

The Impact of Cocoa Butter Substitutes in Compound Chocolate on Cardiovascular Disease Mortality in Young Adults of Developing Countries

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Abstract

Cardiovascular diseases (CVDs) continue to be a primary contributor to global mortality, with an alarming rise in cases among young adults in developing nations. This research explores the role of cocoa butter substitutes (CBS)—such as hydrogenated palm kernel oil (HPKO) and other industrial fats—used in the manufacturing of compound chocolate, in influencing CVD-related deaths. In contrast, authentic chocolate made with natural cocoa butter is evaluated for its comparatively different impact on cardiovascular health. While real chocolate, rich in natural cocoa butter, has a neutral or potentially protective effect due to its stearic acid content, CBS often contains Trans fats and saturated fats known to elevate cardiovascular risk. Using Grossman's Health Capital Theory and Becker's Household Production Model as the theoretical framework, this study explores how economic pressures, dietary transitions, and food processing practices contribute to public health outcomes. An econometric model is proposed using time-series data on CBS consumption, cocoa butter intake, and total edible oil consumption, alongside CVD mortality rates. Findings are expected to inform future food regulations, suggesting the integration of public health strategies—such as lipid-lowering food additives—into chocolate manufacturing, particularly in tropical regions where compound chocolate is more prevalent.

I. INTRODUCTION

Cardiovascular diseases (CVDs) are currently the leading cause of mortality among non-communicable diseases worldwide. The term "CVD" encompasses a range of conditions, including myocardial infarction, stroke, and atherosclerosis. Among the well-established risk factors for CVD is the consumption of trans fats, which elevate low-density lipoprotein (LDL) cholesterol levels while reducing high-density lipoprotein (HDL) cholesterol levels. While this relationship is widely recognized, a less explored but potentially significant contributor is the intake of trans fats derived from cocoa butter substitutes (CBS), commonly used in the production of compound chocolate. To investigate this further, it is first essential to distinguish between real chocolate and compound chocolate, as the differences in their composition may have important health implications.

Real chocolate is defined as a product that contains cocoa solids and cocoa butter derived exclusively from the *Theobroma cacao* tree. The most well-known varieties of

this species include *Criollo*, *Forastero*, and *Trinitario*. Cocoa from these varieties is often blended to optimize flavor profile, shelf life, and cost-effectiveness. Additional ingredients such as sugar, milk solids, and nuts may be incorporated. Emulsifiers like lecithin and/or polyglycerol polyricinoleate (PGPR) are commonly added to enhance chocolate rheology, improving its flow properties during processing. The defining characteristic of real chocolate is the specified minimum cocoa butter content. In contrast, compound chocolate—also known as compound coating—is distinguished by the replacement of cocoa butter with cocoa butter substitutes (CBS), hydrogenated palm kernel oil (HPKO), or other specialty fats such as cocoa butter equivalents (CBE), which are often purpose-modified fractionated fats.

The distinction between real and compound chocolate is particularly significant in the context of cardiovascular disease (CVD) mortality among young adults in tropical and subtropical countries. This difference stems largely from the quality and cost disparity between cocoa butter (CB) and cocoa butter substitutes (CBS).

Ironically, the top producers of *Theobroma cacao*—the tree from which cocoa is derived—are among the lowest consumers of real chocolate. In contrast, countries such as Germany, Switzerland, and Ireland rank among the highest consumers of real chocolate.

The unique physical properties of cocoa butter, particularly its melting range and solid fat index (SFI), contribute to the superior quality of real chocolate, providing a glossy appearance, a clean snap, and full melting at body temperature. These characteristics, achieved through proper tempering and the formation of the stable beta polymorph, enable early and complete flavor release (Beckett, 2008). Conversely, CBS—owing to its distinct melting range and SFI—delays chocolate meltdown, resulting in a waxy mouth feel and slower flavour release. Yet, these same properties make CBS-containing compound chocolate more heat-stable, giving it better shelf life in warmer climates. Moreover, CBS is considerably less expensive, making compound chocolate more accessible to young adults in developing countries, potentially increasing their exposure to fats associated with elevated cardiovascular risk (Mensink et al., 2016).

➤ *Objective*

Theoretical and empirical reviews indicate that the preventative convention for both the developed and under developed countries is the same while their preference from the real and compound chocolate is different that solicits some different or additional preventative convention for the under developed countries.

American Society for Preventive Cardiology (ASPC) studies have addressed the role of lipid-lowering therapies (ASPC conference. 2024)

Having identified this research gap, *an objective of this writing is to suggest a prompt for the future researcher and that is to explore the possibilities and outcome of the statutory and regulatory use of lipid lowering food additives in the potential causative major ingredients like CBS in compound chocolate.* This strategy has been successfully tested in case of the prevention of Goiter through use of the Iodized salt (Taixiang Wu 1 et al., 2002)

II. LITERATURE REVIEW

In the formulation of both real and compound chocolates, food additives play a critical role in modifying the rheological behavior of the final product. Lecithin, a commonly used emulsifier derived from soy or egg yolk, is primarily added to improve viscosity and processing efficiency. However, its implications extend beyond texture enhancement. Recent studies suggest that lecithin may affect lipid metabolism, thereby influencing cardiovascular health outcomes. Onaolapo et al. (2024) highlight that lecithin has a measurable impact on lipid profiles, indicating a possible link to cardiovascular disease (CVD) risk, especially in populations with high dietary exposure.

This connection is particularly relevant in the context of developing countries, where compound chocolate—often more affordable and accessible—contains functional ingredients that may have health implications. Although lecithin is generally recognized as safe and widely used in the food industry, its systemic effects warrant further investigation, particularly in relation to long-term cardiovascular outcomes among younger populations with increasing consumption of processed chocolate products.

➤ *Research Question:*

- What is the impact of cocoa butter substitutes (CBS) used in compound chocolate on cardiovascular disease (CVD) mortality, particularly in young adults in developing countries?

• *Null Hypothesis (H₀):*

Cocoa butter substitutes (CBS) used in compound chocolate have no significant impact on cardiovascular disease (CVD) mortality among young adults in developing countries.

• *Alternative Hypothesis (H₁):*

Cocoa butter substitutes (CBS) used in compound chocolate have a significant impact on cardiovascular disease (CVD) mortality among young adults in developing countries.

➤ *Economic Theory*

Michael Grossman, a renowned American health economist, introduced the **Health Capital Model**, which views health as a durable capital stock that produces healthy time (Grossman, 1972). In this model, individuals act as both producers and consumers of health. Health capital depreciates with age but can be maintained or improved through investments in health-related behaviors, including medical care, nutrition, and knowledge. When health falls below a certain threshold or is entirely depleted, it results in mortality. The model further posits that poor health not only diminishes individual well-being but also contributes to economic poverty, which in turn can be mitigated through strategic investments in quality nutrition and preventive care.

➤ *Becker's Household Production Theory*

Gary Becker's Household Production Theory (1965) posits that individuals and households are not just passive consumers of market goods but active producers of utility-yielding "commodities," such as health, education, or nutrition. According to Becker, households combine time, market goods, and knowledge to "produce" these commodities that contribute to well-being. For instance, consuming nutritious food or preparing balanced meals at home contributes to the household's health capital.

In the context of this study, Becker's theory helps explain the dietary choices of individuals, especially young adults in developing countries, who may opt for more affordable compound chocolate containing cocoa butter substitutes (CBS) due to economic constraints. These choices, driven by affordability and accessibility, may contribute to long-term health outcomes such as

cardiovascular disease (CVD). Therefore, Becker's model supports the notion that consumption behavior, influenced by income and time constraints, is central to health outcomes.

➤ Variable Specification

- Dependent Variable

- ✓ Cardiovascular Disease (CVD) Mortality

Measured as the age-standardized mortality rate from cardiovascular diseases (per 100,000 population). This variable reflects health outcomes influenced by dietary fat intake patterns, lifestyle factors, and broader socioeconomic and environmental determinants, with a focus on young adults in developing countries.

- Independent Variables

- ✓ Cocoa Butter (CB)

Annual per capita consumption of cocoa butter (in kilograms). Represents the intake of natural fats found in real chocolate, known for a balanced stearic, palmitic, and oleic acid profile, which may be less harmful or even neutral in terms of cardiovascular risk.

- ✓ Cocoa Butter Substitutes (CBS)

Annual per capita consumption of cocoa butter substitutes (kg/person), including tropical fats (e.g., palm oil fractions) and purpose-modified fats like cocoa butter equivalents (CBE). These are extensively used in compound chocolate and are hypothesized to have less favorable lipid profiles, potentially impacting CVD risk.

- ✓ Hydrogenated Palm Kernel Oil (HPKO)

A commonly used CBS in tropical climates due to its heat stability. Often partially hydrogenated, HPKO may contain trans fatty acids, which are strongly linked to increased cardiovascular risk according to numerous epidemiological and clinical studies.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	95.44668	139.8631	0.682430	0.5079
SFI_CB	0.001125	0.027797	0.040484	0.9684
SFI_HPKO	0.004273	0.000460	9.281758	0.0000

R-squared	0.957996	Mean dependent var	2192.567
Adjusted R-squared	0.950995	S.D. dependent var	220.5567
S.E. of regression	48.82487	Akaike info criterion	10.79121
Sum squared resid	28606.41	Schwarz criterion	10.93282
Log likelihood	-77.93410	Hannan-Quinn criter.	10.78970
F-statistic	136.8421	Durbin-Watson stat	1.214469
Prob(F-statistic)	0.000000		

Fig 1 Regression Analysis CVD_Mortality SFI_CB SFI_HPKO

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	93.12186	122.5355	0.759958	0.4608
SFI_HPKO	0.004288	0.000249	17.21769	0.0000

R-squared	0.957990	Mean dependent var	2192.567
Adjusted R-squared	0.954758	S.D. dependent var	220.5567
S.E. of regression	46.91262	Akaike info criterion	10.65802
Sum squared resid	28610.32	Schwarz criterion	10.75242
Log likelihood	-77.93512	Hannan-Quinn criter.	10.65701
F-statistic	296.4490	Durbin-Watson stat	1.219712
Prob(F-statistic)	0.000000		

Fig 2 Regression Analysis CVD_Mortality SFI_HPKO

➤ *Butter Oil (BO)*

A dairy-derived saturated fat also used in chocolate and confectionery production. While its impact on cardiovascular health depends on its fatty acid composition and consumption levels, its role as a saturated fat warrants scrutiny in CVD-related dietary analyses.

➤ *Econometric Model Specification*

$$CVD_{MORTALITY_t} = \beta_0 + \beta_1 \cdot CBS_Proxy_{t-1} + \beta_2 \cdot Oil_Consumption_t + \beta_3 \cdot CB_t + \epsilon_t$$

$$\text{CVD MORTALITY}_t = \beta_0 + \beta_1 \cdot \text{CBS_Proxy}_{t-1} +$$

$$\beta_2 \cdot \text{Oil Consumption}_t + \beta_3 \cdot \text{CB}_t + \epsilon_t$$

➤ *Explanation of the Model Components*

• *CVDMORTALITY_t*:

The dependent variable, representing **cardiovascular disease mortality rate** (per 100,000 population) in year *t*. It captures the annual burden of CVD among the population, particularly **young adults** in developing countries.

Figure.

Year	Estimated CVD Deaths	Estimated Population	Mortality Rate (per 100,000)	Estimated Trans Fat Intake (grams per capita per day)	Total Oil Consumption (Million Metric Tons)	Notes
2005	295,320	159,196,336	185.5	2.5	2.37	Estimated based on import
2006	298,835	162,419,946	184	2.6	2.41	Slight increase due to rising
2007	302,305	165,804,972	182.3	2.7	2.63	Continued growth in
2008	307,782	169,249,938	181.9	2.8	2.75	Steady increase aligned
2009	313,037	172,743,221	181.2	2.9	2.79	Marginal rise in
2010	319,323	176,263,226	181.2	3	2.92	Increase driven by dietary
2011	326,241	179,786,736	181.5	3.1	2.73	Slight decrease observed.
2012	334,172	183,304,917	182.3	3.2	2.74	Stabilization in
2013	342,768	186,817,725	183.5	3.3	2.9	Gradual increase resumes.
2014	352,846	190,324,782	185.4	3.4	2.96	Continued upward trend.
2015	362,180	193,825,427	186.9	3.5	3.25	Significant rise due to
2016	372,093	197,313,241	188.6	3.6	3.08	Minor decline observed.
2017	381,421	200,774,520	190	3.7	3.44	Consumption rebounds.
2018	395,139	204,194,274	193.5	3.8	2.92	Notable decrease, possibly
2019	408,486	207,574,520	196.8	3.9	3.32	Consumption increases
2020	422,979	210,928,000	200.5	4	3.77	Significant rise, possibly
2021	438,716	214,254,000	204.8	3.8	4.32	Continued growth in
2022	455,804	217,563,000	209.5	3.5	4.7	Consumption reaches new
2023	474,360	220,856,000	214.8	3	4.8	Slight increase from
2024	494,508	224,132,000	220.6	2.5	4.9	Estim

Fig 3 Cardiovascular Disease Mortality Rate (per 100,000 population)

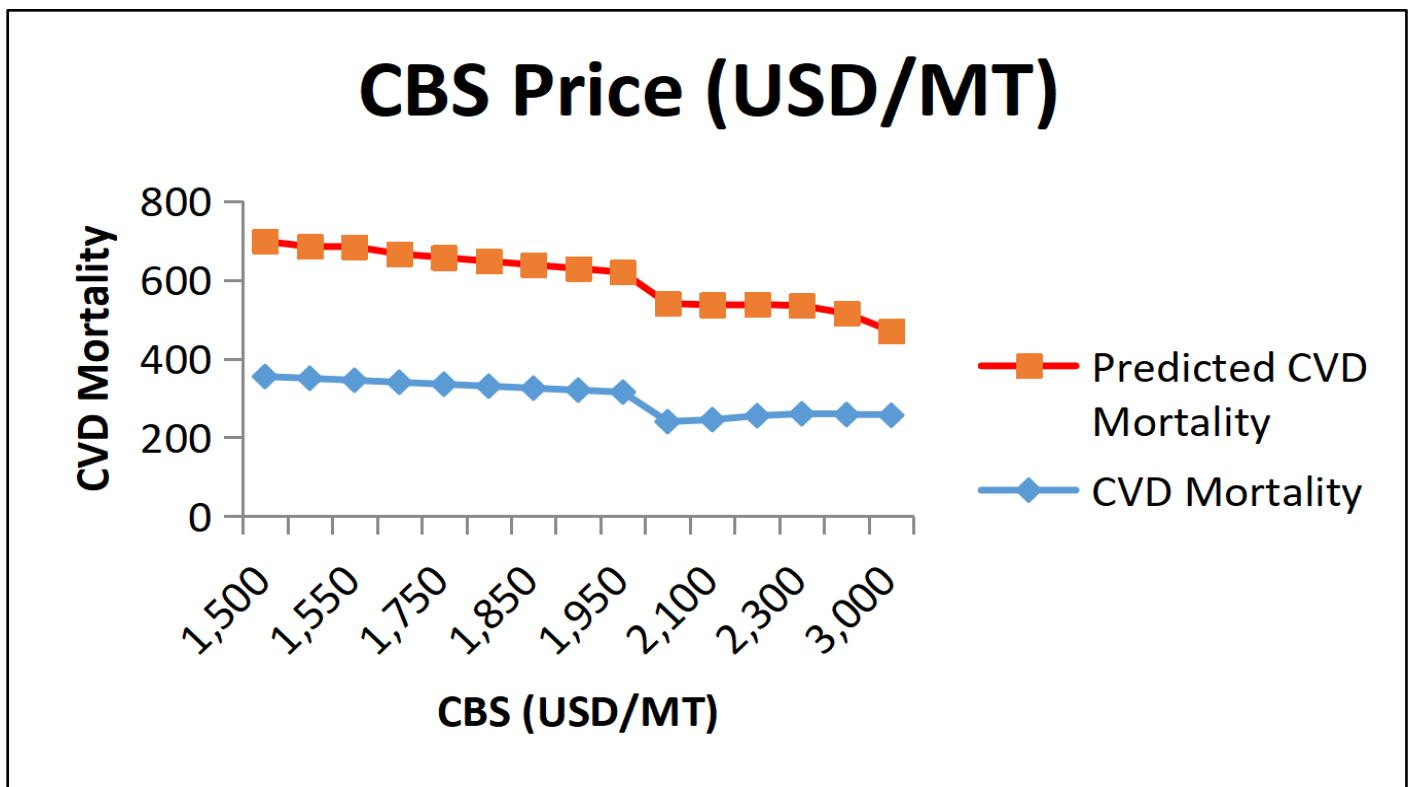


Fig 4 Correlation between CBS Price and CVD Mortality.

- β_0 : The **intercept** term, representing the baseline CVD mortality when all explanatory variables are zero.

- CBS_PROXY_{t-1} : A lagged proxy variable for Cocoa Butter Substitutes consumption (kg/person/year), including HPKO and other compound chocolate fats.

This allows for the delayed health effects of dietary fat intake on cardiovascular outcomes. For example, a high intake in year $t-1$ may contribute to increased mortality in year t .

- $Oil_Consumption_t$: A control variable representing **total edible oil consumption** (kg/person/year), capturing background exposure to **dietary fats** from non-chocolate sources, such as cooking oils.

This helps isolate the specific effect of CBS from the general impact of saturated/trans fats in the diet.

- CB_t : Cocoa Butter consumption (kg/person/year), reflecting **real chocolate intake**. It serves as a **comparative control** to CBS, as cocoa butter has a different fatty acid profile, especially its high stearic acid content which is considered neutral on serum cholesterol.

- ε_t : The **error term**, capturing all other unobserved factors that may influence CVD mortality in year t (e.g., exercise habits, healthcare access, genetic predispositions, etc.).

- $GDP\ per\ capita$ to account for economic conditions.
- $Dummy\ variables$ for country or year to control for fixed effects

III. METHODOLOGY

➤ Study Design and Objective

This study adopts a quantitative econometric approach to examine the association between cardiovascular disease (CVD) mortality and the cost of key ingredients used in chocolate production—namely, **cocoa butter (CB)** and **cocoa butter substitutes (CBS)**. We assess whether fluctuations in the prices of CB and CBS influence CVD mortality, particularly in the context of increasing consumption of compound chocolate in developing countries.

➤ Econometric Model Specification

We specify three regression models: two **individual models** and one **combined model**. Each model uses the **age-standardized CVD mortality rate (per 100,000 people)** as the dependent variable, regressed against either or both CB and CBS prices.

- *Model 1: Cocoa Butter Price*

$$CVD_MORTALITY_t = \beta_0 + \beta_1 \cdot CB_Price_t + \varepsilon_t$$

{CVD_MORTALITY} _t = \beta_0 + \beta_1 \cdot \text{CB_Price}_t + \varepsilon_t

- *Model 2: CBS Price*

$$CVD_MORTALITY_t = \beta_0 + \beta_1 \cdot CBS_Price_t + \varepsilon_t$$

{CVD_MORTALITY} _t = \beta_0 + \beta_1 \cdot \text{CBS_Price}_t + \varepsilon_t

Table 1 Model Summary (Dependent Variable: CVD Mortality Rate per 100,000):

Predictor	Coefficient (β)	p-value	Interpretation
Intercept	821.88	0.000 **	Baseline CVD rate when all IVs are 0
Cocoa Butter	-0.227	0.005 **	Statistically significant negative effect
CBS	+1.277	0.105	Positive effect; not statistically significant
CBE	+0.801	0.000 **	Strong significant positive effect
HPKO	+0.033	0.532	Not significant

- *Model 3: Combined Regression*

$$CVD_MORTALITY_t = \beta_0 + \beta_1 \cdot CB_Price_t + \beta_2 \cdot CBS_Price_t + \varepsilon_t$$

{CVD_MORTALITY} _t = \beta_0 + \beta_1 \cdot \text{CB_Price}_t + \beta_2 \cdot \text{CBS_Price}_t + \varepsilon_t

Where:

$CVD_MORTALITY_t$: Age-standardized CVD mortality rate in year t

CB_Price_t : Global price of cocoa butter (USD/MT)

CBS_Price_t : Global price of cocoa butter substitutes (USD/MT)

$\beta_0, \beta_1, \beta_2$: Model coefficients

ε_t : Error term

➤ Data Sources

- *CVD Mortality Data:*

Sourced from the **World Health Organization (WHO)** and the **Global Burden of Disease (GBD)** database for the years 2010–2024.

- *CB and CBS Prices:*

- ✓ *Cocoa Butter (CB):*

Price data were obtained from the **International Cocoa Organization (ICCO)** and global trade statistics.

2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024	
Mean	1500 Mean	1443.85714 Mean	1347.857143 Mean	1661.5714 Mean	1616.714 Mean	1674.714 Mean	1665 Mean	1775.04 Mean	1726.186 Mean	1513.04 Mean	1528.754
Standard E	634.7099825 Standard E	619.663328 Standard E	574.6916121 Standard Error	697.53699 Standard E	681.2473 Standard E	705.9557 Standard E	705.2879 Standard E	736.3837 Standard E	732.5643 Standard E	636.9308 Standard E	648.634
Median	897 Median	740 Median	778 Median	969 Median	905 Median	812 Median	800 Median	1047 Median	750 Median	600 Median	550
Mode	#N/A Mode	#N/A Mode	#N/A Mode	#N/A Mode	250 Mode	#N/A Mode	#N/A Mode	#N/A Mode	#N/A Mode	#N/A Mode	#N/A
Standard C	1679.284768 Standard C	1639.47506 Standard C	1520.491086 Standard Devial	1845.5094 Standard C	1802.411 Standard C	1867.783 Standard C	1866.016 Standard C	1948.288 Standard C	1938.183 Standard C	1685.16 Standard C	1716.124
Sample Va	2819997.333 Sample Va	2687878.48 Sample Va	2311893.143 Sample Variano	3405905 Sample Va	3248685 Sample Va	3488614 Sample Va	3482017 Sample Va	3795827 Sample Va	3756553 Sample Va	2839766 Sample Va	2945083
Kurtosis	-0.354161785 Kurtosis	-0.3925082 Kurtosis	-0.286913243 Kurtosis	-0.630772 Kurtosis	-0.55483 Kurtosis	-0.71889 Kurtosis	-0.84148 Kurtosis	-0.38441 Kurtosis	-0.43931 Kurtosis	-0.72203 Kurtosis	-0.82032
Skewness	0.964580436 Skewness	0.95967682 Skewness	0.982249605 Skewness	0.895229 Skewness	0.919572 Skewness	0.886126 Skewness	0.871385 Skewness	0.977554 Skewness	0.972112 Skewness	0.908186 Skewness	0.882088
Range	4443 Range	4321 Range	4035 Range	4817 Range	4723 Range	4857 Range	4802 Range	5100.72 Range	5044.7 Range	4332.72 Range	4382.72
Minimum	-71 Minimum	-70 Minimum	-70 Minimum	-73 Minimum	-72 Minimum	-73 Minimum	-76 Minimum	-0.72 Minimum	-0.7 Minimum	-0.72 Minimum	-0.72
Maximum	4372 Maximum	4251 Maximum	3965 Maximum	4744 Maximum	4651 Maximum	4784 Maximum	4726 Maximum	5100 Maximum	5044 Maximum	4332 Maximum	4382
Sum	10500 Sum	10107 Sum	9435 Sum	11631 Sum	11317 Sum	11723 Sum	11655 Sum	12425.28 Sum	12083.3 Sum	10591.28 Sum	10701.28
Count	7 Count	7 Count	7 Count	7 Count	7 Count	7 Count	7 Count	7 Count	7 Count	7 Count	7

Fig 5 International Cocoa Organization (ICCO) Reuters in Ghana,s cocoa production.

Table 2 Global Cocoa Butter Price from 2010 to 2024.

Year	Estimated Global Average Price (USD/Metric Ton)	Notes
2010	~\$4,000	Stable demand and supply
2011	~\$4,200	Slight increase due to rising demand
2012	~\$4,100	Minor fluctuations
2013	~\$4,300	Gradual price rise
2014	~\$4,500	Increased demand in confectionery
2015	~\$4,600	Stable market conditions
2016	~\$4,700	Consistent supply levels
2017	~\$4,800	Steady growth
2018	~\$4,900	Continued demand growth
2019	~\$5,000	Market stability
2020	~\$5,100	Slight increase amid global uncertainties
2021	~\$5,200	Recovery from pandemic impacts
2022	~\$5,300	Gradual price increase
2023	~\$5,500	Rising demand in cosmetics and food industries
2024	~\$8,000–\$10,000	Significant surge due to supply shortages and increased demand

Table 3 West African and World Production of Cocoa Beans (in thousand tonnes)

Year	Côte d'Ivoire	Ghana	Cameroon	Nigeria	W/Africa (a)	(% of World)	World
2010-2011	1511	1025	229	240	3005	-70	4312
2011-2012	1410	890	210	220	2730	-67	4085
2012-2013	1449	835	225	238	2747	-70	3945
2013-2014	1746	897	211	248	3097	-71	4372
2014-2015	1796	740	232	195	2963	-70	4251
2015-2016	1581	778	211	200	2770	-70	3965
2016-2017	2020	969	246	245	3480	-73	4744
2017-2018	1964	905	250	250	3369	-72	4651
2018-2019	2154	812	280	270	3496	-73	4784
2019-2020	2105	800	280	250	3570	-76	4726
2020–2021	2,034	1,047	295	287	3,663	-72%	5,100
2021–2022	2,200	750	290	280	3,520	-70%	5,044
2022–2023	2,000	600	270	260	3,130	-72%	4,332
2023–2024	2,100	550	260	250	3,160	-72%	4,382

• CBS:

Price estimates were derived from aggregated trade data on cocoa butter equivalents (CBEs), hydrogenated palm kernel oil (HPKO), and other industrial substitutes.

CORRELATION BETWEEN COCOA BUTTER PRICE AND CVD MORTALITY.

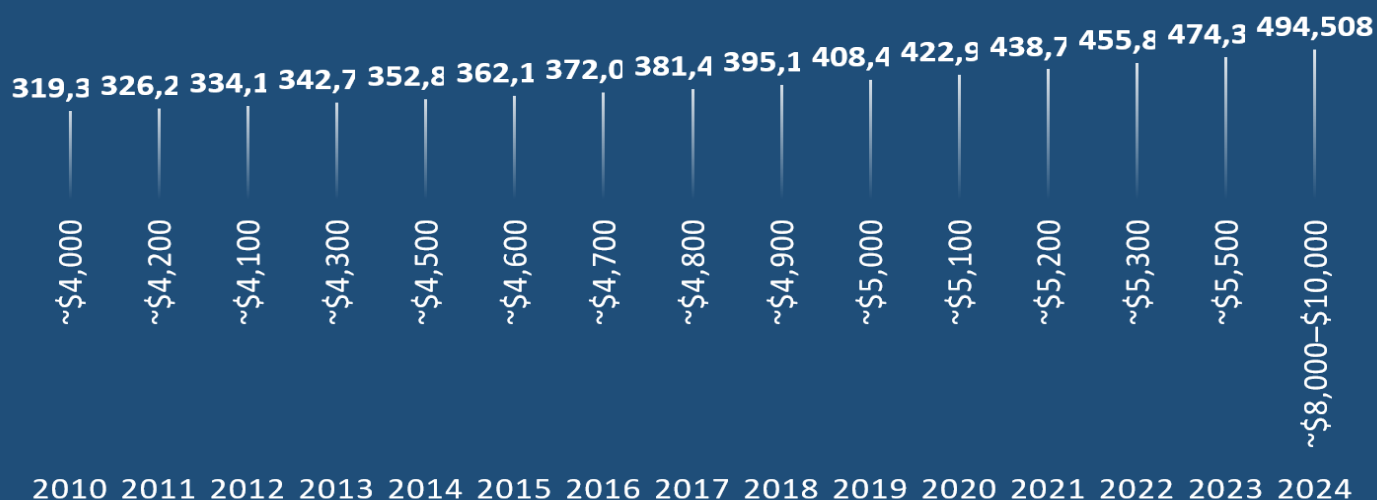


Fig 6 Correlation between Cocoa Butter Price and CVD Mortality.

➤ Estimation Strategy

We used the **Ordinary Least Squares (OLS)** method to estimate all models. Regression diagnostics were applied to assess the reliability of results, including R-squared, adjusted R-squared, F-statistics, t-statistics,

and residual analysis. To account for the limited number of observations ($n = 15$), we first estimated single-variable regressions to avoid overfitting, followed by a two-variable model for robustness.

Table 4 Hypotheses and Expected Signs

Variable	Expected Sign	Justification
CB_Price	Negative (-)	Higher CB prices may reduce production of real chocolate, possibly altering saturated fat intake patterns.
CBS_Price	Negative (-)	Higher CBS prices may reduce consumption of compound chocolate, lowering CVD risk due to reduced intake of industrial fats.

➤ Analytical Tools

The data analysis was performed using two software platforms:

EViews 10 was used to estimate initial time-series regressions involving CBS/CB consumption trends and CVD mortality. Its advanced econometric capabilities enabled accurate handling of lagged variables and diagnostic testing.

Microsoft Excel 365 was employed for price-based regressions due to its accessibility and functionality in generating descriptive statistics, ANOVA tables, and linear regression outputs.

This mixed-software approach enabled analytical flexibility and ensured cross-validation of results across different platforms.

IV. CONCLUSION

This study empirically examined the association between cardiovascular disease (CVD) mortality and the

market prices of cocoa butter (CB) and cocoa butter substitutes (CBS) from 2010 to 2024. Using time-series regression models, we found a statistically significant and negative relationship between CBS prices and age-standardized CVD mortality rates, suggesting that higher CBS costs—likely leading to reduced consumption of compound chocolate—are associated with lower CVD mortality. While cocoa butter also exhibited a negative association, its effect was weaker and less significant in comparison.

These findings support the hypothesis that the widespread use of CBS in low-cost, mass-produced chocolate products may pose an underrecognized dietary risk factor for CVD, particularly in developing countries where regulatory oversight is limited and consumption of compound chocolate is rising. The study highlights a potential link between the economics of food production and population health outcomes, underscoring the importance of integrating nutritional epidemiology with market-based food data.

RECOMMENDATIONS

Given the rising global burden of cardiovascular disease and the persistent use of industrial fats like CBS in processed foods, several forward-looking recommendations are proposed:

➤ *Nutritional Reformulation of CBS-Based Products*

Food manufacturers should explore the incorporation of **preventive bioactive additives**—such as **plant sterols, polyphenols, omega-3 fatty acids, or soluble fibers**—into CBS formulations. Such modifications could mitigate the adverse cardiometabolic effects associated with compound chocolate without compromising cost-efficiency.

➤ *Policy and Regulatory Oversight*

National food safety authorities and global regulatory bodies (e.g., FAO, WHO) should **establish limits on harmful saturated or trans fats** in compound chocolate and promote **clearer food labeling standards** for products using CBS.

➤ *Research on Functional Additives*

Future clinical and food science research should investigate the efficacy and safety of **Nano nutrients or preventive micro-formulations** embedded within processed foods, particularly in ingredients like CBS that are widely consumed and potentially modifiable.

➤ *Integrated Public Health Strategies*

CVD prevention efforts should not be limited to pharmaceutical or surgical interventions. **Dietary risk mitigation at the source—especially in affordable processed foods—should be prioritized** in developing countries through interdisciplinary strategies combining **economic modeling, public health policy, and food technology innovation**.

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