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Abstract: Pacific Islands face challenges of low water accessibility and increasing climate threats posing risks to populations. These challenges are compounded by public health concerns related to poor nutritional outcomes and obesity. Using household survey data from Kiribati, this study contributes to the literature by analyzing the relationship between access to safe drinking water and risky behaviors leading to obesity. The findings reveal a significant negative association between access to a piped water system and purchases of soft and sweet beverages (SSB). Compared to households with a piped water system, those relying on groundwater and rainwater purchase 381 and 406 extra grams of SSB per week, respectively. Thus, improving access to safe water can be a relevant public policy to prevent hazardous beverage consumption and obesity, along with the already documented positive outcomes such policies can have for human health and economic development.

Keywords: water accessibility; nutrition transition; soft drinks; obesity; Small Island Developing States (SIDS).

1. Introduction

Water Sanitation and Hygiene (WASH) constitute important components of global endeavors to alleviate poverty and reduce inequalities. Yet, important gaps in access to clean drinking water persist at the macro level (e.g., across different groups of country income), at the geographical level (e.g., across rural and urban areas), and at the micro-level (e.g., across the household wealth distribution). Three out of 10 people worldwide lacked access to safely managed drinking water services in 2017, highlighting important levels of water insecurity (WHO and UNICEF, 2019).[1] Low water availability and accessibility are major concerns that are expected to be further intensified by climate change-related shocks (e.g., higher frequencies of droughts and storms) and the rise of sea levels (Christensen et al., 2007; Kuruppu, 2009). In addition to potentially threatening economic development and exacerbating income inequality in the most vulnerable countries (Huynh and Hoang, 2024), these issues have important health and nutrition implications and are particularly salient in the case of Small Island Developing States (SIDS), such as the Pacific islands of Kiribati, which is the geographical focus of this paper.

While a substantial body of literature in health economics analyzes the impacts of WASH programs on undernutrition-related outcomes and infectious diseases such as diarrhea (Cuesta, 2007), recent studies demonstrated that water accessibility can mitigate obesity risk (Muckelbauer et al., 2013, 2009; Schwartz et al., 2016). Understanding the relationship between water access and overweight is therefore crucial for designing public health policies. This is especially concerning in the context of developing countries where water insecurity is one of the prevailing forms of extreme poverty. However, literature gaps remain in identifying the transmission pathways between water inaccessibility and obesity. Some studies suggest a potentially high degree of substitution between water and soft and sweet beverages (SSB) in contexts of poor water accessibility (Barquera et al., 2008; Colchero et al., 2015). This substitution pattern is concerning because increased intakes of processed foods and beverages, such as SSB, are important drivers of weight gain and obesity (Marino et al., 2021; Wang et al., 2021; Drewnowski et al., 2013; Kant et al., 2009; Yang and Chun, 2015). These health-risky substitution strategies are likely to be even more prevalent in the obesogenic context of the Pacific Islands such as in Kiribati, where most of the population is classified as obese (Tong et

[1] Water security can be defined through four dimensions that are accessibility, availability, use and sustainability (Young et al., 2021).

al., 2022)[2]. There is therefore a pressing need to investigate these mechanisms to better identify solutions to tackle the public health concern of obesity.

One of the main causes of the obesity epidemic in the Pacific Islands is the obesogenic characteristics of the food supply, a significant proportion of which is imported and processed. Historical factors such as colonization and ongoing urbanization have facilitated trade and external influence in the Pacific Islands (Snowdon and Thow, 2013), leading to significant dietary shifts in line with the nutrition transition theory designed by Popkin (1993). Traditional healthy starchy staples have been supplanted by refined white rice, canned meats, and fish have replaced local fish and seafood. Meanwhile, processed snack foods and beverages have taken the place of local juices and fruits (Snowdon and Thow, 2013). Consequently, there has been a notable increase in fat and sugar intake, especially in urban areas due to an increased accessibility to imported goods. In Kiribati, 23% of teenagers declared drinking at least one soda per day in 2011 (Pak et al., 2014). However, this rate does not account for sweet waters and juices that are highly consumed in Kiribati and are similarly caloric. According to the Kiribati Household Income and Expenditure Survey (2019), an average household purchased approximately 1.3 liters of SSB per week.[3] In contrast, Kiribati only imported 2.5 liters of bottled water per capita per year in 2018 according to the WITS' World Bank data.[4] Given the poor local water accessibility in Kiribati (Kuruppu, 2009) and the marginal use of alternative imported sources (i.e., bottled water), the risk of substituting SSB for drinking water is potentially high. Hence, improving accessibility to a drinkable piped water system may represent a relevant public health strategy for the Pacific Islands.

This article analyzes the relationship between water accessibility and SSB purchases in the islands of Kiribati. Using the Kiribati Household Income and Expenditure Survey (2019), a multivariate OLS estimation allows to identify the relationship between household access to a piped water system and SSB purchases. The aim of this study is twofold: (i) to contribute to the literature on the transmission pathways between water access and obesity, and (ii) to contribute to the broader objective of informing obesity prevention policy in the insular context of the Pacific Islands. The research question is also original insofar it has been rarely empirically

[2] Obesity and related non-communicable diseases (NCD) like diabetes, heart diseases and cancers, are rapidly emerging in low-income countries (Liu et al., 2016). According to the WHO, NCDs are responsible for 41 million deaths worldwide (74% of total deaths), 77% of which happen in low- and middle-income countries.
[3] These statistics are based on information contented in Table 1. In comparison, an average US inhabitant consumes almost 150 liters of SSB per year.
[4] https://wits.worldbank.org/trade/comtrade/en/country/KIR/year/2018/tradeflow/Imports/partner/WLD/product/220110

studied, especially in the unprecedented context of developing countries characterized by high levels of water insecurity (Nkiaka, 2022) and obesity (Popkin, 2014). The case of Kiribati is highly relevant because this archipelago composed of 33 islands and atolls is spread across a wide maritime territory, neighboring other Pacific countries (such as Marshall Islands and Tuvalu). This geographical specificity makes our results relatively generalizable to other enclaved countries and SIDS in Micronesia. Moreover, the extremely low consumption of natural and mineral bottled water among the population of Kiribati this study contributes to understanding the trade-offs between water facilities and water substitutes such as SSB.[5]

This article is organized as follows: Section 2 presents the local development and water security context of Kiribati. Section 3 presents a brief literature review. Section 4 presents the methodology followed by the results (Section 5), a discussion (Section 6), and a conclusion (Section 7).

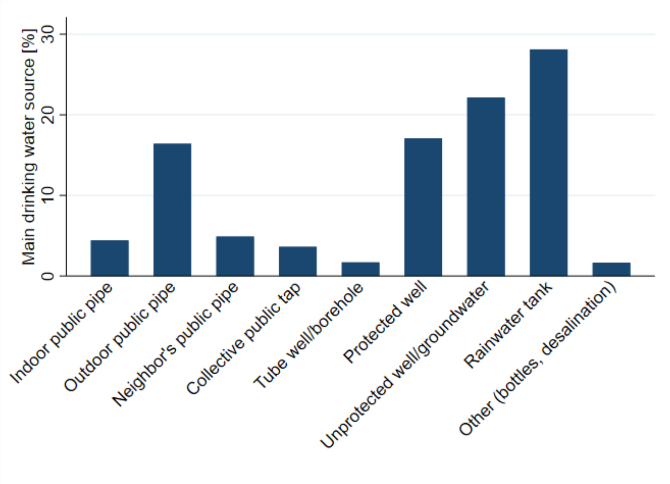
2. The water insecurity context of Kiribati

Located in the middle of the Pacific Ocean, the Republic of Kiribati comprises 33 low-lying islands (with an average height of 3 meters above sea level) and a population of 93,000 inhabitants. Approximately one-third of the population lives in the capital South Tarawa, the country's sole urban area. Kiribati, classified as a lower-middle income country, heavily relies on fishing revenue, copra production and remittances, while facing a high dependency on food and fuel import. Fiscal revenue and public investments are low, and donor-financed projects are the main source of infrastructure development (Kuruppu, 2009; World Bank, 2010).

The quality and availability of drinking water pose significant challenges in Kiribati. Anti-pollution controls are scarce and investments in water infrastructure and monitoring fall short of quality standards. Moreover, climate change exacerbates these issues, potentially affecting the quantity and quality of freshwater lenses. Projected increases in rainfall over the central Pacific may increase pollutant runoff and contribute to higher incidences of water-borne diseases. Rising sea levels threaten to push shallow water tables closer to the surface and, coupled with projected temperature increases that will expose groundwater to higher evaporation (Christensen et al., 2007).

Figure 1: Main drinking sources of water in Kiribati in 2019

[5] Note that an increase in mineral bottled water consumption, especially via imports, would not represent a viable and sustainable solution given the related high environmental footprint (https://bottledwater.org/environmental-footprint/).



Note: N= 2,127 households.
Alt text: Rates of main drinking water sources declared by households. 30% of Kiribati households report using public piped water systems as their main drinking source (including indoor and outdoor pipes, neighbor's pipe, and collective public tap), while 40% and 28% of households respectively report groundwater (including tubed, protected and unprotected wells) and rainwater harvesting as their main sources of drinking water.
Source: Kiribati Household Income and Expenditure Survey (2019).

The availability and reliability of drinking water sources vary between the main atolls and islands in Kiribati. As shown in Figure 1, rainwater harvesting is an important source of drinking water in the island, catering to approximately 28% of households. Note that rainwater harvesting is similarly used in urban and rural areas (Figure A1 in the Appendix). The harvest is mainly operated during the wet season thanks to catchment systems, such as roofs and gutters, to channel rainwater into storage tanks (Kuruppu, 2009). South Tarawa, which is comprised of urban and peri-urban households has a public piped water system connected to two public freshwater reserves. Consequently, approximately one in three Kiribati households report using public piped water systems as their main drinking source (including indoor and outdoor pipes, neighbor's pipe, and collective public tap) as shown in Figure 1. In South Tarawa (urban) this share reached approximately 60% (Figure A1). Across the outer (rural) islands, where public and centralized water supply infrastructures are limited, most households extract groundwater through private wells. In the country, groundwater (including tubed, protected and unprotected wells) is the main source of drinking water for around 40% of households (Figure 1).[6] Finally, where groundwater is unavailable or compromised (e.g., pollution, rising sea level, drought), desalination plants have been implemented to convert seawater into freshwater, particularly on Tarawa Atoll. Moreover, imported bottled water may be used by households, primarily in urban and more economically advantaged settings. Nonetheless, the use of imported bottled and

[6] Groundwater can be tubed or not, as well as protected (with a cover) or not. Private wells and boreholes are used to tap into underground aquifers.

desalinized water is marginal in Kiribati with only 1.65% of households relying on these sources for drinking.

3. Literature on the link between water inaccessibility and SSB consumption

The positive impact of SSB intake on weight gain has been widely demonstrated in intervention studies (Schulze et al., 2004; Vartanian et al., 2007), not only in industrialized settings but also in developing countries. For instance, SSB consumption contributes to 10% of the daily calorie intake across all age groups in Mexico (Malik et al., 2010). Yet, it is likely that plain water consumption influences SSB intake. Also focusing on Mexico, Illescas-Zarate et al. (2015) find that a higher intake of plain water is negatively related to caloric beverage consumption. Similarly, Gazan et al. (2016) observe that the contribution of SSB to total beverage intake[7] decreases when consumed plain water increases. Colchero et al. (2015) and Barquera et al. (2008) find that higher prices of soft drinks (after the implementation of a tax for instance) are associated with an increase in purchases of bottled water in Mexico. Colchero et al. (2015) explain that the substitution for water could be even higher if the consumption of clean tap water had been integrated into their analytical framework. They argue that communities with better accessibility to clean (and quasi-free) piped water may be more likely to substitute water for SSB compared to communities where potable water is scarce. In line with these findings, a study focusing on the Hispanic population in the United States found that a low water quality perception was a driver for SSB intake (Onufrak et al. 2014).

Two main reasons may explain a potential high substitutability between water and SSB. First, mistrust in the quality of available piped water might lead individuals to consume more bottled and processed beverages for hydration purposes, including SSB (Hu et al., 2011; Saylor et al., 2011). Even in high-income countries where piped water quality is high, skepticism regarding tap water persist, probably because of a lack of information about its actual quality. Some studies show that improved information about piped water quality allows to increase its consumption and to reduce the consumption of risky beverages. For example, a randomized control trial testing the implementation of a water promotion campaign involving lessons and activities in Dutch schools shows a significant reduction in SSB intake by children (van de Gaar et al., 2014). Consequently, among countries or regions where piped water quality is highly uncertain, as in most developing countries, the willingness to purchase processed beverages such as SSB as a substitute for water is even more likely.

[7] Plain water, but also the consumption of other beverages and food, are responsible for water intakes.

A second reason explaining potential substitutions between water and SSB relies on economic rationality. From a hedonic perspective, SSB contain a high sugar content that provides more immediate satisfaction or utility than water to consumers (Redondo et al., 2014). Therefore, in countries where the price gap between bottled water and bottled SSB is relatively low, households with poor access to clean water facilities might prefer to purchase SSB than natural and mineral bottled water. Household income (and more generally socioeconomic status) may play a central role in the trade-off between paying for water or paying for SSB. Indeed, since price elasticity decreases with income, it is expected that the price gap between water and SSB mostly affects the demand function of low-income households (Colchero et al., 2015). Further, hedonic and health-risky behaviors are disproportionally observed among low-income vulnerable individuals, for whom investments in future health present a higher level of uncertainty (Levine, 2015).

3. Methods

3.1. Data and indicators

The Kiribati Household Expenditure and Income Survey (HIES) is a cross-sectional study conducted in 2019 and 2020 by the Government of Kiribati. This representative survey publicly provides detailed microdata for 2,182 households, located on 21 different islands (atolls) of the Republic of Kiribati, out of the 33 populated islands.

The analysis excludes 228 households that declared extreme quantities of SSB (>15,000 grams per week) from the sample. In addition, since this study aims to identify the substitution between access to pipes/tanked water and SSB intakes, we also exclude households reporting an unspecified water source as their main drinking source (1.65% of the sample).[8] The final sample of analysis includes 1,621 households.

3.2. Model

To investigate potential pathways through which obesity prevails in contexts of low water accessibility, this study aims to shed light on the potential substitution between SSB and plain water consumption. Despite its importance in terms of public health, this question remains poorly investigated in the literature (Fresán et al., 2016; Vartanian et al., 2007). To determine if such a substitution effect exists, we regress an OLS model of SSB household purchases on

[8] These households are probably referring to imported bottled water and desalinized water.

an indicator of water accessibility, defined as the main drinking source, and covariates, as follows.

$$Y_i = \alpha + \beta_1 W_i^j + \beta_2 X_i + \mu_a + \varepsilon_i \quad \text{(Eq.1)}$$

The dependent variable Y_i refers to the weekly quantity of SSB purchased by the household (in grams).[9] As in studies conducted by Gomez, Perdiguero and Sanz (2019) and Liu, Balasubramaniam and Hunt (2016), W_i^j identifies the main drinking water source used by a household i. According to the specific context of Kiribati (cf., section 2), we consider three categories j: (i) public piped systems (individual or collective taps, as well as indoor and outdoor taps), (ii) groundwater (including private tubed and non-tubed as well as private protected and unprotected wells), and (iii) rainwater. Households using other sources of main drinking water (e.g., bottled water and desalinized water) are excluded from the analysis (they represent 1.65% of the sample). μ_a represents island (atoll) fixed effect to account for territorial disparities.[10] X_i refers to a comprehensive set of control variables that are included in the model to minimize potential measure bias and omitted variables bias and to best explain the outcome variance (Liu et al., 2016). First, we control for a proxy of risky behaviors including household tobacco purchases (in weekly grams).[11] Second, we control for several socioeconomic indicators given the high importance of living standards in explaining food and beverage habits (McLaren, 2007), including the household monthly labor income (i.e., sum of all declared transactions, in AUD[12]), a score for household-owned assets ranging from 0 to 7 (i.e., the sum of the following ownership: stove, fridge, washing machine, television, radio, car, and motorbike), and a

[9] The following SSB types, available in the dataset, were included: chocolate and cola flavor soft drinks, lemonade, coconut toddy, fruit juice, syrup. The quantities are expressed in grams, as provided by the HIES. The 99th percentile of the distribution was removed to remove potential outliers. Considering that rice, oil and bread are basic food consumption items, and consumed by most of the households of the dataset, households that had declared consumption of neither of rice, oil and bread items, as well as no SSB consumption, were considered as missing values and were removed from the distribution as well. Using this variable as the outcome of our models allows us to identify the possible substitution effect between water and SSB consumption.

[10] Both SSB consumption and the type of access to plain water might depend on territorial conditions, as the Kiribati islands are spread across a vast marine territory. The atolls were subject to different influences, such as German and British, before the independence of the Republic of Kiribati in 1979. Water accessibility and infrastructures also differ across islands depending on the state of the water resource, and all atolls might not enjoy the same access to imported goods such as SSB. Therefore, we choose to include island fixed effects.

[11] Smoking is indeed the major cause of mortality among all health risky behaviors, while poor diet and physical inactivity are the second major cause (Cawley and Ruhm, 2011). Moreover, since all risky health behavior tend to be concentrated among households with low socioeconomic status, we can reasonably consider that risky non-food purchases in tobacco is a good proxy for household risky behaviors in general. There are indeed strong intra-household correlations between adult partners regarding risky health behaviors, which make household level analyses highly relevant (Graham et al., 2016).

[12] Note that the survey uses AUD as a currency and that the Kiribati dollar is tied to the Australian dollar at fixed rate.

categorical variable for the main dwelling wall material (i.e., no rigid walls, thatch, galvanized/aluminum, wood, and concrete, brick or stone).

3.3. Robustness checks against potential endogeneity problems

Given potential omitted factors correlated with household water accessibility, our OLS regression model might overestimate the level of SSB purchases when piped water accessibility is low. Indeed, the sample of analysis could be prone to an overrepresentation of households characterized by risky health behaviors with no access to piped water systems, which would lead to a selection bias.

To reject the risk of such a selection bias, we employ a placebo test to identify the correlation between common non-food risky behaviors (i.e., the weekly quantity of tobacco and alcohol purchases) assumed to be unrelated to water intake but potentially correlated with SSB purchases, and the main drinking source.[13] The literature in economics of risky health behaviors indeed shows strong correlations between risky food purchases and risky non-food purchases, highly dependent on socioeconomic status. Households with higher socioeconomic status are indeed less likely to smoke, to drink alcohol, to have a poor diet, and to be impacted by obesity (Cawley and Ruhm, 2011).

This robustness check consists in regressing household tobacco and alcohol purchases on the main drinking source of water and covariates as shown in Equation 2.

$$Z_i = \alpha' + \beta'_1 W_i^j + \beta'_2 X_i + \mu'_a + \varepsilon'_i \qquad \text{(Eq.2)}$$

The dependent variable, Z_i, represents the tobacco and alcohol purchases. β'_1 represents the correlation between riskier drinking water sources and risky behaviors related to tobacco and alcohol purchases. If β'_1 is positive and significant, this result would suggest that Eq. 1 is sensitive to a selection bias. In contrast, if β'_1 is not significant, it would suggest that the estimates from Eq. 1 are not affected by a selection bias. Note that if panel data was available, a more robust identification method could have allowed us to rule out this potential selection bias. Unfortunately, to our knowledge, such data in not available in the context of Kiribati and further data collection efforts might allow to strengthen the identification strategies implemented in this study.

[13] Even if one could assume a theoretical correlation between alcohol and plain water intake (given that alcohol is a source for dehydration), there is no empirical evidence of this link in the literature. Hence, we can assume that there is no significant link between alcohol and water intakes.

4. Results

4.1. Descriptive statistics

Table 1 reports descriptive statistics for each variable used in the study by the three categories of water access available to households (i.e., piped water, groundwater, and rainwater). It is interesting to note that weekly SSB purchases are greater among households facing higher water insecurity (i.e., households that use rainwater or groundwater as main drinking sources). Interestingly, households that have access to piped water report higher levels of other risky health-related behaviors (i.e., alcohol and tobacco purchases).

The descriptive statistics also suggest that household socioeconomic status may play a central role in water access and SSB purchases. First, as shown in Figure A3 of the Appendix, there is a clear positive association between SSB purchases and household income. Second, as displayed in Table 1, households having access to piped water tend to be economically and materially wealthier, and are also more likely to live in urban settings (i.e., South Tarawa), compared with households using groundwater and rainwater as their main drinking source.

Table 1: Characteristics of households according to the main source of drinking water

	Piped water		**Groundwater**		**Rainwater**	
	N	Mean	N	Mean	N	Mean
Household weekly SSB purchased quantity (grams)	383	1167	549	1369	391	1594
Household weekly alcohol purchased quantity (grams)	383	3188	549	2432	391	2614
Household weekly tobacco purchased quantity (grams)	383	1468	549	1360	391	1295
Household size (members)	383	6	549	5	391	5
Monthly household income (in thousands of AUD)	383	1.15	546	0.85	387	0.86
Household asset score (0-to-7 score)	374	1.83	549	1.02	391	1.44
Not rigid wall (dummy)	383	0.20	549	0.50	391	0.40
Thatch walls (dummy)	383	0.08	549	0.19	391	0.17
Galvanized/Aluminum walls (dummy)	383	0.26	549	0.16	391	0.13
Wooden walls (dummy)	383	0.26	549	0.11	391	0.16
Concrete, brick, stone walls (dummy)	383	0.21	549	0.04	391	0.14
Urban area (South Tarawa)	383	0.57	549	0.06	391	0.25

Note: These statistics are based on a sample of households excluding extreme purchases of SSB (>15,000g), alcohol (>15,000g), and tobacco (>5,000g).
Source: Kiribati Household Income and Expenditure Survey (2019).

4.2. Multivariate OLS estimates

Table 2 reports the OLS estimates of the association between the main source of drinking water (i.e., piped, groundwater, or rainwater) and SSB purchases. The regression controls for household composition, household wealth (i.e., income, and owned assets), a proxy of risky health behaviors (i.e., tobacco purchases), and housing characteristics (i.e., type of walls, and geographical location using islands fixed effects). Adjusted estimates are consistent with descriptive statistics presented in Table 1. Compared with households that have access to piped water, we find that households that use groundwater and rainwater tend to purchase 381 and

406 extra grams of SSB per week, respectively (significant at the 5% level). These quantities are substantive and represent respectively 22% and 24% of the constant (which would be the weekly SSB intake if every explanatory variable included in the regression was held at 0). These results are in line with the literature showing substitutability between water and SSB (e.g., Colchero et al., 2015).

Note that in regression results of Table 2, the correlation between SSB purchases and household income is positive (in line with Table 1) but non-significant. The lack of significance in the regression could be explained by the inclusion of covariates highly correlated with household income such as owned assets, wall materials and tobacco purchases, the latter being considered as a proxy of risky health behaviors in general. Likewise, whereas we observed that households having access to piped water are wealthier and consume more SSB in Table 1, once we control for household socioeconomic status, house type, health risky behaviors and island characteristics, multivariate inferential estimates (Table 2) indicate that having access to piped water may decrease SSB purchases, everything else being equal. Consequently, this point suggests that, regardless of household socioeconomic status, access to piped water has a negative association with SSB purchase.

Table 2: OLS regression of SSB purchase on the main source of drinking water and covariates

	Weekly SSB purchase (g/week)
Main drinking source: Groundwater (dummy)	380.698**
	(188.836)
Main drinking source: Rainfall tank (dummy)	406.287**
	(185.291)
Household size (members)	27.155
	(28.417)
Household weekly tobacco purchased quantity (grams)	0.038
	(0.039)
Monthly household income (in thousands of AUD)	1.896
	(76.440)
Household asset score (0-to-7 score)	90.647
	(65.870)
Thatch walls (dummy)	78.728
	(256.211)
Galvanized/Aluminum walls (dummy)	-425.557*
	(232.428)
Wooden walls (dummy)	-91.462
	(234.697)
Concrete, brick, stone walls (dummy)	272.118
	(266.670)
Island fixed effects	YES
Constant	1,696.561***
	(648.822)

Observations	1,493
R-squared	0.045

Notes: For dummy variables, reference groups are: piped water, and not rigid walls respectively. The sample excludes households with extreme purchases of SSB (>15,000g). Standard errors are robust to heteroscedasticity. Linearized standard errors are in parentheses. Levels of significance of fitted coefficients: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Kiribati Household Income and Expenditure Survey (2019).

4.3. Robustness analysis

To reject the risk of selection bias that could overestimate the association between the use of non-piped water system and SSB purchases, we check for potential correlations between the drinking water source and further risky behaviors assumed to be unrelated with water intake (Table 3). The results show that tobacco and alcohol purchases are relatively well balanced between the three categories of drinking water sources, except for tobacco purchases which are slightly lower among households mainly drinking rainwater. However, the negative sign and the low significance (10% level) of this fitted coefficient do not allow us to conclude on the presence of a selection bias, according to which, groundwater and rainwater drinkers would be more willing to adopt risky health behaviors in general. This robustness analysis allows us to conclude that the inclusion of important confounders in the vector of control variables that simultaneously affect water accessibility and consumption patterns, namely household socioeconomic status measurements and islands fixed effect, our regression seems relatively robust against the risk of a selection bias.

Table 3: OLS regression of tobacco and alcohol purchases on water accessibility (placebo test)

	Weekly tobacco purchase (g/week)	**Weekly alcohol purchase (g/week)**
Groundwater as main drinking source (dummy)	-87.296	-403.482
	(85.032)	(259.558)
Rainfall tank as main drinking source (dummy)	-166.198*	-129.978
	(90.061)	(273.636)
Household size (members)	119.173***	17.451
	(13.046)	(37.181)
Monthly household income (in thousands of AUD)	68.073*	251.605**
	(38.578)	(124.799)
Household asset score (0-to-7 score)	-142.774***	-40.248
	(26.522)	(78.572)
Thatch walls (dummy)	-67.441	-364.525
	(84.025)	(229.736)
Galvanized/Aluminum walls (dummy)	0.386	586.684*
	(107.549)	(307.579)
Wooden walls (dummy)	-66.358	-103.685
	(104.968)	(289.482)
Concrete, brick, stone walls (dummy)	-210.828*	249.614
	(113.768)	(343.036)
Island fixed effects	YES	YES
Constant	1,239.677***	1,994.348***

	(195.912)	(525.468)
Observations	1,625	1,621
R-squared	0.124	0.171

Notes: For dummy variables, reference groups are: piped water, and not rigid walls. The sample excludes households with extreme purchases of alcohol (>15,000g) and tobacco (>5,000g). Standard errors are robust to heteroscedasticity. Linearized standard errors are in parentheses. Levels of significance of fitted coefficients: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Kiribati Household Income and Expenditure Survey (2019).

Finally, the high seasonality of drinking water use (Elliott et al., 2017) could bias the results that rely on household data interviewed at one given time in the year especially if SSB purchases are also dependent on seasons. To identify this potential issue, we report the survey periods by island in Table A1 of the Appendix. The table shows that for most islands, the data was collected during a specific time of the year. For example, Beru was surveyed between week 2 and week 7 of data collection, corresponding to May to July 2019. South Tarawa is the only island that was surveyed throughout the entire exercise of data collection. Since each island was surveyed at specific time periods, we argue that the island fixed effects included in the regression model neutralize the potential bias associated with the seasonality of data collection.

5. Discussion

The findings from this study suggest that water access policies can have implications at both ranges of the BMI spectrum. Previous research and decades of interventions have considered the impact of poor water sanitation on diseases such as diarrhea leading to severe forms of undernutrition (see for instance Cuesta, 2007; Jalan and Ravallion, 2003; Zhang, 2012). Our research contributes to the emerging literature showing that the lack of access to high-quality water also affects nutritional behaviors and can contribute to the risk of obesity, which is a global health concern as well as a regional one in SIDS such as Micronesia (WHO and UNICEF, 2019).

This exploratory research opens the way to new research avenues that should focus on the role of water inaccessibility in food-based non-transmissible diseases such as obesity, diabetes type 2, stroke, and some cancers. It is worth noting that SSB-water substitutions, and their potential role in increasing obesity, might be even greater in water-deprived SIDS countries characterized by higher levels of SSB imports and intakes than Kiribati, such as in Niue, Cook Islands, Tonga, Tuvalu, and Palau (Pak et al., 2014).

6. Policy recommendations

The findings from this study have important policy implications for WASH and nutrition. The first recommendation urges policymakers of Pacific Islands such as Kiribati to increase investments in developing clean-water infrastructures. Access to safe drinking water is not only a human right, but these investments also carry positive nutritional impacts via substitution effects, as suggested by our results. In light of global warming and rising sea levels, Pacific Islands could benefit from investing in the seawater desalination industry, especially those utilizing renewable energy sources (Eyl-Mazzega and Cassignol, 2022). Moreover, given the country's high dependency on rainwater for drinking purposes, ensuring the safety of this resource by providing appropriate tank-kits, filters, and treatment systems is essential (Alim et al., 2020). Our findings also emphasize the need to address local obesogenic food environments. Public policy instruments such as taxes can regulate food markets and incentivize healthier consumption choices among households. For instance, soda taxes have proven effective in reducing SSB intake and increasing water intake (Colchero et al., 2015).

7. Conclusion

Using recent household survey data from Kiribati, a Pacific Island highly threatened by water insecurity and the epidemic of obesity, this study shows that ultra-processed energy-dense beverages, such as SSB, are potentially used as substitutes for water. These obesogenic substitutions are even more preoccupying in the current context of climate change, which is likely to increase the pressure on water resources in the islands of Micronesia.

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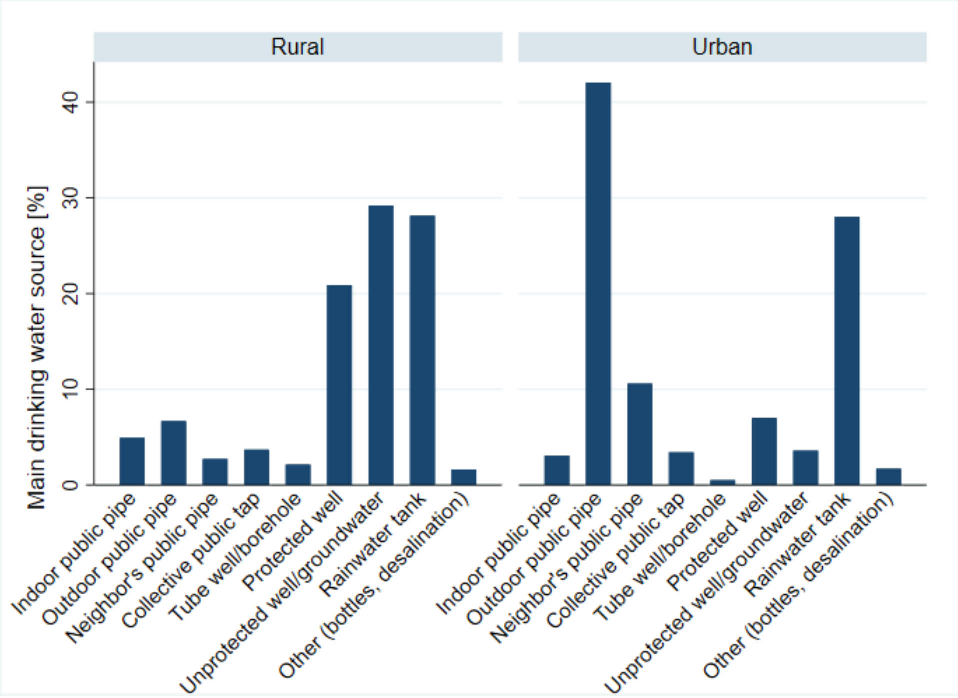
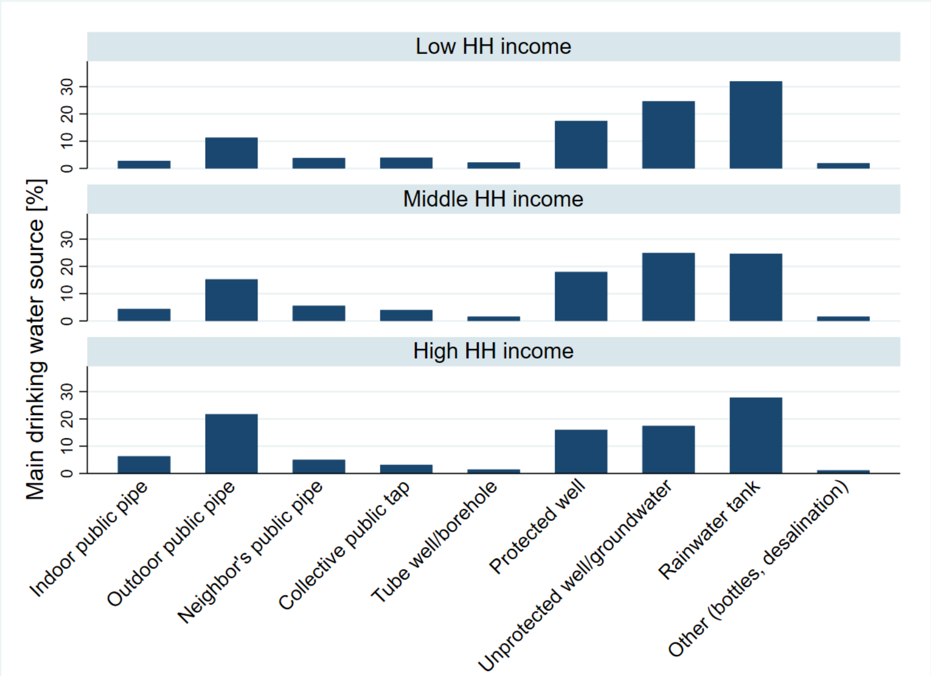
APPENDIX

Figure A1: Main drinking sources of water in Kiribati in 2019 by urban-rural area



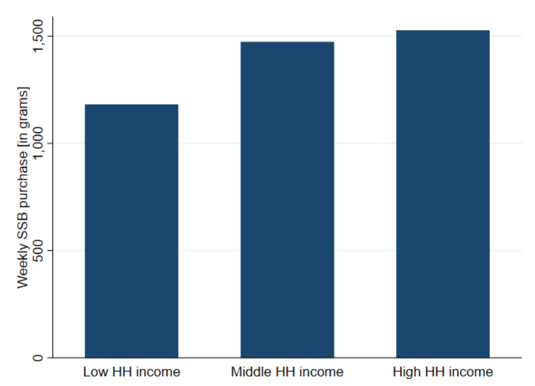
Notes: These statistics are based on 2,127 households, with 585 households in urban areas (South Tarawa) and 1,542 households in rural areas (outer islands).
Alt text: Rates of main drinking water sources declared by rural versus urban households. 60% of urban Kiribati households report using public piped water systems as their main drinking source (including indoor and outdoor pipes, neighbor's pipe, and collective public tap), while 10% and 27% of urban households respectively report using groundwater (including tubed, protected and unprotected wells) and rainwater harvesting as their main sources of drinking water. In rural settings, groundwater is the most used source of drinking water by households (52%), followed by rainwater harvesting (28%) and piped systems (18%).
Source: Kiribati Household Income and Expenditure Survey (2019).

Figure A2: Main drinking sources of water in Kiribati in 2019 by household (HH) income groups



Note: These statistics are based on 2,127 households. Household (HH) income groups are based on income tertiles.
Alt text: Percentages of main drinking water source by levels of household incomes (low, middle, and high), showing that the use of piped systems is more common among the richest households, while rainwater harvesting is more common among lower incomes.
Source: Kiribati Household Income and Expenditure Survey (2019).

Figure A3: Income-based heterogeneity in SSB



Alt text: Weekly SSB purchases (in grams) by levels of household incomes (low, middle, and high), showing that the more the household is rich, the more the purchases of SSB is high.
Source: Kiribati Household Income and Expenditure Survey (2019).

Table A1. Survey schedule of data collection by island

week	beru	nono uti	ntarawa	starawa	tabsouth	tabnorth	arorae	nikinau	onotoa	tamana	abaiang	butaritari	makin	marakei	abemama	aranuka	kuria	maiana	kiritimati	tabuearan	teraina
Week 1				x															x		
Week 2	x			x															x		
Week 3	x		x	x															x		
Week 4	x		x														x		x		
Week 5	x		x														x		x		
Week 6	x		x														x		x		
Week 7	x		x														x		x		
Week 9		x		x								x			x						x
Week 10		x		x								x			x						x
Week 11		x		x								x			x						x
Week 12		x		x								x			x						x
Week 13		x		x								x			x						x
Week 14		x		x								x			x						x
Week 15		x		x									x		x						x
Week 16		x		x									x		x						x
Week 17				x									x		x						
Week 18				x							x				x				x		
Week 19				x		x					x				x				x		
Week 20				x		x					x							x	x		
Week 21				x		x					x							x	x		
Week 22				x		x					x							x	x		
Week 23				x		x					x							x	x		
Week 24				x		x					x							x	x		
Week 25				x		x					x							x	x		
Week 26				x		x					x							x	x		
Week 27				x		x													x		
Week 28				x	x				x										x		
Week 29				x	x				x										x		
Week 30				x	x				x												
Week 31				x					x												
Week 34			x	x												x				x	
Week 35			x	x			x									x				x	
Week 36			x	x			x									x				x	
Week 37			x	x																x	
Week 38			x	x																x	
Week 39				x						x				x						x	
Week 40				x						x				x						x	
Week 41				x						x				x							
Week 42				x										x							
Week 43														x							

Source: Pacific Data Hub, available on: https://pacificdata.org/data/dataset/spc_kir_2019_hies_v01_m_v01_a_puf/resource/a1a3649f-e08b-4702-8aa9-0c99e62ba872