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DOES BIOMASS FUEL USE FOR COOKING AFFECT EARLY CHILDHOOD DEVELOPMENT? A CASE STUDY OF KIRIBATI

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Abstract

Early childhood development (ECD) sets the starting point for future health, learning, and wellbeing; hence the United Nations Sustainable Development Goals recognize the importance of ECD in the global agenda. Therefore, we present evidence of the possible influence of prolonged biomass use for cooking on ECD at the household level using data from MICS 2018–19 for Kiribati in the Pacific islands. These findings have important policy implications for promoting ECD in the Pacific region, particularly for Kiribati, where the use of biomass for cooking is prevalent. The study recommends scaling up the use of clean cooking fuels to improve the health and well-being of young children in the region.

Keywords: biomass use for cooking, clean cooking fuels, early childhood development, Kiribati

JEL Classification: Q40, R20, P46

Contents

1. INTRODUCTION

Globally 2.5 billion people still lack clean fuel for cooking, while a large share of this population belongs to developing countries in Asia (IEA 2022). Around 3 billion individuals in poor countries and about half of the world's population still use solid fuels, such as firewood, crop residue, dung cakes, and other biomass fuels, to meet their basic energy needs for heating and cooking (WHO 2015). Biomass is defined as "matter originating from living plants, including tree stems, branches, leaves as well as residues from agricultural harvesting and processing of seeds or fruits" (Pang 2016). It is anticipated that more biomass will be used overall to produce energy up to 2030 (Bruce et al. 2006).

The reliance on biomass fuels is rooted in ancient practices and is still prevalent in developing nations. Although the world has been rapidly urbanizing, a sizable portion of the global population still lives in rural areas with few services. Burning biomass is one of the primary cooking methods in most rural areas (Arora and Jain 2016) and among poor families in developing countries (Edwards and Langpap 2012). Globally, more than 50% of households rely on solid fuel including wood, coal, dung cake, and crop residue (Ravindra et al. 2019). Previous research has found various health-related negative externalities of using biomass for cooking, including acute respiratory infection among children (Lamichhane et al. 2017; Chávez-Zacarías et al. 2022). Small children who are with their mothers while cooking are the most at risk. Similarly, the adverse effects of using biomass on health issues among adults are also well documented (Rahut et al. 2017a; Chávez-Zacarías et al. 2022).

The household transition to clean fuel is a growing concern in academia and among policymakers. Due to its health (Dear and McMichael 2011) and environmental effects, the United Nations (UN) included access to fuel as its exclusive target in its list of Sustainable Development Goals (SDGs). The use of biomass for cooking is a threat to human health (Thomson et al. 2017), and dirty fuel is also causing increasing global greenhouse gas emissions. Recent literature has found a connection between fuel choice and wellbeing (Thomson et al. 2017; Churchill et al. 2020). In addition to the climatic and health effects of using biomass for cooking, researchers are increasingly interested in children's health and education outcomes. Collecting wood or crop residue consumes time, which adds to the cost of using biomass, in addition to the adverse impact on human and environmental health. Firewood collection consumes time that could be used for child care and educational activities at home (Krishnapriya et al. 2021). Household fuel choice is thus a significant determinant of children's educational outcomes (Choudhuri and Desai 2021; Frempong et al. 2021); however, its impact on early childhood development (ECD) has not been much examined.

The importance of ECD cannot be overstated, as it has a significant impact on a child's health, wellbeing, and future prospects (Khanal et al. 2017). Research has consistently shown that the first few years of life are crucial for a child's developmental and educational outcomes, with the brain developing rapidly and laying the foundation for future learning and behavior. A child's brain develops by 90% in the first five years of life, making this period critical for their later life development (Black et al. 2017). ECD encompasses physical, social-emotional, and cognitive areas of growth and has been shown to affect a child's cognitive abilities and wellbeing, as well as to determine their life trajectories. SDG 4.2 calls for countries to "ensure that all girls and boys have access to quality ECD, care, and pre-primary education so that they are ready for primary education." According to the SDG agenda, ECD should be a top priority in the twenty-first century. Ensuring that all children have access to high-quality ECD, care, and pre-primary education is a critical global goal for the year 2030. However, despite this commitment, 43% of children under the age of five in low- and middle-income countries (LMIC) are at risk of not reaching their full developmental potential (Lu et al. 2016). Recent research has recognized that, in addition to biological influencing factors, the quality of children's homes, neighborhood settings, parental traits, and social circumstances influence their development (Ranjitkar et al. 2019). This growing body of evidence underscores the urgent need for national and global investment in ECD, as well as for research that identifies specific factors within children's social contexts that can be modified to support positive outcomes.

Several factors have been identified as crucial for ECD, including adequate nutrition, access to healthcare, quality education, and a safe and stimulating home environment (Black et al. 2017). Additionally, the caregiver–child relationship and the quality of interactions with caregivers play a vital role in shaping a child's development (Shonkoff et al. 2009). Other factors such as poverty, parental education level, and exposure to violence or trauma can also have negative effects on ECD (Briggs-Gowan et al. 2010; Walker et al. 2011). Moreover, a factor that has been largely ignored in the literature on ECD is the use of biomass fuel for cooking, which is prevalent in many LMIC, including Kiribati. Studies have shown that exposure to household air pollution from cooking with solid fuels such as wood, charcoal, and agricultural waste can have significant adverse effects on children's respiratory health (Mishra et al. 2005). The use of biomass fuel for cooking can also have indirect effects on ECD through its impact on maternal health and time use, as well as household income and expenditure (Dadras and Chapman 2017). Other hazards of a female child going far away from home to collect firewood involve sexual abuse, snake bites, and other physical harm (Matinga and Clancy 2020).

There are three channels through which biomass use for cooking in households is linked with ECD. First, using biomass fuels can require children to spend more time collecting wood or other fuels, which can reduce the time they have available for play and other activities that promote development (Assaad et al. 2010; Levison et al. 2018; Frempong et al. 2021; Kyayesimira and Muheirwe 2021). Second, indoor air pollution from burning solid fuels can lead to respiratory infections, which are a leading cause of childhood morbidity and mortality in LMIC (WHO 2016). Third, exposure to indoor air pollution can also cause developmental delays and cognitive impairment in young (Midouhas et al. 2019).

For most children, the indoor situation at home is the first and most important environment they encounter during their early years. Children spend most of their time at home, with young children staying there for about 15 hours per day and babies for about 20 hours per day. Children are exposed to a wide range of physical, chemical, and biological elements in their home environment, including things that might potentially affect their development. Furthermore, research has confirmed the prevalence of stunting and anemia in households with indoor air pollution due to burning biomass (Mishra and Retherford 2007).

In addition to causing indoor air pollution problems, biomass negatively affects activities for a normal, routine life elements such as concentration, memory, and self-care. Children in developing countries spend significant time helping families arrange fuel, such as collecting firewood and preparing dung cakes. Similarly, domestic work is a strong determinant of school-going children's educational outcomes (Assaad et al. 2010). Clean fuel saves time for all family members, and this time can then be spent on education and leisure, ultimately improving quality of life (Williams et al. 2020). Similarly, clean fuel improves indoor air quality, as the use of dirty fuel emits carbon monoxide and PM2.5 pollution (Mulenga and Siziya 2019). Using biomass for cooking and heating is also reported to cause nutritional deficiency in children. Because child educational outcomes depend on various socio-economic factors, room to identify more promising factors is still required.

The development of children and their early-age learning are crucial determinants of their academic performance later in life (Duncan et al. 2007); this study is therefore significant in terms of human capital development, labor market development, and health improvement in Kiribati. As a member state of the United Nations, Kiribati is committed to achieving the global agenda for sustainable development through the SDGs, which include specific targets for early-age child education (Goal 4.2) and access to affordable clean fuel (Goal 7). A recent report has indicated that only 21.6% of Kiribati children aged 7–14 have foundational numeracy skills, while 30% have foundational reading skills (UNFPA 2021). Despite a high literacy rate of above 99% among individuals aged 15–24, the low-quality education indicators in Kiribati call for in-depth empirical analysis to better inform policy interventions. Although the primary school completion rate in Kiribati is 94%, the upper secondary completion rate is only 12.8%. Kiribati is one of the least developed countries in the Pacific islands, with a GDP of $197 million (2017 estimate) and a population of 121,388 as of 2021 (World Bank 2021). With 21 inhabited islands divided into five divisions (Northern, South Tarawa, Central, Southern, and Line islands), Kiribati has a total land area of only 810 square kilometers, spread over a sizable ocean area of roughly 3.5 million square kilometers. The country has very few natural resources, including coconut, fish, and phosphate (CIA 2022). Kiribati is 4,000 km away from two major economies, Australia and New Zealand (GoKiribati 2022). According to statistics for 2020, access to clean fuel in Kiribati is 10%, while access to electricity is 92%. The country is a net primary energy importer, as it imports 1048 TJ of primary energy and exports zero energy. In addition, 70% of electricity produced in the country is based on fossil fuels and the remaining 30% is obtained from renewable sources such as solar power (IRENA 2022). The national energy policy of Kiribati from 2009 aims to provide affordable and clean energy to improve the environment and sustainable energy options (for details, see Peltovuori 2017).

The present study’s contribution is thus twofold: first, it is the first study on ECD in any Pacific island. Second, to the best of the authors’ knowledge, this is the first study on the association between biomass fuel use for cooking and ECD. Against this backdrop, the present study analyzed the impact of clean fuel used for cooking on child educational outcomes. The next section explains the data and methodology, and the subsequent sections elaborate on the empirical findings and conclusion. The final section also discusses recommendations to guide policymakers in achieving child development goals in relation to energy use for cooking purposes.

2. DATA AND METHODOLOGY

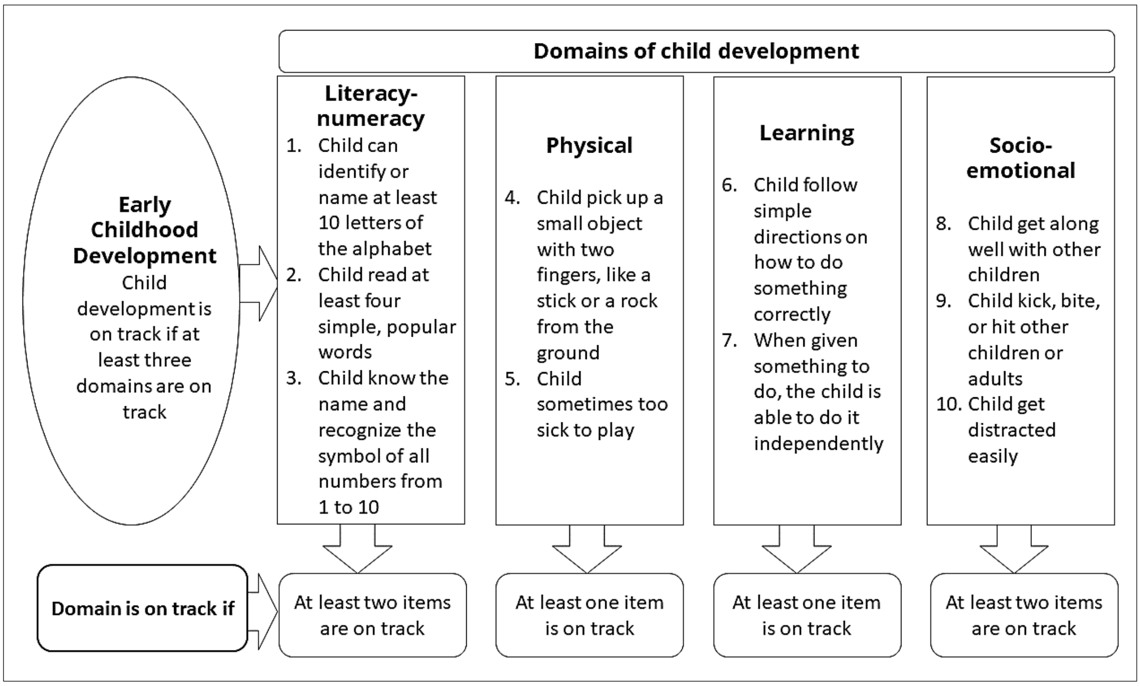
2.1 Data

This study examined the association between biomass fuel use for cooking and ECD in Kiribati using data from the MICS 2018–19. Measuring ECD is a complex task (Loizillon et al. 2017). MICS is a household survey that UNICEF designed that collects data on children in LMIC and is both nationally representative and internationally standardized (UNICEF 2021a), and it provides in-depth information about ECD for children aged between 36 and 59 months. MICS data provide a huge quantity of information about child development, household fuel choice, emotion and social development, and learning cognition among children. In addition, this data set offers various controls for regression analysis, including parenting, children's height and weight, child health, and child functioning, as well as several socio-economic data points. Information about parents regarding access to information communication technologies is also an advantage of the data set. Various wealth-controlling variables are also included in the data set, including income quintile, housing characteristics, and location. The study covered 3,280 households in total. Mothers or those who looked after children under the age of five were asked a series of questions about ECD. For the current study, pertinent information on homes, parents, and children between the ages of 36 and 59 months was gathered. ECD data were available for 847 children who made up the study's sample and were between the ages of 36 and 59 months.

2.2 Outcome Variable

Using the MICS data set for Kiribati, information for ECD was gathered for children between 36 and 59 months. Following the methodology suggested by Loizillon et al. (2017), the ECD method developed by UNICEF was employed to estimate the children's developmental status. Child development studies commonly use the ECD framework; however, this is not beyond criticism, as some think the approach is over-simplified (McCoy et al. 2016; Tran et al. 2017). The ECD tool measures ten items across four domains of ECD: language-cognitive, physical, social-emotional, and methods of learning (Figure 1). Children who scored positively in at least three out of four domains were considered to be on track in terms of their ECD.

Figure 1: Early Childhood Development (ECD) Measures



2.3 Empirical Methodology

To address the issue of selection bias, we employed the propensity score matching (PSM) method (Liu et al. 2020). PSM is a statistical method used to reduce bias in observational studies when random assignment to treatment groups is not possible. In a study where treatment is not randomly assigned, selection bias can occur, leading to systematic differences in characteristics between the treatment and control groups that affect the outcome of interest. PSM attempts to mitigate this bias by creating a control group that is similar to the treatment group in terms of observable characteristics. This allows for a more accurate estimate of the treatment effect by controlling for potential confounding variables. The dependent variable here is child development, which is a binary variable measured through ECD, and covariates are the education level of the household head, the number of children under age five in the household, a dummy for stunting in children, wealth quintiles, and availability of toys for children to play. Furthermore, the study utilized a binary dummy variable to represent the adoption of biomass for cooking purposes, serving as the treatment variable in the analysis. The adoption of biomass was not a random decision; rather, it was a self-selection process carried out by families without any exogenous control. The choice of a household to use biomass or not is influenced by various external influences, including human capital and demographics, wealth, supply of alternative fuels, and socio-economic circumstances. PSM is a suitable methodology that aids in examining the average effects of the treatment—here, biomass fuel used for cooking.

2.4 Propensity Score Matching

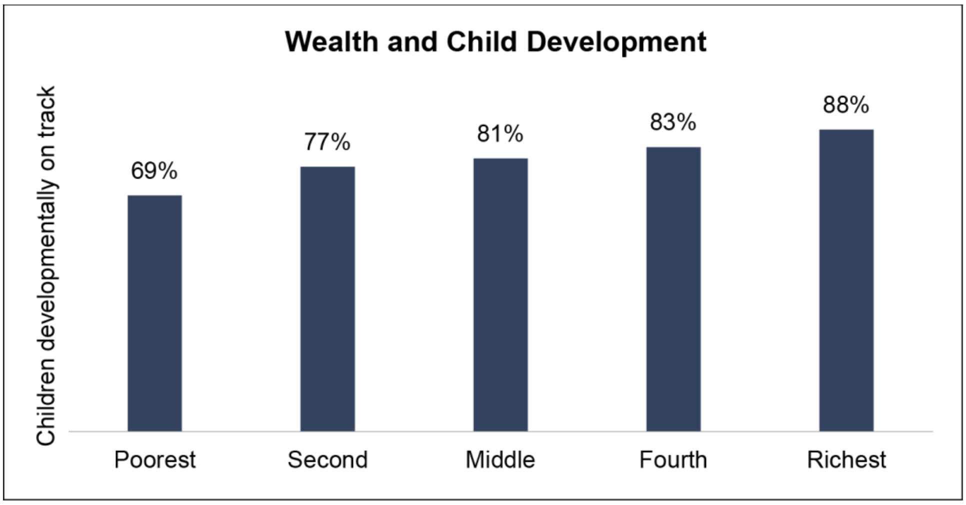
PSM can approximate the conditions of a random experiment when experimental data are unavailable. Moreover, in the absence of experimental data, PSM can account for this sample selection bias (Dehejia and Wahba 2002). Unlike parametric techniques, PSM is not based on the assumption of a functional form for defining the link between results and outcome predictors. PSM is predicated on the idea that, subject to certain observable features, treated and untreated units can be matched as if the treatment had been entirely randomized. To avoid the problems of selection bias that afflict non-experimental approaches, PSM attempts to simulate randomization. The PSM technique has thus been used in the current investigation to account for any possible bias that could result from systematic differences between households that use biomass and those that do not. Once the adopter and non-adopter groups have been identified and matched using kernel, radius, or the nearest neighboring method, a comparison of the pseudo-R square results from the analysis before and after matching the samples is recommended by Sianesi (2004). The pseudo-R square shows how well the regressor accounts for the likelihood of participation. After matching, the pseudo-R square should be low, to guarantee that there are no systematically different covariate distributions between the two groups. The nearest-neighbor, radius, and kernel-matching approaches are used in this study to carry out the empirical investigation. The average treatment effect for the treated (ATT) is the most crucial parameter of relevance for PSM. Biomass adopters for cooking fuel (treatment group) and non-adopters (control group) are matched using the kernel, radius, and neighboring methods based on characteristics such as wealth quantiles, region, and household head education, among others.

3. RESULTS AND DISCUSSION

3.1 Descriptive Analysis

Figure 2 illustrates the relationship between the level of household wealth and child development outcomes. The wealth variable is represented by five ordinal categories, while child development is measured through a binary variable. The results demonstrate that children with on-track development are disproportionately represented in affluent households. Notably, there is a significant difference observed between the richest and poorest quintiles, with 88% of children in the richest quantile showing on-track development, compared to 69% in the poorest quintile. These findings indicate a positive association between wealth quintiles and child development, which implies that financially strong families can provide an environment conducive for child development (Sk et al. 2020).

Figure 2: Child Development and Wealth

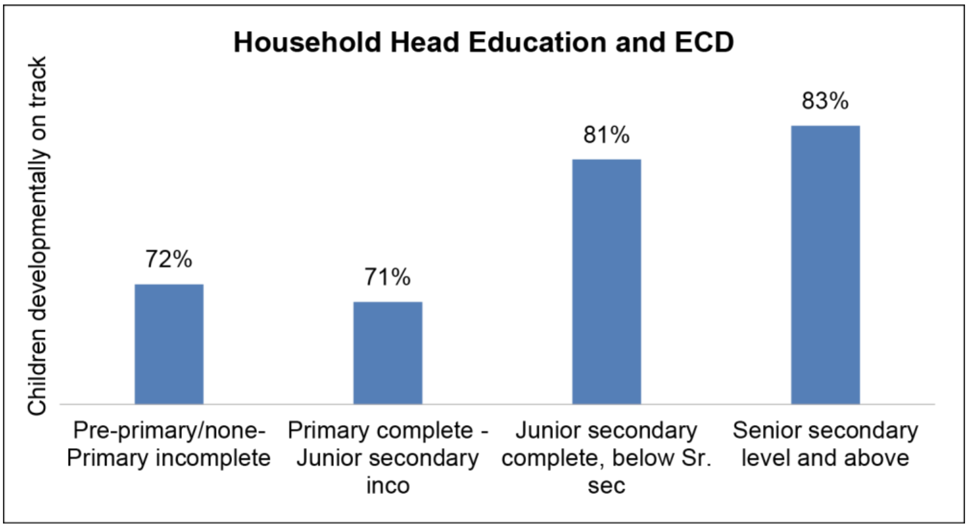


Source: authors won illustration using MICS data.

Figure 3 illustrates the relationship between the education level of the household head and ECD. The graph exhibits a positive correlation between the education level of the household head and the percentage of children on track in their ECD. Notably, the graph indicates a threshold effect for a primary education level, where 71%–72% of children are on track if the head of the household has a maximum primary education. In contrast, the percentage rises to 81% and 83% for junior secondary or senior secondary and above, respectively. This demonstrates that education beyond the primary level fosters awareness and leads to behavioral changes related to child development. Moreover, educated parents—particularly an educated head of the household—make various decisions that have a direct or indirect impact on child development.

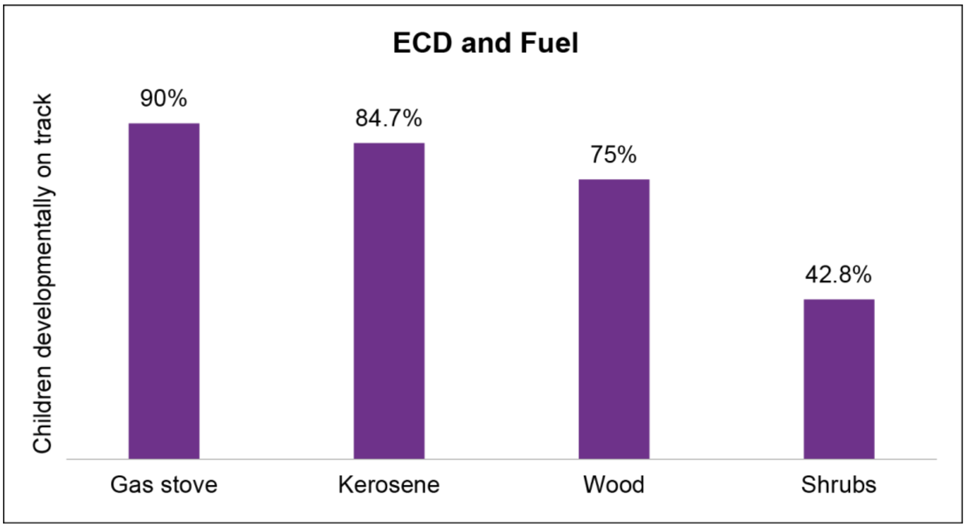
Similarly, Figure 4 depicts the relationship between ECD and fuel types used for cooking in Kiribati. The graph shows a difference in the percentage of children on track among biomass adopters and non-adopters. The prevalence of children who are developmentally on track is highest among households using gas for cooking purposes. This is followed by kerosene; however, biomass users, including wood and shrubs (crop residue), are associated with a low level of child development. Specifically, 90% of children are on track in their early development in households that use gas for cooking, whereas the percentage drops to 84%, 75%, and 42.8% for kerosene, wood, and crop residue, respectively. This finding suggests that the type of fuel used for cooking has an impact on child development, with biomass being associated with a particularly negative effect.

Figure 3: Household Head Education Level and Early Childhood Development (ECD)



Source: authors won illustration using MICS data.

Figure 4: Cooking Fuel and Early Childhood Development (ECD)



Source: authors won illustration using MICS data.

Figure 5 displays the regional variability in child development outcomes across Kiribati's five major regions. The graph demonstrates that South Tarawa has the highest percentage of children who are developmentally on-track, with 82% of children meeting developmental milestones. Northern Gilbert follows closely, with 80% of children meeting the same developmental standards. However, the Central Gilbert, Southern Gilbert, Line, and Phoenix Group regions exhibit lower rates of developmental progress in children.

Figure 5: Early Childhood Development (ECD) in Various Regions of Kiribati

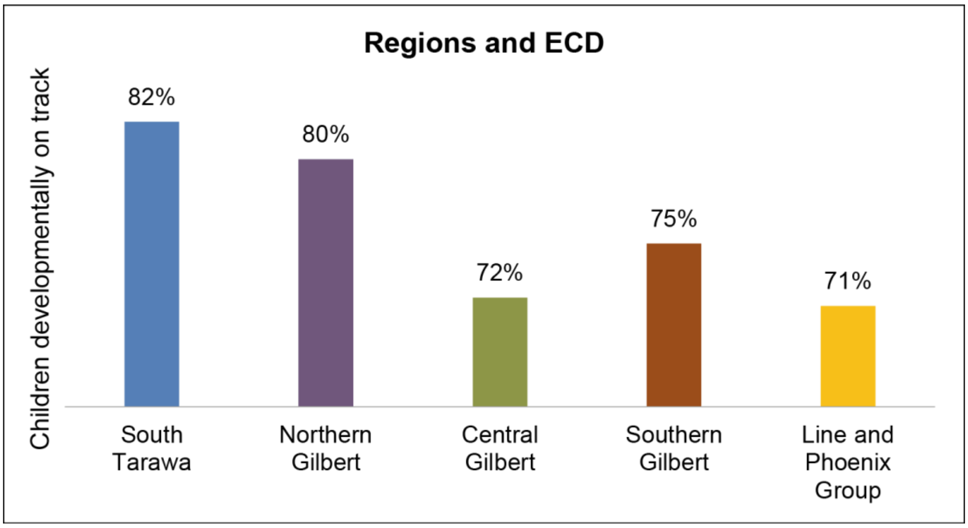


Table 1 presents the descriptive statistics for the outcome variable ECD, the treatment variable fuel type, and several covariates. Our findings reveal that 79% of children in Kiribati are on track for ECD. This result is marginally lower than the 80% reported in previous studies based on MICS conducted in Kiribati (UNICEF 2021b).

Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
ECD	0.79	0.41	0	1
Biomass	0.57	0.49	0	1
Family size	7.6[a]	3.6	2	23
Wealth[b] quantiles 1–5				
Poorest	0.288	0.45	0	1
Second	0.246	0.43	0	1
Third	0.193	0.39	0	1
Fourth	0.138	0.34	0	1
Richest	0.133	0.34	0	1
Roof tin/cement	0.50	0.50	0	1
Head age	43.2	13.0	19	85
Female head	0.24	0.43	0	1
Head education				
Illiterate	0.10	0.39	0	1
Primary	0.22	0.421	0	1
Junior Secondary	0.34	0.47	0	1
Senior secondary and above	0.32	0.46	0	1
Rural-dummy	0.63	0.48	0	1
Access to internet	0.489	0.50	0	1

[a] "Warning: these figures indicate the number of cases found in the final data file. They cannot be interpreted as summary statistics of the population of interest."

[b] The wealth index is a composite indicator of wealth. Starting from Wave 2, questionnaires have included questions on ownership of consumer goods (variables CH11A–CH14I), energy use (variables EU1–EU6), and water and sanitation (variables WS1–WS6). Based on these and a few more variables (e.g., persons per room, access to the internet) related to household wealth, the wealth index was constructed (UNICEF).

Note: ECD, early childhood development.

3.2 Determinants of Biomass in Kiribati: Odds Ratios from Logistic Regression

Table 2 displays the logistic regression results examining the relationship between the use of biomass energy for cooking and several covariates in Kiribati. The outcome variable is a binary variable indicating whether a household uses biomass (assigned a value of 1) or not (assigned a value of 0) for cooking. The regression model includes several covariates, including the education level, age, and gender of the household head; household size; wealth quintiles; roof material; access to internet; and location. Most of the independent variables are found to be statistically significant predictors of biomass usage, so the presence of these covariates must be considered when assessing the relationship between biomass usage and ECD in Kiribati.

Table 2: Determinants of Biomass: Logit estimates

Covariates	Odds Ratio	St.Err.	z-value
Family size	1.09***	0.045	–4.74
Wealth quintiles – poor as base category	1.10**	0.05	1.89
– Second	0.49**	0.039	–6.73
– Middle	0.91***	0.17	–4.45
– Fourth	0.63***	0.06	–8.06
– Highest	0.34***	0.03	–8.56
Education of household head none or primary incomplete as base category			
– Primary completed	0.162	.375	0.47
– Junior secondary	0.847*	.587	1.93
– Senior secondary and above	0.341**	.799	2.49
Female head	0.95	0.26	–0.18
Age of head	1.00	0.009	0.17
RURAL dummy	3.118***	1.221	2.91
Division/district base= South Tarawana			
– Northern Gilbert	.368**	.157	2.54
– Central Gilbert	.561	.288	–1.13
– Southern Gilbert	.312**	.145	–2.51
– Line and Phoenix group	.127	.102	–1.58
Roof tin/cement dummy	2.34**	0.84	2.35
ICT-dummy for access to internet	0.36***	0.12	-2.95
Constant	.04	.038	-3.43

Note: *** Level of significance p < 1%. ** Level of significance p < 5%. * Level of significance p < 10%.

3.3 Impact of Solid Fuel on ECD

The findings from the PSM analysis on the impact of biomass usage for cooking purpose on ECD are presented in Table 3. This study examined the impact of biomass fuel use for cooking on ECD and its four domains. Three matching algorithms, including the radius, kernel, and nearest neighboring methods with replacement, were used to compute the average treatment effect of the treated. The PSM results show that using biomass for cooking adversely affects ECD, which is consistent and significant across all four domains of ECD. Moreover, the findings indicate that the likelihood of a child being developmentally on track declines by 9–13 percentage points if the household utilizes biomass fuel for cooking.

Table 3: Average Treatment Effect of the Treated of Using Biomass on ECD Using PSM

Matching Technique	Outcome	ATT	S.E.	T	Treated	Controls
Radius	ECDI	–0.1223	0.029	–4.18	521	326
Kernel	ECDI	–0.1223	0.020	–5.87	521	326
Nearest neighbor	ECDI	–0.125	0.029	–4.18	521	326
Radius	Literacy numeracy	–0.07	0.027	–2.63	521	326
Radius	Physical	–0.015	0.006	–2.47	521	326
Radius	Socio-emotional	–0.04	0.023	–2.02	521	326
Radius	Learning	–0.05	0.024	–2.40	521	326
NN(5)	Literacy numeracy	–0.09	0.033	–2.99	521	326
NN(5)	Physical	–0.02	0.007	–3.03	521	326
NN(5)	Socio-emotional	–0.036	0.028	–2.25	521	326
NN(5)	Learning	–0.093	0.023	–4.04	521	326

Note: ECD, early childhood development; PSM, propensity score matching.

To examine the robustness of the inference about the effect of biomass adoption on ECD, matching quality analysis is required. Comparing the median absolute bias before and after matching, the value of the R-square before and after matching, and the joint significance of covariates before and after matching are necessary because the main goal of PSM is to balance the covariates among different groups—that is, the households that adopt biomass and those that do not. Table 4 presents the findings regarding matching quality. Before matching, the median absolute bias was fairly large; after matching, it was quite low, which shows that the bias significantly decreased. Before matching, the bias is between 90% and 91%. After matching, the bias lies between 5% and 6%. The range of 68% to 93% in the percentage of bias reduction shows that a sizable amount of bias has been eliminated. The R-square value is quite high before matching and quite low after matching, which shows that there are no systematic differences between the two groups after matching and that the variables have been balanced. After matching, the joint significance of covariates should always be accepted, which suggests that both groups are substantially similar to one another, because the combined significance of the covariates should never be rejected before matching.

Table 4: Balancing Test Before and After Matching

Matching	Outcome	Mean Bias Before	Mean Bias After Matching	Bias Reduction %	R-Square Before Matching	R-square After Matching	Covariant Joint Significance Before Matching	Covariant Joint Significance After Matching
Kernel	ECDI	91.1	6.7	85	0.53	0.012	0.000	0.297
Radius	ECDI	91	8.1	10	0.53	0.47	0.000	0.210
NN (1)	ECDI	91.1	8.2	93	0.538	0.025	0.000	0.209
NN (5)	ECDI	91.1	12.3	68	0.538	0.022	0.000	0.223
NN (10)	ECDI	91.1	7.0	92	0.538	0.008	0.000	0.593
NN(5)	Soci-emo.	91.1	12.36	85	0.530	0.012	0.000	0.423
NN(5)	Lit-num.	91.1	12.3	68	0.538	0.022	0.000	0.383
NN(5)	Phy.	91.1	12.3	68	0.530	0.022	0.000	0.623
NN(5)	learn	91.1	12.7	68	0.530	0.022	0.000	0.543

Note: ECD, early childhood development.

The balancing of covariates among various groups is shown in Figure 6, which demonstrates the robustness of the outcome. Children under the line are the control sample, while children above the line are the treated sample exposed to biomass fuel used for cooking. According to the graph, most of the sample observations were able to find a good match in the opposing group, and very few observations were left unmatched. The figure also demonstrates that the propensity score distributions between the groups had a good degree of overlap, which made it possible to observe any combination of characteristics of the children seen in the treatment group in the control group. This was an ideal circumstance for PSM to generate reliable estimates and for us to have trust in the analysis.

Figure 6: Distribution of Propensity Scores

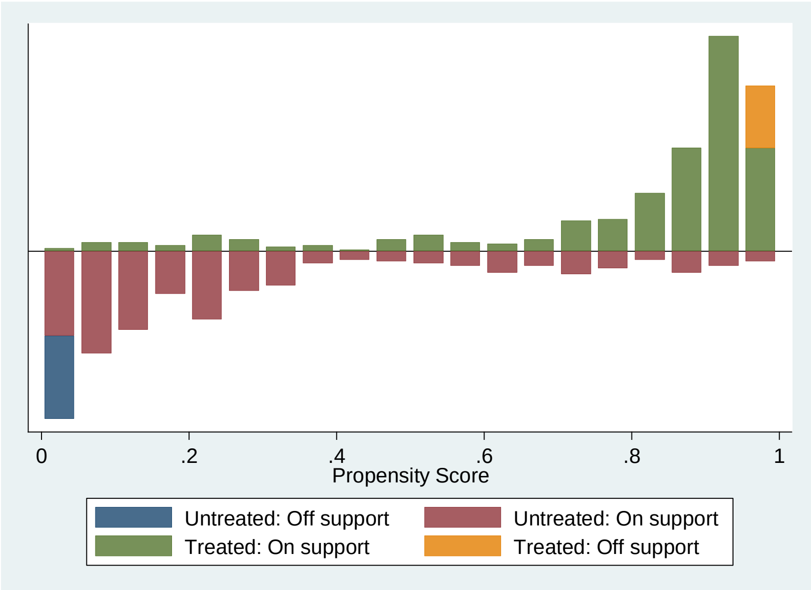


Figure 7: Comparison of Propensity Score Before and After Matching

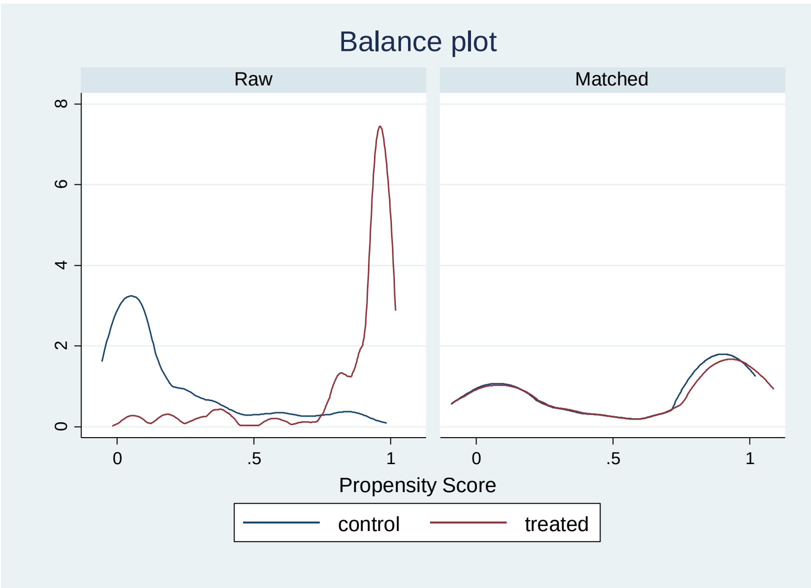


Figure 7 shows the biases of covariates before and after PSM. This highlights the area of common support between the treatment and control groups before and after matching. This graphical method makes it easy to illustrate the two groups' matching quality. The distribution of the treated and control group propensity scores in the matched sample almost overlaps after the matching process. Therefore, it can be assumed that the data in this study have improved conditions for the common support domain, with the majority of observations being within the common value range.

3.4 Robustness Analysis

To test the robustness of the analysis, we conducted some heterogeneous effects of biomass use for cooking on ECD in subgroups of the sample. For this purpose, Tables 5–7 present the PSM outcomes that show the negative impact of biomass on ECD stratified for subgroups of the samples. Table 5 shows that the use of three stones as a cooking stove, which is linked with dirty fuel including biomass, has a negative effect on ECD. Similarly, Table 6 indicates that the sub-sample based on child age also shows the negative effect of biomass fuel on ECD; we used children aged 36–48 and 49–59 months as two separate samples. Similarly, Table 7 shows the disaggregated analysis of sub-samples stratified by mother's education, which again showed the robustness of our earlier findings.

Table 5: Average Treatment Effect for Using Three-Stone Stove on ECD Using PSM

Matching Technique	Outcome	ATT	S.E.	T	Treated	Controls
Radius	ECD	–0.1067	0.02	–3.56	500	347
Kernel	ECD	–0.093	0.033	–2.99	500	347
Nearest neighbor	ECD	–0.0927	0.076	1.37	500	347

Note: ECD, early childhood development; PSM, propensity score matching.

Table 6: Average Treatment Effect for Stratification by Child Age

Child Age	Matching Technique	Outcome	ATT	S.E.	T	Treated	Controls
3 years	Radius	ECD	–0.097	0.04	–2.99	252	168
	Kernel	ECD	–0.106	0.055	–1.84	252	168
	Nearest neighbor	ECD	–0.091	0.043	–2.60	252	168
4 years	Radius	ECD	–0.11	0.090	–1.96	248	179
	Kernel	ECD	–0.11	0.028	–2.64	248	179
	Nearest neighbor	ECD	–0.11	0.028	–3.91	248	179

Note: ECD, early childhood development; PSM, propensity score matching.

Table 7: Average Treatment Effect of the Treated of Stratified for Mother's Education

Mother's Education	Outcome	ATT	S.E.	T	Treated	Controls
None: Primary incomplete						
Primary complete	ECD	–0.106	0.065	–5.78	100	41
Junior secondary complete	ECD	–0.0727	0.036	–1.98	124	67
Secondary	ECD	–0.095	0.035	–2.66	145	169
Senior secondary						

Note: There were not enough observations available for primary incomplete and senior secondary. ECD, early childhood development.

3.5 Sensitivity to Hidden Bias

According to Table 8, which shows the Mantel-Haenszel (M-H) bounds test findings, we can generally reject the basic hypothesis that a concealed bias causes overestimation of the predicted treatment effect. If there is a bias, it will probably cause the treatment impact to be underestimated. However, as noted by (Becker and Caliendo 2006), the unconfoundedness assumption cannot be explicitly justified by the M-H bounds test.

Table 8: Sensitivity Analysis to Hidden Bias: M-H Bounds Test

Gamma	Q_mh+	Q_mh−	p_mh+	p_mh−
1	2.82245	2.82245	0.002383	0.002383
1.05	3.07078	2.57924	0.001067	0.004951
1.1	3.30641	2.34606	0.000473	0.009487
1.15	3.53241	2.12388	0.000206	0.01684
1.2	3.74961	1.91167	0.000089	0.027959
1.25	3.95875	1.70857	0.000038	0.043765
1.3	4.16047	1.5138	0.000016	0.065039
1.35	4.35532	1.32668	6.60E-06	0.092308
1.4	4.54381	1.14661	2.80E-06	0.125771
1.45	4.7264	0.973064	1.10E-06	0.165261
1.5	4.90347	0.80556	4.70E-07	0.210248

Gamma: odds of differential assignment due to unobserved factors; Q_mh+: Mantel-Haenszel statistic (assumption: overestimation of treatment effect); Q_mh−: Mantel-Haenszel statistic (assumption: underestimation of treatment effect); p_mh+: significance level (assumption: overestimation of treatment effect); p_mh−: significance level (assumption: underestimation of treatment effect).

4. CONCLUSION AND POLICY IMPLICATIONS

ECD refers to a child's physical, cognitive, social, and emotional growth and development in early life. It is a critical period in a child's life, as it lays the foundation for future learning, economic, and health outcomes. This is crucial to guarantee that every child develops to their greatest potential. The UN recognizes the importance of ECD and has incorporated it into the SDGs, specifically SDG 4: Quality Education. In this study, we examined the prevalence and disparities of reported child development delays in Kiribati. This is the first study on the impact of adopting biomass fuels for cooking on ECD, and we analyzed the effect of biomass usage on child development using PSM. This paper is based on the comprehensive data set of the MICS 2018–19. The findings show that, after matching covariates through the PSM method and reducing bias, biomass adoption has a significant effect on ECD. In addition, the results from both the logit and PSM models show that the likelihood of child development being on track declines significantly if the child belongs to a household that consumes biomass fuel for cooking. We examined biomass fuel's impact on ECD and its four domains for the robustness analysis, which also shows a negative role of biomass fuel consumption on child development, as well as in all four domains (literacy-numeracy, socio-emotional, learning, and physical). Based on the findings from the empirical analysis, the present study makes the following policy suggestions.

The provision of small gas tubes at affordable prices or through subsidies should be accessible to poor households in rural areas (Rahut et al. 2017b). Identifying families without clean energy for cooking is crucial to achieving SDGs related to clean energy and child development. After being identified, the appropriate energy policy should focus on helping those households with no access to clean energy or who have limited access to clean energy. Priority one is gaining access to clean fuel for cooking, and priority two is increasing the intensity of clean fuel use. Additionally, the policy requires different approaches to off-grid and on-grid families. Making these households switch to clean fuels from biomass can benefit children's development. Our findings thus lend support to global initiatives to promote clean cooking fuel as a child development intervention. To achieve SDGs related to ECD and transition to clean fuel for cooking, church-based interventions for child development through fuel choice and other factors have been suggested elsewhere (Gittelsohn et al. 2011; Kodish et al. 2019).

As the results of the present study show factors that affect the development of children aged 3–5 years using MICS data, this snapshot for achieving child development–related goals in SDGs in Kiribati should be further explored with other models and methodologies for a larger view. We believe that although these results were obtained using observational data, the selection bias was reduced, if not eliminated, by using the PSM method and other tests to ensure the matching was accurate. The estimates held up well against various matching algorithms. Despite the preliminary status of our estimates, they could be particularly sensitive to potential unobserved confounding factors that the PSM technique cannot account for.

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