Regulatory Heterogeneity, Trade Mediation and Nutrient Intake: The Case of Trans Fat

Dixit Poudel
Munisamy Gopinath

Abstract

National nutrition regulations can shape diets in two distinct ways: directly, through domestic policy mechanisms, and indirectly, by mediating trade flows. This study assesses how trans fat (TF) intake is affected by both pathways. When countries act alone – by banning or limiting TF – their rules often differ in timing, stringency, and enforcement. These differences may create loopholes that allow unhealthy products to move across borders. This study estimates the causal effects of TF regulations on its intake by constructing a food-item-level panel dataset for 161 countries (2010–2022, validated with established benchmarks), and applying a staggered difference-in-differences approach combined with mediation analysis. The findings show that strict, enforceable regulations, such as those in the United States and European Union, significantly reduce TF intake and imports, acting as effective filters against TF-rich foods. In contrast, countries with weaker regulations experience rising TF imports and, eventually, increased intake, effectively placing them at risk of becoming "dietary risk havens." Even modest rules work better when backed by strong monitoring. These results demonstrate that unilateral action can deliver meaningful health gains, but fragmented regulatory approaches likely create opportunities for "regulatory dumping." The evidence underscores the need for global cooperation – through harmonized standards or trade-linked enforcement – to prevent cross-border displacement of dietary risks. Beyond TF, the findings offer timely insights for emerging national and global mandates on other nutrients, such as salt, sugar, and saturated fats.

Keywords: food regulation, DID, mediation analysis, nutrition policy, monitoring mechanism

JEL Codes: Q18, I18, F13

* Poudel and Gopinath are Postdoctoral Associate and Professor, respectively, at the Department of Agricultural and Applied Economics (AAE), University of Georgia. Authors thank Brantly Callaway, Shanjukta Nath and Chen Zhen for their valuable feedback. Authors are grateful to the Food and Agriculture Organization of the United Nations, the World Health Organization, the U.S. Department of Agriculture, and the Food Systems Dashboard for making the data publicly available.
Corresponding Author: Dixit Poudel, 312F Conner Hall, Department of Agricultural and Applied Economics, University of Georgia, 147 Cedar St., Athens, GA 30602. Email: dp80717@uga.edu.

Regulatory Heterogeneity, Trade Mediation and Nutrient Intake:

The Case of Trans Fat

1. Introduction

Global rise in diet-related non-communicable diseases has drawn significant regulatory attention to harmful nutrients such as industrially-produced trans fats (hereafter, TF). For instance, World Health Organization (WHO, 2019) linked TF intake to an estimated 500,000 deaths, and placed an additional five billion people at such risk. Also, the share of coronary heart disease deaths attributable to TF intake ranged from 0.88 to 8.39 percent across countries, with that of the United States near the upper end at 7.5 percent. In sync with these alarming statistics, WHO launched a REPLACE (Review, Promote, Legislate, Assess, Create, Enforce) initiative in 2018 to reduce and eventually eliminate TFs from global food supply to promote healthier diets (WHO, 2023).[1]

TF regulations precede REPLACE, but have been uneven: national rules vary widely in timing or incidence, strength, and monitoring. To illustrate, the United States implemented a full ban in 2018, while Denmark, a pioneer, introduced mandatory limits in 2004, Russia imposed partial restrictions in 2018, and China mandated labeling in 2011. In addition, some countries – the United States, Denmark, and Russia – have also adopted formal monitoring (enforcement) mechanisms, including laboratory testing, label reviews, inspections, and border-point screenings. Others, like China, do not have such mechanisms. This uneven regulatory landscape – termed here "regulatory heterogeneity" following Sykes (1999) and Grossman et al. (2021) – raises two questions: (a) how do internal TF regulations ranging from bans to labeling shape

[1] In 2021 alone, Global Burden of Diseases estimated that approximately 23.41 million (37.75 percent) deaths were attributable to diet-related factors, such as excess intake of unhealthy fats, sodium, and sugar, and insufficient whole grains, nuts, seeds, and vegetables intake. In United States, it was 53.51 percent of all 2021 deaths (Institute of Health Metrics and Evaluation, IHME, 2024).

within-country TF intake (direct effect), and (b) does cross-country regulatory heterogeneity generate spillovers via trade that mediate (magnify or moderate) post-regulation TF consumption responses (indirect effect)?

This study addresses both questions by conceptualizing TF exposure through two core pathways. First, the internal (direct) pathway captures the impact of producer-targeted regulations on domestic intake. Second, the external (mediation, or indirect) pathway picks up exposure through trade of (TF-rich) processed foods, either from regulated markets with policy loopholes or from unregulated third countries (WHO, 2023; Parziale & Ooms, 2019). Such cross-border flows, amplified by regulatory gaps, can dilute internal regulatory effectiveness and create unintended dietary risks.

Trans fats indeed offer a unique and previously underexplored setting to examine regulatory effects on nutrient intake. They are the only major nutrient subject to a formal global phase-out effort. Along with sugar, sodium, and other unhealthy fats, TFs have become pervasive in diets due to ease of artificial production, low cost, long shelf life, and flavor/texture enhancing properties.[2] For instance, between 1990 and 2010, TF intake rose in almost all regions, with the highest levels observed in South Asia, where intake increased from 1.3 to 1.7 percent of daily energy, equivalent to 3.2 to 4.2 grams per person (Wang et al., 2016). While some TFs occur naturally in dairy and meat products (via biohydrogenation in ruminants), most regulations target industrially-produced TF (partial hydrogenation of oils, PHOs) (U.S. Food and

[2] Processed foods – typically high in calories, added sugar, sodium, and unhealthy fats, and low in fiber, protein, and micronutrients – have well-documented negative health impacts (Popkin et al., 2021). Ultra-processed foods account for about two-thirds of U.S. and U.K. adult caloric intake and over 70 percent among children (Maxted, 2024; Stabile, 2024), with growing penetration in baby and toddler markets (Todd, 2025). Industrially produced TFs are commonly found in margarine, shortening, vanaspati ghee, fried foods, and baked goods, as well as in many street and restaurant foods (WHO, 2024).

Drug Administration, FDA, 2024).[3] Furthermore, the globalization of food supply chains has further accelerated cross-border TF spread and use, with processed foods now accounting for 48 and 35 percent of total food imports in developed and developing countries, respectively (UNCTAD, 2024). Finally, the staggered adoption of TF regulations across countries allows for a quasi-experimental setting with rich policy variation to estimate causal effects – direct and indirect.

Despite the heightened awareness in recent years, evidence on TF regulation and its impact remains limited. Most studies to date are qualitative assessments of nutrient consumption and policies, including TFs (Downs et al., 2017; Parziale & Ooms, 2019; Bruce, 2023; Musicus et al., 2025), or single-country/region studies. For instance, a study with U.S. scanner data (2012–2020) found TF-embodied product availability declined but persisted among low-income consumers, and convenience and dollar stores (Rojas et al., 2025). In Austria, impacts of TF regulations were found to be insignificant (Grabovac et al., 2018). Using pre-ban data from New York counties, another study found a 4.5 percent reduction in cardiac mortality, valued at about $3.9 million per 100,000 persons annually (Fiankor et al., 2025; Xiong & Beghin, 2012)(Fiankor et al., 2025; Xiong & Beghin, 2012)(Restrepo & Rieger, 2016). Note that such individual contexts often lack sufficient policy variation for assessing regulatory effects on intake.

On the trade side, the Food and Agriculture Organization (FAO)'s State of Agricultural Commodity Markets (SOCO, 2024) notes that while trade openness improves nutrition, it can also drive unhealthy dietary shifts in import-reliant economies. Some studies have analyzed other forms of regulatory heterogeneity, finding that differences in pesticide regulations can affect

[3] Biohydrogenation in ruminants produces trans fatty acids (TFAs) at 2-8 percent of total fat, whereas industrial process (fats and oils that have been hydrogenated, but not to complete or near complete saturation) can yield 40-50 percent of total fat (WHO, 2020). Though TF and trans fatty acids (or trans unsaturated fatty acids) differ slightly in chemical structure, both WHO (2024) use the terms interchangeably—a convention followed in this study. For chemical details, see Annex I of WHO (2020).

firm-level productivity in Switzerland, while variations in aflatoxin limits in the EU had no post-treatment effect on African exports (Fiankor et al., 2025; Xiong & Beghin, 2012). Unlike multilateral trade-oriented regulations such as sanitary and phytosanitary (SPS) and technical barriers to trade (TBT) (Disdier et al., 2008; Winchester et al., 2012), TF regulations are largely unilateral and embedded within domestic public health frameworks. As such, mediation effects of such measures – particularly via trade – remain empirically underexplored.

This study offers the first cross-country nutrient-level policy evaluation, quantifying direct and trade-mediated effects of TF-specific regulations on TF intake. It builds on foundational nutrient policy work (FAO, 2025; Lividini & Masters, 2022; Silvestrini et al., 2024) and contributes to the growing literature on nutrition economics and nutrient trade (Martin & Laborde, 2018; Finaret & Masters, 2019; Thow & Nisbett, 2019). From a data viewpoint, the study's contributions include construction and validation (FAO, 2025; Lividini & Masters, 2022; Silvestrini et al., 2024) of a food-item-level cross-country dataset on TF intake and imports for 161 countries (2010–2022), distinguishing between processed and unprocessed foods; the dataset draws from publicly available sources – FAO, UN Conference on Trade and Development (UNCTAD), and the U.S. Department of Agriculture (USDA) – and compiles detailed policy and implementation timelines from WHO and the Food Systems Dashboard. Methodologically, this study combines frontier methods in staggered difference-in-differences (DID) approach (Sun & Abraham, 2021; Callaway & Sant'Anna, 2021) with a mediation analysis (Imai et al., 2010; De Brauw et al., 2018; Pace et al., 2022), accounting for differential timing of TF regulations across countries and allowing decomposition into direct and trade-mediated effects. The study's findings are especially relevant today as global efforts to regulate other harmful nutrients – salt,

sugar, and saturated fat – are gaining momentum (Smith et al., 2018; WHO-Sugar, 2022; WHO-Sodium, 2023; Cawley et al., 2019; Musicus et al., 2025).

The rest of the study is organized as follows. Section 2 discusses the global TF regulation landscape. Section 3 presents the basic model and empirical strategy, while Section 4 describes the data used in the study. Section 5 reports the results followed by conclusions in Section 6.

2. Trans Fat Regulatory Context with the U.S. Example

FAO (2006, pp: 39) defines food regulations as mandatory rules issued by ministries, detailing specific requirements for food production, handling, marketing, and trade. They supplement broader food legislation (or food law), which is enacted generally by a country's parliament or its equivalent. In the United States, food regulations were mostly employed at the local and state levels until 1883, when U.S. Congress passed the first national law to prevent the import of adulterated tea. With advances in chemistry and food science, and as food production shifted from homes to factories, federal food regulation significantly expanded in scope (Fortin, 2022). International institutions like WHO issues food-related recommendations, which remain non-binding unless adopted into national law or formalized through treaties or agreements. However, most countries incorporate these measures into national legislation to facilitate trade and ensure safety. A key example is the WHO-FAO Codex Alimentarius Commission (CAC), established in 1963, whose international food standards are widely adopted.

While early clinical trials like Mensink & Katan (1990) provided evidence on TFs harmful effects, the CAC (2004) formally addressed this issue only in 2004. The major global push came with WHO's REPLACE initiative in 2018, aiming to eliminate TF (and replacing them with healthier fats and oils) worldwide by 2023. The REPLACE package supports

countries with tools to assess their food systems, design national policies, and strengthen monitoring mechanisms. Some countries acted before WHO's guidance. Denmark was the first to implement a mandatory TF limit – restricting them to 2 grams (g) per 100 grams of fat or oil – starting in 2004. Countries have since adopted a variety of regulations tailored to their contexts, ranging from mandatory labeling to full bans.

The United States followed a phased approach for TF regulation. FDA proposed a rule in November 17, 1999 to require nutrition labeling of TF content (FDA, 1999). A final rule mandating TF labeling was issued on July 11, 2003, with an effective date of January 1, 2006 (FDA, 2003). However, labeling rules allowed products with up to 0.5g of TF per serving to be reported as 0g, leading to underreporting concerns. FDA took a major step on November 7, 2013, when it preliminarily determined that PHOs, the primary source of industrial TF, were no longer "generally recognized as safe" (GRAS). This determination was finalized on June 17, 2015, and thus, began a regulatory phase-out. The initial effective date to prohibit the addition of PHOs to foods was set for June 18, 2018. To allow an orderly transition, the FDA extended the compliance deadline to January 1, 2020, for pre-existing products already in the market, and January 1, 2021, for a small subset of petitioned uses, making 2021 the "final compliance date" (FDA, 2024).[4]

While global efforts to date have led to a decline in TF-related deaths – from an estimated 500,000 in 2019 to 278,000 in 2024 (WHO, 2024) – substantial progress is still needed. Although regulating the status quo can be costly and may face industry resistance, the long-term public health and economic benefits of food-related regulations are considerable. For instance,

[4] Note that there is early evidence of sub-national TF regulations. For example, prior to the U.S. federal ban, Tiburon, California mandated TF-free cooking oils in all restaurants as early as 2005, and New York City Department of Health and Mental Hygiene required restaurants to eliminate trans fats by July 2008. While these partial bans efforts are starting points, this study focuses exclusively on national-level policies, as they offer broader scope for cross-country comparison and analysis.

FDA's 2015 cost-benefit analysis estimates that removing PHOs would impose costs of $6.2 billion (range: $2.8 to $11 billion) in net present value over a 20-year period but generate health benefits worth up to $140 billion (range: $11 to $440 billion). Similarly, a 2015 assessment by the European Union found TF regulations to be highly cost-effective, potentially preventing up to 3.73 million disability-adjusted life years (DALYs) and saving over €51 billion in economic cost including healthcare expenditures (FDA, 2015; Martin-Saborido et al., 2016).

Information on monitoring (enforcement), critical to effective TF regulation, is also available from WHO (2023). Some countries, even though, have mandatory restrictions, lack monitoring mechanism. REPLACE framework provides detailed guidance on designing enforcement mechanisms and identifying key areas for implementation and monitoring (WHO, 2020). Recommended inspection methods include laboratory testing, label analysis, facility investigations (e.g., factories, processing plants, and oil refineries engaged in partial hydrogenation), and document reviews such as shipping records, supply contracts, and bills of lading. To enhance compliance, REPLACE suggests that monitoring should focus on critical control points in the supply chain, such as oil refiners, large manufacturers, major food producers, and ports of entry. In the United States, monitoring is carried out under the Federal Food, Drug, and Cosmetic Act (§§402 and 409), which classified foods containing PHOs (food additives) as adulterated. At border, authorities can conduct physical inspections, issue import alerts, and detain or refuse entry to non-compliant products (FDA, 2019). TF checks and testing protocols should be integrated into broader food safety and health inspections. Penalties for violations may range from warnings and product recalls to fines, sanctions, license revocation, or

even imprisonment in extreme cases. The data section below provides additional information on country-wise regulatory scores and monitoring mechanism.[5]

3. Stylized Model and Empirical Methods

The basic model assumes that a representative consumer allocates their spending between food and other non-food goods (clothing, housing, transportation and others), while staying within a limited budget. Maximization of the consumer's satisfaction (utility) – shaped by their preferences and by the relative price of food to non-food items – yields Marshallian demand as functions of income and prices (Deaton & Muellbauer, 1980). Government regulations can influence food consumption through two major pathways: by changing the price of food – via taxes or subsidies – or by shifting consumer preferences, such as through labeling laws or outright bans (Dubois et al., 2018; Zhen et al., 2014). As noted in the context section, trans fat regulation belongs to the latter pathway: demand shifter. Since prices of nutrients are unavailable (attempts to construct them are likely to suffer from specification biases and measurement errors), this study employs a reduced-form nutrient (TF) demand equation with controls for national income and food prices, consistent with the literature in this context (Li et al., 2022; Zhen et al., 2014). Specifically, it focuses on the effect of TF regulation on TF intake, assuming the nutrient-specific regulation primarily affects the targeted nutrient and that substitution among nutrients is limited (i.e., separable or independent preferences). However, TF regulation may induce substitution toward other nutrients – healthier or less-healthy alternatives (cross-effects) (Dubois et al., 2018). A shift can occur toward unhealthy substitutes, i.e., slippage effect of TF policy, a possibility which is explored in a later section.

[5] WHO (2020) acknowledges the challenges of enforcing regulations in informal food markets, which are widespread in low- and middle-income countries. However, it emphasizes that enforcement, particularly penalties, should be designed in a way that does not compromise the livelihoods of small-scale producers.

To estimate the TF intake, the following specification is employed (Li et al., 2022; Zhen & Zheng, 2020):

$$Y_{ifpt} = \delta_i + \delta_t + \delta_{fpt} + \delta_{ifp} + \beta_1 D_{it} + \boldsymbol{X'}_{it}\zeta + e_{ifpt} \quad (1)$$

where,

- Y represents TF intake from food category f and processing-level p of the representative consumer i in a given country in year t,
- D is the binary treatment variable indicating the year a country's TF regulation takes effect, and
- X includes household consumption expenditure per capita.[6]

Term δ's capture various combinations of country, time, food category, and processing-level fixed effects (FE). These time-invariant (δ_i, δ_{ifp}) and time-varying (δ_t, δ_{fpt}) FEs absorb structural drivers of reformulation, trade, and production. Note here that effect of the dummy variable D can vary depending on regulatory stringency: national bans, policies limiting consumption (grams or percent daily value), complementary measures (labeling only), and just national commitment. Countries with national commitment only along with those with no policies, serve as the never-treated units in the control group. Additionally, among treated countries (bans and limits), some have formal monitoring mechanisms, allowing for further segregation to identify causal effects for this policy dimension. Recommended inspection methods include laboratory testing, label analysis, facility investigations (e.g., factories, processing plants, and oil refineries engaged in partial hydrogenation), and document reviews

[6] While nutrient-specific price data are unavailable, this study includes national-level consumer food price indices from FAOSTAT for robustness checks—results remain consistent. Zhen & Zheng (2020) note that prices in demand equations can be endogenous, particularly at the store level, where price-setting may reflect demand shifters observed by retailers but unobserved by the econometrician. To address this, they employ a Hausman-type instrument—using average prices of the same products in nearby cities within the same Census region. Unlike store-level prices, national-level price indexes used as a control in this study are influenced not only by micro-level demand and supply but also by broader macroeconomic factors, such as agricultural and food trade and input costs. Consequently, national-level prices may not present the same endogeneity concerns.

such as shipping records, supply contracts, and bills of lading. To enhance compliance, REPLACE suggests that monitoring should focus on critical control points in the supply chain – such as oil refiners, large manufacturers, major food producers, and ports of entry. In the United States, monitoring is carried out under the Federal Food, Drug, and Cosmetic Act (§§402 and 409), which classifies foods containing PHOs (food additives) as adulterated. At the border, authorities can conduct physical inspections, issue import alerts, and detain or refuse entry to non-compliant products (FDA, 2019).

The staggered (differential) timing of TF regulation across countries creates a quasi-experimental setting for causal inference. However, traditional FEs estimators may yield biased results under staggered adoption due to negative weighting (Callaway & Sant'Anna, CS, 2021; Sun & Abraham, SA, 2021). These biases arise when treated units in some periods are inappropriately compared to already-treated units, rather than untreated ones. To address this, the analysis employs staggered difference-in-differences (DID) estimator that is robust to treatment effect heterogeneity. Under the parallel trends and no anticipation effect assumption, β_1 identifies the Average Treatment Effect on the Treated (ATT) – Figure 1A presents a stylized diagram of how β_1 captures changes in TF demand following regulation, relative to the appropriate control group. Put simply, as shown in figure 1A, countries that adopt a TF regulation in year t are compared to countries that have either never adopted the regulation (never-treated) or will adopt it in a future period (not-yet-treated). Treated countries are expected to exhibit a downward shift in their demand curve following regulation. In addition to robustness checks, the comparison group can also be limited to only not-yet-treated countries.

Imports contribute between 3 (butter) and 42 percent (vegetable oil) of global intake, showing that countries rely partly on external sources to meet internal nutrient demand (Smith &

Glauber, 2020). Thus, internal effects can interact with external channels like imports, which partly mediate the relationship between D and Y. In fact, if TF imports (M) are both a direct determinant of Y and correlated with D as hypothesized, omitting M from equation (1) would introduce omitted variable bias. To account for this, M is included in the extended intake equation (2) below, with identification considerations discussed later in this section.

$$Y_{ifpt} = \delta_i + \delta_t + \delta_{fpt} + \delta_{ifp} + \beta_1 D_{it} + \alpha M_{ifpt} + \boldsymbol{X'}_{it}\zeta + e_{ifpt} \quad (2)$$

Note that β_1 estimates the direct regulatory effect on consumption response, but it does not fully account for the possibility that this relationship may be mediated through imports. To explore this mechanism, the analysis adopts a linear mediation framework (Alem & Colmer, 2022; Imai et al., 2010; Pace et al., 2022). The goal is to decompose the total effect of TF regulation into two distinct components: the direct impact on intake, and the mediated (indirect) effect operating through import exposure, with M functioning as a mediator. Although the partial mediation effect α – the effect of imports on intake – is already obtained from equation (2), the second half of the mediation pathway is estimated using equation (3), which models the effect of regulation on imports:

$$M_{ifpt} = \delta_i + \delta_t + \delta_{fpt} + \delta_{ifp} + \beta_2 D_{it} + \boldsymbol{X'}_{it}\gamma + \varepsilon_{ifpt} \quad (3)$$

Equation (3) is estimated using staggered DID with the same set of FEs as in equation (2). The mediation structure is illustrated diagrammatically in Figure 1B, and the total effects is obtained by substituting equation (3) to (2) as:

$$Y_{ifpt} = [1 + \alpha]\{\delta_i + \delta_t + \delta_{fpt} + \delta_{ifp}\} + [\beta_1 + \alpha\beta_2]D_{it} + \boldsymbol{X'}_{it}[\zeta + \alpha\gamma] + [e_{ifpt} + \alpha\varepsilon_{ifpt}] \quad (4)$$

$$\text{Total (Treatment) Effect} = \frac{\partial Y_{ifpt}}{\partial D_{it}} = \underbrace{\beta_1}_{Direct\ Effect} + \underbrace{\alpha\beta_2}_{Mediation\ Effect} \quad (5)$$

Total effects are computed using the estimated β_1, α and β_2 in equation (5). Although mediation analysis has been applied in (quasi-)experimental settings (Pace et al., 2022; De Brauw et al., 2018), this study is among the first to combine it with staggered DID in a global nutrient policy context. SA estimator is used for food-item level analysis, while other recent DID estimators are used for robustness checks with country-level data (Borusyak et al., 2024; CS; Gardner, 2021).[7]

3.1. Impact Pathways

TF regulations can influence TF intake through two primary pathways, internal and external, both shown in Figure 1B and tested empirically in Results section:

i) **Internal or Direct Pathway**

Producer-oriented regulations restrict or eliminate the use of TFs at the manufacturing stage, ultimately reducing TF content in food reaching consumers.[8] Regulations range from labeling requirements to full bans (with or without a monitoring mechanism in place), and are expected to have stronger internal effects when more stringent (Martin-Saborido et al., 2016). The estimate $\widehat{\beta_1}$ from equation (2) provides a valid test for this internal pathway hypothesis, allowing also an assessment across regulatory-stringency levels. A statistically significant $\widehat{\beta_1} < 0$ indicates a reduction in TF intake due to regulation (policy success).

ii) **External or Mediation Pathway**

[7] Country-year panel analysis is highly aggregated (small sample size) and may obscure important variation, especially since TF content is concentrated predominantly in processed foods. Estimating effects at this level can yield naïve results. Additionally, models at the country level typically do not control for processing-by-year interactions, meaning structural changes in the food industry over time are not captured, highlighting the need for high-dimensional specifications. The food-item-level analysis addresses this by incorporating rich fixed effects. For this purpose, the user-written sunab() function in the fixest package (feols::fixest) in R enables the implementation of SA estimator, and has been widely validated and cited in recent applications including Berge & McDermott (2024), Naqvi (2024) and Roth et al. (2023).

[8] The point-of-incidence in regulation refers to where a regulation applies within the food system: either at the producer level (targeting manufacturers) or the consumer level (influencing individual behavior). TF regulations primarily operate at the producer level by banning or restricting the use of industrially-produced TFs, thereby reducing intake through supply-side control. In contrast, salt reduction policies operate at both levels (e.g., sodium limits and front-of-pack labeling), and sugar reduction efforts, particularly sugar-sweetened beverage taxes, are largely consumer-oriented.

In a globalized system, less-regulated countries often import cheaper (TF-rich) processed foods. At the same time, countries with strong bans may export these products to less-regulated markets – creating regulatory dumping (WHO, 2023; Parziale & Ooms, 2019). These cross-border flows, driven by uneven regulations, can moderate the internal pathway. The estimate $\widehat{\beta_2}$ in equation (3) tests this external pathway. A finding of $\widehat{\beta_2} < 0$ would suggest TF import reduction (policy success), while $\widehat{\beta_2} > 0$ signals leakage through increased TF imports (policy failure). Together with $\hat{\alpha}$ (equation 2), the mediation effect is computed as in equation (5).

On another dimension, countries may adopt TF regulations with or without formal monitoring mechanisms, even when full bans are in place. While food imports improve accessibility, weak or uneven monitoring can turn imports into a channel for dietary risk. To assess whether the presence of monitoring mechanisms strengthens policy effectiveness by curbing risky imports, equation (3) is estimated only among countries that have adopted formal monitoring. As mentioned before, such monitoring may occur at production sites, processing facilities, or ports of entry, linking enforcement more directly to the supply side. As this study focuses on downstream consumer demand, and governments cannot directly observe or regulate individual consumption behavior, the role of monitoring is examined only in relation to imports.[9]

3.2. Identification Assumptions

Given the permanent nature of TF regulations, this study uses a staggered DID with mediation analysis to identify causal effects on nutrient intake. Two core assumptions are required for valid

[9] Monitoring typically occurs at key control points such as production sites, food processing facilities, and ports of entry, making enforcement mechanisms more plausibly linked to the supply side. In contrast, this study focuses on downstream consumer demand, where governments cannot directly observe or regulate individual consumption behavior. However, the presence of a monitoring mechanism may still influence outcomes indirectly, particularly through import exposure. Regarding trade, even deep trade agreements with sanitary/phytosanitary measures and/or technical barrier provisions may fail to block unhealthy nutrients in processed foods, which often meet technical import requirements – unlike many raw or minimally processed foods (SOCO, 2024). However, direct enforcement clauses that limit harmful ingredients, like TFs, can be more effective.

identification in DID approaches. These are extensively discussed in SA, CS, and Roth et al. (2023). However, relevant estimation issues for DID and mediation analysis are briefly addressed below with robustness checks conducted wherever appropriate.

a. Parallel Trends Assumption (PTA) and No Anticipation:

The PTA requires that, in the absence of regulation, treated and control countries would have exhibited similar trends in TF intake. Although high-income countries are more likely to adopt regulations earlier, both not-yet-treated and never-treated countries can serve as valid counterfactuals, provided there are no confounding factors. To assess the plausibility of the PTA in the current setting, pre-treatment trend checks are conducted along with complementary placebo tests (later in robustness checks) (Jia et al., 2024).

The no-anticipation assumption holds that producers do not alter their behavior prior to the formal implementation of the regulation. This is plausible in most cases: reducing TF content entails reformulation costs, and producers are unlikely to preemptively act against their profit motives. However, early adjustments may occur in some cases, e.g., when regulations involve phased rollouts as in the case of the United States, with an original effective date and a later final compliance date. This concern can be addressed by checking the sensitivity of results to the use of effective or final compliance dates as treatment thresholds.

b. Sequential Unconfoundedness: The mediation analysis requires (Imai et al., 2010; Pace et al., 2022):

- $(Y, M) \perp D \mid X$: Regulation adoption is assumed to be independent of intake and imports, conditional on observed covariates. Given the use of staggered DID with controls, this assumption is plausible for both equations (2) and (3).

- $Y \perp M \mid D, X$: After conditioning on treatment and covariates, there are no other sources of endogeneity in equation (2) that violate the independence between intake and imports. This is a stronger assumption, but later tested in a robustness check.

b.1. Reverse Causality: Conditional on FEs, nutrient-level imports of TF are a plausibly exogenous source of variation in dietary intake for two reasons. First, TF is not directly traded – it is embedded within processed foods. Thus, countries do not make targeted import decisions for TF, limiting concerns that TF demand drives imports. This concern would be more relevant for directly traded inputs like PHOs. Second, since nutrient imports are constructed from food trade volumes using conversion factors, the causal direction runs from imports to intake, not vice versa.[10]

b.2. Simultaneity: To address potential simultaneity, such as unobserved industry behavior or country-level reforms that influence both imports and intake, the model includes a high-dimensional FEs: time-invariant (country, country–food category–processing) and time-varying (year, food category–processing-year), standard in trade literature (Fajgelbaum et al., 2020). These absorb structural drivers of reformulation, trade, and production. To avoid overfitting, model's sensitivity and stability are tested across various combinations of FE.

With regard to potential measurement errors, although both imports and intake are derived from food balance data, their relationship is not fixed. Differences in re-exports, food uses, and consumption behavior across countries allow for meaningful variation. Finally, as

[10] De Brauw et al. (2018) acknowledge that the second part of the sequential ignorability assumption may be violated if a mediator is influenced by unobserved factors that also affect the outcome. To address this, they apply the sensitivity analysis proposed by Imai et al. (2010), which we also discuss later in the results. Pace et al. (2022), working with household-level data, use soil quality as an instrument for a mediator in a 2SLS framework. However, this study is at the country-food-processing-year level, where such detailed instruments are not available. Instead, following similar approach of Bellemare (2015), natural disaster intensity – measured as the total number of people affected by all natural disasters in a given year – is used as an instrument at the country-year level panel data. The results remain stable, supporting that mediator is less likely to be endogenous. More details in the section on robustness checks.

additional controls, national-level consumer food price indices, and salt and sugar regulations are included to proxy broader health regulation trends (for robustness checks).

4. Data

For identifying the effect of regulations on TF intake (within- and cross-country), this study constructs a primary food-item-level dataset for 161 countries spanning 2010 to 2022, comprising 46 distinct food-item combinations derived from the intersection of 15 food categories and 4 processing levels. Each item (crop, livestock, or fisheries) from FAO's Supply Utilization Accounts (SUA) is matched to its corresponding food category and UNCTAD (2024) is used to classify into four processing levels, producing a unique food-item identifier and allowing for nutrient-level estimates of intake and imports. In addition, USDA's nutrient composition tables are used to translate intake and import quantities into nutrient values (USDA, 2016). This method is used by FAO (2025), Lividini & Masters (2022) and Silvestrini et al. (2024), and the results are validated against these benchmarks for consistency. While recent SUA releases offer nutrient-level coverage, they exclude TF – the key variable in this study – and do not provide food-item level granularity with processing distinctions. This is crucial, as nutrient profiles differ substantially across processing levels (e.g., raw poultry vs. sausages). As such, the constructed dataset offers a more reliable basis for assessing the cross-country impacts of targeted policies like those regulating trans fats. Brief descriptions are provided in the following, while Appendix 1A has stepwise details on data construction and validation.

Note that 15 food categories include: Cereal Grains and Pasta, Vegetables and Products, Fruits and Fruit Juices, Nuts and Seeds, Spices and Herbs, Fats and Oils, Dairy and Eggs, Red Meat, Poultry Products, Finfish and Shellfish, Sweets, Baby Foods, Beverages, Baked Products,

and Meals, Snacks, and Fast Foods. Each food category can have products falling into at least one of four processing levels: unprocessed, minimally processed, processed with salt/sugar/fermentation, or composite (processed) foods including refined oils. This means, an average consumer i in any country is assumed to choose from among 46 combinations, with each combination represented as a row for that country in a given year of the dataset.

4.1. Variables of Interest

a) **Nutrient (Apparent) Intake**: Nutrient intake, with a primary focus on TF, is measured as the quantity of specific nutrient available for human consumption through food accessible in retail and institutional settings, including direct household use as well as meals prepared in schools, hospitals, and similar facilities. For example, margarine and shortening (M-S) products contain TFs; thus, TF intake (expressed in grams per capita per day, gpcpd) at the country–year–food-item level is calculated by multiplying the per capita intake of M-S by its TF content (details in Appendix 1A).

It is derived using the "Food" component from SUA. Since this variable includes edible food waste post-retail (spoilage, plate waste, and food fed to pets), general refuse, and cooking retention factors are also applied, but household-level waste is not captured due to data limitations. Following FAO (2025) and Lividini & Masters (2022), this measure is referred to as "apparent intake" (also called absorption or disappearance).[11] While common in nutrition and food policy research, apparent intake measures food availability, not actual consumption, and cannot capture individual diets, distributional differences, or informal food sources. These limitations should be considered when interpreting results and policy implications.

[11] Estimation methods and issues are reported in detail in FAO (2025) Handbook for FBS and SUA. Basic food balance identity and definitions are presented in page 7 and 11-13.

This study focuses on targeted nutrients: TF, carbohydrates, proteins, fat, potassium, saturated fat, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), cholesterol, sugar, sodium, along with energy. TF serves as the main outcome variable for causal estimation, while the remaining nutrients are used for either validation or cross-nutrient substitution analyses.

b) **Nutrient Imports:** Nutrient import quantities, including TF, in SUA refer to total imports, regardless of end use (e.g., food, feed, or industrial). Unlike the "Food" variable, they are not limited to human consumption. These national-level import volumes are used to estimate nutrient-level imports.[12]

c) **Regulations:** Regulation data are compiled from multiple sources, including the WHO, Food System Dashboard, and targeted country-specific searches (details provided in Appendix 1B). WHO (2023) classifies countries by regulatory stringency, defined as the degree to which TF regulations are adopted:

   - Regulation Score 2 (RS2) reflects the weakest policy framework, characterized by complementary measures only,
   - RS3 includes countries with mandatory limits in certain food products, though these are less restrictive,
   - RS4 captures the most stringent policies, such as national bans (this is the best practice TF policies according to WHO), and

[12] This analysis uses national-level import quantities as a proxy for external exposure to TF. While these imports are not limited to direct human consumption – potentially including re-exports, animal feed, or industrial use – they offer a meaningful signal of exposure risk at the macro level. As such, import volumes should not be interpreted as individual-level intake or uniformly scaled to per capita daily estimates; in some cases, import-to-intake ratios can exceed 1. Despite this, aggregate import volumes remain a valid proxy for national-level exposure. A validation exercise comparing per capita nutrient imports (converted to daily values) with matched data from the Global Nutrient Database (GNTD) shows over 70 percent correlation, supporting their use. Per capita import measures are also directly tested in Equation (2), but they introduced considerable noise and instability, reinforcing choice to use aggregate import quantities in the main analysis.

- RS0 countries (no regulation) and RS1 countries (no regulation during the study period but a commitment for future adoption) serves as the never-treated group.

Additionally, some RS3 and RS4 countries have formal monitoring mechanisms in place. For example, in the United States, monitoring involved both domestic inspections and border control measures, with violative products detained and manufacturers added to FDA Import Alerts (FDA, 2019). Countries with such active systems are classified as having a high level of enforcement.

Figure 2 maps TF regulation stringency and monitoring mechanisms across countries and is complemented by a summary table outlining the types of regulatory instruments employed. The figure highlights that RS3 and RS4 policies are predominantly adopted by high- and upper-middle-income countries. By 2022, 67 countries had adopted some form of regulation, including 54 implementing RS3 or RS4 measures. This variation in stringency and monitoring enables estimation of heterogeneous treatment effects of TF regulations across different regulatory regimes.

Two implementation dates are compiled to capture the timing of TF regulatory adoption: (i) the original effective date, and (ii) the final compliance date. The latter is used in the main analysis; the former is used for robustness and to test the no-anticipation assumption. For instance, the U.S. policy was announced in 2015 with a 2018 effective date, but granted final compliance extensions until January 2021. Appendix 2 tabulates treatment timing, regulation stringency, and monitoring classifications across countries.

The primary analysis is conducted at the food-item level, while robustness checks are performed at the more aggregated country-year level. The analysis spans 2010-2022, aligning with data availability and the timing of global TF policy diffusion. Of the 161 countries, five had adopted

TF regulations before 2010 and are excluded as already treated. Six additional countries that implemented regulations between 2010-2012 are also excluded to ensure at least two years of pre-treatment data, critical for testing the PTA.

As a control variable, household final consumption per capita, sourced from the World Development Indicators (2025), is included as a proxy for income. It measures actual consumption and reflects the spending behavior or disposable income of an average citizen in a country.[13] Due to large disparities in import volumes and consumption expenditures, the inverse hyperbolic sine (asinh) transformation is applied. It allows for zeros in the data while maintaining a log-like interpretation for large values. High-dimensional FEs controls for unobserved industry behavior or concurrent national reforms influencing both nutrient imports and intake. Similarly, to assess heterogeneity in policy effects, World Bank's 2025 income classifications and regional groupings are used. Note that for estimation, standard errors are clustered at the country-food category-processing level in equations (2) and (3), and are bootstrapped in the case of equation (5).

Summary statistics (Appendix 3) from the constructed dataset, based on the nutrient data-generating process, show that global TF intake averages 0.077 grams per capita per day (gpcpd) at the food-item level (panel A). Note that these figures are averages from food products ranging from no TF to those with the highest content. At the product-level, the estimated average for North America (NA) is 0.2171 gpcpd TF intake. USDA Report by Rahkovsky et al. (2012) reported that a single serving of a bakery product (among the highest in TF) contained around 0.22g of TF. Given that most individuals do not consume a full serving of such products daily and eat a variety of lower-TF foods, food-item level average in this study appears reasonable.

[13] Due to large disparities in import volumes and consumption expenditures, inverse hyperbolic sine (asinh) transformation is applied. It allows for zeros in the data while maintaining a log-like interpretation for large values.

Aggregated to the country-level (panel B), global TF intake average amounts to 3.229 gpcpd. Regionally, Sub-Saharan Africa (SSA) reports the lowest food-item-level intake (1.31 gpcpd), while North America (NA) shows the highest (9.70 gpcpd). These estimates align well with the literature: for instance, in 2010, TF accounted for 1.4 percent (range: 1.3–1.5) of total energy intake globally – equivalent to approximately 3.2 to 3.7 gpcpd based on a 2200 kcal/day diet (Wang et al., 2016). For NA, the figure was 2.9 percent (2.8–3.0), or roughly 7.1 gpcpd (range: 6.8–7.3), while SSA's TF intake was estimated at 0.8–0.9 percent, or 2.0–2.2 gpcpd. This study's country-level estimates mirror these benchmarks (Appendix 3, Panel B).

Likewise, TF imports follow a similar regional pattern, with the highest levels observed in NA and the lowest in SSA at the national-level, and in East Asia & Pacific at the food-item level. Consumption expenditure also mirrors this gradient, with NA at the top and SSA at the bottom across both levels of analysis. Summary statistics for other nutrients are available upon request.

5. Results and Discussion

Using a staggered DID approach with a mediation analysis, this section tests the causal effects of TF regulations on its intake and whether trade exposure magnifies or moderates them. Note that TF intake (gram/capita/day) is measured at the country–year–food-item level as the product of per capita consumption of each food item and the item-specific TF content. The analysis proceeds in three parts: (i) internal regulatory effects, (ii) external mediation via imports, and (iii) total effects combining both channels. For brevity, policy stringency levels are denoted as regulation score 2 or RS2 (complementary measures only), RS3 (less restrictive), and RS4 (most restrictive). Results are first presented for all foods and then for a TF-rich subset – dairy,

fats/oils, red meat, baked goods, and fast foods – which are the primary contributors to TF exposure in the real world and in the database. TF-rich foods are defined as those containing on average ≥0.5 g TF per 100 g of food.

5.1. Direct Effect: Stronger Rules Cut Trans Fat Intake

Table 1 reports result for the internal pathway hypothesis ($\widehat{\beta_1}$ from Figure 1B), i.e., the direct effect. Results are disaggregated by RS2, RS3, and RS4 policy categories. While RS2 and RS3 effects are statistically insignificant, RS4 countries – those with the most stringent regulations – exhibit a significant reduction of 0.0072 grams per capita per day (gpcpd) across all food items (Column 3), and a larger reduction of 0.0171 gpcpd among TF-rich foods (Column 6).

To interpret the economic significance of these effects at the national level, consider first the case of TF-rich foods. The RS4 estimate of -0.0171 gpcpd implies a total impact of 0.342 gpcpd (i.e., -0.0171 × 20) or 342 mg/day – which corresponds to a 10.6 percent decline from the global average of 3.229 gpcpd in the dataset.[14] A similar calculation for all foods (note, some do not have TF) yields a total reduction of 0.144 gpcpd, or a 4.5 percent decline. Together, these estimates suggest that RS4 real-world effects fall between 4.5 percent (lower bound) and 10.6 percent (upper bound), depending on the food basket and exposure to TF-rich foods. Regulatory heterogeneity results in divergent within-country outcomes, with RS4 policies outperforming RS2 and RS3, highlighting the value of uniform, stringent regulation. Moreover, targeting TF-rich foods substantially magnifies policy effectiveness.[15]

[14] WHO recommends that TF intake should be less than 1 percent of total daily energy intake, which equates to less than 2.2 grams per day for a 2,000-calorie diet.

[15] Note that if one were to simply group all TF regulations together—without distinguishing their stringency—the estimated effect would average –0.0027 gpcpd for the full sample and –0.0067 gpcpd for TF-rich foods, both statistically insignificant. This underscores the importance of disaggregating policy types to uncover meaningful effects.

To explore cross-country heterogeneity, Table 2 estimates the direct effect ($\widehat{\beta_1}$) across subsamples by income group (high-, upper-middle-, and lower-middle-income) and by region (North America and Europe & Central Asia [NA/ECA] and Rest of World [ROW]). Because low-income countries (except for Ethiopia) do not have TF regulations by 2022, they are excluded from this analysis. Results indicate that reductions are concentrated in high-income countries (columns 1 and 6) – especially NA/ECA (columns 4 and 9) – where RS4-type policies are prevalent. Other regions, dominated by RS2 or RS3, show no significant changes as discussed previously.

Zooming into NA/ECA, the estimated regulatory effects are even stronger than those in Table 1. Scaling food-item-level estimates (-0.0099 for the full sample and -0.0235 for TF-rich foods; Table 2, Columns 4 and 9) yields total reductions of 0.198 and 0.470 gpcpd post-treatment, respectively. These correspond to 4.3 and 10.1 percent decline relative to NA/ECA's average TF intake (4.65 gpcpd). For context, Rojas et al. (2025) report a 0.289 gpcpd post-2018 reduction in the U.S. using a random-effects model. By comparison, this study's DID estimates suggest average TF reductions across NA/ECA nearly double that figure.

5.2. Mediation Effect: Weak Rules Invite Trans Fat Imports

As depicted in Figure 1B, the mediation pathway includes two components: (i) the effect of imports on intake ($\hat{\alpha}$ from Table 1) and (ii) the effect of regulations on imports ($\widehat{\beta_2}$ from Table 3). Their product yields the mediation effect. The second component is especially critical as it captures whether regulations actively reduce exposure at the border.

The first component is positive and significant: a 1 percent increase in TF imports raises intake by 0.43 gpcpd (i.e., 0.0043 × 100 from Table 1, Column 1). However, this association weakens with stricter policies and becomes insignificant in RS4 countries when limited to TF-

rich foods (Column 6), suggesting that in more regulated environments, imports are no longer a key contributor to TF intake. Further disaggregation (results available upon request) shows that this effect is largely driven by processed foods, not unprocessed items.

Turning to the second component (Table 3), the focus shifts to whether TF regulations actually reduce the exposure to TF-embodied products entering a country. Again, regulatory heterogeneity matters. In RS2 countries (column 1), TF imports increase by 32.33 percent, indicating unwanted imports coming in due to weakly regulated settings. In contrast, RS4 countries (column 3) demonstrate a 20.38 percent reduction in imports. This suggests that stringent regulations are not only effective domestically but also deter the entry of TF-embodied foods, preventing leakages. The effect is consistent when focusing exclusively on TF-rich foods (columns 3-6). These patterns hold for TF-rich foods (Columns 4-6), and when imports are disaggregated into processed and unprocessed components (Appendix 4).

Interestingly, RS3 countries, despite having some regulatory measures, also experience magnified imports (columns 2 and 5 in table 3). This likely reflects a gap in policy design, as these countries often regulate specific products like fats and oils while leaving processed or packaged foods unregulated, e.g., Russia. Such asymmetries can create opportunities for TF to enter through unregulated product categories, underscoring the limitations of partial policy coverage.

Further investigation by disaggregating countries based on the presence or absence of a monitoring mechanism (i.e., estimating $\widehat{\beta_2}$ on the subsample of RS3 and RS4 countries) reveals that monitoring substantially enhances regulatory outcomes. Interestingly, RS3 countries with monitoring reduce TF imports by 28.22 percent, reversing the earlier pattern of increased imports when monitoring was not accounted for. In RS4 countries, the reduction reaches 30.40 percent

(Table 3, lower panel, Columns 2 and 3). A similar pattern holds for TF-rich foods (Columns 5 and 6), highlighting the robustness of the result.

Importantly, within RS4 countries, monitoring improves import reductions from 20.38 to 30.40 percent, marking a nearly 49 percent gain in policy impact. This suggests that formal enforcement mechanisms do not merely support but significantly amplify the impact of even the strongest policies. Overall, the results point to a clear implication: strong internal regulations must be paired with credible monitoring systems to effectively block TF at the border. Without monitoring, even countries with regulations remain susceptible to import-driven exposure. With monitoring in place, however, moderately strict policies (RS3) can achieve nearly the same effectiveness as the most restrictive (RS4) regimes.

5.3. Combined Effects from Regulatory Heterogeneity and Import Mediation

While the sections above isolated the internal (direct) and external (import-mediated) pathways of TF regulations, Table 4 combines them to estimate the total effect: how do these channels jointly shape plate-level outcomes?

Several important patterns emerge. In RS2 countries, internal regulations alone do not significantly reduce TF intake (as shown earlier in Table 1). Instead, the total effect is slightly positive (+0.0048 gpcpd, Table 4, Column 1), driven entirely by the significant mediation effect – i.e., continued exposure through imports from either highly regulated or unregulated third countries. This implies that in weakly regulated settings, continued TF imports offset any marginal policy effects and, in fact, increase TF intake. The mediated component accounts for 29.17 percent of the total effect. In contrast, RS4 countries, with the most stringent policies, see a total reduction of -0.0079 gpcpd (Column 3), significant at the 5 percent level. Here, the mediation effect is negative and significant, accounting for 10.13 percent of the total effect,

indicating that strict policies help mitigate both domestic and imported TF exposure. Coupled with monitoring measures, the effect increases significantly.

The TF-rich food subsample (Columns 4-6) further confirms these patterns: RS2 countries show a 0.0039 gpcpd increase, while RS4 countries see a 0.0186 gpcpd reduction. For TF-rich foods, these effects translate into a TF-intake increase of 2.4 percent (0.078 gpcpd) for RS2, and decrease of 11.5 percent (0.372 gpcpd) for RS4 relative to global average intake.

5.4. Cross-Effects

Producer-oriented TF regulations may inadvertently induce substitution toward other nutrients – either healthier or less healthy – depending on how manufacturers reformulate products to maintain palatability and production costs. As a result, consumers may increase intake of certain substitute nutrients. While TF regulations are not designed to directly alter consumption of other nutrients, they can raise consumer awareness and shift broader dietary patterns.

Table 5 examines these cross-nutrient effects by estimating the impact of TF regulations on saturated fat, MUFA, PUFA, cholesterol, sugar, and sodium across different stringency levels. Most coefficients are statistically not significant, suggesting minimal cross-nutrient effects. However, a notable exception is cholesterol: in RS2 and RS3 countries, TF regulations are associated with significant increases in cholesterol intake (Columns 4 and 10). This suggests that producers may be reformulating products in ways that substitute TF with cholesterol-heavy ingredients—an unintended response referred here as a slippage effect (Dubois et al., 2018). This pattern is not observed in RS4 countries, which once again underscores the value of implementing the most stringent and comprehensive regulatory frameworks that also limits unhealthy substitutions. Otherwise, the intended health benefits may be partially offset.[16]

[16] While adult physical inactivity is a key cardiovascular risk factor, comparable data are only available for 2022 (WHO, Global Physical Inactivity Report). Future research could examine how nutrient policies interact with lifestyle factors.

Although empirical evidence on cross-nutrient effects remains limited, case studies offer some context. For instance, Jones & Zidenberg-Cherr (2008) found no increase in saturated fat consumption following Denmark's 2004 TF regulation, suggesting that slippage is not an universal outcome. This study contributes to the emerging literature by identifying cholesterol substitution as a potential concern—particularly in countries with partial or weak regulations. This may be driven by the types of fats used to replace TFs, especially in processed foods. When trans fats are removed, manufacturers often substitute them with saturated fats such as palm oil or animal fats like butter or lard. Bruce (2023) notes that in the UK, most TFs were replaced with palmitic acid from palm oil. These substitutes can raise dietary cholesterol and LDL levels; for instance, the USDA Agricultural Research Service (ARS, 2009) found palm oil similarly increases LDL cholesterol as TFs do. In settings with limited regulation and weak reformulation incentives, cost-effective but less healthy substitutes may be used, potentially undermining policy goals. Further analysis is needed to better understand the scope of these cross-nutrient effects.

5.5. Robustness across Data and Assumptions

This section presents a series of sensitivity checks based on details presented in *Identification Assumptions* in the Methods section, addressing both methodological assumptions and data-level concerns. These are organized across two levels of analysis: food-item level (Appendix 5) and country-year level (Appendix 6).[17] Appendix 5A re-estimates the main models using a standard FE specification, without accounting for staggered adoption. The results remain statistically significant and directionally consistent, though slightly larger in magnitude. Appendix 5B

[17] Note that the main analysis is disaggregated by RS2, RS3, and RS4 policy categories. If one were to simply group all TF regulations together – without distinguishing their stringency – the estimated effect would average –0.0027 gpcpd for the full sample and –0.0067 gpcpd for TF-rich foods, both statistically insignificant. This underscores the importance of disaggregating policy types to uncover meaningful effects.

excludes the never-treated group (dropping RS0, and RS1 countries that never adopt a TF regulation during the sample period) and compares results to the main specification, which includes both never- and not-yet-treated countries. It means the analysis uses remaining units that are eventually treated at different times. It avoids bias from permanent differences between never-treated and treated countries. Findings remain highly consistent, except for RS4 in the import equation – likely due to small sample size and limited variation. Appendix 5C checks the no-anticipation assumption by using the initial effective date (instead of final compliance). The results remain robust and only slightly attenuated, showing minimal anticipatory behavior even with phased policy implementation. Appendix 5D evaluates parallel trends using the two available valid pre-treatment years. While trends hold in most models, some violations appear in the import regressions, likely due to small sample sizes, so results from the mediation pathway should be interpreted with caution. Another point worth noting is that the event study in Appendix 5D indicates a delay in policy impact (although this paper is solely interested in point estimates). As explained by Fanzo et al. (2023), such delays can arise from enforcement lags (while major countries' border monitoring is observed in this analysis, the exact monitoring dates are uncertain, and enforcement in domestic markets is not directly observed) and, importantly, from the time consumers need to adjust to reformulated products, as they are accustomed to the original taste. A similar pattern was observed in the United Kingdom's sodium reduction initiative, where substantial decreases occurred only gradually over many years. Appendix 5E conducts complementary placebo tests (1000 iterations) by randomly assigning treatment dates in equations (2) and (3); the resulting distribution centers around zero, with true estimates lying in the extreme tails, supporting that main effects are not driven by random assignment or chance as in Jia et al. (2024).

Three additional tests are conducted to validate sequential unconfoundedness in the mediation framework. First, lagged imports are added as controls in the intake equation to test for reverse causality, yielding no change in results. Second, salt and sugar regulations (mostly voluntary) are also controlled for, given that they may coincide with TF policies, that also yields no change in results. Third, following Imai et al. (2010) and De Brauw et al. (2018), residuals from the intake and import equations (2 and 3) are estimated and their correlation computed. The resulting value, $E[\hat{e} \times \hat{\varepsilon}] \approx 0$, indicates little evidence of unobserved confounding between a mediator (imports) and the outcome (intake), supporting the assumption of mediator exogeneity. While results are robust, future studies could strengthen this assumption using more granular data (e.g., scanner-level data across countries).

Appendix 6A replicates the main analysis (tables 1 and 3) using country-level data. Country-year data is highly aggregated (small sample size) and may obscure important variation, especially since TF content is concentrated predominantly in processed foods. Estimating effects at this level can yield naïve results. Additionally, models at the country level typically do not control for processing-by-year interactions, meaning structural changes in the food industry over time are not captured – highlighting the need for high-dimensional specifications. The food-item-level analysis (used in main analysis) addresses this by incorporating rich fixed effects.

While less granular than food-item data, country-year level confirms the overall results: estimated TF reduction for RS4 is 0.1671 gpcpd (close to the 0.142 gpcpd from the main model). Mediation effects, however, are less stable due to inability to isolate processed imports. Finally, Appendix 6B compares multiple DID estimators: two-way FE, SA, CS, Gardner (2021) and Borusyak et al. (2024). The average estimated effects remain negative across specifications, reinforcing that the findings are not model-specific. Together, these checks confirm the main

conclusions. While simpler models at the country-year level detect meaningful effects, food-item-level analysis better captures heterogeneity across product types and processing stages – providing stronger policy insights.

6. Conclusion

Progress toward eliminating TF intake has been uneven worldwide: countries differ widely in when they regulate, how strict those rules are, and whether they are enforced. In a globalized food system, such disparities matter: what one country bans TF, another may import TF knowingly or inadvertently. This study assessed how heterogeneous TF regulations shape intake, directly through domestic action and indirectly through trade exposure, and what role does monitoring play.

Using a new food-item-level dataset covering 161 countries (2010–2022) and employing causal inference tools, the results show that regulatory heterogeneity produces measurable cross-border externalities. TF intake varies significantly across countries, largely due to import mediation. Countries with the strongest rules (RS4) – such as the United States, which paired comprehensive bans with formal monitoring, achieved significant reductions in TF intake, cutting up to 0.372 g/capita/day (10.6 percent decline) from the global average or 0.470 g/capita/day (10.1 percent decline) from the North American and European average. Sustained at this pace, countries could reach WHO's recommended threshold of 2.2 g/day within 5-10 years. These reductions reflect both domestic restrictions and barriers to imports, making strict rules act as "filters" against TF-rich products.

By contrast, countries with weaker policies (RS2), including Bolivia, Costa Rica, Indonesia and Mongolia, with limited regulation and no monitoring, saw increases in TF intake

(0.078 g/capita/day), driven largely by leakage from TF-embodied imports. Even intermediate cases, such as Russia (RS3), showed limited impact, likely because partial measures did not cover imported processed foods. These findings mirror warnings in FAO's SOCO (2024): while trade can expand access and reduce undernutrition, it can also shift diets toward unhealthy products, especially in import-dependent economies. In such settings, fragmented regulation turns some countries into "dietary risk havens," where they absorb the external cost of global regulatory disparities. This study tackles a critical policy question for the first time with limited but valuable data. The mediation results, in particular, warrant cautious interpretation. Further research that integrates consumer-level (scanner) data with cross-country food composition tables – currently unavailable for many settings – would allow more precise identification of the mechanisms.

Together, internal policy success is contingent on the external regulatory environment, and with enforcement, less-strict policies can perform nearly as effectively as the most-strict ones. Yet, as WHO (2023) and Parziale & Ooms (2019) caution, countries with stringent rules may still indirectly export TF-rich products to weaker jurisdictions. This study provides evidence that such "regulatory dumping" is occurring, though the precise origin of these exports remains unclear. Some may stem from regulated markets operating under exemptions or from unregulated countries without domestic TF controls during the study period, highlighting the need for further research to trace their origins.

The flip side is also plausible: Parziale & Ooms (2019) suggest that countries with strict regulations may sometimes advocate for global standards to protect their exporters and ensure fair competition against low-cost producers in unregulated markets. In fact, this could be a strategic path forward. With their early adoption of stringent TF policies, North America and

Europe hold a first-mover advantage and are well-positioned to trigger a "*California Effect*" or "*Brussels Effect*," where higher domestic standards shape global supply chains. Such leadership could spark a race to the top, encouraging regulatory convergence and reducing the risk of "dietary risk havens." Coordinated harmonization, through regulatory tools like PHO bans, WHO-aligned enforcement, trade agreements with related clauses, and World Trade Organization-aligned trade practices and border controls, can prevent internal and external exposure, akin to calls for "new trade agreements" (Grossman et al., 2021) or "regulatory harmonization" (Sykes, 1999). These approaches would not only deliver health gains but also close trade loopholes, ensuring fairer competition. Such strategic international collaboration can make trade a mechanism for convergence, rather than a source of divergence, in global nutrition policy.

FIGURES

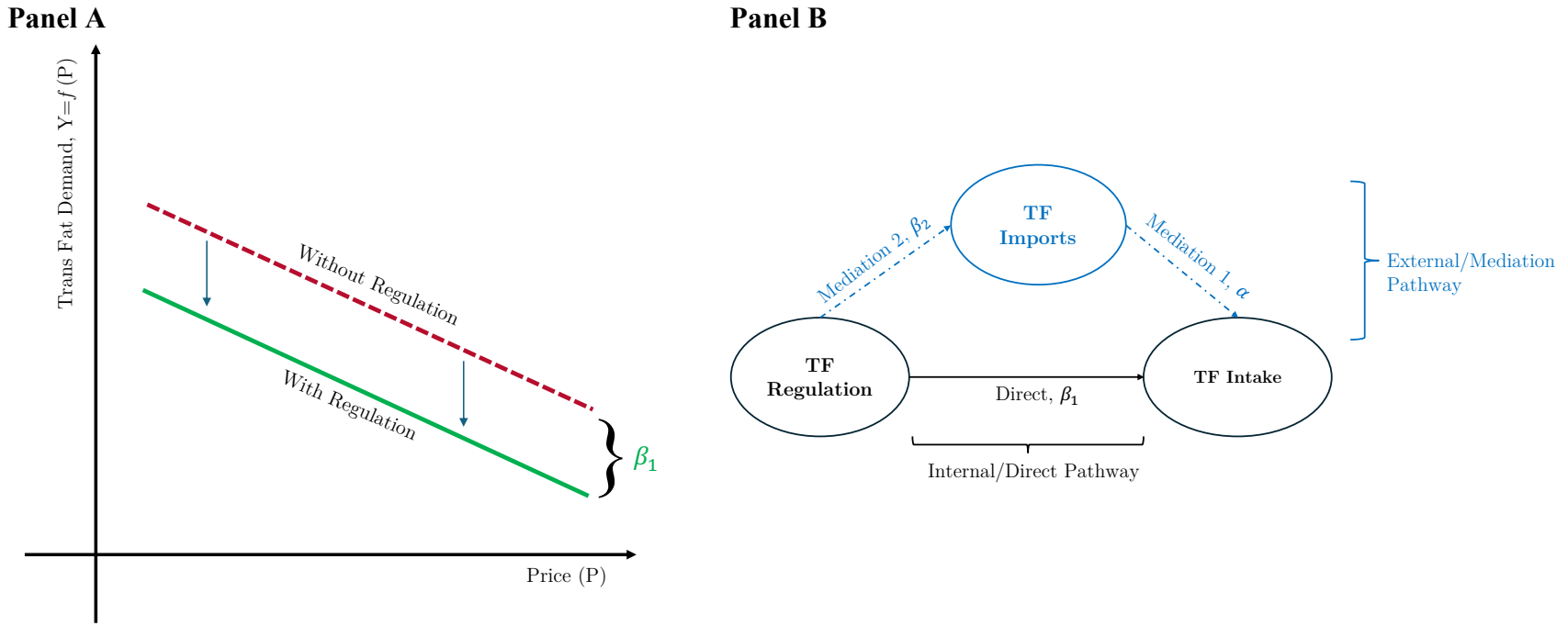
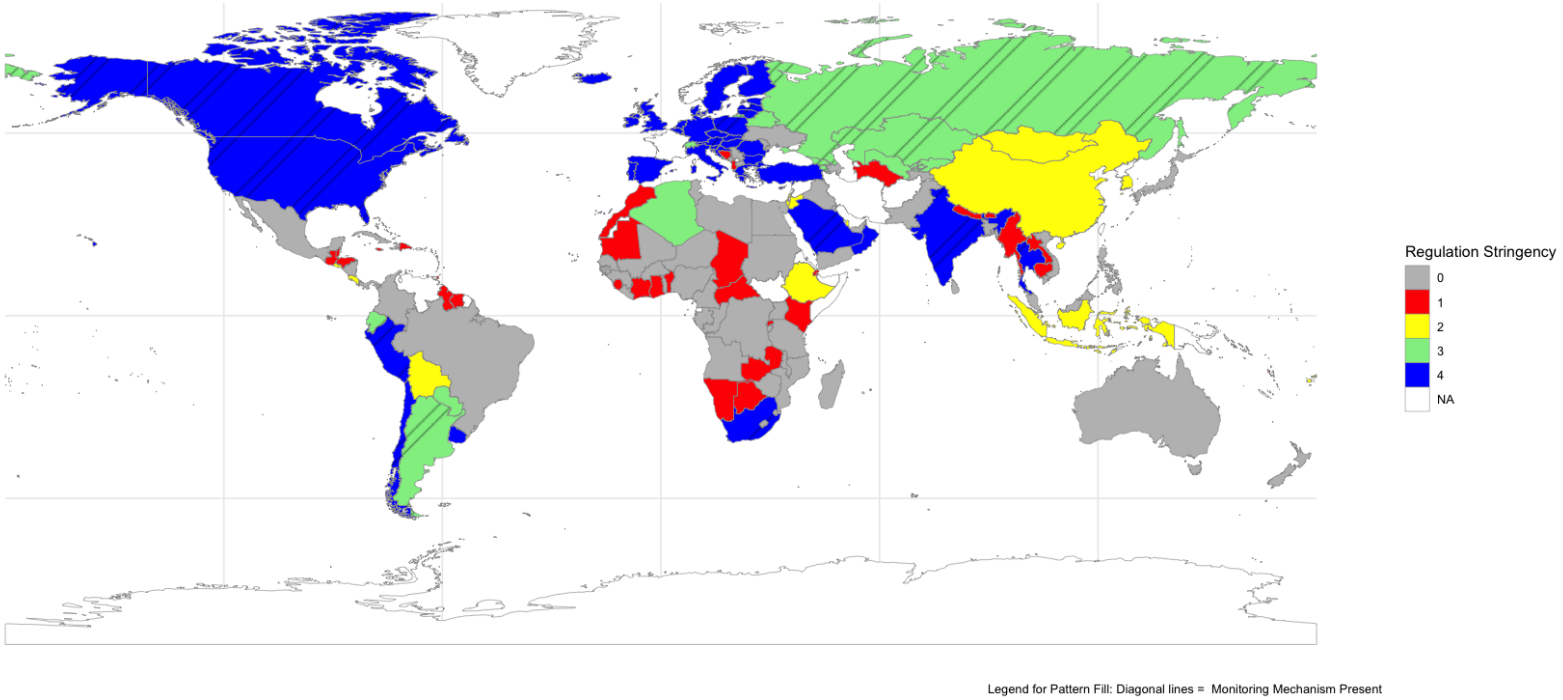


Figure 1: Panel A: Effect of Regulations on Trans Fat Intake; Panel B: Acyclic Graph showing Direct and Mediation Effects

Notes: β_1 in figure 1A estimates the Average Treatment Effect on the Treated (see Methods for details), capturing changes in TF demand following regulation relative to the control group. Figure 1B illustrates the mediation structure used in this study, showing internal and external pathways (β_2 and α).
Source: Authors



Score	Regulation Instruments as Defined by Nations
RS4	Mandatory national ban on PHO in all foods, Mandatory national ban on PHO, Mandatory national limit (iTFA <2 g/100 g total oils and fats in all foods), Food establishment operators are prohibited from using PHO; mandatory national limit (iTFA <2 g/100 g total oils and fats in all foods) Food products in which edible oils and fats are used as an ingredient shall not contain TFAs more than 2% by weight of the total oils/fats present in the product
RS3	2% TFA limit in oils and fats only; 2% TFA limit in oils and fats, and 5% limit in other foods
RS2	Reformulation to reduce/eliminate TFA Mandatory declaration of TFA on nutrition labels; reformulation to reduce/eliminate TFA Front-of-pack labelling system that includes TFA; reformulation to reduce/eliminate TFA Mandatory limit of iTFA on foods in specific settings Tax on food products with high levels of TFA

Figure 2: Mapping Trans Fat Regulation Stringency Score and Monitoring Mechanisms

Notes: WHO (2023) classifies countries by regulatory stringency, defined as the degree of adoption of trans fat (TF) regulations. Levels range from 0 to 4 (RS0–RS4 in this manuscript). Countries shown with diagonal shading on the map indicate those with a monitoring mechanism.
Source: Authors using multiple sources (see Appendix 1B for details)

TABLES

Table 1: Effect of Trans Fat Regulations on Intake

	Full Sample			**Trans Fat Rich Foods**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Outcome: TF Intake	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
TF Regulation = 1 (β_1)	0.0034	-0.0021	-0.0072**	0.0076	-0.0046	-0.0171**
	(0.0200)	(0.0015)	(0.0030)	(0.0547)	(0.0029)	(0.0077)
HH Consumption	0.0209**	0.0199**	0.0211***	0.0524**	0.0489**	0.0519**
Expenditure [a]	(0.0023)	(0.0021)	(0.0079)	(0.0064)	(0.0057)	(0.0209)
TF Imports (α) [a]	0.0043**	0.0042*	0.0038*	0.0080*	0.0082*	0.0074
	(0.0015)	(0.0015)	(0.0022)	(0.0057)	(0.0042)	(0.0047)
N	53027	54860	75205	19435	20137	27677
R2 Adj.	0.941	0.946	0.966	0.941	0.946	0.966
BIC	-57186.9	-59049.4	-78917.3	-2878.9	-3088.6	-3697.5

Notes: High-dimensional FE are used, as in equation (2) in the methods section. "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001
Source: Authors' Data created using FAO (2010-2022), USDA (2016), and UNCTAD

Table 2: Heterogenous Effects of Trans Fat Regulations on Intake

	Full Sample					Trans Fat Rich Foods				
	Income Classes			Geographic Region		Income Classes			Geographic Region	
Outcome: TF Intake	**High Income**	**Upper Middle**	**Lower Middle**	**NA/ECA**	**ROW**	**High Income**	**Upper Middle**	**Lower Middle**	**NA/ECA**	**ROW**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Complementary Measures Only (RS2)										
TF Regulation = 1	0.0125	0.0057	-0.0022	–	0.0034	0.0248	0.0152	-0.0065	–	0.0076
	(0.0203)	(0.0035)	(0.0038)		(0.0200)	(0.0488)	(0.0097)	(0.0101)		(0.0547)
HH Consumption Expenditure [a]	0.0216**	0.0220**	0.0220**	–	0.0209**	0.0539**	0.0546**	0.0546**	–	0.0524**
	(0.0088)	(0.0088)	(0.0088)		(0.0023)	(0.0234)	(0.0233)	(0.0233)		(0.0064)
TFA Imports [a]	0.0043*	0.0040*	0.0040*	–	0.0043**	0.0081*	0.0077	0.0077	–	0.0080*
	(0.0023)	(0.0024)	(0.0024)		(0.0015)	(0.0048)	(0.0050)	(0.0050)		(0.0057)
N	47710	50050	48906		53027	17511	18343	17953		19435
R2 Adj.	0.934	0.939	0.938		0.941	0.934	0.939	0.937		0.941
BIC	-48768.0	-52036.3	-50909.3		-57186.9	-2097.1	-2162.4	-2307.4		-2878.9
Less Restrictive Policy (RS3)										
TF Regulation = 1	0.0031	-0.0037	-0.0023	-0.0039	-0.0004	0.0104	-0.0088	-0.0059	-0.0099	0.0007
	(0.0149)	(0.0024)	(0.0032)	(0.0027)	(0.0068)	(0.0397)	(0.0063)	(0.0099)	(0.0077)	(0.0180)
HH Consumption Expenditure [a]	0.0214**	0.0217**	0.0218**	0.0223***	0.0212**	0.0532**	0.0538**	0.0541**	0.0554**	0.0526**
	(0.0088)	(0.0086)	(0.0087)	(0.0086)	(0.0088)	(0.0233)	(0.0228)	(0.0231)	(0.0228)	(0.0232)
TFA Imports [a]	0.0043*	0.0039*	0.0039	0.0039*	0.0042*	0.0083*	0.0076	0.0077	0.0076	0.0082*
	(0.0023)	(0.0023)	(0.0024)	(0.0023)	(0.0010)	(0.0049)	(0.0049)	(0.0050)	(0.0049)	(0.0026)
N	48295	52468	48295	51285	50674	17719	19253	17719	18824	18590
R2 Adj.	0.937	0.947	0.938	0.940	0.944	0.937	0.946	0.938	0.940	0.944
BIC	-49177.5	-55458.8	-50289.8	-56096.9	-50900.7	-1962.0	-2619.1	-2346.8	-3414.0	-1577.5
Most Restrictive Policy (RS4)										
TF Regulation = 1	-0.0076**	-0.0036	0.0001	-0.0099***	0.0027	-0.0183**	-0.0079	0.0033	-0.0235**	0.0055
	(0.0033)	(0.0043)	(0.0014)	(0.0037)	(0.0041)	(0.0083)	(0.0114)	(0.0065)	(0.0093)	(0.0109)
HH Consumption Expenditure [a]	0.0234***	0.0196**	0.0204**	0.0223***	0.0195**	0.0573***	0.0481**	0.0506**	0.0550**	0.0482**
	(0.0084)	(0.0084)	(0.0082)	(0.0084)	(0.0080)	(0.0221)	(0.0223)	(0.0219)	(0.0221)	(0.0212)
TFA Imports [a]	0.0039*	0.0039*	0.0038	0.0039*	0.0038*	0.0076	0.0074	0.0074	0.0075	0.0074
	(0.0023)	(0.0023)	(0.0023)	(0.0023)	(0.0023)	(0.0048)	(0.0048)	(0.0048)	(0.0049)	(0.0047)
N	71032	52494	51883	67444	57863	26130	19279	19058	24804	21268
R2 Adj.	0.964	0.944	0.935	0.965	0.943	0.964	0.944	0.934	0.965	0.943
BIC	-71586.5	-55222.5	-54725.7	-67008.7	-63357.4	-2408.5	-2708.7	-2814.1	-2088.3	-3680.5

Notes: High-dimensional FE are used, as in equation (2) in the methods section. NA/ECA refers to North America, Europe and Central Asia (based on World Bank Classification). "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001

Source: Authors' Data created using FAO (2010-2022), USDA (2016), and UNCTAD

Table 3: Effect of Trans Fat Regulations on Import (Mediator)

	Full Sample			**Trans Fat Rich Foods**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Outcome: **TF Import** [a]	**Complementary Measures Only**	**Less Restrictive Policy**	**Most Restrictive Policy**	**Complementary Measures Only**	**Less Restrictive Policy**	**Most Restrictive Policy**
	(RS2)	**(RS3)**	**(RS4)**	**(RS2)**	**(RS3)**	**(RS4)**
All Countries Included						
TF Regulation = 1 (β_2)	0.3233***	0.4349****	-0.2038****	0.4784**	0.6331****	-0.2006****
	(0.1240)	(0.1082)	(0.0241)	(0.2369)	(0.1898)	(0.0430)
HH Consumption Expenditure [a]	1.0341****	0.7527****	1.1438****	1.4788****	1.1145***	1.5649****
	(0.1903)	(0.1918)	(0.1563)	(0.3603)	(0.3617)	(0.2932)
N	53027	54860	75205	19435	20137	27677
R2 Adj.	0.935	0.938	0.959	0.913	0.919	0.946
BIC	268346.1	275418.2	350981.9	102916.2	105279.5	134909.1
Only Countries with Monitoring Mechanisms						
TF Regulation = 1 (β_2)	–	-0.2822****	-0.3040****	–	-0.3240***	-0.2994****
		(0.0708)	(0.0412)		(0.1226)	(0.0721)
HH Consumption Expenditure [a]	–	1.1602****	1.1284****	–	1.6381****	1.5414****
		(0.1856)	(0.1771)		(0.3508)	(0.3344)
N		52481	57863		19266	21268
R2 Adj.		0.940	0.948		0.921	0.930
BIC		260732.6	282013.3		99676.3	108519.3

Notes: Estimates are based on Equation (3) in the methods section (with high-dimensional fixed effects). The subscript "a" denotes inverse hyperbolic sine (asinh) transformation. Monitoring mechanisms are present only in countries with either less restrictive (RS3) or most restrictive (RS4) policies. * <0.1, ** <0.05, *** <0.01, ****<0.001
Source: Authors' Data created using FAO (2010-2022), USDA (2016), and UNCTAD

Table 4: Total Effect of Trans Fat Regulations on Intake after accounting for Mediation Effect

	Full Sample			Trans Fat Rich Foods		
Variable	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Direct Effects (DE)						
TF Regulation = 1 on Demand ($\widehat{\beta_1}$)	0.0034	-0.0021	-0.0072**	0.0076	-0.0046	-0.0171**
	(0.0200)	(0.0015)	(0.0030)	(0.0547)	(0.0029)	(0.0077)
Mediation Effect 1						
TF Imports [a] on Demand ($\hat{\alpha}$)	0.0043**	0.0042*	0.0038*	0.0080*	0.0082*	0.0074
	(0.0015)	(0.0015)	(0.0022)	(0.0057)	(0.0042)	(0.0047)
Mediation Effect 2						
TF Regulation = 1 on Imports ($\widehat{\beta_2}$)	0.3233***	0.4349****	-0.2038****	0.4784**	0.6331****	-0.2006****
	(0.1240)	(0.1082)	(0.0241)	(0.2369)	(0.1898)	(0.0430)
Total Mediation Effect, ME = $\hat{\alpha}\widehat{\beta_2}$	0.0014***	0.0018***	-0.0008***	0.0039**	0.0052***	-0.0015***
	(0.0004)	(0.0005)	(0.0002)	(0.0018)	(0.0018)	(0.0005)
Total Effects, TE = $\widehat{\beta_1} + \hat{\alpha}\widehat{\beta_2}$	0.0048**	-0.0003	-0.0079**	0.0114*	0.0006	-0.0186**
	(0.0023)	(0.0024)	(0.0035)	(0.0065)	(0.0069)	(0.0091)
Share of Total Mediation Effect in Total Effect $\{ME/_{TE} \times 100\}\%$	29.17	ns	10.13	34.21	ns	8.07
N	53027	54860	75205	19435	20137	27677

Notes: DE, ME1, and ME2 are obtained from Tables 1 and 3. ME and TE estimates, along with standard errors and p-values, are computed using 500 bootstrap replications based on Equation (5) in the methods section. The subscript "a" denotes variables expressed in inverse hyperbolic sine (asinh) transformation. "ns" indicates that the total effect is not statistically significant, and thus, the share is not reported. * <0.1, ** <0.05, *** <0.01, ****<0.001
Source: Authors' Data created using FAO (2010-2022), USDA (2016), and UNCTAD

Table 5: Cross-Effects of Trans Fat Regulations on Other Nutrients

	Full Sample						Trans Fat Rich Foods					
	Saturated Fat	**MUFA**	**PUFA**	**Cholesterol**	**Sugar**	**Sodium**	**Saturated Fat**	**MUFA**	**PUFA**	**Cholesterol**	**Sugar**	**Sodium**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Complementary Measures Only (RS2)												
TF Reg = 1	-0.0039	0.0390	0.0165	0.8514***	-0.0850	1.5548	0.0449	0.1228*	0.0727*	1.6907**	0.0476	4.0908
	(0.0873)	(0.0456)	(0.0374)	(1.0643)	(0.5783)	(1.8559)	(0.1674)	(0.1096)	(0.0863)	(2.6506)	(0.2037)	(4.4879)
N	53027	53027	53027	53027	53027	53027	19435	19435	19435	19435	19435	19435
R2 Adj.	0.085	0.280	0.246	0.271	0.216	0.161	0.216	0.323	0.331	0.333	0.258	0.189
BIC	269772.2	199926.7	152291.5	432111.7	390133.6	591886.7	91009.8	89154.7	67908.2	168898.7	83917.6	230380.3
Less Restrictive Policy (RS3)												
TF Reg = 1	-0.0329	0.0071	-0.0071	0.4356*	-0.1057	-0.2277	0.0678	0.0836	0.0246	1.0784*	0.0090	1.7922
	(0.0213)	(0.0233)	(0.0162)	(0.2955)	(0.2404)	(0.9240)	(0.0337)	(0.0324)	(0.0189)	(0.6392)	(0.0555)	(0.9584)
N	54860	54860	54860	54860	54860	54860	20137	20137	20137	20137	20137	20137
R2 Adj.	0.089	0.281	0.250	0.290	0.220	0.156	0.209	0.310	0.319	0.372	0.249	0.177
BIC	278205.8	213094.4	163621.5	447654.7	406476.1	612023.0	95301.9	95186.1	73742.3	175008.6	93048.9	238594.4
Most Restrictive Policy (RS4)												
TF Reg = 1	0.0016	0.0135	0.0051	0.1074	0.0224	0.1154	0.0310	0.0139	-0.0050	0.2204	-0.0416	-0.0845
	(0.0219)	(0.0139)	(0.0082)	(0.1074)	(0.0493)	(0.9304)	(0.0371)	(0.0349)	(0.0199)	(0.2674)	(0.0548)	(2.1494)
N	75205	75205	75205	75205	75205	75205	27677	27677	27677	27677	27677	27677
R2 Adj.	0.120	0.289	0.271	0.345	0.230	0.170	0.234	0.319	0.342	0.377	0.266	0.195
BIC	372117.1	322795.0	231670.5	618984.1	566033.8	854455.0	136138.8	142633.4	105030.9	245536.2	130207.9	333430.7

Notes: High-dimensional FE are used, as in equation (2). Except Sodium, which is in mg/cap/day, all other nutrients are in g/cap/day (adopting standard measurement practice). "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001

Source: Authors' Data created using FAO (2010-2022), USDA (2016) and UNCTAD

References:

Alem, Y., & Colmer, J. 2022. Blame it on the rain: Rainfall variability, consumption smoothing, and subjective well-being in rural Ethiopia. *Am J Agr Econ*, 104(3), 905–920.

ARS. (2009). *Palm Oil Not a Healthy Substitute for Trans Fats*. U.S. Department of Agriculture, Agriculture Research Service.

Bellemare, M. F. 2015. Rising Food Prices, Food Price Volatility, and Social Unrest. *Am J Agr Econ*, 97(1), 1–21.

Berge, L., & McDermott, G. 2024. *Fast Fixed-Effects Estimation: Short Introduction*.

Borusyak, K., Jaravel, X., & Spiess, J. 2024. Revisiting event-study designs: Robust and efficient estimation. *Review of Economic Studies*, 91(6), 3253–3285.

Bruce, J.H. 2023, Eliminating industrially produced trans fats from our diet–How well is it going?. *Nutr Bull*, 48: 427-434.

CAC. 2004. Food Standards Programme Codex Committee on Nutrition and Foods for Special Dietary Uses. Codex Alimentarius Commission.

Callaway, B., & Sant'Anna, P. H. C. 2021. Difference-in-Differences with multiple time periods. *J. of Econometrics*, 225(2), 200–230.

Cawley, J., Thow, A. M., Wen, K., & Frisvold, D. 2019. The Economics of Taxes on Sugar-Sweetened Beverages: A Review of the Effects on Prices, Sales, Cross-Border Shopping, and Consumption. In *Annual Review of Nutrition* (Vol. 39, Issue Volume 39, 317–338).

De Brauw, A., Eozenou, P., Gilligan, D. O., Hotz, C., Kumar, N., & Meenakshi, J. V. 2018. Biofortification, crop adoption and health information: Impact pathways in Mozambique and Uganda. *Am J Agr Econ*, 100(3), 906–930.

Deaton, A., & Muellbauer, J. 1980. *Economics and Consumer Behavior*. Camb. Univ. Press.

Disdier, A.-C., Fontagné, L., & Mimouni, M. 2008. The Impact of Regulations on Agricultural Trade: Evidence from the SPS and TBT Agreements. *Am J Agr Econ*, 90(2), 336–350.

Downs, S. M., Bloem, M. Z., Zheng, M., Catterall, E., Thomas, B., Veerman, L., & Wu, J. H. 2017. The Impact of Policies to Reduce Trans Fat Consumption: A Systematic Review of the Evidence. *Current Developments in Nutrition*, 1(12), cdn.117.000778.

Dubois, P., Griffith, R., & O'Connell, M. 2018. The effects of banning advertising in junk food markets. *The Review of Economic Studies*, 85(1), 396-436.

Fajgelbaum, P. D., Goldberg, P. K., Kennedy, P. J., & Khandelwal, A. K. 2020. The return to protectionism. *The Quarterly Journal of Economics*, 135(1), 1-55.

FAO. 2006. Strengthening National Food Control Systems Guidelines to Assess Capacity Building Needs.

FAO. 2025. Food Balance Sheets and Supply Utilization Accounts Resource Handbook 2025.

FDA. 1999. Food Labeling: Trans Fatty Acids in Nutrition Labeling, Nutrient Content Claims, and Health Claims; Reopening of the Comment Period. Federal Register.

FDA. 2003. Small Entity Compliance Guide on Labeling Trans Fatty Acids; Availability. Federal Register.

FDA. 2015. Estimate of Costs and Benefits of Removing Partially Hydrogenated Oils (PHOs) from the US Food Supply. Memorandum.

FDA. 2019. Food Labeling: TFA in Nutrition Labeling, Nutrient Content Claims, and Health Claims; Reopening of the Comment Period. Compliance Program Guidance Manual.

FDA. 2024. Final Determination Regarding PHOs (Removing Trans Fat).

Fiankor, D.-D. D., Dalheimer, B., & Mack, G. 2025. Pesticide regulatory heterogeneity, foreign sourcing, and global agricultural value chains. *Am J Agr Econ*, 107(2), 611–634.

Finaret, A. B., & Masters, W. A. 2019. Beyond Calories: The New Economics of Nutrition. In *Annual Review of Resource Economics* (Vol. 11, Issue Volume 11, 2019, pp. 237–259).

Fortin, N. D. 2022. Food Regulation: Law, Science, Policy, and Practice. John Wiley & Sons.

Gardner, J. 2021. Two-stage differences in differences. arXiv Preprint arXiv:2207.05943.

Grabovac, I., Hochfellner, L., Rieger, M., Jewell, J., Snell, A., Weber, A., Stüger, H.P., Schindler, K.E., Mikkelsen, B. and Dorner, T.E. 2018. Impact of Austria's 2009 trans fatty acids regulation on all-cause, cardiovascular and coronary heart disease mortality. European Journal of Public Health, 28: 4–9.

Grossman, G. M., McCalman, P., & Staiger, R. W. 2021. The "New" Economics of Trade Agreements: From Trade Liberalization to Regulatory Convergence? *Econometrica*, 89(1).

IHME. 2024. Global Burden of Disease (2024) – with minor processing by Our World in Data: High blood pressure [Dataset].

Imai, K., Keele, L., & Yamamoto, T. 2010. Identification, Inference and Sensitivity Analysis for Causal Mediation Effects. *Statistical Science*, 25(1), 51-71.

Jia, W., Xie, R., Ma, C., Gong, Z., & Wang, H. (2024). Environmental regulation and firms' emission reduction – The policy of eliminating backward production capacity as a quasi-natural experiment. *Energy Economics*, *130*, 107271.

Jones, A., & Zidenberg-Cherr, S. 2008. Nutrition & Health Info Sheets for Consumers—Trans Fats. UC Davis Dept of Nutrition.

Li, W., Finkelstein, E. A., & Zhen, C. 2022. Intended and unintended consequences of salient nutrition labels. *Am J Agr Econ*, 104(2), 853–872.

Lividini, K., & Masters, W. A. 2022. Tracing global flows of bioactive compounds from farm to fork in nutrient balance sheets can help guide intervention towards healthier food supplies. *Nature Food*, 3(9), 703–715.

Martin-Saborido, C., Mouratidou, T., Livaniou, A., Caldeira, S., & Wollgast, J. 2016. Public health economic evaluation of different European Union–level policy options aimed at reducing population dietary trans fat intake. *Am J Clin Nutr*, 104, 1218–1226.

Martin, W., & Laborde, D. 2018. Trade: The free flow of goods and food security and nutrition. IFPRI.

Maxted, A. 2024. How to stop your teens (and yourself) eating ultra-processedfood. *The Times.*

Mensink, R. P., & Katan, M. B. 1990. Effect of Dietary trans Fatty Acids on High-Density and Low-Density Lipoprotein Cholesterol Levels in Healthy Subjects. New Eng. Journal of Medicine, 323(7), 439–445.

Musicus, A. A., Xu, J., Kannarkat, J. T., & Lurie, P. 2025. Appraising the FDA's Sodium Reduction Efforts. *JAMA*.

Naqvi, A. 2024. Fixest::sunab (Sun and Abraham 2020).

Pace, N., Sebastian, A., Daidone, S., Prifti, E., & Davis, B. 2022. Mediation analysis of the impact of the Zimbabwe Harmonized Social Cash Transfer Programme on food security and nutrition. *Food Policy*, 106, 102190.

Parziale, A., & Ooms, G. 2019. The global fight against trans-fat: The potential role of international trade and law. *Globalization and Health*, 15(1), 46.

Popkin, B. M., Barquera, S., Corvalan, C., Hofman, K. J., Monteiro, C., Ng, S. W., Swart, E. C., & Taillie, L. S. 2021. Towards unified and impactful policies to reduce ultra-processed food consumption and promote healthier eating. *Lancet Diab. & Endo*. 9(7), 462–470.

Rahkovsky, I., Martinez, S., & Kuchler, F. 2012. New Food Choices Free of Trans Fats Better Align U.S. Diets with Health Recommendations, EIB-95. USDA.

Restrepo, B. J., & Rieger, M. 2016. Trans fat and cardiovascular disease mortality: Evidence from bans in restaurants in New York. *Journal of Health Economics*, 45, 176–196.

Rojas, C., Espín, A., Jaenicke, E. C., & Page, E. T. 2025. Food manufacturers' compliance with the FDA's trans fat ban: Evidence from scanner data. *Agri Econ*, 56(2), 303–321.

Roth, J., Sant'Anna, P. H. C., Bilinski, A., & Poe, J. 2023. What's trending in difference-in-differences? A synthesis of the recent econometrics literature. *J. of Econometrics*, 235(2).

Silvestrini, M. M., Smith, N. W., Fletcher, A. J., McNabb, W. C., & Sarti, F. M. 2024. Complex network analysis and health implications of nutrient trade. *G F Sec*, 40, 100743.

Smith, E., Scarborough, P., Rayner, M., & Briggs, A. D. M. 2018. Should we tax unhealthy food and drink? *Proceedings of the Nutrition Society*, 77(3), 314–320. Cambridge Core.

Smith, V. H., & Glauber, J. W. 2020. Trade, policy, and food security. *Agri Econ*, 51(1).

SOCO. 2024. Trade and nutrition: Policy coherence for healthy diets in State of Agricultural Commodity Markets 2024.

Stabile, A. 2024. Expert sounds the alarm on popular foods Americans eat posing serious health risks. *New York Post.*

Sun, L., & Abraham, S. 2021. Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. *J. of Econometrics*, 225(2), 175–199.

Sykes, A. 1999. The (limited) role of regulatory harmonization in international goods and services markets. *Journal of International Economic Law*, 2(1), 49–70.

Thow, A. M., & Nisbett, N. 2019. Trade, nutrition, and sustainable food systems. *The Lancet*, 394(10200), 716–718.

Todd, S. 2025. How ultra-processed foods captured the baby and toddler market. *Stat.*

UNCTAD. 2024. New UNCTAD-WHO analysis reveals trends in processed foods trade.

USDA. 2016. Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28 [Dataset].

Wang, Q., Afshin, A., Yakoob, M.Y., Singh, G.M., Rehm, C.D., Khatibzadeh, S., Micha, R., Shi, P., Mozaffarian, D. and Global Burden of Diseases Nutrition and Chronic Diseases Expert Group. 2016. Impact of Nonoptimal Intakes of Saturated, Polyunsaturated, and Trans Fat on Global Burdens of Coronary Heart Disease. *J. Amer Heart. Asso.*, 5(1), e002891.

WHO-Sodium. 2023. WHO global report on sodium intake reduction. WHO.

WHO-Sugar. 2022. Manual on SSB taxation policies to promote healthy diets. WHO.

WHO. 2019. Five billion people still at risk from industrial trans fat exposure. WHO

WHO. 2020. Global protocol for measuring fatty acid profiles of foods, with emphasis on monitoring trans-fatty acids originating from partially hydrogenated oils. WHO

WHO. 2023. Countdown to 2023: 5-year milestone report on global trans-fat elimination.

WHO. 2024. Trans fat.

Winchester, N., Rau, M.-L., Goetz, C., Larue, B., Otsuki, T., Shutes, K., Wieck, C., Burnquist, H. L., Pinto de Souza, M. J., & Nunes de Faria, R. 2012. The Impact of Regulatory Heterogeneity on Agri-food Trade. *The World Economy*, 35(8), 973–993.

Xiong, B., & Beghin, J. 2012. Does European aflatoxin regulation hurt groundnut exporters from Africa? *European Review of Agricultural Economics*, 39(4), 589–609.

Zhen, C., Finkelstein, E.A., Nonnemaker, J.M., Karns, S.A. and Todd, J.E. 2014. Predicting the Effects of Sugar-Sweetened Beverage Taxes on Food and Beverage Demand in a Large Demand System. *Am J Agr Econ*, 96: 1-25.

Zhen, C., & Zheng, X. 2020. The Impact of NuVal Shelf Nutrition Labels on Food Purchase. *Applied Economic Perspectives and Policy*, 42(4), 870–887.

APPENDIX

Appendix 1: Data Appendix

1A. Nutrient Intake and Imports Dataset Construction and Validation

Food and Agriculture Organization of the United Nations (FAO) provides annual data on food supply and total national imports (in tonnes) through its Supply Utilization Accounts (SUA) for approximately 535 items (hereafter, SUA items) from 2010 to 2022. This includes fish products from FAO Food Balance Sheets (FBS) because SUA do not provide information on fish products.[1] A key strength of this dataset is its highly disaggregated, "food-item"-level nutrient tracking for each country-year pair. Stepwise process to obtain nutrient is clearly tabulated below, and then provided as a flowchart with an example of "margarine and shortenings" as one of the SUA-items.

Stepwise process to obtain the intake and import data:

Steps	Description
1. SUA Item List and Quantity Conversion:	The dataset includes 535 SUA items, each classified using the Central Product Classification (CPC 2.1) and matched to one of 15 food categories and 4 processing levels (as detailed in Step 2). These items provide annual food intake and import quantities in tonnes, which are converted to per capita values in 100 grams to align with nutrient composition tables (details in Step 3).
2. Classifying Processed Foods:	The classification of processed foods follows a two-tiered approach. First, the FAO SUA classification provides basic categorization of (a) processed and (b) unprocessed foods across all SUA items. However, processed foods exist on a spectrum, ranging from minimally processed to ultra-processed, so relying on two category is not a right approach. Therefore, secondly using United Nations Conference on Trade and Development (UNCTAD, 2024) classification, it is "processed" ones are further classified to three categories: (a) minimally processed foods (Code B), (b) processed foods containing salt or sugar (Codes C and D), and (c) composite foods (Code E). Composite which involves processed ones not-specific to salt, sugar, or fermentation.[2] UNCTAD (2024) provides a classification for HS-2022 products, with detailed descriptions available for each HS-commodity. Additionally, UN-DESA (2015) offers a concordance between HS-2007 and CPC 2.1. To ensure accurate matching, HS-2022 is first aligned with HS-2007 using the World Integrated Trade

[1] Only the "Food" variable from the SUA data is used to compute nutrient intake, as it represents food available for direct human consumption. While some commodities also report values for "Food Processing," these refer to intermediate uses – such as raw commodities processed into edible forms – and are already accounted for in the final "Food" quantities after conversion. To test whether including "Food Processing" could improve estimates, these values are incorporated to obtain resulting nutrient totals and compared with the FAO-derived values. However, correlations dropped significantly (ranging from 0.192 to 0.390), and linear regressions showed poor fit. This confirms that relying solely on the "Food" variable yields estimates that align more closely with those used by FAO SUA, Lividini & Masters (2022) and Silvestrini et al. (2024).

[2] Original UNCTAD (2024) (pdf document) classifies food products based on their level of processing. This classification aligns with the Harmonized System (HS) codes and provides a structured approach to analyzing food trade. **Code B.** Cooked (Steamed or Broiled), Dried or Desiccated Foods; and Crude Oils, **Code C.** Foods that Have Been Sweetened, Salted/Brined (Whether Smoked or Not), **Code D.** Fermented, Smoked (but Neither Salted nor Brined), and **Code E.** Composite Foods, Preparations, and Refined Oils.

	Solution (WITS) HS versions concordance, followed by mapping it to CPC 2.1. However, since some items may be missing from the HS-CPC concordance, manual matching is done based on contextual suitability. This hybrid approach ensures a more precise classification of processed food products.
3. Nutrient Composition Tables:	To ensure uniformity and completeness, intake and import quantities for each SUA items are converted to nutrient values using USDA's Standard Reference (SR) Legacy 28 (2016), one of their 13 composition tables FAO (2025) have listed, which offers the most comprehensive coverage of food items, including processed foods with a wide range of additives and preparation methods. The extensive nature of the USDA dataset allows us to account for variations in nutrient composition due to processing, making it a reliable reference. Note that, only few composition tables trans-fat data, which is core for this study, and USDA SR is one of them. For instance, Composition of foods integrated dataset (CoFID) of the United Kingdom, Australian Food Composition Database - Release 2.0, New Zealand Food Composition Database (2024), Frida 5.3 from Denmark, also has trans-fat values comparable to USDA-SR tables.[3] USDA-SR had several updates between Releases 23 and 28 (post-2010), which are relevant for this study. To assess potential changes in nutrient values over time, a comparison of Releases 23 to 28 revealed that only 0.8 percent of items showed updated nutrient values, indicating minimal variation. Given this consistency, USDA-SR 28 (2016) is used as a stable and reliable reference for nutrient data in this analysis. In case of USDA-SR there are 23-28 releases that happened after 2010, so any updates after this period is relevant for this study. To assess potential updates in nutrient values, Releases 23 to 28 were compared and found that only 0.8% of items had updated nutrient values across versions, indicating minimal changes. Given this low variation, the USDA-SR 28 (2016) dataset serves as a stable and reliable reference for this analysis.[4]
4. Matching SUA items to Nutrient Composition Tables:	To compute nutrient values for each SUA item, a two-step matching process was employed using the USDA-SR database: (1) exact product matches, and (2) suitable or substitute matches where exact items were unavailable.[5] For example, the processed "food prepared, n.e.c." item, mix of USDA-SR items such as burgers, pizza, spaghetti, biscuits, breakfast cereals, chapati, and chicken rolls are matched. In another case, buffalo milk—absent in USDA-SR—was substituted with cow milk, given their similar nutritional profiles as ruminant milks.[6] While buffalo milk may have slightly higher fat and solids-not-fat content, using a consistent substitute across countries ensures comparability. Substitute values were used for 82 out of 535 SUA items. A full list of matched and substituted items is available upon request. Each SUA item (identified by its CPC code) is now matched with at least one NDB

[3] If there was the time series for each commodity in each country, that would make the best nutrient composition table. Because none of the available composition databases have nutrient values time series for all commodities, using different databases is just about rescaling the levels, but not the change. This rescaling problem matters for one who just want to build the nutrient data, but to use it for regression analysis, rescaling is simply a problem that rescales our estimate.

FAO's 2025 Handbook lists 13 food composition tables used in their assessments, and the INFOODS website provides access to additional datasets. Many of these tables are commodity-specific (e.g., FAO/INFOODS uPulses1.0 for pulses, uFiSh1.0 for fish) or country-specific with limited applicability for global nutrient tracking. Moreover, several major databases lack trans-fat data—such as the West African Food Composition Tables (2012, 2019), Indian or Bangladesh Food Composition Tables, Brazil's Brazilian Food Composition Database (TBCA 7.2), Japan's MEXT Standard Tables of Food Composition, and Bahrain's national database.

There are also broader initiatives that compile or estimate nutrient data, including the Global Food Matters Database, the Global Dietary Database (5-year interval), the Delta Method's Nutrient Trade data, Silvestrini's Global Nutrient Trade Database, the Nutrient Balance Sheet by Lividini and Masters (2022), and Schmidhuber et al. (2018)'s Global Nutrient Database. While some are publicly accessible, none extend to 2022, which is critical for this analysis given that most countries adopted trans-fat regulations in or after 2018.

[4] USDA SR28 dataset contains two types of data: (a) abbreviated and (b) complete. The abbreviated version includes data for all food items but does not contain values for certain nutrients, such as trans-fat, starch, fluoride, betaine, vitamin D2 and D3, added vitamin E, added vitamin B12, alcohol, caffeine, theobromine, phytosterols, individual amino acids, individual fatty acids, and individual sugars. Complete version has all of these data. Nutrient values in both of them are presented per 100 grams of the edible portion, but each nutrient is measured in its own unit (USDA ARS, 2020). For example: protein, total fat, carbohydrates, total sugar, trans-fat, saturated fat, mono- and poly-unsaturated fatty acids are measured in grams per 100 grams of food. Energy is measured in kilocalories (kcal) per 100 grams of food. Sodium and Potassium is measured in milligrams (mg) per 100 grams of food.

[5] Since fuzzy matching was not feasible due to the large number of words, abbreviations (e.g., CHK, CHICK, CHICKEN, BROILER, POULTRY) and multiple combinations of cooking/processing methods (SMK, CND, CKD, RAW, FLR), automated word matching risked misclassification—for example, incorrectly linking almond oil to almonds simply because of the shared word "almond." Given these complexities, manual matching was necessary to ensure accuracy.

[6] Categorization of aquatic products and corresponding NDB matches follow the approach used by Lividini and Masters (2022). For the infant food category, their NDB list is adopted and supplemented with additional items that best represent foods commonly consumed by infants.

	code from USDA-SR. In cases where USDA-SR includes multiple versions of the same item multiple NDB codes were matched to capture the range of variation and ensure a comprehensive nutrient estimate.
5. Aggregation and Deriving Nutrient Multipliers:	Each SUA item may correspond to multiple USDA-SR matches. Aggregating these into a single nutrient value to create a multiplier requires assumptions about the distribution of matched products. In the absence of detailed quantity shares—particularly country-specific distributions—uniform distribution is assumed across matched items. That is, nutrient multipliers for each SUA item is computed using the mean across matched products; robustness checks using the median and maximum yielded consistent results.[7] While the uniform distribution assumption is a simplification, it offers a practical solution given data limitation. This approach is efficient for the small set of key nutrients analyzed.
6. Adjustments to SUA Quantities:	Before applying nutrient multipliers, quantities in step 1 are adjusted using refuse and retention factors to ensure accurate estimation of final nutrient values. ***Refuse Factor:*** Refuse factors (percent of total quantity that goes unused) for each SUA item were used from FAO (2020). For items not explicitly listed, closely related substitutes were selected. For example, the refuse factor for "Meat, nes, preparations" was applied to "Poultry meat preparations." This approach is consistent with methods used in previous studies, including Schmidhuber et al. (2018). ***Nutrient Retention in Processing and Cooking:*** Since the dataset is already disaggregated into specific categories—such as bran, flour, husked and dehusked grains, and both raw and processed forms of fruits (e.g., juice)—there is no need to apply additional processing retention rates. The structure of the dataset inherently reflects different processing stages, removing the necessity for conversion from primary commodities to their processed forms. Moreover, each SUA commodity is pre-matched to nutrient composition data based on its processing status, ensuring accuracy and consistency in nutrient flow calculations. Nutrient loss during cooking is commonly addressed in final nutrient derivation process, such as in Lividini and Masters (2022). While the USDA (2007) retention dataset includes data for 270 foods, it does not report on trans fat. Moreover, trans fat content is generally stable during cooking below 200 °C, and may even increase at higher temperatures or with prolonged heating (Bhat et al., 2022). Given the uncertainty about whether specific foods are cooked above or below this threshold, no retention factor is applied. ***Food Loss and Waste:*** According to FAO (2025), the food supply data used to estimate nutrient quantities do not exclude post-retail (i.e., post-sale) food loss and waste. While data on pre-retail losses are available at FAOSTAT, item-specific post-retail loss data are not. Moreover, substantial cross-country variation in total food loss further limits the feasibility of applying uniform adjustments. As a result, the reported values reflect apparent intake rather than actual or effective consumption.
7. Computing Intake and Imports:	For each country-year, nutrient intake is computed by multiplying each adjusted SUA item (Step 6) by its corresponding nutrient multiplier (Step 5) and summing across all SUA items for each nutrient. Total nutrient volumes are then converted to per capita per day values using contemporaneous population data from the FBS. For nutrient imports, national-level totals are calculated similarly, without population adjustment. This process generates two datasets: (i) a country-year level dataset containing total nutrient intake and imports, and (ii) a disaggregated dataset at the country–food category–processing level–year level.[8] While the disaggregated dataset is used for primary analysis, the aggregated version serves as a robustness check and offers a more interpretable view for deriving policy implications.

[7] In computing mean, median and maximum nutrient values, both missing and zero values were encountered. To avoid introducing bias, missing values were retained as missing rather than imputed as zeros. As a robustness check, an alternative analysis was conducted in which missing values were replaced with zeros to assess the potential impact on results. The findings remained consistent across both approaches.

[8] In disaggregated dataset, rows are only removed when all nutrient values are missing (i.e., entirely NA). Some food items (combinations of food category and processing level) can have zero intake or zero imports across all years and countries due to regulatory bans or no consumption – these zero values carry important information and are therefore retained. Furthermore, food items that are inherently invalid have been excluded. For instance, *BabyFood*, being inherently processed, is removed from unprocessed categories (processing levels 0–2) across all country-year observations. This step ensures that the dataset reflects realistic food classification structures and prevents the inclusion of invalid combinations.

Step 1: SUA Item List and Quantity Conversion

Central Product Classification (CPC, version 2.1) for Margarine and Shortenings (M-S) = 21700.02
- M-S Classified to Food Category = Fats and Oils, Processing Level = Composite (details in Step 2)
- Annual intake and import quantities (tonnes) → converted to 100 grams to align with nutrient composition tables (details in Step 3, 4)

Step 2: Classifying Processed Foods (Two-Tiered Process)

1. M-S is classified as "processed foods" by FAO [other categories: unprocessed]
2. Using UNCTAD (2024), M-S is further classified to composite foods (inc. refined oils) [other categories: unprocessed, minimally processed, salt/sugar-processed]. Used HS–CPC concordance from UN-DESA (2015) for matching CPC to HS codes in UNCTAD (2024)

Step 3: Nutrient Composition Table Selected

USDA's Standard Reference (SR) Legacy 28 (2016), one of their 13 composition tables in FAO (2025), offers the most comprehensive coverage of food items, including processed foods with a wide range of additives and preparation methods.

Step 4: (Two-Step) Matching SUA items to Nutrient Composition Table

(1) exact product matches,
(2) suitable or substitute matches where exact items were unavailable

M-S is matched with multiple elements as shown on the right, NDB is the Nutrient Database Number for product identification.

NDB_No	USDA-SR Items
04617	margarine,reg,80% fat,comp,stk,wo/ salt
04618	margarine,reg,80% fat,comp,tub,wo/ salt
04073	margarine,reg,hard,soybn (hydr)
04655	margarine-like shortening,indus,soy(part hydr),cttnsd,& soy
04595	shortening,multipurpose,soybn (hydr)&palm (hydr)
04587	shortening,spl purpose for baking,soybn (hydr) palm&cttnsd
04550	shortening frying (hvy duty),bf tallow&cttnsd
04559	shortening household soybn (hydr)&palm
04544	shortening,household,lard&veg oil
04031	shortening,household,partially hydrog soybn-cottonseed
04615	shortening,veg,household,comp
04667	shortening,indus,soy (part hydr) for baking & confections

Step 5: Aggregation and Deriving Nutrient Multipliers

$$SUA\ Multiplier_{fp}^{n} = \frac{\sum_{NDB} Nutrient\ Value^{n}}{Total\ NDB\ Matches}$$

- n={energy, trans-fat, sat-fat, ...}

For M-S, multipliers are:
- Energy Mean: 823.416 kcal/100 g of food
- Trans-Fat Mean: 22.493 g/100 g of food
- Saturated Fat Mean: 25.603 g/100 g of food

For robustness checks: using median and maximum values as well

NDB_No	Energy (kcal/100g)	Trans-Fat (g/100g)	Satur-Fat (g/100g)	.....
04617	717	14.890	15.189	
04618	713		14.224	
04073	719		16.700	
04655	628	19.068	22.869	
04595	884		30.423	
04587	884		28.843	
04550	900		44.900	
04559	884		25.020	
04544	900		40.300	
04031	884		25.000	
04615	884	13.164	24.980	
04667	884	42.851	18.788	

Step 6: Adjustments to SUA Quantities (Intake and Import)

$$Adjusted\ SUA\ Intake_{ifpt} = Adjusted\ SUA\ Intake_{ifpt} \times Refuse\ Factor_{fp}$$
$$Adjusted\ SUA\ Import_{ifpt} = Adjusted\ SUA\ Import_{ifpt} \times Refuse\ Factor_{fp}$$

Refuse Factor:
For M-S: 0% (FAO, 2020)

Nutrient Retention in Processing and Cooking:
- M-S's quantities are already after processing
- <200 °C (trans-fat is stable); may even increase >200 °C (Bhat et al., 2022)

Food Loss and Waste:
FAO (2025) does not provide post-retail losses

Step 7: Computing Nutrient-Level Intake and Imports

Food item level for country-year pair:

$$Intake_{ifpt}^{n} = \frac{Adjusted\ SUA\ Intake_{ifpt} \times SUA\ Multiplier_{fp}^{n}}{Population_{it} \times 365}$$

$$Import_{ifpt}^{n} = Adjusted\ SUA\ Import_{ifpt} \times SUA\ Multiplier_{fp}^{n}$$

- n={energy, trans-fat, sat-fat, ...}
- i=country, t =year, f=food category, p = processing level

Country level for each year:

$$Intake_{it}^{n} = \frac{\sum_{fp} Adjusted\ SUA\ Intake_{ifpt} \times SUA\ Multiplier_{fp}^{n}}{Population_{it} \times 365}$$

$$Import_{it}^{n} = \sum_{fp} Adjusted\ SUA\ Import_{ifpt} \times SUA\ Multiplier_{fp}^{n}$$

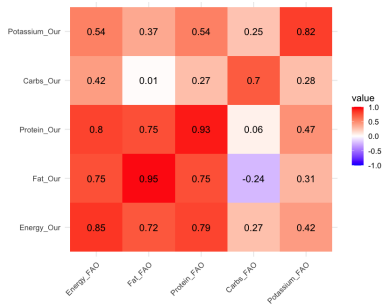
- n={energy, trans-fat, sat-fat, ...}
- i=country, t =year, f=food category, p = processing level

1A.2. Validation using FAO and GNTD:

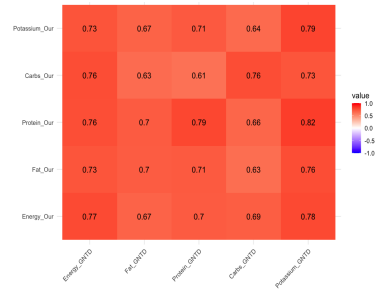
The study compares its estimates with two established datasets: (i) FAO SUA database (FAO, 2025), which shows strong alignment with nutrient intake estimates from Lividini & Masters (2022), and (ii) Global Nutrient Trade Database from Silvestrini et al. (2024) (with data link), which reports nutrients embodied in bilateral trade. The comparison uses country-year panel, and is limited to Energy, Fat, Protein, Carbohydrates, and Potassium, as these nutrients are consistently available across all datasets.

While the main analysis expresses intake in per capita per day (pcpd) terms and imports as total national volumes, both intake and imports are converted to pcpd units here (only for validation purpose) to allow direct comparison with GNTD, which reports consumption in these terms.[9] The comparison plots below demonstrate close alignment between this study's estimates and those from FAO and GNTD, both in terms of variation (high correlations for intake and import estimates) and levels (consistent relationship in linear regressions).

a. Correlation Heatmaps:



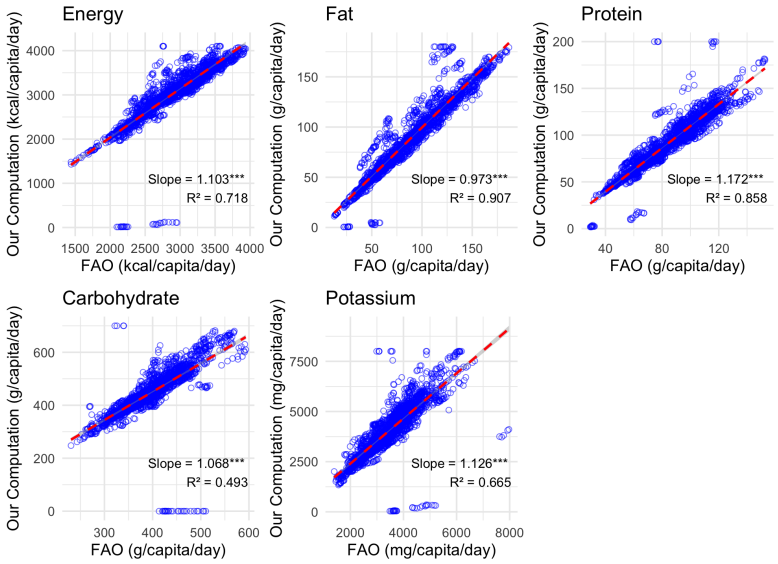
Intake: Correlation between Our Estimates and FAO's Estimates



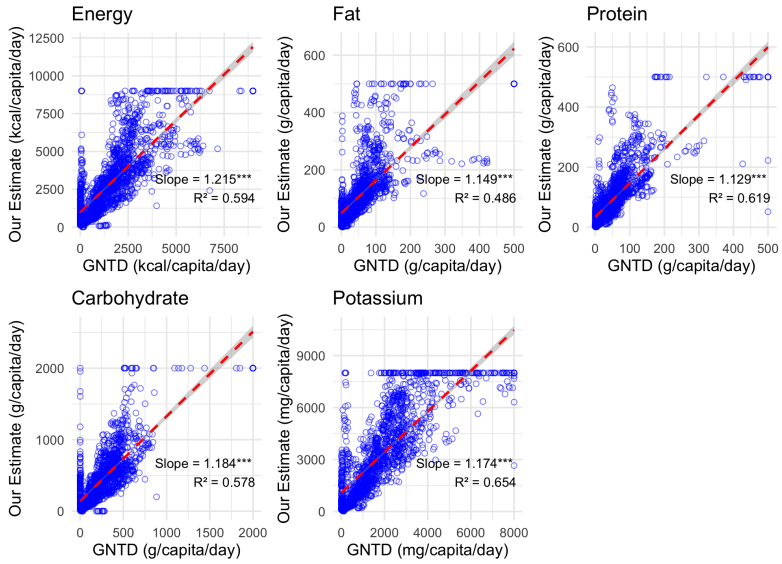
Imports: Correlation between Our Estimates and GNTD's Estimates

[9] The main analysis uses national-level import quantities as a proxy for external exposure to TF. While these imports are not limited to direct human consumption—potentially including re-exports, animal feed, or industrial use—they offer a meaningful signal of exposure risk at the macro level. As such, import volumes should not be interpreted as individual-level intake or uniformly scaled to per capita daily estimates; in some cases, import-to-intake ratios can exceed 1. Despite this, aggregate import volumes remain a valid proxy for national-level exposure. A validation exercise comparing per capita nutrient imports (converted to daily values) with matched data from the Global Nutrient Database (GNTD) shows over 70 percent correlation, supporting their use. Per capita import measures are also directly tested in Equation (2), but they introduced considerable noise and instability—reinforcing choice to use aggregate import quantities in the main analysis.

b. Using Linear Regression



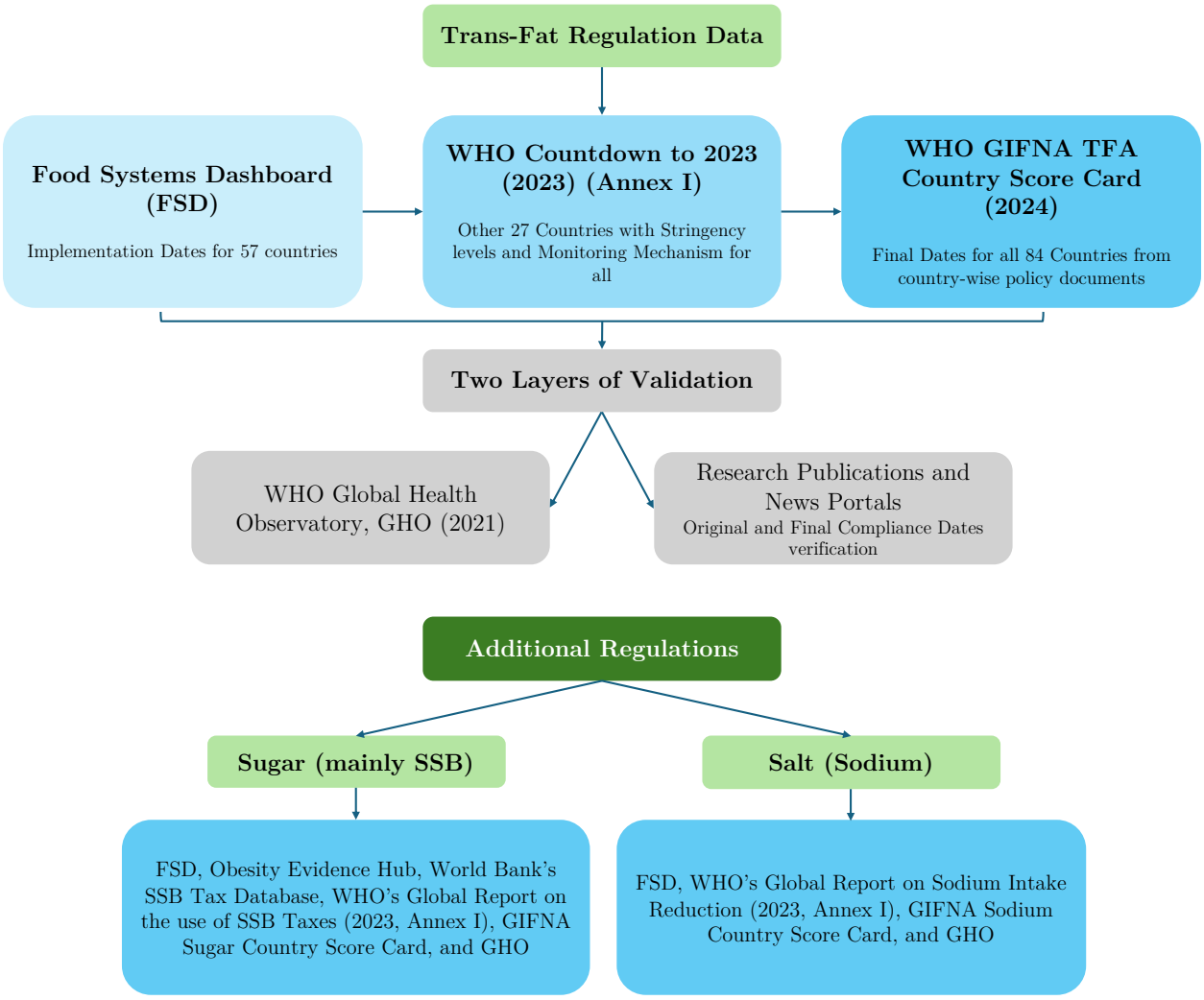
Intake[10]



Imports

[10] In addition, Bland-Altman statistics plots indicate that this study's estimates tend to be higher than FAO's, especially for energy, carbohydrates, and potassium, with many values falling below the zero-difference line. Agreement is better for fat and protein, though some overestimation remains. These discrepancies likely stem from the use of USDA SR nutrient data, which reflects high-quality foods typical of developed markets, whereas FAO's estimates are based on global food compositions, including lower-quality or less nutrient-dense items. Global nutrient composition tables cannot be used due to their lack of trans fat content, which is essential for this study.

1B. Regulations Compilation

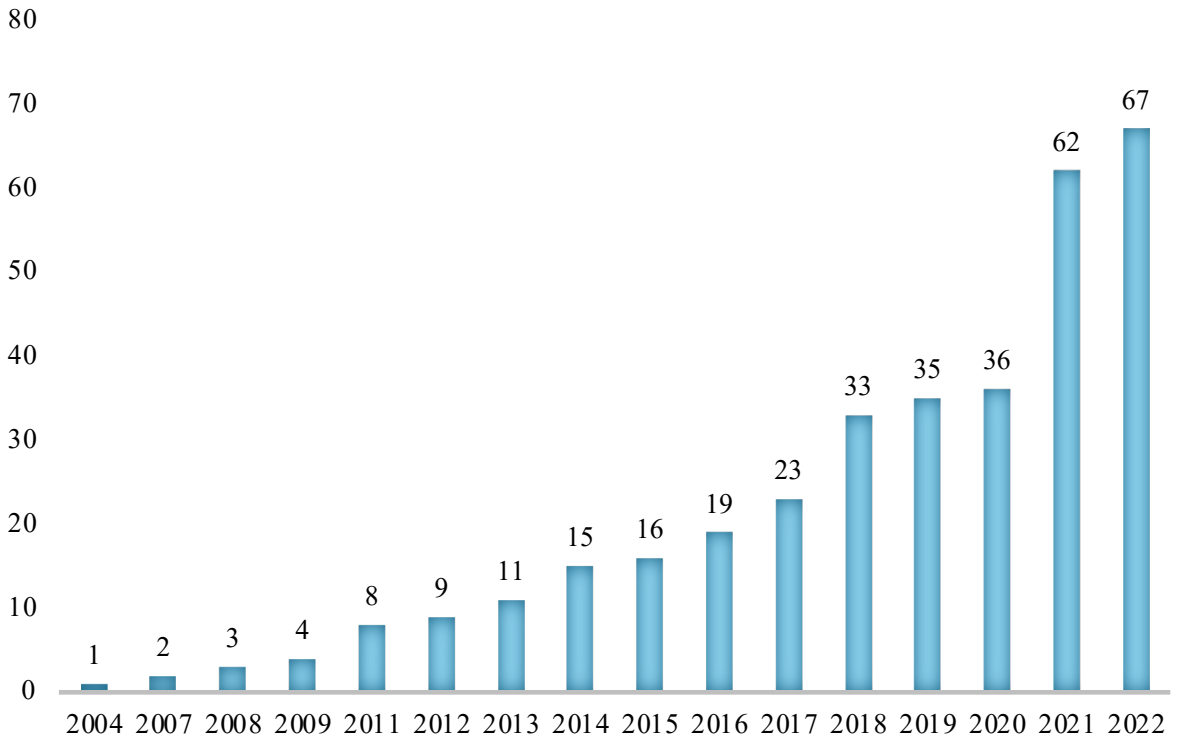


Appendix 2:

2A: List of Countries with their Initial Effective and Final Compliance Dates

Country Code	Initial Date	Final Date	Score	Monitoring Mechanism	Country Code	Intitial Date	Final Date	Score	Monitoring Mechanism	Country Code	Intitial Date	Final Date	Score	Monitoring Mechanism
ALB	0	0	1	0	GEO	2017	2017	3	1	NER	0	0	0	0
DZA	2018	2018	3	0	DEU	2021	2021	4	0	NGA	2023	2023	4	0
AGO	0	0	0	0	GHA	0	0	1	0	NOR	2014	2014	4	1
ARG	2010	2014	3	1	GRC	2021	2021	4	0	OMN	2021	2022	4	0
ARM	2018	2018	3	1	GTM	0	0	1	0	PAK	2023	2023	3	0
AUS	0	0	0	0	GIN	0	0	0	0	PAN	0	0	0	0
AUT	2009	2009	4	1	GNB	0	0	0	0	PRY	2022	2022	3	0
AZE	2023	2023	2	0	GUY	0	0	1	0	PER	2021	2021	4	1
BHR	2016	2016	3	0	HTI	0	0	0	0	PHL	2023	2023	4	0
BGD	2022	2023	4	0	HND	0	0	1	0	POL	2021	2021	4	1
BRB	0	0	1	0	HUN	2014	2014	4	1	PRT	2021	2021	4	0
BLR	2018	2018	3	1	ISL	2011	2011	4	1	QAT	2017	2017	2	0
BEL	2021	2021	4	0	IND	2022	2022	4	1	ROU	2021	2021	4	0
BLZ	0	0	1	0	IDN	2022	2022	2	0	RUS	2018	2018	3	1
BEN	0	0	1	0	IRQ	0	0	0	0	RWA	0	0	1	0
BTN	0	0	1	0	IRL	2021	2021	4	0	SAU	2020	2020	4	1
BOL	2015	2015	2	0	ISR	2011	2011	2	0	SEN	0	0	0	0
BIH	0	0	1	0	ITA	2021	2021	4	0	SRB	0	0	0	0
BWA	0	0	1	0	JAM	0	0	1	0	SYC	0	0	1	0
BRA	2021	2023	4	0	JPN	0	0	0	0	SLE	0	0	1	0
BGR	2021	2021	4	0	JOR	2017	2017	2	0	SVK	2021	2021	4	0
BFA	0	0	0	0	KAZ	2018	2018	3	1	SVN	2018	2018	4	0
BDI	0	0	0	0	KEN	0	0	1	0	SLB	0	0	0	0
KHM	0	0	1	0	KIR	0	0	0	0	ZAF	2011	2011	4	1
CMR	0	0	0	0	KWT	2022	2025	4	0	KOR	2007	2007	2	0
CAN	2018	2018	4	1	KGZ	2018	2018	3	1	ESP	2021	2021	4	0
CPV	2016	2016	2	0	LAO	0	0	1	0	LKA	2022	2025	4	0
CAF	0	0	1	0	LVA	2018	2018	4	1	SDN	0	0	0	0
TCD	0	0	1	0	LSO	0	0	0	0	SUR	0	0	1	0
CHL	2011	2014	4	1	LBR	0	0	0	0	SWZ	0	0	0	0
CHN	2011	2011	2	0	LBY	0	0	0	0	SWE	2021	2021	4	0
COL	2012	2023	3	1	LTU	2019	2019	4	1	CHE	2008	2008	3	1
COG	0	0	0	0	LUX	2021	2021	4	0	TJK	0	0	0	0
CRI	2012	2012	2	0	MKD	0	0	0	0	TZA	0	0	0	0
CIV	0	0	1	0	MDG	0	0	0	0	THA	2019	2019	4	1
HRV	2021	2021	4	0	MWI	0	0	0	0	GMB	0	0	0	0
CUB	0	0	0	0	MYS	0	0	0	0	TGO	0	0	0	0
CYP	2021	2021	4	0	MDV	0	0	1	0	TTO	0	0	1	0
CZE	2021	2021	4	0	MLI	0	0	0	0	TUN	0	0	0	0
COD	0	0	0	0	MLT	2021	2021	4	0	TUR	2021	2021	4	0
DNK	2004	2004	4	1	MRT	0	0	1	0	TKM	0	0	1	0
DJI	0	0	1	0	MUS	0	0	1	0	UGA	0	0	0	0
DMA	0	0	0	0	MEX	2023	2023	4	0	UKR	2023	2023	4	0
DOM	0	0	1	0	MDA	2023	2023	4	0	ARE	2022	2023	4	0
ECU	2013	2013	3	1	MNG	2018	2018	2	0	GBR	2021	2021	4	0
EGY	2023	2023	4	0	MNE	0	0	0	0	USA	2018	2021	4	1
SLV	2017	2017	2	0	MAR	0	0	1	0	URY	2021	2022	4	1
EST	2021	2021	4	0	MOZ	0	0	0	0	UZB	2016	2016	3	0
ETH	2021	2021	2	0	MMR	0	0	1	0	VUT	0	0	1	0
FSM	0	0	0	0	NAM	0	0	1	0	VNM	0	0	0	0
FJI	2013	2013	2	0	NPL	0	0	1	0	YEM	0	0	0	0
FIN	2021	2021	4	0	NLD	2021	2021	4	0	ZMB	0	0	1	0
FRA	2021	2021	4	0	NZL	0	0	0	0	ZWE	0	0	0	0
GAB	0	0	0	0	NIC	0	0	0	0					

2B: Staggered Implementation of Trans-Fat Policies



Notes: Although more countries had adopted regulations by 2025, the data extend only to 2022; the graph reflects only countries included in the dataset.
Source: Authors using WHO Reports

Appendix 3: Summary Statistics

Panel A:

Food Item Level	TFA Intake (g/cap/day)	TFA Imports [a]	Consumption Expenditure [a]
N	93,639	93,639	92,772
Global Average	0.0777	10.056	8.8015
	(0.0016)	(0.0258)	(0.0040)
East Asia & Pacific	0.0548	9.7900	8.7000
	(0.0033)	(0.0791)	(0.0105)
Europe & Central Asia	0.1050	11.4000	9.6100
	(0.0035)	(0.0501)	(0.0057)
Latin America & Caribbean	0.1000	10.2000	9.0900
	(0.0046)	(0.0615)	(0.0045)
Middle East & North Africa	0.0651	9.8100	9.1600
	(0.0045)	(0.0844)	(0.0097)
North America	0.2171	13.2790	11.0450
	(0.0417)	(0.2542)	(0.0066)
South Asia	0.0525	8.7160	7.9600
	(0.0061)	(0.1200)	(0.0093)
Sub-Saharan Africa	0.0344	8.9900	7.4800
	(0.0018)	(0.0483)	(0.0054)

Panel B:

Country Level	TFA Intake (g/cap/day)	TFA Imports [a]	Consumption Expenditure [a]
N	2,020	2,029	2,048
Global Average	3.2286	23.089	8.7797
	(0.0573)	(0.0406)	(0.0274)
East Asia & Pacific	2.2758	22.5512	8.6976
	(0.1197)	(0.1578)	(0.0712)
Europe & Central Asia	4.4192	23.7327	9.6087
	(0.1017)	(0.0607)	(0.0389)
Latin America & Caribbean	4.1848	23.2696	9.0927
	(0.0967)	(0.0842)	(0.0303)
Middle East & North Africa	3.0292	23.8816	9.1646
	(0.1468)	(0.0986)	(0.0662)
North America	9.6992	25.7168	11.0449
	(0.9769)	(0.1254)	(0.0455)
South Asia	2.3537	24.5325	7.9558
	(0.2105)	(0.2356)	(0.0631)
Sub-Saharan Africa	1.3091	22.0780	7.4640
	(0.0754)	(0.0636)	(0.0353)

Notes: Countries are categorized based on World Bank Classification. “a” index represents the asinh transformation (as used in the analysis).

Appendix 4: Effect of Trans Fat Regulations on Processed and Unprocessed Imports (Mediation Effects)

Outcome: **Processed Imports** [a]	**Full Sample**			**Trans Fat Rich Foods**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Complementary Measures Only (RS2)	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
All Countries Included						
TFA Regulation = 1	0.2066**	0.2909****	-0.0899****	0.3445*	0.3470**	-0.1057****
	(0.0971)	(0.0842)	(0.0157)	(0.1856)	(0.1502)	(0.0238)
N	53027	54860	75205	19435	20137	27677
R2 Adj.	0.970	0.971	0.982	0.980	0.981	0.989
BIC	227620.5	234143.1	291347.1	81083.2	82631.4	100314.1
Only Countries with Monitoring Mechanisms						
TFA Regulation = 1	–	-0.1230***	-0.1299****	–	-0.1774***	-0.1433****
		(0.0454)	(0.0263)		(0.0581)	(0.0404)
N		52481	57863		19266	21268
R2 Adj.		0.974	0.978		0.984	0.986
BIC		218903.6	235138.1		75573.8	81668.1

Outcome: **Unprocessed Imports** [a]	**Full Sample**			**Trans Fat Rich Foods**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Complementary Measures Only (RS2)	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
All Countries Included						
TFA Regulation = 1	0.1168	0.1439*	-0.1139****	0.1339	0.2861*	-0.0949***
	(0.0865)	(0.0825)	(0.0190)	(0.1661)	(0.1575)	(0.0370)
N	53027	54860	75205	19435	20137	27677
R2 Adj.	0.949	0.951	0.970	0.925	0.928	0.957
BIC	236418.6	242947.3	306470.6	95657.1	98308.0	125784.3
Only Countries with Monitoring Mechanisms						
TFA Regulation = 1	–	-0.1592***	-0.1741****	–	-0.1466	-0.1562**
		(0.0573)	(0.0340)		(0.1125)	(0.0633)
N		52481	57863		19266	21268
R2 Adj.		0.953	0.960		0.930	0.940
BIC		229548.1	248318.6		93290.9	101555.4

Note: only Score 3 and 4 nations have monitoring mechanisms

Appendix 5: Tables for Robustness Checks on Assumptions

5A. Fixed Effects Results (Without Staggered Treatment Consideration)

	Full Sample			Trans Fat Rich Foods		
Outcome: TF Intake	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
TF Regulation = 1	0.0013	-0.0028	-0.0091***	0.0016	-0.0058	-0.0224***
	(0.0038)	(0.0036)	(0.0034)	(0.0104)	(0.0096)	(0.0092)
HH Consumption	0.0180**	0.0191**	0.0205***	0.0451*	0.0465**	0.0517**
Expenditure [a]	(0.0090)	(0.0086)	(0.0076)	(0.0236)	(0.0226)	(0.0203)
TF Imports [a]	0.0043**	0.0042**	0.0039*	0.0081*	0.0083*	0.0075
	(0.0021)	(0.0021)	(0.0022)	(0.0043)	(0.0043)	(0.0046)
N	53027	54860	75205	19435	20137	27677
R2 Adj.	0.942	0.946	0.966	0.941	0.946	0.966
BIC	-58175.0	-59781.7	-79622.8	-3771.4	-3744.7	-4341.8

	Full Sample			Trans Fat Rich Foods		
Outcome: TF Import	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
TFA Regulation = 1	0.4088*	0.2693*	-0.3856***	0.6099+	0.3591	-0.3704***
	(0.1658)	(0.1170)	(0.0308)	(0.3271)	(0.2264)	(0.0568)
HH Consumption	0.5889**	0.8421***	1.1368***	0.9612*	1.2551***	1.5405***
Expenditure [a]	(0.1997)	(0.1852)	(0.1536)	(0.3821)	(0.3512)	(0.2881)
N	53027	54860	75205	19435	20137	27677
R2 Adj.	0.933	0.935	0.959	0.911	0.914	0.946
BIC	268498.1	277199.6	350651.9	102482.4	105796.3	134329.9

Notes: High-dimensional FE are used, as in equation (2) and (3) for upper and lower panels, respectively. "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001

Source: Authors' Data created using FAO (2010-2022), USDA (2016) and UNCTAD

5B. Using Not-Yet-Treated Only (Excluding Never-Treated)

	Full Sample			Trans Fat Rich Foods		
Outcome: TF Intake	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
TF Regulation = 1	-0.0031	0.0074	-0.0070**	-0.0068	0.0211	-0.0168*
	(0.0435)	(0.0041)	(0.0035)	(0.1192)	(0.0094)	(0.0090)
HH Consumption	-0.0194	0.0057	0.0167	-0.0748	0.0137	0.0394
Expenditure [a]	(0.0020)	(0.0020)	(0.0181)	(0.0057)	(0.0051)	(0.0479)
TFA Imports [a]	0.0057****	0.0053	0.0024***	0.0091***	0.0109	0.0045***
	(0.0046)	(0.0021)	(0.0008)	(0.0128)	(0.0071)	(0.0018)
N	6513	8346	28691	2366	3068	10608
R2 Adj.	0.979	0.980	0.982	0.979	0.980	0.982
BIC	-9038.6	-10059.2	-31963.0	-922.3	-756.6	-2090.6

	Full Sample			Trans Fat Rich Foods		
Outcome: TF Import	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
TF Regulation = 1	1.7440****	0.4459***	0.0099	1.9483***	0.4864**	0.0181
	(0.3025)	(0.1378)	(0.0344)	(0.6020)	(0.2302)	(0.0622)
HH Consumption	-16.4270****	-6.2775****	0.7996****	-19.0561****	-7.7490****	0.9854***
Expenditure [a]	(2.4542)	(1.1247)	(0.1962)	(4.7993)	(1.9254)	(0.3637)
N	6513	8346	28691	2366	3068	10608
R2 Adj.	0.930	0.949	0.991	0.901	0.942	0.988
BIC	37117.5	43894.3	95569.5	14336.0	16477.1	36911.6

Notes: High-dimensional FE are used, as in equation (2) and (3) for upper and lower panels, respectively. "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001

Source: Authors' Data created using FAO (2010-2022), USDA (2016) and UNCTAD

5C. No Anticipation Assumption: Using Original Effective Date of the Policy

	Full Sample			Trans Fat Rich Foods		
	(1)	(2)	(3)	(4)	(5)	(6)
Outcome: TF Intake	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
TF Regulation = 1	0.0034	-0.0024	-0.0058**	0.0076	-0.0058	-0.0143*
	(0.0200)	(0.0035)	(0.0028)	(0.0547)	(0.0095)	(0.0071)
HH Consumption	0.0209**	0.0198**	0.0205***	0.0524**	0.0487**	0.0505**
Expenditure [a]	(0.0023)	(0.0091)	(0.0079)	(0.0064)	(0.0241)	(0.0209)
TFA Imports [a]	0.0043**	0.0042*	0.0038*	0.0080*	0.0082*	0.0074
	(0.0015)	(0.0022)	(0.0022)	(0.0057)	(0.0046)	(0.0047)
N	53027	54859	75205	19435	20136	27677
R2 Adj.	0.941	0.946	0.966	0.941	0.946	0.966
BIC	-57186.9	-59056.8	-78791.6	-2878.9	-3096.8	-3566.4

	Full Sample			Trans Fat Rich Foods		
	(1)	(2)	(3)	(4)	(5)	(6)
Outcome: **TF Import [a]**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**	**Complementary Measures Only (RS2)**	**Less Restrictive Policy (RS3)**	**Most Restrictive Policy (RS4)**
All Countries Included						
TF Regulation = 1	0.3233***	0.3926****	-0.2129****	0.4784**	0.6216****	-0.1783****
	(0.1240)	(0.1043)	(0.0252)	(0.2369)	(0.1785)	(0.0467)
HH Consumption Expenditure [a]	1.0341****	0.7786****	1.0991****	1.4788****	1.1365***	1.5108****
	(0.1903)	(0.1907)	(0.1563)	(0.3603)	(0.3595)	(0.2934)
N	53027	54859	75205	19435	20136	27677
R2 Adj.	0.935	0.938	0.963	0.913	0.919	0.946
BIC	268346.1	275447.1	351065.7	102916.2	105304.6	135021.1
Only Countries with Monitoring Mechanisms						
TFA Regulation = 1	–	-0.3255****	-0.3276****		-0.3179****	-0.2855****
		(0.0630)	(0.0421)		(0.0953)	(0.0775)
HH Consumption Expenditure [a]	–	1.1826****	1.1471****		1.6552****	1.5913****
		(0.1846)	(0.1785)		(0.3487)	(0.3372)
N		52480	57863		19265	21268
R2 Adj.		0.940	0.948		0.921	0.930
BIC		260760.4	282123.7		99701.9	108913.6

Notes: High-dimensional FE are used, as in equation (2) and (3) for upper and lower panels, respectively. "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001

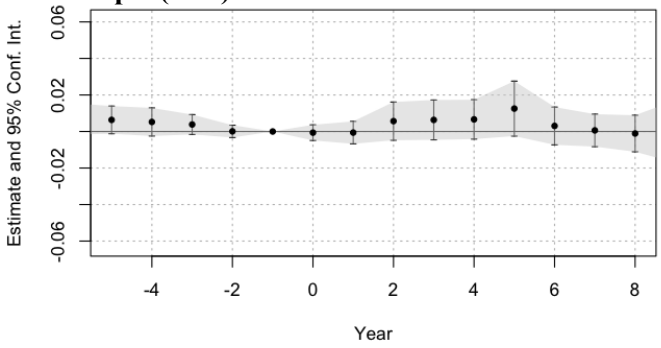
Source: Authors' Data created using FAO (2010-2022), USDA (2016) and UNCTAD

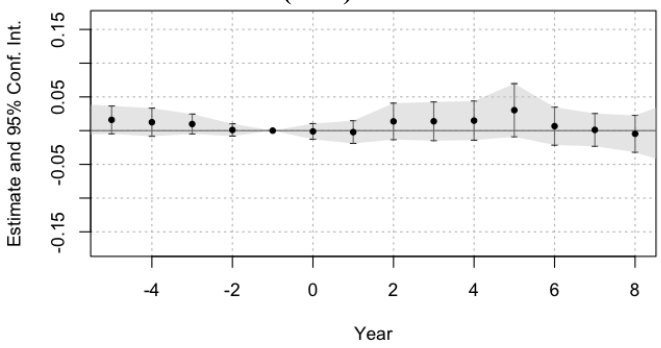
5D. Parallel Trends

Full Sample (RS2)

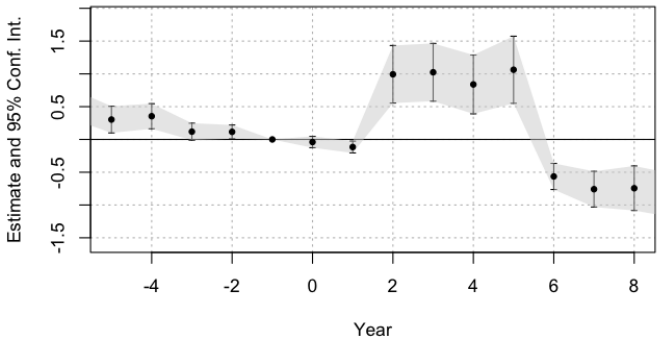
Trans Fat Rich Foods (RS2)

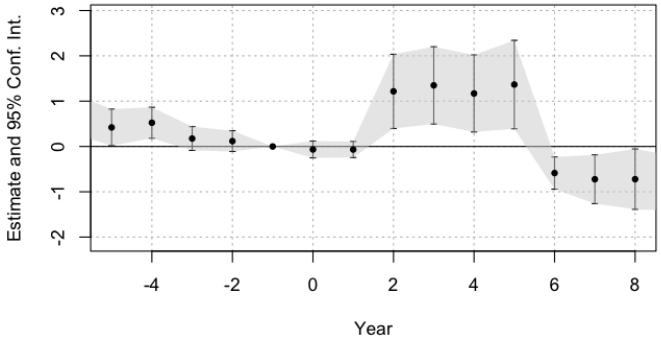
Intake Equation





Import Equation

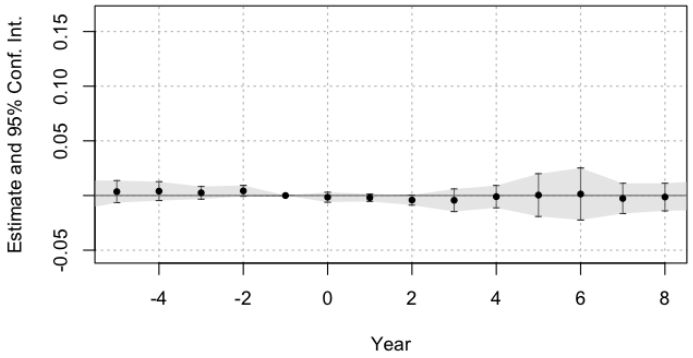


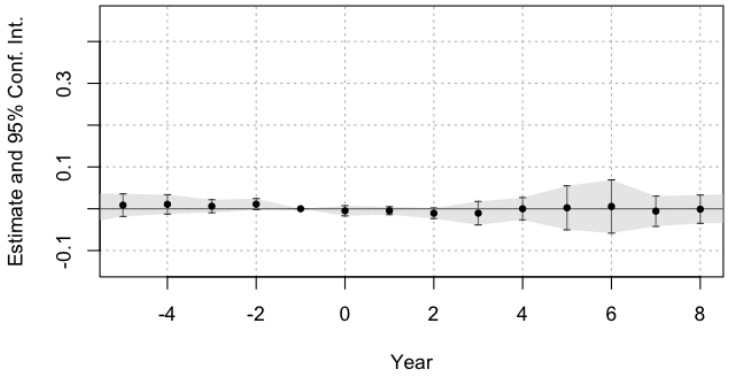


Full Sample (RS3)

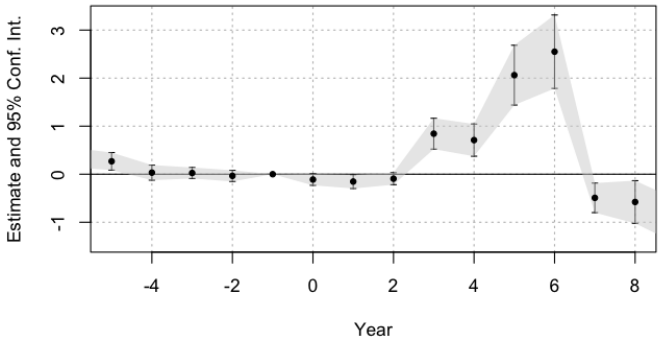
Trans Fat Rich Foods (RS3)

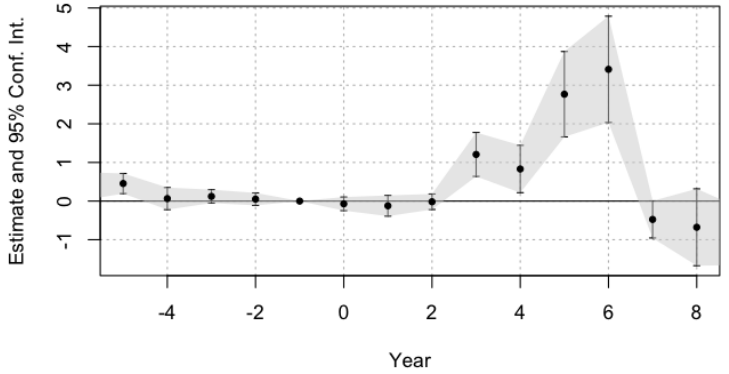
Intake Equation





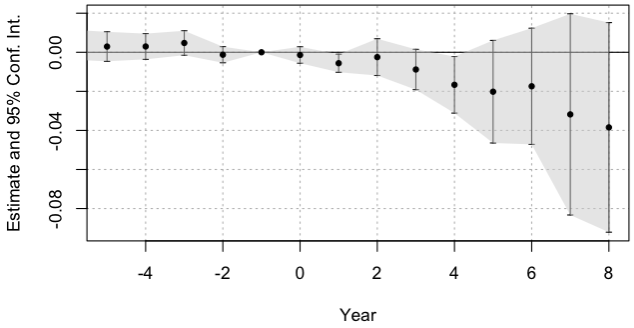
Import Equation



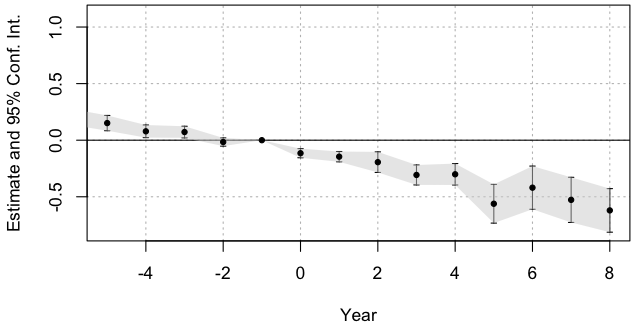


Full Sample (RS4)

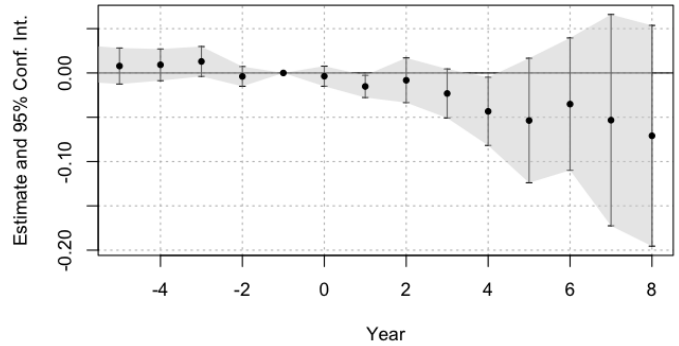
Intake Equation

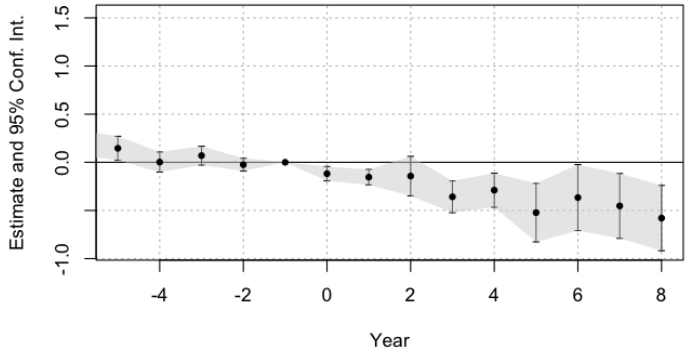


Import Equation



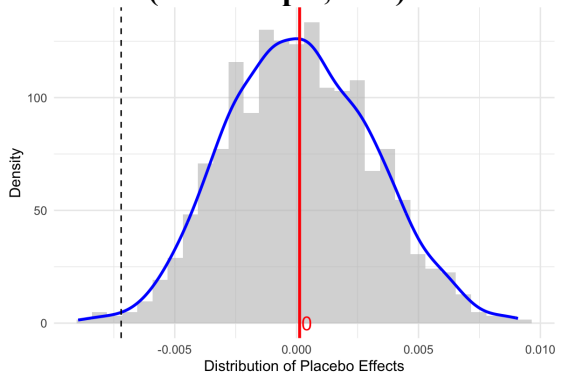
Trans Fat Rich Foods (RS4)

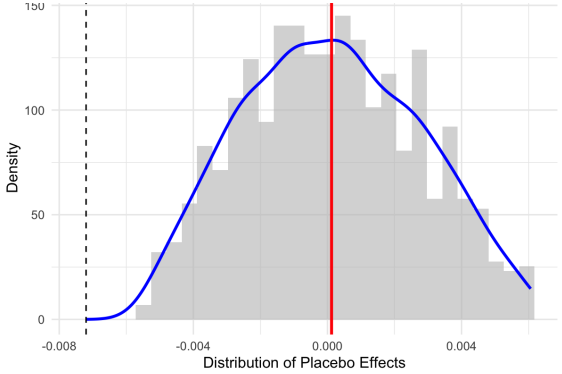




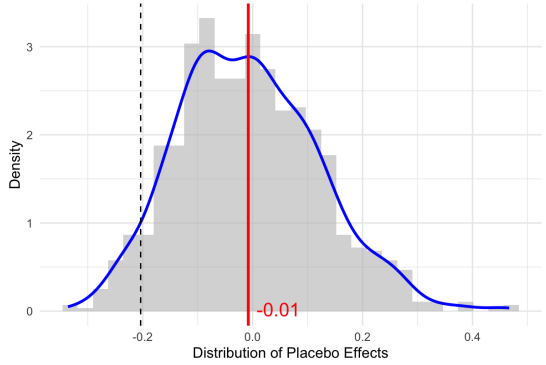
5E. Placebo Tests

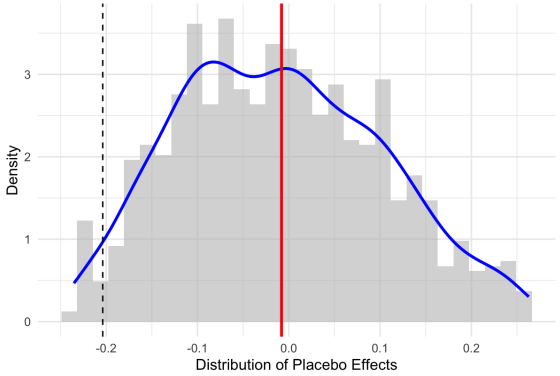
TF Intake (Full Sample, RS4)



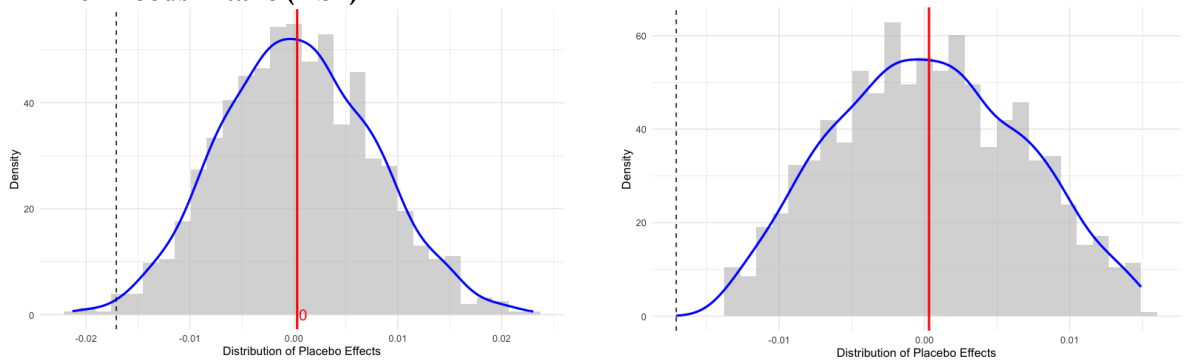


TF Import (Full Sample, RS4)

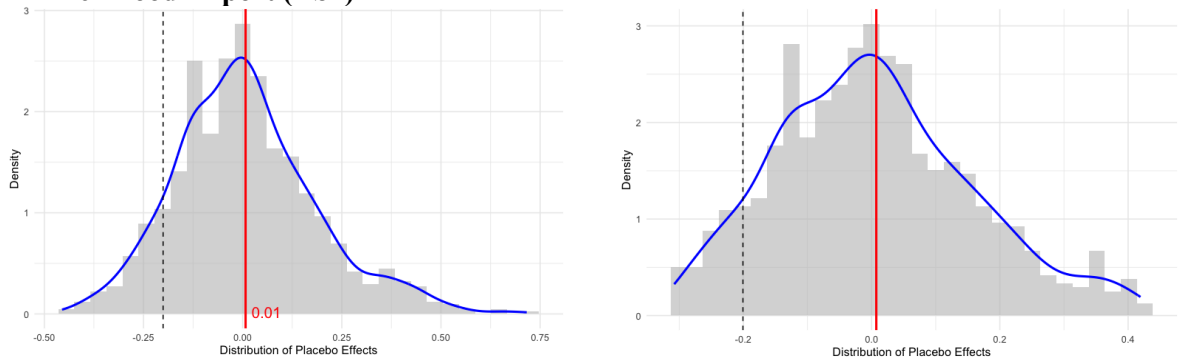




TF Rich Foods Intake (RS4)



TF Rich Food Import (RS4)



Notes: The left panel in each row shows the full distribution of placebo estimates, while the right panel displays the same distribution after trimming the extreme tails. The black dotted line represents the actual treatment effect estimates reported in Tables 1 and 2. The red solid line indicates the mean of the placebo distribution.

Appendix 6: Tables for Robustness Check using Country-Year Panel

6A: Total Effect of Trans Fat Regulations on Intake

Variable	Complementary Measures Only (RS2)	Less Restrictive Policy (RS3)	Most Restrictive Policy (RS4)
Direct Effects (DE)			
TF Regulation = 1 on Demand	0.2171****	0.0420	-0.1671*
	(0.0935)	(0.0430)	(0.0862)
Mediation Effect 2 (ME2)			
TF Imports [a] on Demand	0.5966****	0.5962****	0.5269****
	(0.0446)	(0.0826)	(0.1076)
Mediation Effect 1 (ME1)			
TF Regulation = 1 on Imports	-0.1002***	-0.1267***	-0.0602
	(0.0361)	(0.0389)	(0.0417)
N	1154	1193	1631

Notes: Results uses full sample. "a" index represents the asinh transformation. * <0.1, ** <0.05, *** <0.01, ****<0.001
Source: Authors' Data created using FAO (2010-2022), USDA (2016) and UNCTAD

6B: Comparing across DID estimators

