs) which are known to have several adverse health effects when consumed in excess relative to omega-3 PUFAs.[2] Yet the possible health consequences of changes in dietary fat composition are largely unknown to the field of economics.[3]

To explain the rise of seed oils and obesity, I propose a theory of imperfect information in which inattentive consumers rely on dietary advice from the government and medical providers, while simultaneously receiving advertisements from food and drug companies. Food companies innovate new food products in an effort to take advantage of production

[1] Henceforth, I refer to "vegetable seed oils" as simply "seed oils." Shanahan (2024) has identified eight varieties that are particularly adverse to human health: canola (rapeseed), corn, cottonseed, grape seed, rice bran, safflower, soybean, and sunflower. Opinions vary on whether peanut oil is problematic (Means and Means, 2024, p. 173). Virtually all plant seeds can be turned into oils, but these eight are produced at the greatest scale and put into fast foods and other convenience foods at the highest rates.

[2] The balance between omega-6 and omega-3 PUFAs is critical for health outcomes. A higher relative proportion of omega-3 tends to improve health in a variety of ways (Simopoulos, 2016; Hulbert, 2023).

[3] While some economics papers have paid attention to omega-3 (Shimshack and Ward, 2010; Hill et al., 2011; Rosenzweig and Santos Villagran, 2020), I found no mentions of omega-6 PUFAs in a broad search of the literature. Most discussion surrounding omega-3 tends to focus on the tradeoff between fish being a good source of omega-3 PUFAs while simultaneously posing a risk for mercury poisoning.

economies without forecasting potential adverse health consequences. Scientists supply dietary information, but its quality may be distorted by research funding from both government and industry sources. Government regulations and dietary recommendations may be influenced by lobbying activities of food and drug companies. Food companies then repeatedly adapt product formulations to conform to ongoing regulations and recommendations. Drug companies play an indirect role by funding medical education and promoting pharmaceutical solutions to health problems to both medical providers and consumers.[4] This interaction of incentives across many different actors contributes to the imperfect information that consumers eventually receive regarding optimal health choices.

The theory is consistent with the US history of food innovation, dietary advice, food regulations, and food companies' regulatory responses. Seed oils have been a significant part of the American food supply since the early 20th century, with the debut of Crisco ("crystallized cottonseed oil") in 1911 marking a pivotal moment. The success of Crisco depended on technological innovations in oil processing in the late 1800s and early 1900s—extraction, purification, deodorization and hydrogenation.[5] The prominence of these oils accelerated beginning in the 1960s (Blasbalg et al., 2011). This was in response to several scientific articles in the 1950s that claimed that saturated fat caused elevated levels of LDL cholesterol, which was linked to greater heart attack risk (Keys, 1953a,b). In 1961, the American Heart Association (AHA) recommended replacing saturated fats with omega-6 PUFAs, such as those found in seed oils, in order to reduce blood cholesterol levels (American Heart Association, 1961). In response to the AHA, as well as consumer advocacy pressure and other economic factors, food companies accelerated their substitution of partially hydrogenated seed oils for saturated fat in their product formulations, which had the unintended consequence of producing trans fats (Schleifer, 2012). By 1980, the US government issued its first dietary guidelines for Americans, which included a recommendation to reduce saturated fat intake (Davis and Saltos, 1999).

[4] Furthermore, medical providers often generate more money from performing procedures than from addressing chronic diseases, which may further distort their advice (Sinsky and Dugdale, 2013). Spending time with a patient that is not accounted for by a specific procedural billing code does not generate revenue (Ghaly and Knezevic, 2018).

[5] Deodorization was perfected by David Wesson in 1899 and removed unseemly color and odor from the cottonseed oil, while hydrogenation, patented in Germany in 1902, created a solid fat from liquid oil. (Robins, 2018, pp. 326, 329)

Seed oils accelerated in the food supply throughout the 1980–2000 period, as food companies embraced partially hydrogenated seed oils in their product formulations. Two high-profile examples from the 1990s illustrate this phenomenon. In 1990, McDonald's shifted its frying medium from beef tallow to a seed oil mix that included trans fats. In 1997, Oreo changed its creme filling formula by replacing lard with a partially hydrogenated (trans fat) seed oil blend. Since 2000, seed oils have continued to accelerate in the food supply as trans fats have become recognized as harmful, forcing food companies to switch away from partial hydrogenation and come up with new ways to preserve texture without relying on saturated fats or processes that produce trans fats.[6]

Currently, seed oils are now found in nearly every prepackaged or restaurant food, with soybean oil by far the most commonly used. Baked goods and snack foods use seed oils in place of butter or lard, fried foods are cooked in seed oils instead of animal fat, and salad dressings and mayonnaise use seed oils instead of olive oil and eggs. Seed oils are also commonly used in vegetarian and vegan foods such as plant-based milk and meat alternatives, which have become more common throughout the 21st century. Moreover, oilcrop seeds have become more and more commonly used as grain-based animal feed which has led to meat and other animal products having a higher level of PUFA concentration over time, particularly for poultry and pork (Butler, 2014).

While seed oils' rise in the US food supply is coincident with obesity rates to a much greater degree than are trends in calories or sugars, this does not prove causality. In order to support this hypothesis, I rely on three sources of evidence. First is evidence from biochemistry about the importance of dietary fat composition for human health and energy metabolism. This evidence shows that seed oils are more readily oxidized in the body, which disrupts metabolism, appetite regulation, and fat storage. Second is that seed oils are able to explain existing hypotheses for obesity cited in the economics literature. For example, seed oils offer an explanation for why french fries and potato chips—which are typically fried in seed oils—are associated with much higher levels of weight gain than baked, boiled or mashed potatoes (Mozaffarian et al., 2011), a specific example cited in Cutler, Glaeser, and

[6]See Nagpal et al. (2021) and Zambelli (2021) for complete details. Common methods include the following: interesterification; oleogelation; selectively breeding vegetables to produce seeds with low PUFA content; fractionation; and blending. I explain each of these approaches in Appendix B.

Shapiro (2003). Third is auxiliary evidence that the predicted health effects of a secular increase in seed oil intake are consistent with observed population health trends—including a secular decline in population levels of LDL cholesterol, a secular increase in PUFA content of body fat (Guyenet and Carlson, 2015), as well as gradual increases in body weight over the life cycle and across birth cohorts. Moreover, seed oils are known to fatten livestock.

It is ultimately difficult to definitively prove that seed oils cause obesity due to how they are stored in the body and the gradual way in which Americans have become exposed. Excess dietary PUFA is stored in fat cells, which are long-lived (Guyenet and Carlson, 2015). Thus, running an experiment where a group of people with obesity is kept off of seed oils would require dietary compliance for several years.[7] Because I cannot definitively prove causality, I also discuss data trends that do not support the seed oil hypothesis. These include within- and across-country geographic variation in obesity, environmental contaminants and food additives, or other components of processed foods that happen to be highly correlated with seed oil content (e.g. food dyes, other chemical additives, etc.). In the end, it is clear that something in the US food supply is causing obesity, but it is impossible to say that seed oils per se are the sole cause. It is also clear that the status quo is only exacerbating obesity, so this paper argues that seed oils should at the very least receive more scholarly attention.

If seed oils are indeed a major underlying cause of obesity, then reducing their supply will likely require a multifaceted effort similar to what finally proved successful at curbing tobacco use—namely, raising public awareness, reducing or eliminating seed oil crop subsidies, restricting advertising, adjusting food label regulations, levying taxes, and restricting the age of users or location of use (McGoldrick and Boonn, 2010).

Moving away from seed oils and towards saturated fats may pose several difficult tradeoffs. The primary source of the tradeoffs come through the fact that animal products require more land than plant-based products (Cornelius and Schnitkey, 2023). While plant-based saturated fats (primarily coconut oil and palm oil) have higher yield per land area than oilseed plants (Our World in Data, 2021), they may drive tropical deforestation (Byerlee, Falcon, and Naylor, 2016). Technological solutions to these tradeoffs would require coming

[7] Hall et al. (2019) attempted a similar experiment over the course of one month but randomizes "unprocessed" and "ultraprocessed" diet while holding fixed macronutrient content of the two. Other diet RCTs have been limited to similarly brief time periods.

up with new ways to produce saturated fats at scale. Yet, the rise and fall of trans fats in the late 20th century is a cautionary tale about looking to food producers for technological solutions to the tradeoff. It may be more prudent to take a “guilty until proven innocent” approach to any new food formulations.

The rest of the paper is organized as follows. In section 2, I review several data sources to provide empirical support for the claim that seed oils are causing obesity. Section 3 presents several sources of evidence that support my primary claims, including providing background on biochemistry mechanisms. Section 4 presents a conceptual economic model that explains the rise of seed oils and obesity. Section 5 reviews counterarguments to my claims, Section 6 discusses policy implications, and Section 7 concludes.

2 Trends in obesity, diet, and exercise

This section presents several pieces of empirical evidence that support the link between the rise of obesity and the increased consumption of omega-6 PUFAs from seed oils in the US. The primary data source for obesity and other health outcomes is the National Health and Nutrition Examination Survey (NHANES), which has been conducted by the Centers for Disease Control and Prevention (CDC) since the early 1960s. I supplement the NHANES data with data from the National Longitudinal Surveys of Youth (NLSY)—a longitudinal survey that tracks people over their life cycle beginning in their teenage years.[8] For data on physical activity, I consult the National Health Interview Survey (NHIS). For data on the food supply, I consult the United States Department of Agriculture’s (USDA) Economic Research Service (ERS), which tracks agricultural sales of various products and commodities. I also make use of the Food and Agriculture Organization of the United Nations (FAO) food balance sheets, which provide an alternative perspective on the national-level food supply.

[8] A key difference between NHANES and NLSY is that NLSY height and weight is self-reported, while NHANES is clinically measured.

2.1 Obesity across cohorts and over the life cycle

Figure 1 plots the distribution of body mass index (BMI) across three waves of NHANES. The figure shows that BMI has continued to skew rightward over time as also shown in Cutler, Glaeser, and Shapiro (2003) and Lang, De Sterck, and Abrams (2017). The key point is that the entire body mass distribution is still represented in the population, but leaner individuals are becoming more rare over time.

Figure 2 plots obesity rates by age for three different cohorts of the NLSY surveys. This graph shows that obesity has a life-cycle component as well as a cohort component. The oldest cohort (NLSY79) has the lowest obesity rates at all ages, while the other two cohorts (NLSY97 and NLSY79 Children and Young Adults) have obesity rates that are much higher and that track each other closely.[9] These findings are consistent with other findings of increased incidence of childhood obesity (Cunningham et al., 2022).[10]

2.2 Obesity, calories, and exercise

Figure 3 compares obesity rates since 1960 with estimates of the per-capita caloric value of the food supply as well as exercise rates. The obesity rate data in panel (a) come from Fryar, Carroll, and Afful (2020) and Emmerich et al. (2024) and document a near tripling in the obesity rate, from about 14% in 1960 to 40% in 2022.[11] Notable is an apparent inflection point around 1980 when the rate of increase suddenly rose, as well as a slight dip after 2020. The per-capita amount of calories in the food supply in panel (b) differs by source in levels but in both sources steadily increased in a linear fashion until about 2000 or 2005, after which there was a flattening. Panel (c) uses data from the National Health Interview Survey (NHIS) to show that exercise rates have increased since 2000.[12] Thus, this figure illustrates

[9] The NLSY97 cohort is slightly older. Individuals in the NLSY97 cohort were born between 1980 and 1984, while individuals in the NLSY79 Children and Young Adults cohort were born between 1972 and 1997. The NLSY79 Children and Young Adults cohort have 1985 as the modal year of birth, with essentially symmetric birth year frequencies in either direction.

[10] Appendix Figure C.1 shows NLSY cohort trends in body weight quantiles (10th and 90th percentiles), confirming that right-skewing occurs in the NLSY data as well as the NHANES data. By age 30, the 10th percentile body weight was about 10–15 pounds heavier in the later two cohorts compared to the oldest cohort. However, the 90th percentile body weight was about 30–40 pounds heavier.

[11] These rates roughly match the implied rates of BMI$\geq$ 30 in Figure 1.

[12] Appendix Figure C.2 shows stable exercise rates throughout the 2000s using data from NHANES.

a puzzle whereby obesity has gone up despite people exercising more while eating about the same amount of calories. Speakman et al. (2023) confirms this result. They find that total daily energy expenditure has declined over the last three decades, accompanied by a decrease in basal energy expenditure, while physical activity expenditure actually increased. They propose this previously unrecognized decline in basal metabolic rate as a potential new factor contributing to the rise in obesity, but do not claim it is a major cause.

2.3 Obesity, sweeteners, and seed oils

Figure 4 reproduces the obesity rate from panel (a) of Figure 3 but compares it instead with the estimated food supply of sugar and other caloric sweeteners in panel (b) and seed oils (canola, corn, cottonseed, soybean, and sunflower oils) in panel (c). Panel (b) shows a sharp decline in the supply of sugar and other natural sweeteners since 1999, while panel (c) shows a steady increase in seed oils. The increase in panel (c) is much steeper when measured by the USDA as opposed to the FAO, but both series show a significant increase.[13]

The sudden drop in sugar supply just before 2000—and flattening of calories just after 2000—provide useful context for ruling out sugar or calories as primary drivers of the obesity epidemic. Coupled with the steady increase in seed oils that more closely mirrors the rise in obesity both before and after 2000, the evidence suggests that seed oils may be playing an important role in obesity, and likely more so than sugar or calories.

2.4 Food intake surveys

Because the food supply data in Figures 3 and 4 does not directly measure consumption, I corroborate the trends in these figures with Appendix Figure C.3. This figure uses food intake surveys (as part of NHANES) as summarized in the USDA's "What We Eat in America" reports. These are only available since 1999, but the food intake surveys show similar trends in calories, sugar, and seed oils as the food supply data. As is generally recognized, the food intake surveys appear to underestimate actual consumption (Cutler, Glaeser, and Shapiro,

[13] Due to a methodology adjustment in 2010, I adjust the data as discussed in Vonderschmidt et al. (2024) and Piva, Conforti, and d'Ortigue (2024). See Appendix A for complete details.

2003; Archer, Hand, and Blair, 2013). However, the trends for each component largely match those in the food supply data.

2.5 Seed oils in branded foods

I further document the rise in seed oil consumption by examining the USDA's Branded Food Database, provided as part of its FoodData Central website. The USDA first released this database in 2018 and updates it semiannually. It contains information on the product details (including full ingredient lists) of millions of food products sold in the US based on when each product was first introduced. Thus, the database tracks cutting edge food formulation rather than reflecting the stock of existing products.

I use this database to calculate the incidence of seed oils and seed oil derivatives (e.g. emulsifiers such as lecithins or mono and diglycerides) in the food supply. Panel (a) of Figure 5 shows that, even over the short time horizon of seven years, the incidence of seed oils in the food supply has increased by about 20%. Panel (b) shows the evolution within broad product category for select categories. Not surprisingly, the types of foods that are typically stocked in the middle of the grocery store (e.g. snacks, sweets, and bakery items) persistently have the largest incidences of seed oils. Surprisingly, 100% of baby formulas in the database contain seed oils. Nearly all categories have higher incidence levels in 2023 than in 2017.

3 Evidence on seed oils and human health

The previous section showed a strong correlation between obesity and seed oils, alongside much weaker correlations between obesity and calories or caloric sweeteners. This section presents three different sources of evidence that seed oils may be causing obesity. First, I explain biochemistry mechanisms. Second, I point out ways in which seed oils fit with previously offered explanations of obesity in the economics literature. Third, I provide auxiliary empirical evidence that is consistent with the biochemistry mechanisms.

3.1 Biochemistry mechanisms

With the prima facie evidence on seed oils and obesity in the previous section, I now explain reasons for why seed oils could plausibly be detrimental to human health, using some basic biochemistry. This requires a bit of context, so I first describe how different types of dietary fats interact differently in the body. I then describe the human metabolic process and then highlight the metabolic consequences of eating different types of fats, based on clinical trials in humans and animals.

3.1.1 Taxonomy of fats

This subsection provides a brief taxonomy of different types of fats. Helpful references accessible to a lay audience include Allport (2006); Hulbert (2023) and Shanahan (2024). Fats are one of the three macronutrients (along with protein and carbohydrates) that humans consume.[14] Within fats, there are three main varieties: saturated, monounsaturated, and polyunsaturated. These three types of fats have different molecular structures and, as a result, interact with the human body in different ways. Each fat variety appears in some quantity in most foods; however, some foods have much more saturated than unsaturated fat content, for example.

Saturated fatty acids (SFAs) are typically solid at room temperature and derived from animal products.[15] They are so named because their hydrocarbon chains have no double bonds between adjacent carbon molecules. Monounsaturated fatty acids (MUFAs) are typically liquid at room temperature and are found in foods such as olive oil, avocados, and nuts. They have one double bond between carbon atoms in the fatty acid chain; hence the moniker "mono." Polyunsaturated fatty acids (PUFAs) are also liquid at room temperature and are found in foods such as fish, nuts, and seeds. As the "poly" prefix implies, PUFAs have at least two double-bonded carbon sites in the fatty acid chain.

Within PUFAs, there are two primary varieties: omega-3 and omega-6. The difference between the two has to do with the exact locations of the carbon double bonds. Both omega-

[14] These three macronutrients are primarily composed of carbon, hydrogen, and oxygen, with proteins also containing nitrogen. The specific molecular structures and atomic ratios of these elements determine the classification and properties of each macronutrient.

[15] Notable exceptions are coconut and palm oils.

3 and omega-6 fats are essential to human health, meaning that humans cannot synthesize them and must obtain them from their diet, similar to vitamins, minerals and some amino acids. Omega-3 fats tend to come from the leaves of plants, while omega-6 fats tend to come from the seeds of plants.[16]

The distinction between omega-3 and omega-6 has implications for human health due to how these two different types of fats interact with the body. Appendix Figure C.4 shows the configuration of four different 18-carbon fatty acid molecules: stearic acid (SFA); oleic acid (MUFA); linoleic acid (omega-6 PUFA); and alpha-linolenic acid (omega-3 PUFA). Linoleic acid has been identified by much prior literature to be particularly harmful to a variety of the body's processes, as I describe below.

3.1.2 Human metabolism and oxidation

Human metabolism takes place in the mitochondria of each cell and is the process by which food calories—in the form of glucose (from carbohydrates), fatty acids (from fats) or amino acids (from proteins)—are converted into adenosine triphosphate (ATP), the body's primary energy currency (Judge and Dodd, 2020). Recent research challenges the simplistic "calories in, calories out" model of metabolism, emphasizing the importance of metabolic flexibility—the body's ability to efficiently switch between fuel sources (Muoio, 2014; Smith et al., 2018).[17] This flexibility is crucial for maintaining energy homeostasis and overall metabolic health.

Malfunctioning mitochondria prevent metabolic flexibility and result in persistently elevated weight levels due to indecision on the part of mitochondria as to whether to use fat or sugar to produce ATP (Muoio, 2014). A person categorized as overweight or obese is not metabolically flexible because their body does not make use of its excess stored fat for energy (Friedman et al., 2024). In effect, it does not choose to burn the calories that are

[16]Exceptions include flaxseeds, chia seeds, and walnuts, which are plant-based sources of omega-3 fats. Fish and other seafood are also rich sources of omega-3 fats because the phytoplankton they feed on are a sort of "plant leaf." Grass-fed animals also tend to have higher levels of omega-3 fats in their meat and milk compared to grain-fed animals because grass is a "leaf" while grains are "seeds" (Hulbert, 2023).

[17]Aside from metabolic flexibility, Pontzer et al. (2012) show that energy expenditure is not additive in physical activity. Rather, after an energy expenditure shock, the body down-regulates energy expenditure from low-priority processes to conserve total energy expenditure. This means that "calories out" is regulated by the body, which provides further evidence against the simplistic energy balance model of obesity.

sitting in storage. This is the primary conundrum that explains why people categorized as overweight or obese do not naturally shed their excess weight: the body is calling for more sugar to be used as energy when there is excess fat that could also be used. This leads to feelings of hunger driven by reduced blood sugar levels, and over time results in diabetes and obesity as the body compensates by chronically elevating blood sugar levels (Shanahan, 2024, p. 76).

A key part of human metabolism is oxidation, which is how each cell "breathes" and which involves the transfer of electrons from one molecule to another. Oxidation requires oxygen and is a normal part of metabolism, but when it is disrupted, it can lead to excessive production of free radicals, which can damage cells and tissues. Antioxidants can inhibit the excess production of free radicals (Pham-Huy, He, and Pham-Huy, 2008; Chaudhary et al., 2023). In the context of body fat, when fat cells do not get enough oxygen, it can lead to increased oxidative stress. This stress can cause the fat cells to malfunction, potentially contributing to broader issues with how the body processes and stores energy (Netzer et al., 2015).

3.1.3 Health consequences of dietary fats

The body uses all types of fats (SFA, MUFA, PUFA) for various purposes, including energy storage, cell membrane structure, and metabolic processes (German, 2011). While saturated fats are more often associated with energy storage and unsaturated fats (both MUFA and PUFA) play crucial roles in cell membrane function, all types of fat contribute to multiple functions in the body. The balance and proportion of these fats in the diet can influence overall health in several different aspects, especially omega-6 vs. omega-3 PUFA (Hulbert, 2023).

The available evidence from clinical trials in humans and animals suggests that excess intake of linoleic acid—abundant in seed oils—has the following health effects:[18] (*i*) increased oxidative stress (Turpeinen, Basu, and Mutanen, 1998); (*ii*) reduced LDL cholesterol levels (thought to be a good thing; Mensink and Katan, 1989); but (*iii*) increased oxidation

[18] Clinical evidence on seed oils and human obesity is sparse because funding and scientific interest was focused on testing the diet-heart hypothesis. Thus, nearly all human clinical trials were done in the 1960s and did not pay any attention to possible obesity implications of seed oil consumption.

of LDL cholesterol particles, which has negative implications for heart disease and stroke (Reaven et al., 1993; Kim et al., 2017); (*iv*) weight gain and disrupted appetite regulation (in mice; Alvheim et al., 2012); and (*v*) enlargement of fat cells (in mice; Alvheim et al., 2014). Additionally, laboratory experiments provide evidence that oxidized LDL particles impair insulin sensitivity in fat cells through multiple mechanisms, collectively contributing to insulin resistance (Scazzocchio et al., 2009).

Foods fried in liquid oils appear to be particularly harmful. Grootveld, Percival, and Grootveld (2018) found that when common (high-seed-oil) cooking oils are heated to high temperatures, they break down and produce large amounts of toxic chemicals, collectively called Lipid Oxidation Products (LOPs). This process is similar to how PUFAs can oxidize in the human body, though at a much faster rate in the frying pan due to higher temperatures. Their study of fast-food french fries showed surprisingly high levels of harmful aldehydes, a type of LOP. The authors note that the amount of aldehydes in one serving of fries is similar to what one would consume from smoking 1–2 packs of cigarettes. Moreover, the amount of LOPs produced is directly proportional to the amount of unsaturation of the fat. This implies that frying in SFAs—as was traditionally done before 1900—would not produce as many LOPs.

3.2 Seed oils are consistent with the economics literature on obesity

The previous subsection establishes the biochemistry causal pathways from seed oils to obesity. Rosin (2008) outlines 14 different explanations for obesity covered in the economics literature. Here, I strengthen my argument by pointing out that seed oils fit in with several of these explanations.

Several explanations of obesity proposed by economists center around food addiction, satisfaction, time inconsistencies, and time preference. Seed oils fit in well here, given the evidence cited above that they disrupt appetite regulation, as well as the fact that they are disproportionately found in convenience foods. Rosin (2008) also mentions that obesity may have a biological basis, which is what section 3.1 is all about. Finally, seed oils explain well the impact of technological change on obesity, with rising incomes resulting in people consuming more food made outside the home, which is more likely to contain seed oils. In section 4, I present a unified economic theory that ties together information asymmetries, production economies, consumption incentives, government regulation, and other factors to explain why seed oils have become more prevalent.

Seed oils also fit in well with other findings from the economics literature. For example, Courtemanche and Carden (2011) show that Walmart market entry increases obesity. This is likely driven by Walmart selling more high-seed-oil foods than their displaced competitors. Other economics papers have documented little effect of providing calorie information on obesity (Courtemanche et al., 2020). Additionally, many economics papers recognize a distinction between "junk" food and "healthy" food, with no more specific descriptions offered.[19] Seed oils provide a useful way to characterize what is junk food, aligning with the general observation that foods in the "center of the supermarket" and "ultraprocessed foods" or fast foods tend to be unhealthy, while "ancestral" or "whole food" diets tend to be healthy.[20] Finally, the mixed evidence on the effectiveness of sugar-sweetened beverage taxes on obesity Cawley and Frisvold (2023) also fits with the idea that obesity is driven by more than simple energy imbalance.

3.3 Auxiliary evidence confirming biochemistry mechanisms

This subsection presents auxiliary evidence that supports the claims made in subsection 3.1 by showing that they bear out in general population health trends.

3.3.1 Seed oil supply correlates with lower cholesterol levels in the population and higher omega-6 PUFA concentrations in body fat

Lending additional support to the hypothesis that omega-6 PUFAs are a driver of the obesity epidemic is evidence that greater consumption of these fats is consistent with their predicted

[19] For example, Giuntella, Rieger, and Rotunno (2020) document that obesity in Mexico is driven in part by imports of "prepared foods" from the United States. Similarly, Currie et al. (2010) show that fast food restaurant supply causes obesity. In epidemiology, Bethancourt et al. (2019) document a fattening of an Amazonian hunter-gatherer tribe after the introduction of "market-based" food.

[20] The primary argument here is that seed oils did not exist prior to 1900.

health effects. As mentioned above, omega-6 PUFAs have been experimentally shown to reduce LDL cholesterol. In addition, consumption of linoleic acid has also been experimentally shown to result in higher concentrations of the same in body fat (Dayton et al., 1966, Figure 6).

Johnson et al. (1993) and Gao et al. (2023) show a secular decline in LDL cholesterol levels over the period of 1960–2022 using data from NHANES. Appendix Figure C.5 shows a 14% decline in average LDL since 1999 using NHANES. Guyenet and Carlson (2015) show that body fat concentrations of omega-6 PUFAs have increased alongside the increased levels of consumption of the same. Both declining cholesterol levels and increasing body fat concentrations of omega-6 PUFAs are consistent with what biochemistry predicts would happen if intake of omega-6 PUFAs increased.

3.3.2 Cohort and life cycle trends in body weight and obesity are consistent with the seed oil hypothesis

Cohort trends presented in Figure 2 point to increased rates of childhood obesity. On this point, evidence suggests that excessive exposure to omega-6 PUFAs while young can lead to permanent changes in metabolism and body composition (Hulbert, 2023, pp. 114–116). This is particularly significant given that the number of fat cells is established during childhood and adolescence and remains relatively constant throughout adulthood (Spalding et al., 2008). Thus, early exposure to an obesity-inducing environment could have more profound effects on adulthood obesity compared to similar exposure in young adulthood.

The gradual increase in obesity rates and body weight—both within and across cohorts—is consistent with the hypothesis that the obesity epidemic is driven by a slow and steady increase in consumption of omega-6 PUFAs. This aligns with findings that changes in adult fat mass occur primarily through enlargement of existing fat cells rather than an increase in the number of fat cells (Spalding et al., 2008). The long lifespan of fat cells (median age of about 10 years) further supports the idea of gradual fat accumulation over time, potentially due to continuous exposure to dietary factors like seed oils. While other explanations for obesity trends could also be consistent with these observations, the seed oil hypothesis provides a coherent framework for understanding these patterns.

3.3.3 Animal science experiments confirm the role of omega-6 PUFA in altering body composition and increasing body mass

While the results of Alvheim et al. (2012, 2014) show the health impacts of seed oils in mice, it is also noteworthy that similar findings exist for cows (Klopatek et al., 2022) and pigs (Averette Gatlin et al., 2002). Specifically, animals that were fed greater amounts of linoleic acid had greater amounts of linoleic acid in their body tissue and gained more body mass. These findings across different species, combined with the above discussion, further support the idea that increased consumption of seed oils high in linoleic acid could be behind the obesity trends in humans.

Further evidence supporting the metabolic harm of excess omega-6 PUFA intake comes from studies using mice that were genetically engineered to convert omega-6 PUFA to omega-3 PUFA (Kang et al., 2004). When fed a high-omega-6 diet, the engineered mice showed reduced weight gain, decreased fatty liver development, and improved glucose tolerance compared to wild-type mice (Kim et al., 2012; Smith et al., 2010). Additionally, they also exhibited lower levels of inflammation and oxidative stress (Li et al., 2016). These findings underscore the importance of dietary fat composition on health outcomes, and PUFA composition specifically.

4 Economic dynamics reinforcing seed oil consumption

Having established a potential relationship between obesity rates and consumption of seed oils, I now turn to the question of how these oils have become so prevalent in the first place by examining the roles of various economic actors and forces. I first describe the information environment. Then I discuss production incentives, consumption incentives, and the incentives of government and drug companies.

4.1 Information Flows and Asymmetries

Figure 6 graphically depicts the various information and incentive flows and forms the basis of my conceptual model. Central to the model is a pool of information which is supplied by scientific researchers. Food and drug companies, government, medical educators, medical providers, and scientists all draw on the information pool to inform their decisions. However, the information pool can be distorted by the fact that food and drug companies themselves fund some of the research that contributes to the pool (Lexchin et al., 2003; Nestle, 2016). This has implications for which policies and recommendations the government will choose to promote. I model consumers as uninformed and relying on messaging from food and drug companies, government, and medical providers for guidance on healthy behaviors.

4.2 Food Production Incentives

Incentives to produce seed oils come at three margins: (*i*) factor market production economies (to produce the seed oil commodities from raw plants); (*ii*) advantages in final production conferred by enhanced food formulation properties; and (*iii*) responses to government food regulations and consumer activism.

4.2.1 Factor Market Production Economies

Key to the factor market is that plant-based fats tend to be more economical and resource-efficient than animal-based fats. Plant-based fats typically have lower climate, land, and water use than animal-based alternatives (Liao et al., 2020) and may also be more efficient to extract and process. This resource efficiency then translates to lower production costs, potentially driving down prices if the market is highly competitive.

In addition to economies of scale in seed oil production, there are also economies of scope. In fact, seed oil processing closely resembles crude petroleum processing. A single crop of oilcrop seeds can be used to produce not only seed oils, but also animal feed, emulsifiers, components for cosmetics, biodiesel, and much more (Karak, 2012).

4.2.2 Advantages in Food Formulation

Final goods producers also see production advantages to using seed oils. Not only are they cheaper, but they are also more versatile in creating many different textures and can be blended with other products to lengthen shelf stability and enhance product uniformity.

These last two properties are particularly useful for product branding and value.

4.2.3 Response to government regulations and consumer activism

As discussed at the beginning of this paper, there is a long history of food companies innovating beyond the knowledge frontier of foods' health effects. A key objective of food companies is minimize costs while at the same time producing food that consumers will eat. Food chemists who develop new products may not consider the health impacts of new food formulations, paying attention only to getting around the constraints imposed by regulations or consumer activists. This is exactly what led to the rise in trans fats (Robins, 2018, p. 340) and also with the response to the trans fat ban (Korver and Katan, 2006).

4.3 Consumption Incentives

Incentives for consuming seed-oil-based foods largely come in the form of reduced price or food preparation time costs, increased shelf life, and improved convenience and portability. Seed oils also form the backbone of nearly every restaurant food, especially fast food.

Beyond cost and convenience, there are other economic factors at play. These include habit persistence, social norms, perceived health benefits, environmental and ethical considerations, and dietary restrictions. Habit persistence and social norms may increase seed oil consumption due to establishing baseline tastes or cultural traditions tied to seed-oil-based foods.[21] The long history of medical and government promotion of vegetable oils as improving health also influences consumption decisions. The recent rise in awareness of environmental and animal welfare also favors consumption of plant-based fats. Finally, seed-oil-based foods tend to be more dietarily inclusive, meaning that they can be shared in larger groups without infringing on allergies or personal preferences.

[21] Indeed, Hut (2020) finds that American households change their food consumption very little when moving to a new area, consistent with habit persistence. Hut and Oster (2022) further support this argument by showing that households tend to make gradual changes to their diet over time.

4.4 Governmental Oversight

Government plays a critical role in determining the content of the food supply by mediating between the different actors. Oilcrop subsidies, food and drug regulations, funding of scientific research, and health and nutrition recommendations are all ways in which government influences production and consumption of seed oils. As mentioned earlier in the discussion of Figure 6, government interacts with food and drug companies through regulation and lobbying and with farmers through subsidies. Regulations include food product labeling requirements, safety standards, or drug approvals.

4.5 Drug Companies' Incentives

Drug companies also play an indirect role in dietary and health recommendations eventually given to consumers. First, like food companies, drug companies directly fund scientific research, which may distort the quality of information. Drug companies also interact with the government in a similar manner as food companies. Beyond this, drug companies also partially fund medical education in the United States (Tanne, 2007), in addition to funding continuing medical education of seasoned physicians (Avorn and Choudhry, 2010) and being able to advertise directly to consumers (Donohue, Cevasco, and Rosenthal, 2007). The sum total effect of all of this is that consumers may receive health advice from medical providers that favors pharmaceutical solutions to illness. Furthermore, drug companies may elect not to develop new treatments that could reduce demand for their existing, profitable medications.

5 Counterarguments and other explanations

While the evidence presented so far supports the hypothesis that high consumption of seed oils is a major driver of the obesity epidemic, there are several counterarguments and alternative explanations that are worth discussing here. These include within-country geographic variation in obesity rates, across-country geographic variation in obesity rates, the role of environmental contaminants, and other potential explanations.

5.1 Within-country geographic variation

There is substantial and persistent variation in obesity rates across US states. In 2022, the most-obese state (West Virginia, 41%) had an obesity rate over 60% (15 percentage points) higher than that of the least-obese state (Colorado, 25%).[22]

This geographic variation is not easily explained by differences in food supply alone. Allcott et al. (2020) find that supply-side factors account for only about 10% of the nutritional inequality between high- and low-income households, with demand-side factors playing a more significant role. However, Hut (2020) demonstrates a correlation between less healthy grocery purchases and higher levels of obesity.[23] This suggests that local food environments may still play a role, albeit indirectly through shaping consumer preferences and behaviors.

The persistence of these geographic differences over time further complicates the picture. Figure 7 illustrates the strong correlation between state-level obesity rates in 2000 and 2022, resulting in stable rankings over time. This persistence aligns with recent research by Bor et al. (2024), which highlights the influence of area-level human capital on health outcomes, including obesity, through enduring place-based factors and health-related behaviors.

While the seed oil hypothesis may not fully account for the persistent cross-state variation in obesity rates, it remains consistent with the overall upward trend observed across nearly all states. Figure 7 shows that the obesity rate of *every* state aside from Washington, DC has increased by at least 40% (9 pp) since 2000, with five states more than doubling their rates (Delaware, Minnesota, Montana, Oklahoma, and Virginia). This common increase suggests that, while local factors contribute to baseline differences, a common national trend—potentially linked to changes in dietary composition such as increased seed oil consumption—may be driving the overall rise in obesity rates.

[22] See `https://www.cdc.gov/obesity/php/data-research/adult-obesity-prevalence-maps.html` (accessed August 23, 2024). These numbers are based on the Behavioral Risk Factor Surveillance System (BRFSS) which uses self-reported height and weight but is considered to be reasonably comparable to NHANES (Hsia et al., 2020).

[23] Unfortunately, his definition of "healthy" foods is independent of seed oil content.

5.2 Across-country geographic variation

There is also substantial variation in obesity rates across countries. Some of the most-obese countries are in the South Pacific and Middle East. According to the Global Health Observatory, the United States ranks 14th worldwide in obesity. If seed oil consumption drives obesity, then we would expect the food supply of seed oils to at least be correlated with obesity rates across countries.

Using data from the Food and Agriculture Organization of the United Nations (FAO) and the Global Health Observatory, Figure 8 shows a weak relationship between obesity rates and amount of seed oils in the food supply. The correlation is just 0.2 and there is little visual evidence of a relationship.

However, it is difficult to make comparisons using this data. As with US states, there has been a general upward trend in obesity rates worldwide, as depicted in Figure C.6. Only France and Spain have lower obesity rates in 2022 than in 2000.

5.3 Environmental contaminants and food additives

Another relationship that the seed oil hypothesis overlooks is the role of environmental contaminants and food additives in obesity. While seed oils are easily oxidized in the body (as explained in Section 3.1.3), there are many other substances that have also been shown to disrupt the body's metabolism and lead to weight gain. On the chemical side, these include air pollution (PM2.5), cigarette smoke, nicotine, petrochemicals (e.g. BPA, phthalates, microplastics), pesticides, and animal antibiotics (Simmons, Schlezinger, and Corkey, 2014; Bikman, 2021; Willis et al., 2022). On the food additive side, flavor enhancers, artificial sweeteners, and artificial colors are thought to contribute to obesity (Ibid.).

There is evidence that exposure to certain chemicals can disrupt the endocrine system and lead to weight gain (Song et al., 2014; Biemann, Blüher, and Isermann, 2021; Völker et al., 2022; Grandjean et al., 2023). For example, bisphenol A (BPA) is a chemical used in the production of plastics that has been linked to obesity and other health problems. Similarly, phthalates, which are used in a variety of consumer products, have been associated with weight gain and metabolic disorders.

Another similar line of argument put forth by a pseudonymous internet blog (Slime Mold Time Mold, 2024) is that increased trace exposure to lithium—in the water supply, food products, and from industrial sources such as fossil fuel prospecting—is responsible for the obesity epidemic. The reasoning behind this claim is that lithium is known to cause weight gain in patients taking it as a medication for bipolar disorder (Gomes-da Costa et al., 2022). Evidence in favor of the lithium hypothesis includes the sudden obesity epidemic among the Pima Indian tribe, reduced obesity rates in high-elevation areas, obesity rates across occupations (Caban et al., 2005; Gu et al., 2014), and results from testing the lithium contents of common foods, among other pieces of evidence (Slime Mold Time Mold, 2024).

5.4 Other potential explanations

Foods high in seed oils tend to also be processed foods that are generally understood by most people to be "unhealthy" or "junk" food. Indeed, folk nutrition wisdom is to "avoid the center aisles of the grocery store" where most processed foods are stocked. The data from branded food products in Figure 5 confirms this intuition. But, of course, there could be something else in food that is perfectly correlated with seed oils content that is truly driving obesity. Or there could be interaction effects between seed oils and other processed food ingredients. van Tulleken (2023) excoriates "ultra processed food" but provides little in terms of policy prescription aside from regulating food advertising and restricting how scientists and medical researchers are funded.

Beyond these vague characterizations of "ultraprocessed" or "junk" foods, Means and Means (2024) put forth several other potential explanations of obesity, including micronutrient deficiencies, microbiome disruptions, chronic stress, sleep deprivation, circadian rhythm disruptions, and increased time in thermoneutrality—the idea that humans have been spending more time in comfortable ambient temperatures, resulting in less metabolic stimulation. It is difficult to find evidence that these sorts of issues have varied in as systematic and broad-based way as the continued increase of seed oils in the food supply.

6 Path Forward

In this section, I discuss several possible policy changes and make several suggestions for how economists could contribute to future obesity research. Throughout this section, I maintain the assumption that seed oils do, in fact, cause obesity and other chronic diseases. Economists have much to contribute to this question as popular medical advice is unable to identify which actions have the greatest marginal benefits relative to their marginal costs.[24]

6.1 Nutrition labeling

One straightforward and easy-to-implement policy change would be to require food manufacturers to report the amount of omega-6 and omega-3 PUFA in their products. Manufacturers are already required to report total fat content, saturated fat content, and trans fat content. Giving consumers more information about PUFA content would enable them to make more informed decisions.[25] Indeed, Cawley (2015, p. 259) cites several studies showing that food manufacturers respond to changes in nutrition labeling requirements.

Additionally, de-emphasizing the role of calories in weight gain and instead emphasizing the composition of fats would be an improvement over the status quo. Currently, calories are the most prominent number printed on a nutrition label. Increasing the prominence of omega-6 PUFA content instead would draw consumers to the most salient information.

6.2 Government nutrition recommendations

Government nutrition recommendations also need to be adjusted, though it is unclear how politically feasible this would be. This includes guidelines for school lunches, but also definitions of which foods are "healthy." For example, as of 2024, the NHANES Healthy Eating Index (HEI)—which is used to measure diet quality of NHANES respondents, among many

[24]See, for example, Shanahan (2024) and Means and Means (2024). Both of these sources emphasize removing seed oils and refined sugars from the diet, but also emphasize the importance of avoiding environmental toxins and trace chemicals. However, they do not provide a rank-ordered list of "bang for buck" in taking these actions.

[25]Ironically, the American Heart Association (1961, p. 136) made this exact recommendation over 60 years ago, but for the opposite reason—its goal was to maximize PUFA in the diet in order to reduce blood cholesterol levels with the end goal to reducing heart disease.

other uses—penalizes SFAs and rewards consumption of MUFAs and PUFAs.[26] However, it treats MUFAs and PUFAs as perfect substitutes and does not distinguish between omega-3 and omega-6 PUFAs.

6.3 Food company formulations

One lesson from the past is that governments have not required as extensive testing of new product formulations as they probably should have. The introduction of Crisco in 1911 is a prime example. Another example is the fight against saturated fat in the 1960s, which inadvertently led to the rise of trans fats by the 1980s as food chemists discovered ways to substitute partially hydrogenated unsaturated fats for saturated fats. Once trans fats were accepted as harmful to human health, new forms of artificial fats or plant-based fats have grown in prominence since 2000, such as interesterified fats and palm oils. The nutritional consequences of these products have yet to be fully realized. More scrutiny of food products before they become broadly introduced into the food supply would help to reduce these sorts of trial-and-error costs.

6.4 Taxes and subsidies

If seed oils are indeed causing obesity, then taxing their use may be successful at reducing overall supply and consumption. Additionally, removing oilcrop subsidies may also prove beneficial. However, as Allcott, Lockwood, and Taubinsky (2019) show, there are many complexities in arriving at an efficient amount of tax or subsidy on foodstuffs.

6.5 Other restrictions

Other policies could follow alcohol and tobacco legislation by restricting minimum age of seed oil consumption, placing restrictions on how seed-oil-rich foods can be advertised, or restricting locations in which they can be consumed. The difficulty with seed oils is that they nearly universally mixed into all manufactured foods, which presents logistical problems.

[26] See Allcott et al. (2020), O'Connell, Smith, and Stroud (2022), and Bitler et al. (2023) (among many others) for papers in the economics literature that have used the HEI to quantify diet quality. See https://www.fns.usda.gov/cnpp/how-hei-scored for how the HEI is defined.

6.6 New tradeoffs?

The primary hypothesis of this paper is that overconsumption of omega-6 PUFAs in vegetable seed oils has led to increased rates of obesity. Moving away from seed oils would likely entail greater consumption of saturated fats, either from plants (palm, coconut) or animal sources. The tradeoff is that these alternative sources may be more resource-intensive to produce than soybeans or other oilcrops, though I could not find an established literature on this topic. Greater resource-intensivity of saturated fats would imply greater costs of final goods sold, due to greater input costs. Additionally, it would imply greater consumption of animal products and resource-intensive plant products.

Thus, moving away from seed oils may pose several tradeoffs between improved human health at the cost of more expensive food, less environmentally friendly production (Errickson, Kuruc, and McFadden, 2021), and/or less animal-friendly production (Kuruc and McFadden, 2023). These tradeoffs would be in addition to the large costs of adjusting food manufacturing and distribution processes.

7 Conclusion

I argue in this paper that excessive consumption of vegetable seed oils high in omega-6 PUFAs is driving the continued growth of obesity in the United States. Several pieces of evidence from biochemistry and data on the US food supply support my claims. I provide greater insight into the economic forces driving the growth in seed oils in the food supply by presenting a conceptual economic model centered on information asymmetries. The interconnected nature of the various incentives of the government and food and drug companies means that displacing seed oils from the food supply will require substantial, coordinated effort.

While the causal link between seed oils and obesity is not iron-clad, it is clear that something in the status quo needs to change. Food companies appear to be using seed oils in product formulations at increasing rates, while drug companies have begun distributing GLP-1 agonist drugs (e.g. semaglutide [brand name: Ozempic]). Neither of these addresses the fundamental problem of what is ultimately causing obesity.

A key part of the fundamental problem is the continued characterization of saturated fat as bad for human health.[27] This is tightly linked with the idea that elevated levels of cholesterol in the blood lead to heart disease, when in fact there is strong evidence that it is *oxidized* LDL cholesterol—caused by seed oils and other oxidizing metabolic disruptors—that is the problem (DiNicolantonio and O'Keefe, 2018). Until this is cleared up, obesity rates will likely continue to remain high in the absence of pharmaceutical intervention.

Economists have much to contribute to furthering our understanding of obesity. For example, economists can study the effects of retrospective or prospective changes in food labeling, government nutrition recommendations, or public health policies. They can also leverage their knowledge of political economy and analyze the landscape of taxes and subsidies to find areas of improvement. Additionally, dynamic general equilibrium models from macroeconomics could prove to be applicable to "systems biology" approaches to health which view the human body as an economy of interacting components (Hood and Price, 2023).

Looking forward, recent technological advances may prove beneficial to discovering the truth about obesity's source. Innovations in health sensing, along with maturing of the internet, have enabled citizen scientists to contribute knowledge based on self-experimentation and informal clinical trials.[28] Innovation in artificial intelligence may make it possible to deliver individualized health recommendations, and emerging technologies such as lab-grown meat or chemosynthetic food (Davis et al., 2024) may offer a scalable dietary fat alternative to vegetable seed oils.

[27]See Lee et al. (2022) and Walrabenstein et al. (2022) for a recent back-and-forth on this topic. The American Heart Association continues to promote vegetable seed oils as healthy (Sacks et al., 2017; American Heart Association, 2024).

[28]See, e.g. Slime Mold Time Mold (2022) and Experimental Fat Loss (2023), among others.

Generative AI Disclosure Statement

I utilized multiple Generative AI tools (Elicit; OpenAI's GPT-4 [including through GitHub Copilot]; and Anthropic's Claude 3 Opus and Claude 3.5 Sonnet models) in the production of this manuscript, in the following ways:

- Producing computer code for data cleaning and analysis
- Locating relevant research articles in the literature
- Summarizing findings of research articles in the literature
- Succinctly explaining complex biochemical pathways beyond my immediate expertise
- Brainstorming ideas and outlining the structure of the paper
- Proposing sentences to include in the manuscript
- Improving the organization, conciseness and clarity of the writing

I have carefully reviewed all aspects of the manuscript for accuracy and coherence. All errors are my own.

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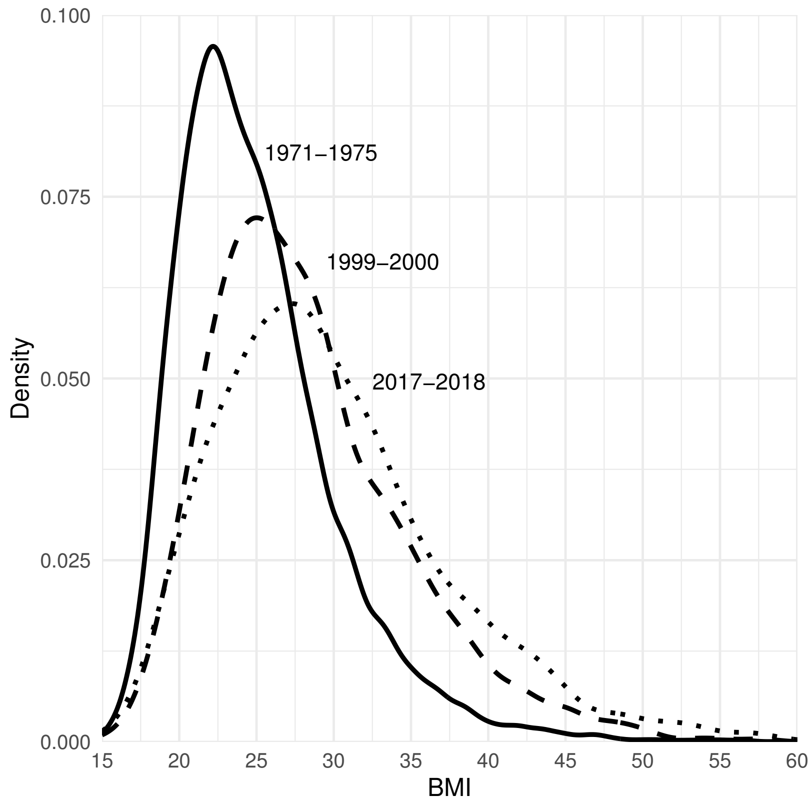
Figures and Tables

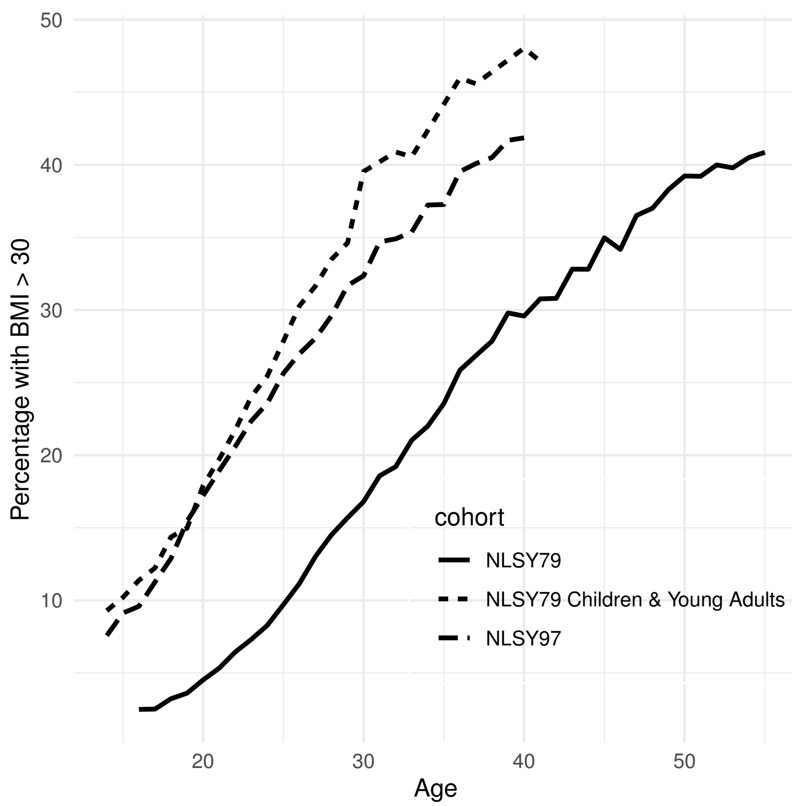
Figure 1: BMI Distribution for Three NHANES Waves



NOTES.—Sample restricted to adults aged 20–55.

SOURCE.—National Health and Nutrition Examination Survey (NHANES) data from the Centers for Disease Control and Prevention.

Figure 2: Life Cycle Obesity Rates (%) Across Three NLSY Cohorts

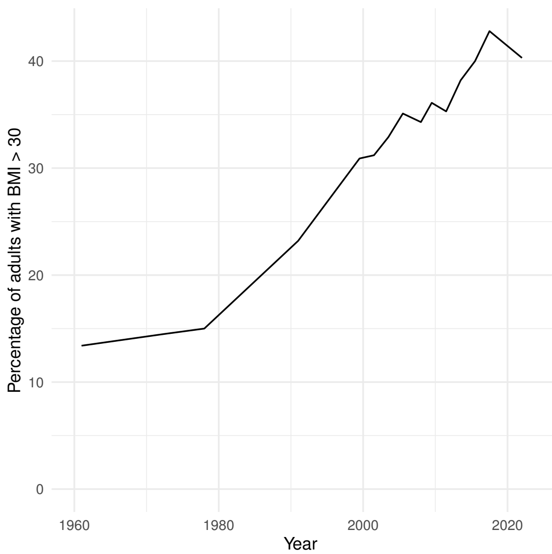


Notes.—Obesity rates are calculated as the percentage of individuals with a body mass index (BMI) of 30 or higher, where BMI is computed using self-reported body weight and height. I restrict to cohort-age cells that have at least 300 observations. The NLSY79 cohort are born in 1957–1964, the NLSY97 cohort are born in 1980–1984, and the NLSY79 Children and Young Adults cohort are born in 1970–1997.

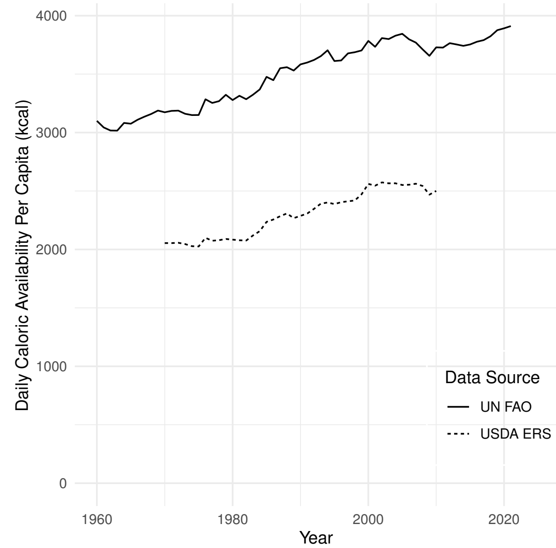
Source.—National Longitudinal Survey of Youth (NLSY) data from the Bureau of Labor Statistics.

Figure 3: US Adult Obesity Rate, Caloric Availability and Exercise, 1960–2022

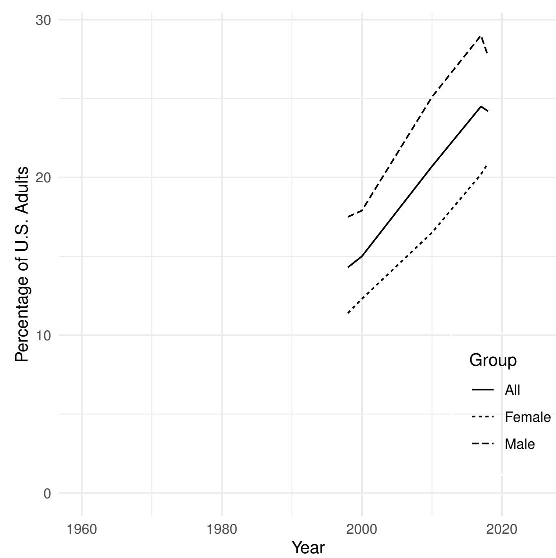
(a) Obesity rate (%)



(b) Per-capita daily availability of calories (kcal)



(c) Percentage of adults who meet the 2008 American physical activity guidelines for both aerobic and muscle-strengthening

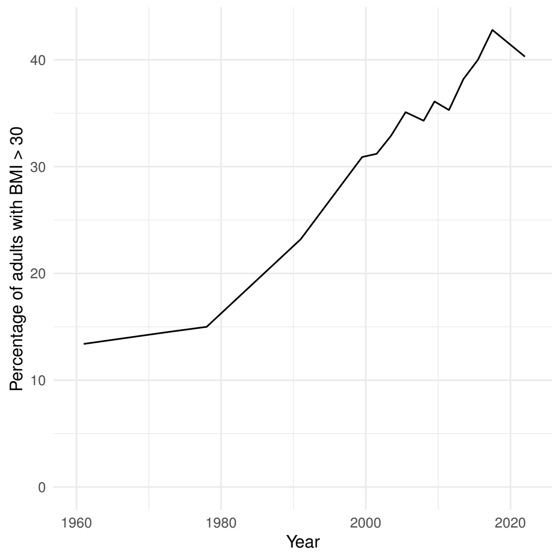


Notes.—Caloric availability is a measure of the total amount of food available for human consumption and is an estimate of total consumption. The USDA figure is adjusted for spoilage and waste.

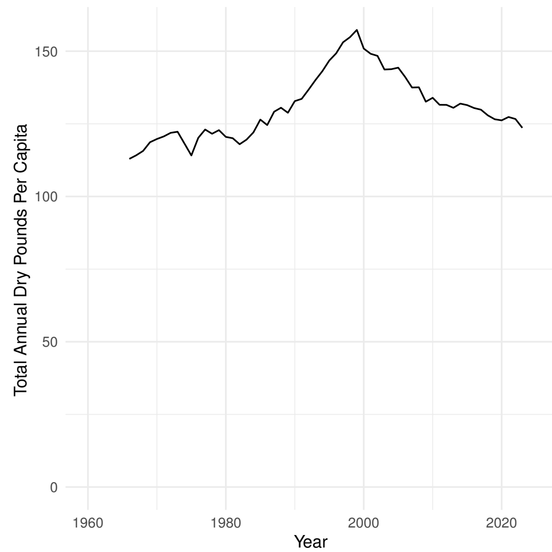
Sources.—Obesity rate data from Fryar, Carroll, and Afful (2020) and Emmerich et al. (2024). Caloric availability data from the USDA Economic Research Service or the United Nations Food and Agriculture Organization, accessed via the website “Our World in Data.” Data on physical exercise is taken from the National Center for Health Statistics’ National Health Interview Survey, Family Core and Sample Adult questionnaires.

Figure 4: US Adult Obesity Rate, Availability of Caloric Sweeteners, and Disappearance of Seed Oils, 1960–2022

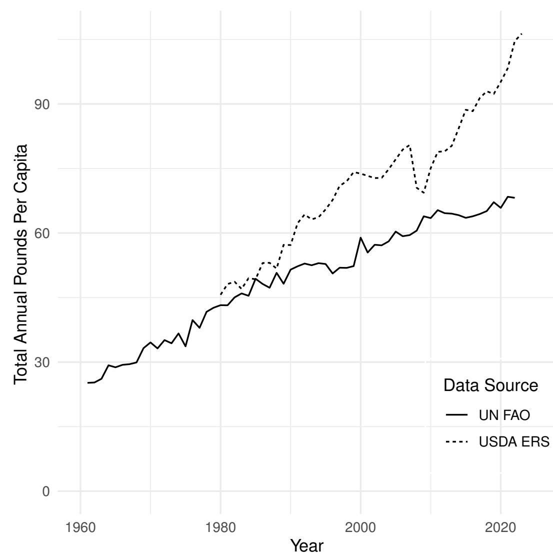
(a) Obesity rate (%)



(b) Per-capita annual availability of caloric sweeteners (lbs.)



(c) Per-capita annual disappearance of seed oils (lbs.)

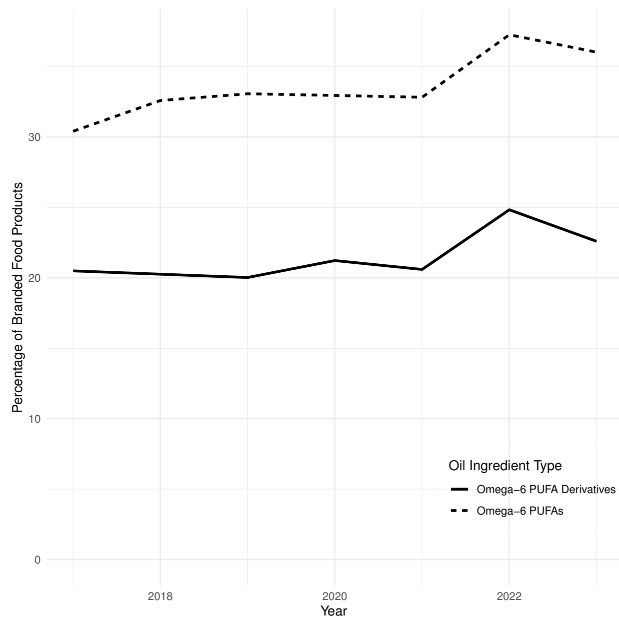


Notes.—Caloric sweeteners include cane/beet sugar, high fructose corn syrup, and other sweeteners such as honey. Seed oils refer to canola, corn, cottonseed, soybean, and sunflower oils.

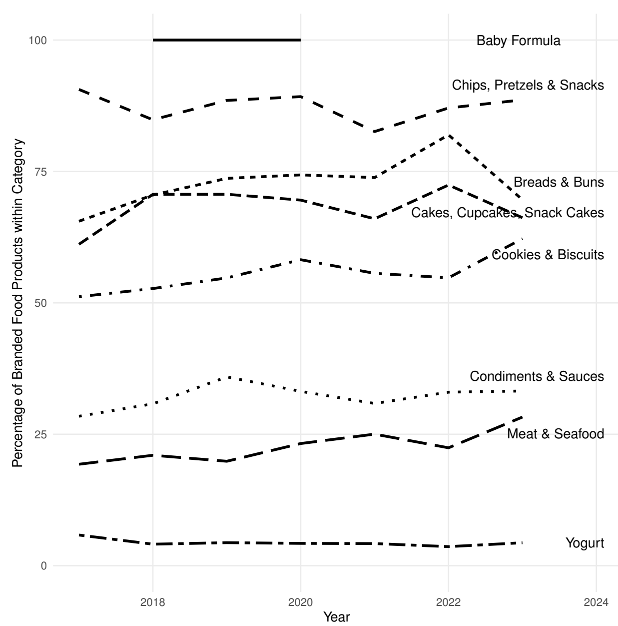
Sources.—Obesity rate data from Fryar, Carroll, and Afful (2020) and Emmerich et al. (2024). Data on caloric sweetener availability and seed oil disappearance comes from the USDA Economic Research Service and/or the Food and Agriculture Organization of the United Nations. FAO data is adjusted as described in Appendix A.

Figure 5: Incidence (%) of Omega-6 PUFAs in Branded Foods, 2017–2023

(a) Overall incidence of omega-6 PUFAs and their derivatives



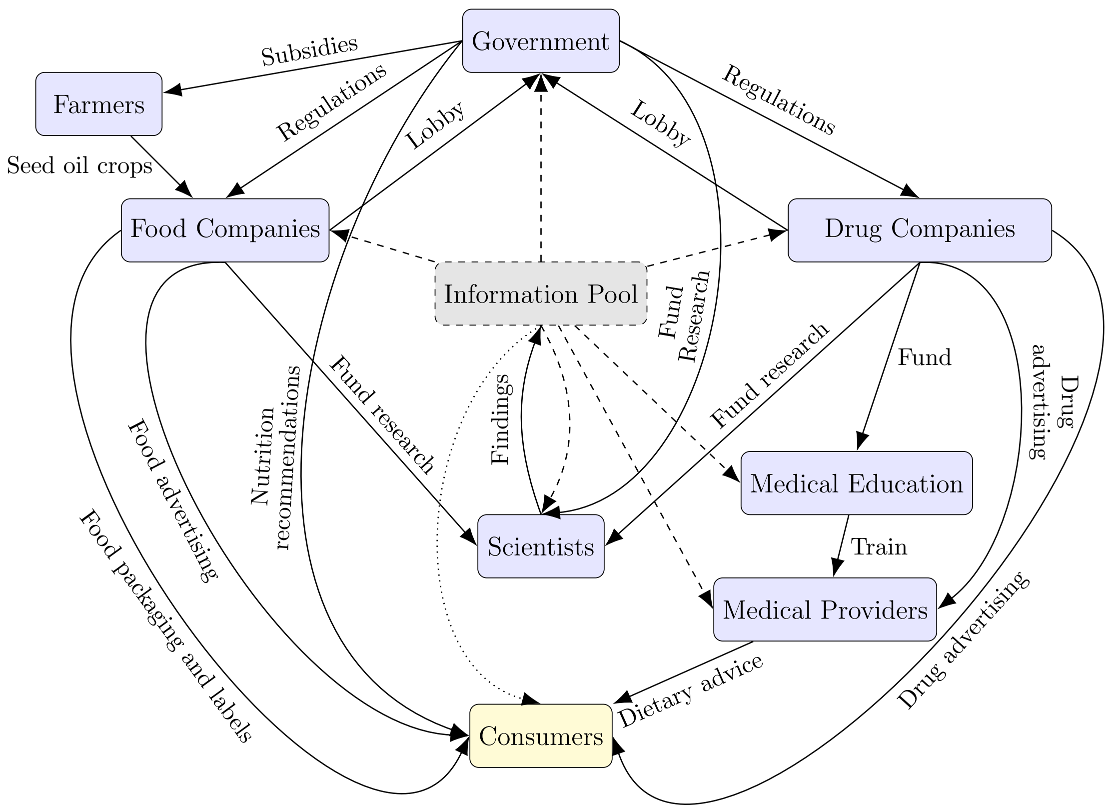
(b) Overall incidence by food category



Notes.—This figure reports the percentage of branded food products that contain any seed oil in their ingredient lists. These include corn, canola, cottonseed, sunflower, soybean, safflower, grapeseed, rice bran, and seed oil derivatives. Derivative products include lecithins, polysorbate, and mono and diglycerides.

Source.—USDA Branded Foods database, accessed from the FoodData Central website (https://fdc.nal.usda.gov/index.html).

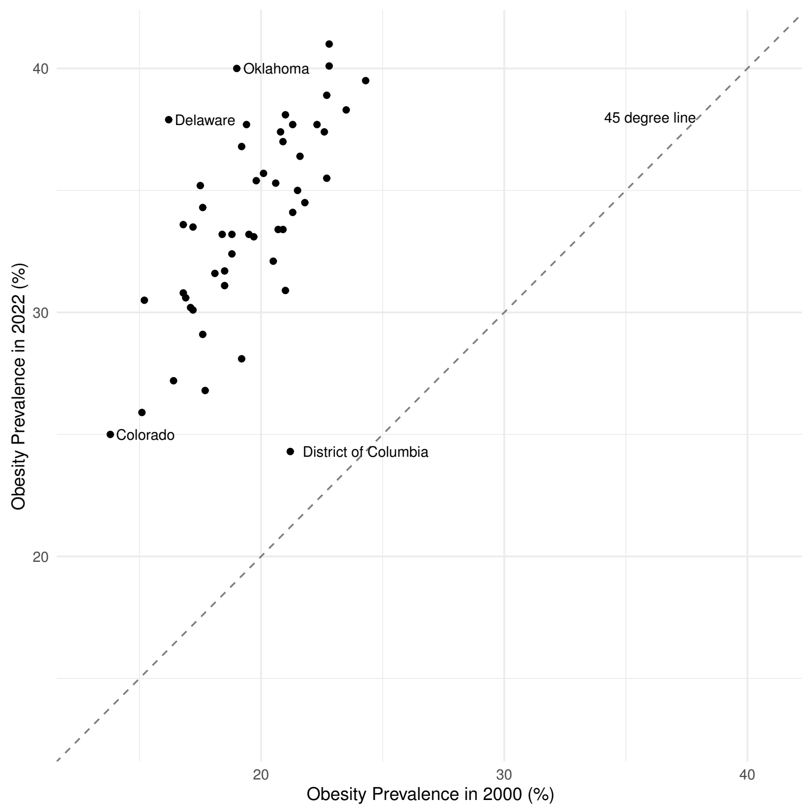
Figure 6: Information and Incentive Flows Influencing Seed Oil Consumption



Notes.—Dashed lines indicate flows out of the information pool. The dotted line from the information pool to consumers emphasizes that the corresponding flow may be lower than other flows out of the information pool due to consumer inattention and lack of expertise.

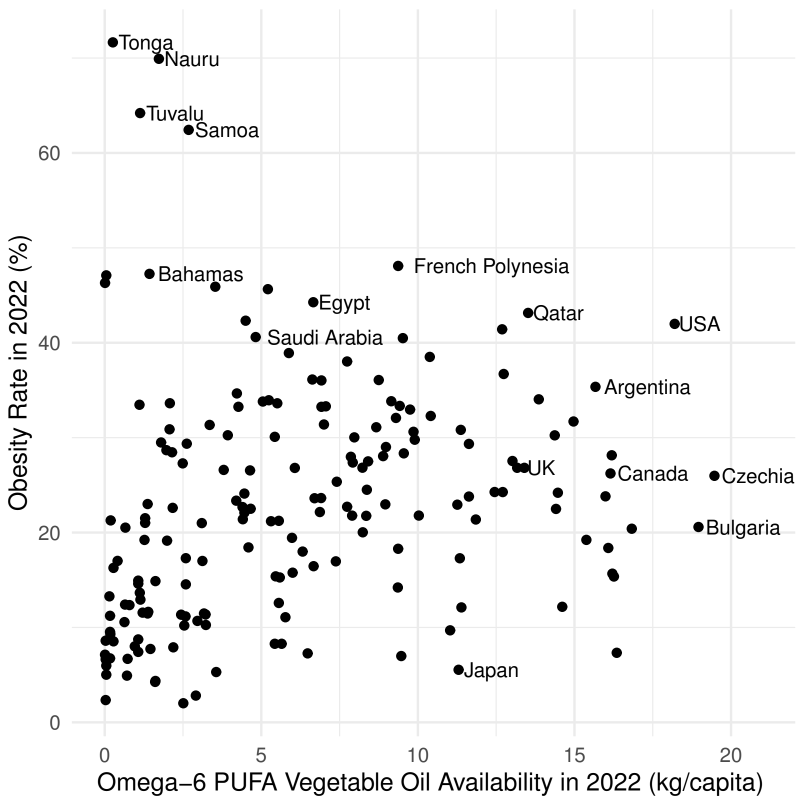
This figure depicts how information influences governments, farmers, food producers, pharmaceutical companies, and medical providers. Scientists contribute their research findings to the information pool. Then, the government, food producers, pharmaceutical companies, and medical providers draw on the information pool when making production decisions or policy recommendations. Consumers may also have access to the information pool directly, but primarily rely on the other actors for advice on what to eat or how to behave (including the media, which is not explicitly depicted here).

Figure 7: State-level Adult Obesity Rates in 2000 and 2022



Sources.—Obesity rates in 2000 come from Mokdad et al. (2001). 2022 rates come from https://www.cdc.gov/obesity/php/data-research/adult-obesity-prevalence-maps.html (accessed August 23, 2024). Both sources are originally based on self-reported height and weight in the Behavioral Risk Factor Surveillance System (BRFSS) data.

Figure 8: Country-level Adult Obesity Rates vs. Country-level supply of seed oils, 2022



Sources.—Obesity rates in 2022 come from the World Health Organization's Global Health Observatory data repository. Supply of seed oils is calculated as the total amount of canola, corn, cottonseed, soybean, and sunflower oils, as reported by the Food and Agriculture Organization of the United Nations.

Appendices

A Harmonization of FAO account data

In this appendix, I briefly describe my method of harmonizing the UN FAO food supply data referenced in panel (c) of Figure 4 and panel (f) of Appendix Figure C.3. In 2010, the FAO changed its accounting methodology in order to improve its measurement of food availability (Piva, Conforti, and d'Ortigue, 2024). This results in discontinuities in the time series beginning in 2010, although FAO used both methodologies over the 2010–2013 period to aid in harmonization.

Vonderschmidt et al. (2024) analyze the differences between the old and new methodologies and find that, in some cases, simple adjustments to the time series result in comparable measurements across the two. However, they also caution against broad-based adjustments over different foods within the same country, or different countries within the same food, because the accounting differences may not be the same.

In the body of this paper, I use the following six seed oil accounts tracked by the FAO since 1961: canola; corn; cottonseed; soybean; sunflowerseed; and other oilcrops (which definitely excludes oils from peanuts, olives, palm, palm kernels, coconuts, and sesame seeds, and possibly excludes rice bran oil).

In Appendix Figure C.7, I plot the annual pounds per capita of each of the above six seed oil accounts under both the old and new methodologies. As can be seen, there are only slight discrepancies for canola, corn, and cottonseed. However, there are large discrepancies for soybean, sunflowerseed, and other oils. In level terms, the "other" category seems to have soaked up the entire discrepancy in the soybean category.

To create the overall time series for the analyses in Figure 4 and Appendix Figure C.3, I aggregate these six oils into a single series and apply a level adjustment to the 1961–2013 period of the aggregated series. The results of this exercise are shown in Appendix Figure C.8. Treating Soybean and Other as a single oil results in only very small discrepancies across the 2010 change in methodology, which is evidence of adequate harmonization.

B Food chemistry responses to food regulation and consumer activism

This appendix section provides more context for the food industry's processes for incorporating seed oil products into food. I first describe chemically modified fats and then discuss current food industry methods for innovating vegetable oils.

B.1 Trans and interesterified fats

Independent of the molecular structure of fats (i.e. SFA, MUFA, or PUFA) are fats that have been chemically modified from their natural state for use in industrial food production. These include trans fats and interesterified fats.

Trans fats are unsaturated fats (usually PUFAs) that have had some of their *cis* double bonds converted to *trans* double bonds through a process called partial hydrogenation.[B1] This process was developed in the early 20th century as a way to increase shelf stability of food, but has since been found to have significant negative health implications (Zambelli, 2021). As a result, trans fats are now largely banned in 40 countries (World Health Organization, 2021).[B2]

Interesterified fats, on the other hand, are typically made from a mixture of liquid seed oils and fully hydrogenated seed oils (originating from either MUFAs or PUFAs in both cases).[B3] These have risen in prominence in response to the ban on trans fats as a way to create fats with desirable properties for food processing (Mills, Hall, and Berry, 2017).

[B1] The terms *cis* and *trans* refer to the arrangement of hydrogen atoms around the double bond: in *cis* configuration, they are on the same side, while in *trans*, they are on opposite sides. In partial hydrogenation, some double bonds are converted to single bonds while others change from *cis* to *trans* configuration. Full hydrogenation converts all double bonds to single bonds, resulting in a PUFA that behaves like a SFA.

[B2] Some trans fats occur in nature, such as in the meat and milk of ruminant animals, but these are a tiny share of the total fat profile of any naturally derived food.

[B3] Interesterification involves rearranging the position of fatty acids that have joined together to make a triglyceride molecule. The process can use various combinations of oils and fully hydrogenated oils to achieve desired properties.

B.2 Food industry responses to trans fat bans

Aside from interesterification described above, food scientists have innovated several other alternatives to trans fats. These include innovation in both agriculture and processing. Nagpal et al. (2021) list the following: selectively breeding vegetables to produce seeds with low PUFA content; modification in the hydrogenation process; blending; fractionation; and oleogelation. For each approach, I comment on whether adoption is likely to substitute towards or away from seed oils.

B.2.1 Modification of plant seeds

One way to avoid trans fats is to use a genetically modified plant that does not produce as much PUFA. These so-called "high-oleic" breeds have lower levels of linoleic acid and are thus less prone to oxidation. However, they are not useful for products that require solid or semi-solid fat and are instead primarily useful for frying applications (Nagpal et al., 2021). Zambelli (2021) points to high-oleic sunflower oil as a key product in this category because it has extremely low levels of linoleic and α-linolenic acids. This approach to substituting trans fats reduces overall PUFA content of seed oils, but stimulates demand for seed oils.

B.2.2 Modification in the hydrogenation process

Hydrogenation is what produces trans fats from liquid oils. As such, another alternative that food chemists have looked at is to adjust the conditions under which the hydrogenation process occurs. By doing so, they can minimize the formation of trans fatty acids while still achieving the desired functional properties of the oil (Nagpal et al., 2021).[B4] This strategy may or may not result in greater amounts of PUFA in the food supply.

B.2.3 Blending

Another way to get a similar consistency to trans fats without hydrogenation is to blend unsaturated and saturated fats together in certain proportions. For example, coconut and

[B4] These adjustments include using lower temperatures, employing more selective catalysts, controlling reaction time, and utilizing alternative hydrogenation techniques. These modified processes aim to produce partially hydrogenated oils with significantly reduced trans fat content—often below 2%—while maintaining the texture, stability, and versatility that make hydrogenated oils valuable in food production.

palm oil (SFAs) have been combined with soybean oil and cottonseed oil (high in PUFAs) as well as palm kernel oil and peanut oil to produce a non-dairy creamer (Nagpal et al., 2021). This approach likely increases the amount of seed oils in the food supply.

B.2.4 Fractionation

Fractionation (also known as fractional distillation) is most commonly associated with the petroleum refining industry. However, it can also apply to vegetable oils. The idea is similar to the petroleum context: different parts of the oil will have different melting or solidifying points and can thus be separated by centrifuge or other means (Nagpal et al., 2021). The resulting oils can have similar properties of trans fats without actually containing any trans fats. This strategy has increased demand for coconut and palm oils but may also raise demand for high-omega-6-PUFA seed oils.

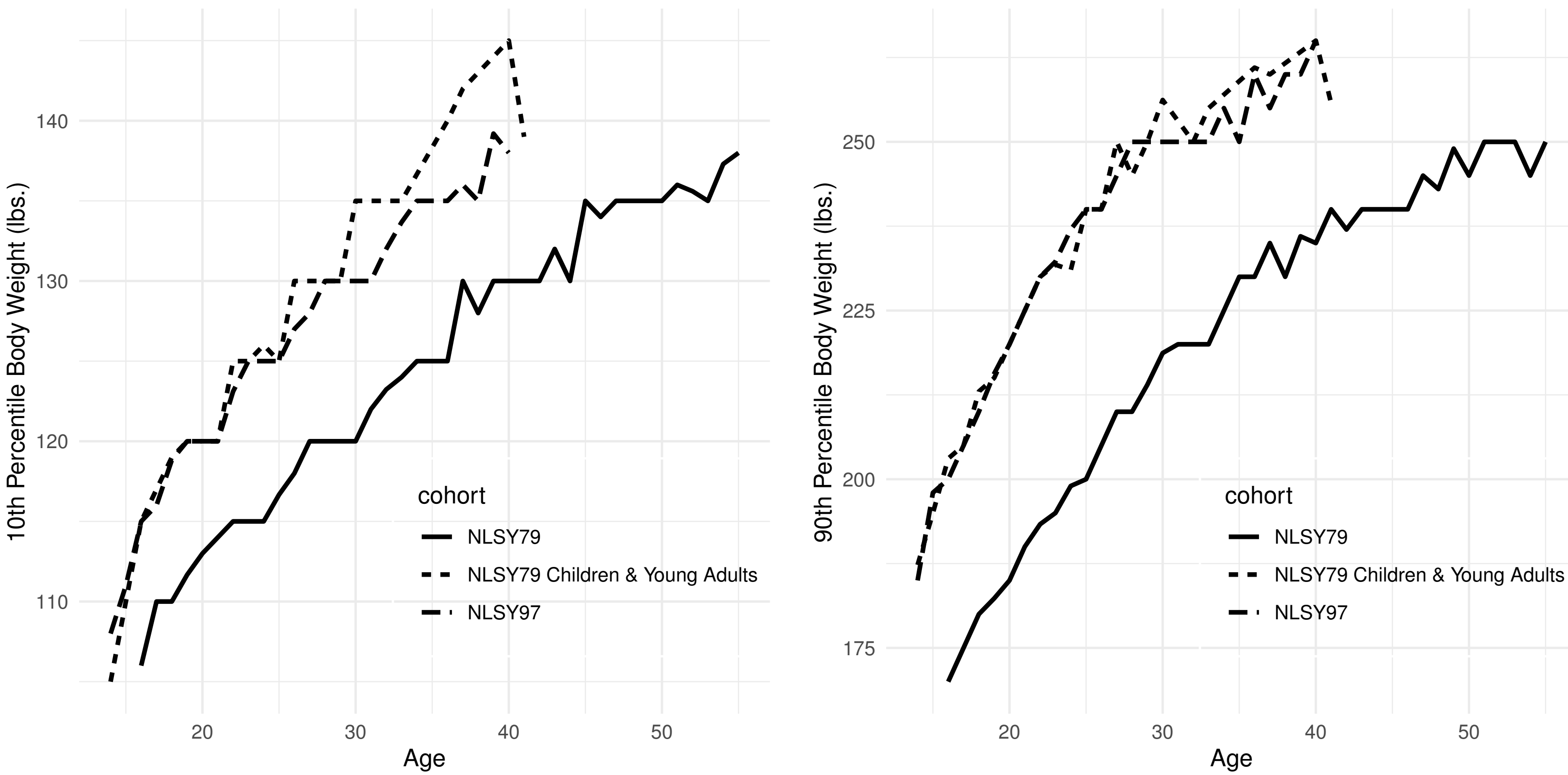
B.2.5 Oleogelation

Oleogelation is another method for getting a solid-like fat from a liquid oil. This method is particularly useful for eliminating both trans fats and SFAs (Nagpal et al., 2021). Oleogels are structuring molecules that give added stability to a liquid oil to get it to behave more like a solid. Common oleogels include cellulose (plant fiber) and waxes. This method of substituting trans fats unambiguously raises demand for seed oils.

C Supporting Figures and Tables

Figure C.1: Life Cycle Body Weight Quantiles Across Three NLSY Cohorts

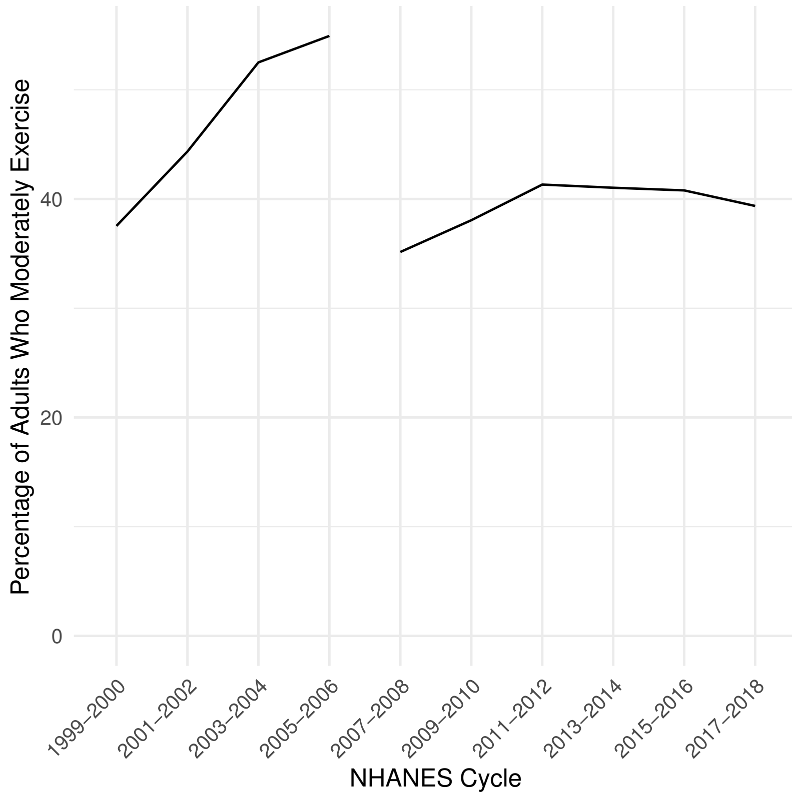
(a) 10th percentile (b) 90th percentile



Notes.—This figure reports the 10th and 90th percentiles of body weight by age as recorded in three separate NLSY survey cohorts. Body weight is self-reported. I restrict to cohort-age cells that have at least 300 observations. The NLSY79 cohort are born in 1957–1964, the NLSY97 cohort are born in 1980–1984, and the NLSY79 Children and Young Adults cohort are born in 1970–1997.

Source.—National Longitudinal Survey of Youth (NLSY) data from the Bureau of Labor Statistics.

Figure C.2: Rates of Moderate Exercise in US Adults from NHANES

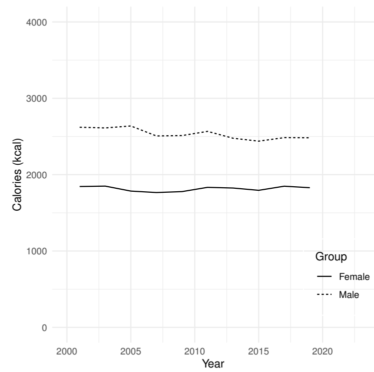


Notes.—This figure reports average rates of moderate exercise by NHANES survey year. The data is restricted to adults aged 20 and over. The NHANES methodology changed prior the 2007 survey, which is why the line does not connect. Prior to 2007, I use the variable "PAD320" and for 2007 and later, I use "PAQ665." Both variables are meant to measure whether the respondent did any moderate exercise in the past 30 days (or does so regularly), including brisk walking, bicycling, dancing, or golf.

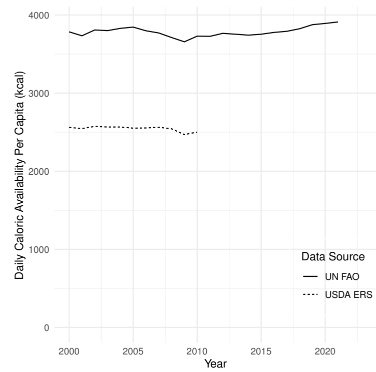
Sources.—National Health and Nutrition Examination Survey (NHANES) data from the Centers for Disease Control and Prevention.

Figure C.3: Comparison of US food diary and agricultural sales data, 2000–2022

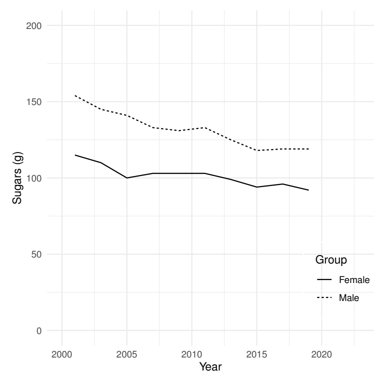
(a) Average calories consumed per day (kcal)



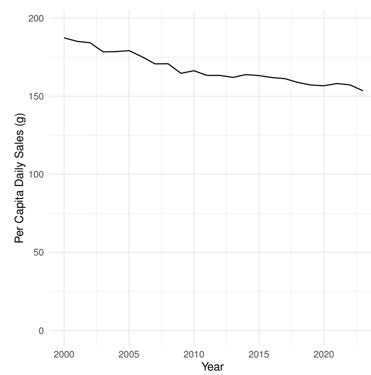
(b) Per-capita daily availability of calories (kcal)



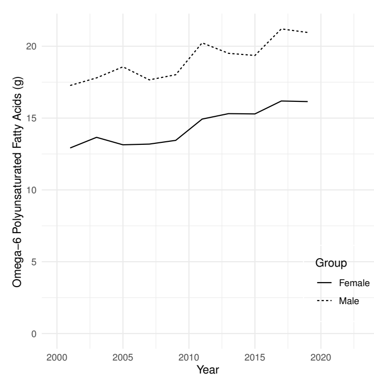
(c) Average sugars consumed per day (g)



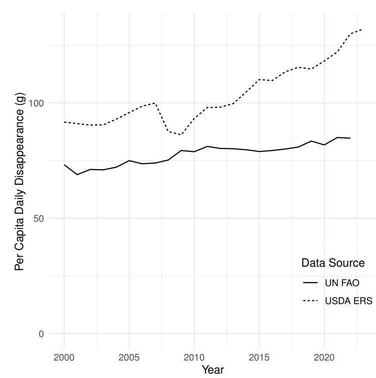
(d) Per-capita daily availability of caloric sweeteners (g)



(e) Average omega-6 PUFAs consumed per day (g)



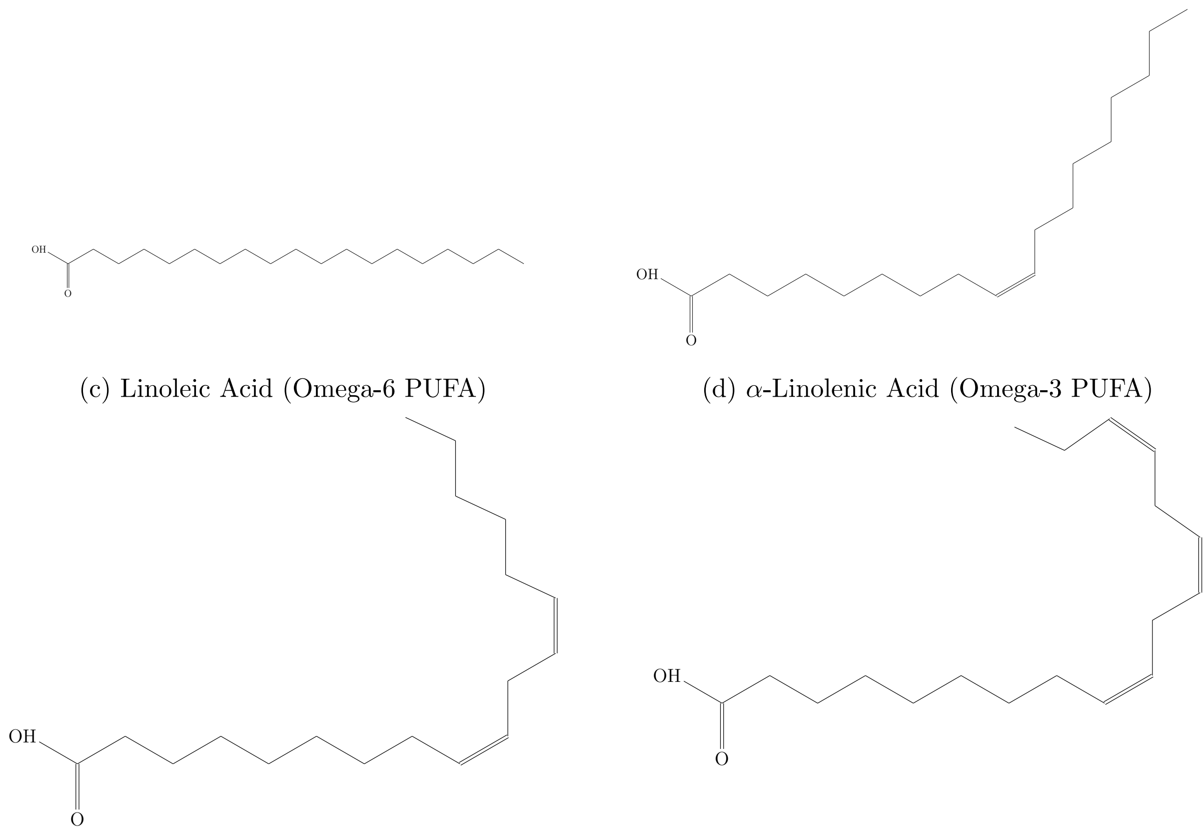
(f) Per-capita daily disappearance of seed oils (g)



Notes.—All quantities are converted to be in the same units and plotted on the same axes for ease of comparison. The lone exception is the seed oils graphs, as these scales were too far off to be comparable. One pound per annum is approximately equal to 1.24 grams per day.

Sources.—Consumption data comes from NHANES food surveys as aggregated by the USDA's "What We Eat in America," respondents aged 20 and over. Agricultural sales data comes from the USDA Economic Research Service and/or the Food and Agricultural Organization of the United Nations. See Shan et al. (2019) for a more detailed analysis of the food intake survey data.

Figure C.4: Molecular structures of common 18-Carbon fatty acids

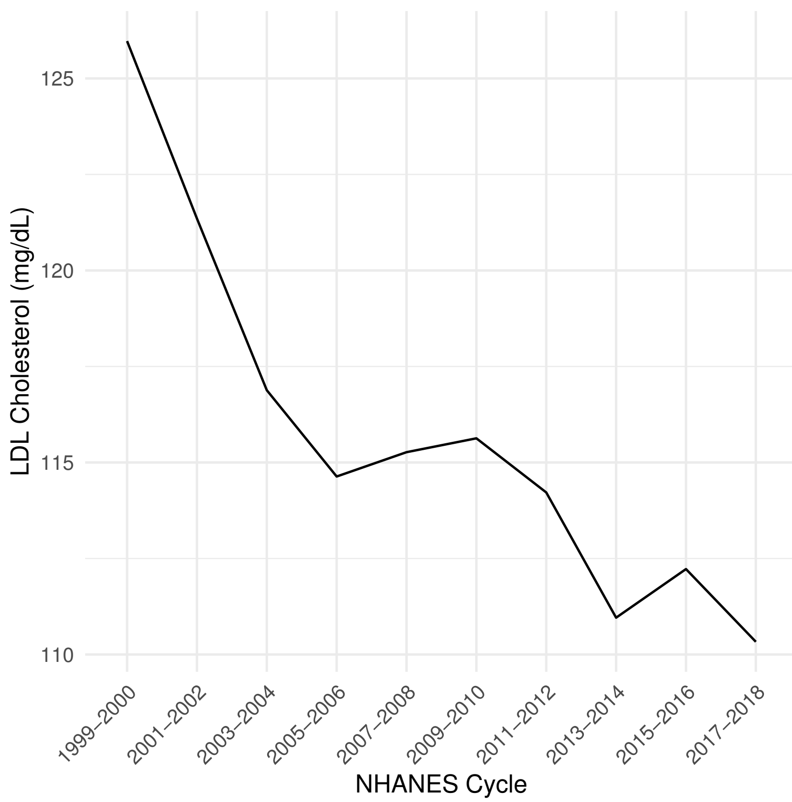


(a) Stearic Acid (Saturated)
(b) Oleic Acid (Monounsaturated)
(c) Linoleic Acid (Omega-6 PUFA)
(d) α-Linolenic Acid (Omega-3 PUFA)

Notes.—This figure depicts the molecular structure of four different fatty acid molecules, each with 18 Carbon atoms. Unlabeled nodes are Carbon atoms, which if single bonded together have two implied Hydrogen atoms attached. O stands for Oxygen while H stands for Hydrogen. When there are double bonds between carbons (indicated by two parallel lines in the bond), the angle of the atoms changes, which changes the overall shape of the hydrocarbon chain.

Source.—Author's calculations from PubChem data.

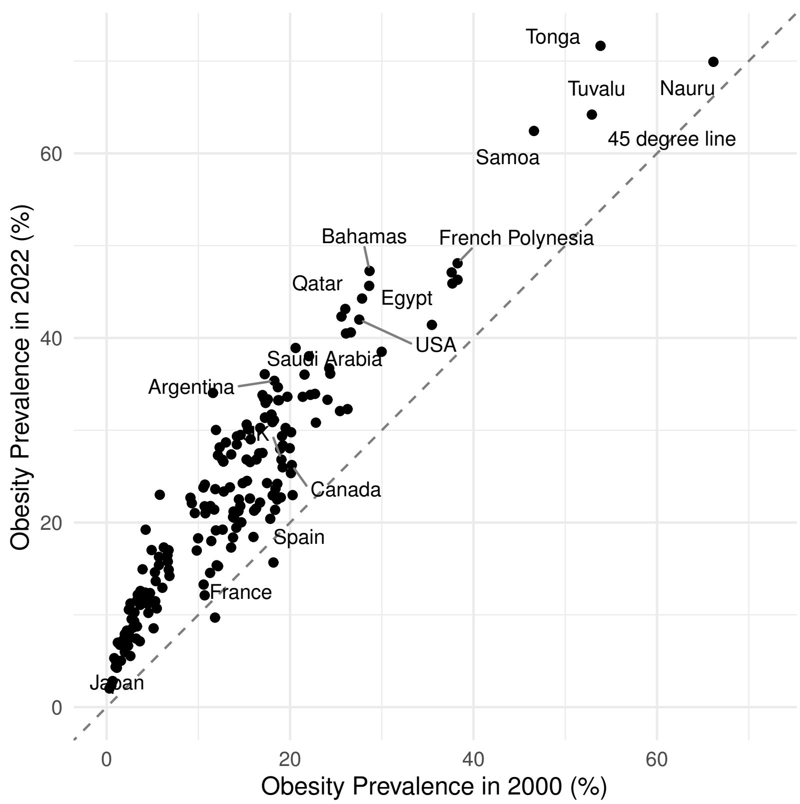
Figure C.5: LDL Cholesterol Levels in US Adults from NHANES



NOTES.—This figure reports average LDL cholesterol by NHANES survey year. The data is restricted to adults aged 20 and over.

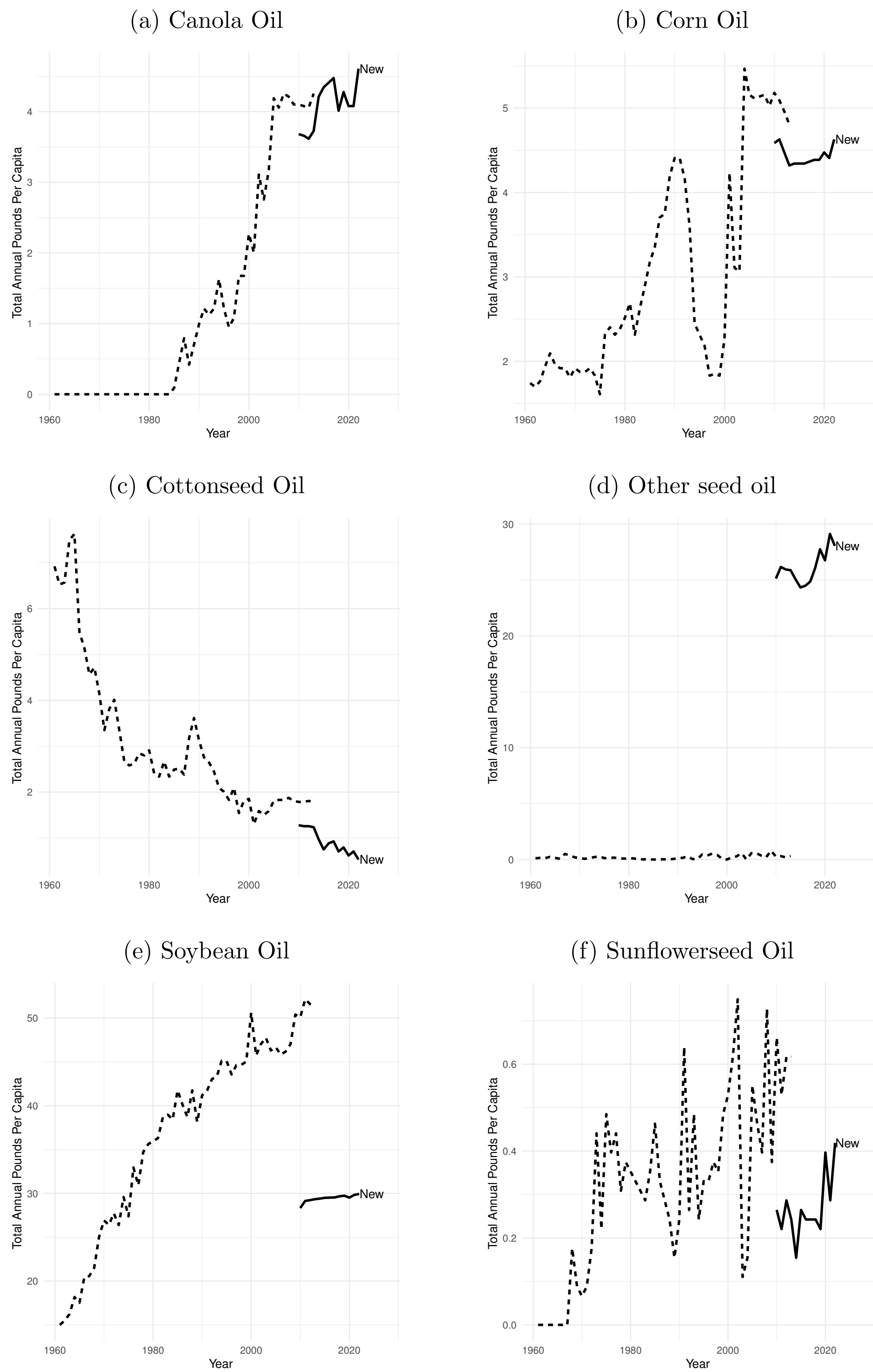
SOURCES.—National Health and Nutrition Examination Survey (NHANES) data from the Centers for Disease Control and Prevention.

Figure C.6: Country-level Adult Obesity Rates in 2000 and 2022



Sources.—Obesity rates in both 2000 and 2022 come from the Global Health Observatory data repository of the World Health Organization.

Figure C.7: Comparison of FAO's Old vs. New Methodology for Food Balance Sheets of Different Types of Seed Oils in the US



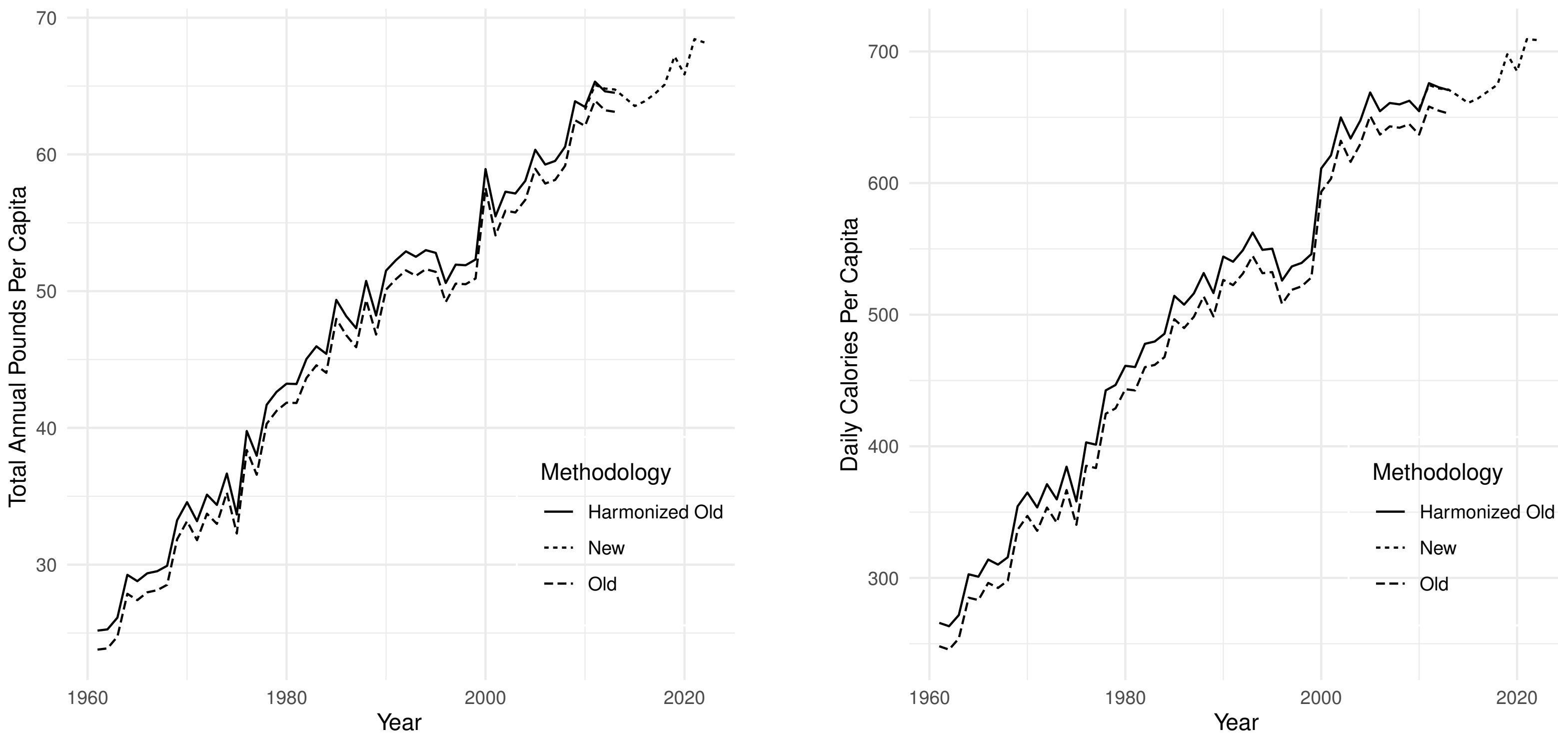
NOTES.—This figure compares different methodologies for calculating the annual supply per capita of different types of seed oils in the US.

SOURCE.—Food and Agricultural Organization of the United Nations.

Figure C.8: Comparison of FAO's Old vs. New Methodology for Food Balance Sheets of Aggregated Seed Oils in the US

(a) Supply of all seed oils

(b) Calories per day from all seed oils



Notes.—This figure compares different methodologies for calculating the annual supply per capita and daily energy per capita of aggregate seed oils in the US. Aggregation taken across all seed oils reported in Appendix Figure C.7.

Source.—Food and Agricultural Organization of the United Nations.

Appendix References

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