Does biomass fuel use for cooking affect early childhood development? A case study of Kiribati

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Abstract

Early childhood development sets the starting point for future health, learning, and wellbeing; hence the United Nations Sustainable Development Goals (SDGs) recognize the importance of early childhood development in the global agenda. Therefore, we present evidence of the possible influence of prolonged biomass use for cooking on early childhood development at the household level using data from MICS 2018-19 for Kiribati from the Pacific Islands. The Propensity score matching method shows that using biomass for cooking reduces the likelihood of on-track early childhood development. Based on the robust results, the present study recommends scaling clean cooking fuel use to promote early childhood development in the Pacific, particularly Kiribati.

1. Introduction

Globally 2.5 billion people still lack clean fuel for cooking, while a large share of this population belongs to developing 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 things like heating and cooking (WHO, 2015). Biomass defined as "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). Up until 2030, more biomass is anticipated to be used overall to produce energy (Bruce et al., 2006)

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

The household transition towards clean fuel is a growing concern in academia and policymakers. Due to its health (Dear and McMichael, 2011) and environmental effects, the United Nations included access to fuel as its exclusive target in Sustainable Development Goals (SDG) list. The use of biomass for cooking is a threat to human health (Thomson et al., 2017). Dirty fuel is also causing increasing global greenhouse gas emissions. Recent literature found a connection between fuel choice with wellbeing (Churchill et al., 2020; Thomson et al., 2017). 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, besides the adverse impact on human and environemntal health. Firewood collection consumes time which can be used for child care and educational activities at home (Krishnapriya et al., 2021). Household fuel choice is a significant determinant of children's educational outcomes (Choudhuri and Desai, 2021; Frempong et al., 2021); however, its impact on early childhood development is not much examined.

There is substantial empirical evidence that the first few years of life are the most critical for a child's developmental and educational outcomes. Early childhood development (ECD) is essential for children because it affects their health and wellbeing as they approach adulthood. Since a child's brain develops by 90% in the first five years, these are crucial years for a child's later life development. ECD affects the cognitive abilities and wellbeing of children and determines their life trajectories. It covers the physical, social-emotional, and cognitive areas of growth (Black et al., 2017). One of the most important times in a human's life is between conception and age 5, when the brain develops the fastest and children start to establish the core skills that will affect their later life learning and behavior (Black et al., 2017). Sustainable Development Goal (SDG) 4.2 calls for countries to "ensure that all girls and boys have access to quality early childhood development, care, and pre-primary education so that they are ready for primary education." According to the SDG agenda, ECD will be a top priority in the twenty-first century. The new global agenda includes SDG goal 4.2 , pertinent to ECD. By 2030, countries are to ensure that all girls and boys have access to high-quality early childhood development, care, and pre-primary education so they are prepared for primary education. However, 250 million (or 43%) children under the age of five in low- and middle-income countries (LMIC) are at risk of not achieving their early child developmental potential (Lu et al., 2016). It is now widely 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). Growing evidence has set the stage for national and worldwide funding for early childhood development and for researchers to pinpoint particular elements of children's social settings that may be changed to help or impede early development.

The channel through which biomass use for cooking in households is linked with the ECD is that time involved in fetching firewood, and crop residue increases the opportunity cost of time allocated to childcare activities by both parents and children (Assaad et al., 2010; Frempong et al., 2021; Levison et al., 2018). Existing literature found that the number of children and women in the household increases the chance of biomass for cooking (Jan, 2012). On the other hand, literature also documented low education outcomes in the case of biomass consumption by the household. Other hazards of a female child going far away from home to collect firewood involve sexual abuse, snake bite, and other physical harm (Matinga and Clancy, 2020). Furthermore, clean fuel is indirectly linked with the educational outcomes of children (Krishnapriya et al., 2021).

For most children, the indoor situation of a house 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 a child's development. Furthermore, research has shown the prevalence of stunting and anemia in households with indoor air pollution due to burning biomass (Mishra and Retherford, 2007).

Biomass negatively impacts activities for a normal routine life like concentrating, remembering, and self-care. Children in developing countries spend significant time helping families arrange fuel, such as collecting firewood and preparing dung cake. 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, which is spent on education and leisure and eventually improves the 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 (Mulenga and Siziya, 2019). Using biomass for cooking and heating is reported to cause a nutritional deficiency in children (Fullerton et al., 2008). In a recent study, household educational expenditures are found to influence child educational outcomes (Zhang and Zhou, 2017). Since child educational outcomes depend on various socio-economic factors, room to identify more promising factors is still required.

Child development and early-age learning are significant determinants of later-life academic performance (Duncan et al., 2007); thus, the significance of the present study is related to human capital development, labor market development, and health improvement in Kiribati. The United Nations, through the Sustainable Development Goals (SDGs), set a global agenda for sustainable development, and goals 4.2 and 7 targets early-age child education and access to affordable clean fuel. In a recent report, 21.6 percent of Kiribati children (7-14 years old) showed foundational numeracy skills, and 30 percent showed foundational reading skills (UNFPA, 2021). A high literacy rate with low-quality education indicators calls for in-depth empirical analysis for better policy intervention. The literacy rate is above 99 percent among male and female individuals aged 15-24. The primary school completion rate in Kiribati is 94 percent; however, the upper secondary completion rate is 12.8 percent. The national energy policy of Kiribati 2009 aims to provide affordable and clean energy to improve the environment and sustainable energy options (for details, see Peltovuori, 2017). 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 4000 km away from two major economies of 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 (IRENA, 2022).

Therefore, the present study's contribution is twofold; first, it is the first study on any pacific island early childhood development. Second, to the best of the authors' knowledge, this is the first study on the association between biomass fuel use for cooking and early childhood development. Against this backdrop, the present study aims to analyze 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 last section also discusses some policy recommendations to guide policymakers in achieving child development goals in relation to energy use for cooking purposes.

2. Data and methodology

2.1 Data

The study examines the association between biomass fuel use for cooking and early child development in Kiribati. We used the MICS data from 2018-19 to analyze the association between biomass use for cooking and early childhood development in Kiribati. Measuring early child development is a complex task (Loizillon et al., 2017); however, MICS provides in-depth information about early child development for children aged between 36-59 months. MICS is a household survey that UNICEF designed that collects data on children in low- and middle-income countries and is both nationally representative and internationally standardized (UNICEF, 2021a). MICS data has huge information about child development, household fuel choice, emotion, social development, and learning cognition of children. In addition, this data set offers various controls for regression analysis, including parenting, height, and weight of children, child health and child functioning, and several socio-economic information. Information about parents regarding their exposure to media and information communication technologies is also an advantage of the data set. The data set offers various wealth-controlling variables, including income quartiles, livestock information, water, sanitation, and housing structure information. 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 early childhood development. For the current study, pertinent information on homes, parents, and kids between the ages of 36 and 59 months was gathered. Early childhood development data were available for 846 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 the ECD was gathered for children between 36-59 months. As suggested by (Loizillon et al., 2017), the ECD method used by UNICEF is estimated. The ECD consists of 10 items that address the language-cognitive, physical, social-emotional, and methods of learning as domains of early childhood development (Figure 1). If a kid is on track in at least three out of four domains, their early childhood development is on track.

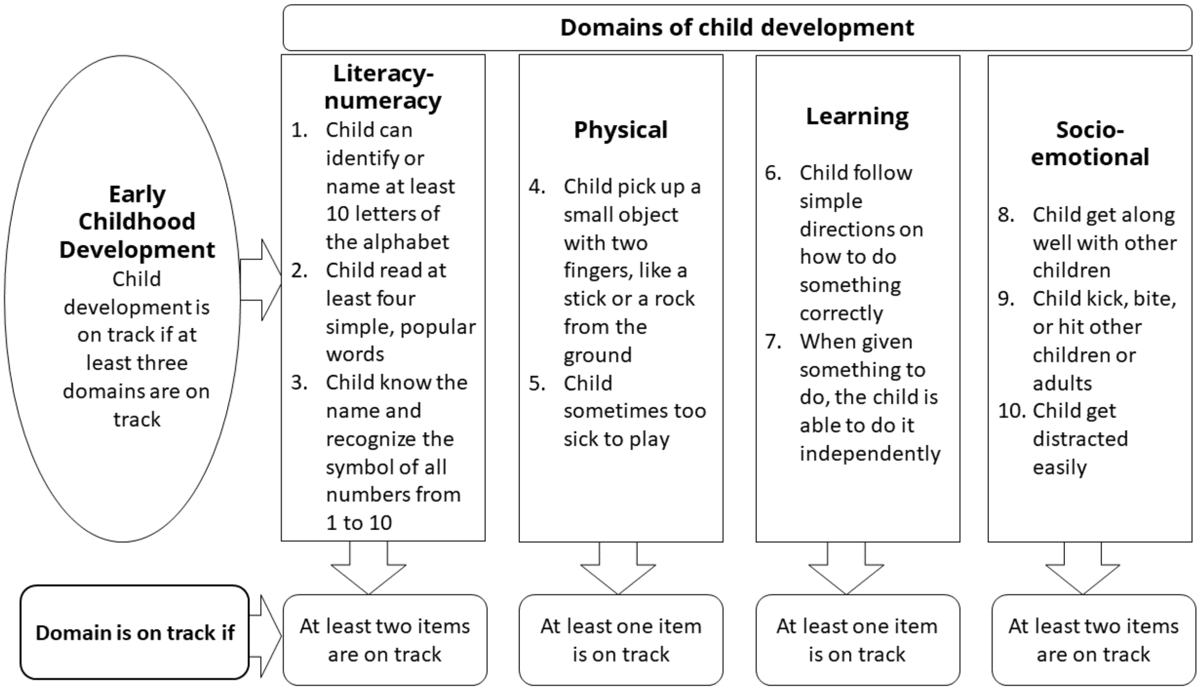

Figure 1: ECD measure

Child development studies commonly use the ECD framework; however, this is not without criticism, as some think it is over simple (McCoy et al., 2016; Tran et al., 2017).

2.3 Empirical Methodology

The study aims to use the propensity score matching method following Liu et al., 2020, to deal with selection bias. The dependent variable is child development outcomes, and covariates are the education level of the household head, the number of children under age five in the household, dummy for stunting in children, wealth index, availability of toys for children to play while cooking fuel choice as a dummy for biomass as the treatment variable.

The adoption of biomass was not a random decision; rather, it was a self-selection process carried out by the 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 likely to be the methodology that aids in examining the average effects of the treatment - biomass fuel used for cooking in our case.

2.4 Propensity Score Matching

Propensity score matching can approximate the conditions of a random experiment when experimental data is unavailable. Moreover, In the absence of experimental data, the PSM can account for this sample selection bias (Dehejia and Wahba, 2002). Unlike the 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 randomised. To avoid the problems of selection bias that afflict non-experimental approaches, PSM attempts to simulate randomization. Therefore, the PSM technique is used in the current investigation to account for any possible bias that can result from systematic differences between households that use biomass and those that do not. Once the adopters and non-adopters groups are 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 was 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 lower 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 propensity score matching.

Biomass adopters for cooking fuel (treatment group) and non-adopters (control group) are matched using the kernel, radius, and neighboring methods using characteristics such as wealth quantiles, region, household head education, etc.

3. Results and Discussion

3.1 Descriptive analysis

Figure 2 presents the association between the wealth level of the household and child development. The wealth variable has five ordinal outcomes, whereas child development is a dummy variable. The graph shows that children whose development is on track are high in percentage terms in rich households. There is a significant difference in the richest quantile, where 88% of the children are on track, compared to the poorest quantile, with only 69% on track. Wealth quantiles are positively associated with child development, exhibiting that affluent families can provide a conducive environment for their children to develop.

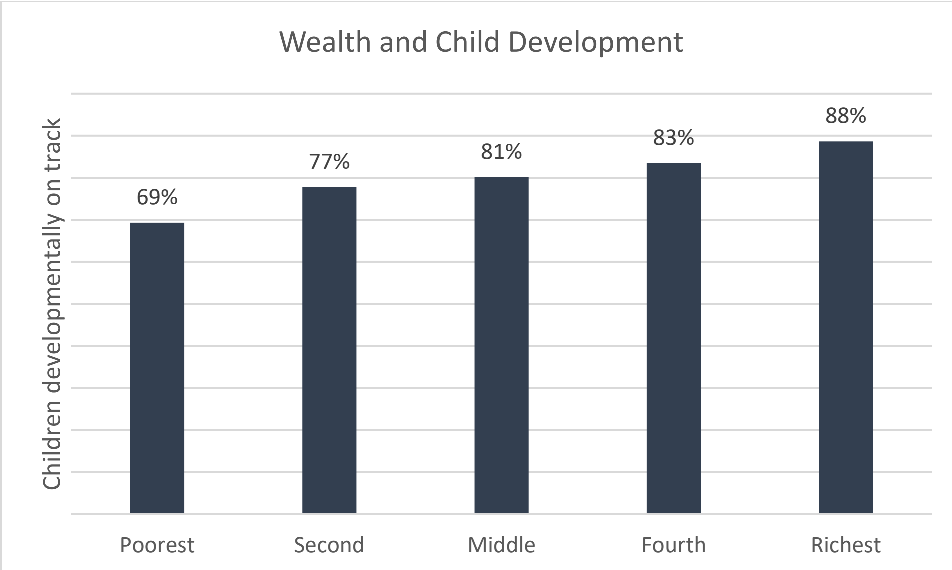

Figure 2 Child development and wealth

Figure 3 shows early childhood development stratified for various education levels of the household head. The graph shows that the percentage of children on track increases with the education level of their household head. Notably, primary education level is a threshold level- 71-72 percent of children are on track if the head of household has a maximum primary education, whereas the percentage is 81 and 83 percent for junior secondary or senior secondary and above, respectively. It shows that education above the primary level brings awareness and behavioral change related to improving child development. In addition, educated parents, particularly the head of the household, make various decisions that directly or indirectly affect child development.

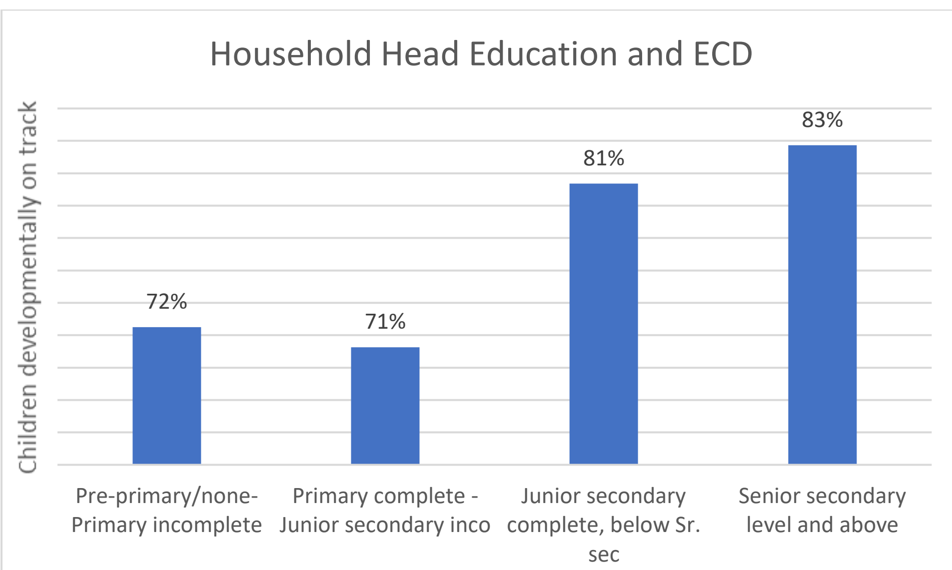

Figure 3: Household Head education level and ECD

Similarly, Figure 4 depicts the relation between early child development and fuel types used for cooking in Kiribati. The graph shows a difference in the percentage of children on track among households using biomass adopters and non-adopters. The prevalence of children who are developmentally on track is highest among households using gas for cooking purposes. It is followed by kerosene; however, biomass users, including wood and shrubs (crop residue) are associated with a low level of child development. Ninety percent of children are on track in their early development living in households using gas for cooking. This percentage is 84, 75, and 42.8 for kerosene, wood, and crop residue, respectively.

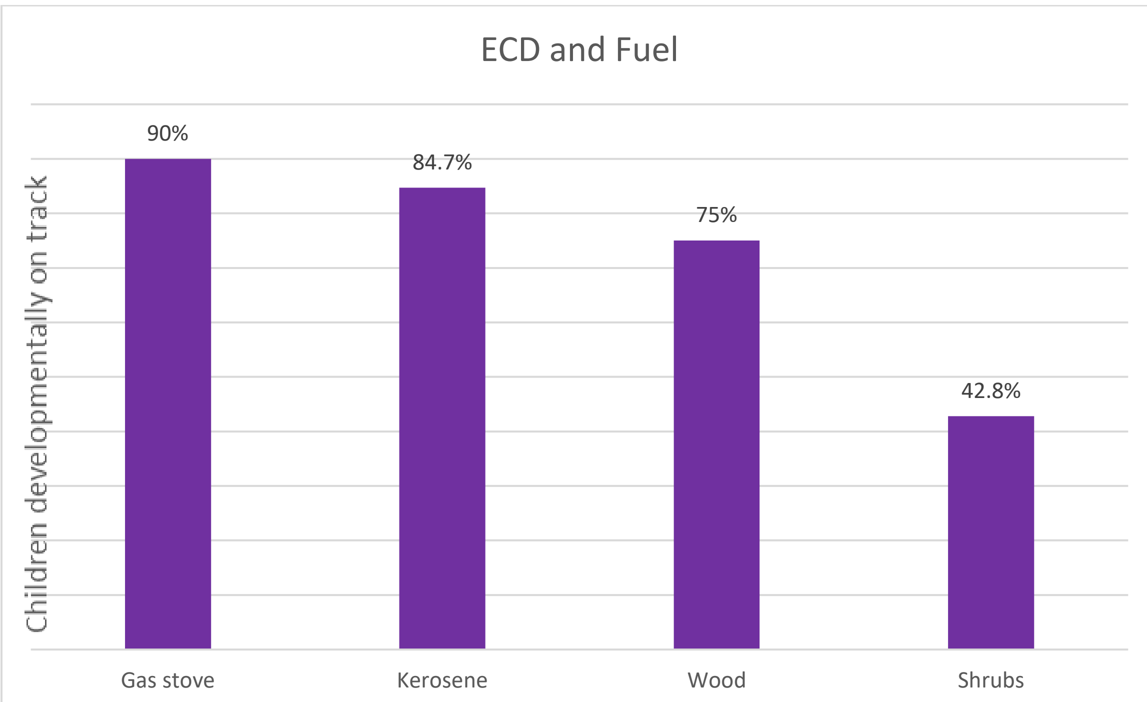

Figure 4 Cooking fuel and early child development

Figure 5 shows regional heterogeneity among Kiribati regions regarding child development. Among all five major regions, developmentally on-track children are the highest in South Tarawa. This region has 82% of children who are developed and on track. South Tarawa is followed by Northern Gilbert, where 80% of children are developmentally on track. Whereas in Central Gilbert, Southern Gilbert, Line, and Phoenix Group.

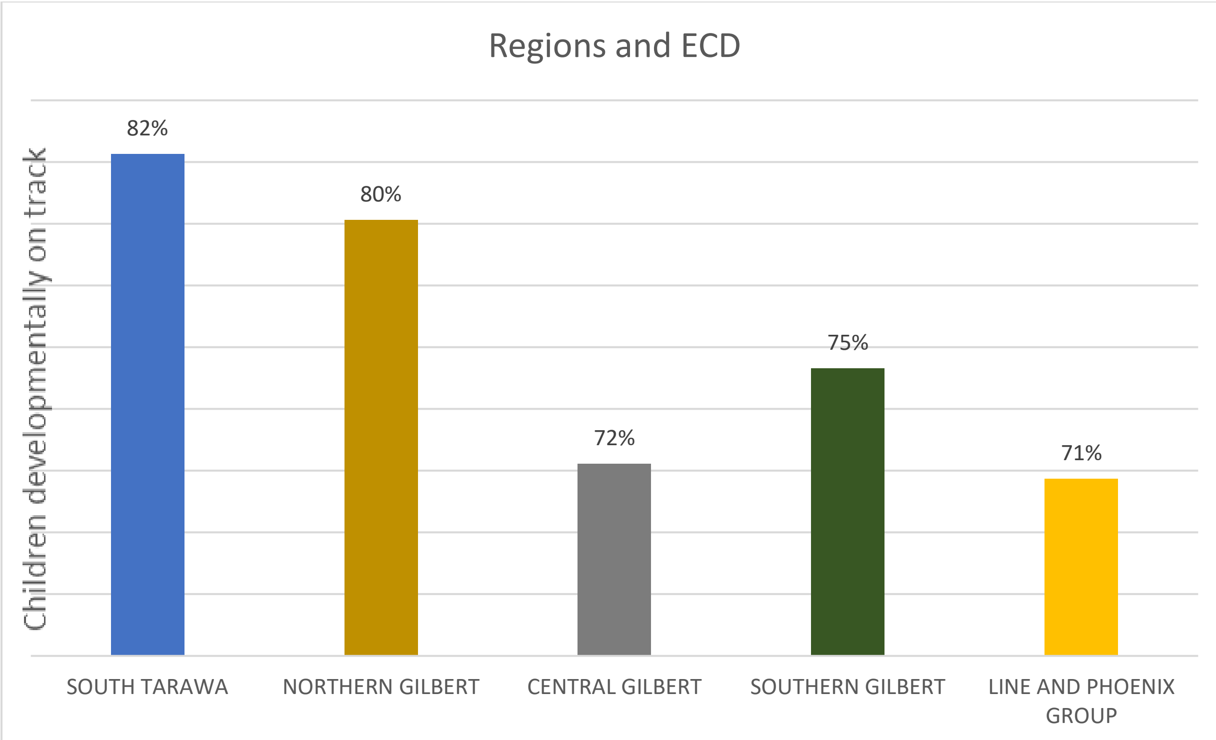

Figure 5 Child development in various regions of Kiribati

Table 1 shows the descriptive statistics of the outcome, treatment variables, and various covariates. Our descriptive statistics show that 79% of children in Kiribati are on track for early childhood development. This figure is slightly lower than the 80% reported in various MICS-based reports on Kiribati (UNICEF, 2021b).

Table 1 Descriptive statistics

Variable	Mean	Standard deviation	Minimum	Maximum
ECD	0.79	0.41	0	1
Biomass	0.45	0.49	0	1
Wealth[1] quantiles 1-5				
Poorest	0.288[2]	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
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
Number of child 0-5 yrs	1.77	0.88	1	5
Age of child in months	47	6.7	36	59
Stunting	0.41	0.49	0	1
Toys for children	0.57	0.49	0	1
Child gender Male	0.50	0.500	0	1

3.2 Determinants of biomass in Kiribati: odd ratios from logistic regression

Table 2 shows results from the logistic regression model. The dependent variable used for this regression is the dummy variable that takes value 1 if the household uses biomass energy for cooking and zero otherwise. Various covariates from the literature are identified, including education, age and gender of the household head, household size, wealth quantiles, house/roof material structure, ICT, access to electricity, region, and districts. Most of the variables on the independent side are significant predictors of biomass usage. Therefore, these covariates will confound the impact of biomass on early child development in Kiribati.

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

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

Table 2. Determinants of biomass

Covariates	**Odd Ratio**	**St.Err.**	**z-value**
Family size	1.09***	0.045	-4.74
Wealth index quantiles – poor as base category			
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	0.09**	0.69	2.22
ICT-dummy for access to internet	0.36	0.10	-3.37
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 results from the PSM on the impact of dirty fuel use and its effects on early child development are presented in Table 3. We examined the impact of biomass fuel use for cooking on the ECD and its four domains. In addition, we checked the average treatment effect of the treated using three different matching algorithms, including Radius, Kernel, and Nearest Neighboring methods with replacement. The PSM results show that using biomass for cooking affects early child development negatively. This finding is robust and significant for the ECD and individually for all four domains of early child development. Furthermore, the results show that the chance that a child is developmentally on track decreases by 9-13 percentage points if the household consumes biomass energy 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	-0.1399***	0.06	-5.50	521	326
Kernel	ECDI	-0.136***	0.65	2.13	521	326
Nearest Neighbor	ECDI	-0.0927***	0.056	2.01	521	326
Radius	Literacy numeracy	-0.08***	0.025	-4.58	521	326
Radius	Physical	-0.013***	0.004	-3.66	521	326
Radius	Socio-emotional	-0.12***	0.021	-2.62	521	326
Radius	Learning	-0.04***	0.012	-2.46	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	-0.106***	0.05	-1.98	521	326

To examine the robustness of inference about biomass adoption on ECD, matching quality analysis is required. Comparing the median absolute bias before and after matching, the value of R-square before and after matching, and the joint significance of covariates before and after matching are necessary because the main goal of the PSM is to balance the covariates among different groups, i.e., 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, showing that the bias has significantly decreased. Before matching, the bias is between 90 and 91%. After matching, the bias lies between 5 and 6 percent. 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, showing 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, suggesting that both groups are substantially similar to one another. This is because the combined significance of 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's joint significance before matching	Covariants' 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	0.53	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

The balancing of covariates among various groups is shown in Figure 6, demonstrating 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 the child's characteristics seen in the treatment group in the control group. This was an ideal circumstance for the PSM to generate reliable estimates and for us to have trust in the analysis.

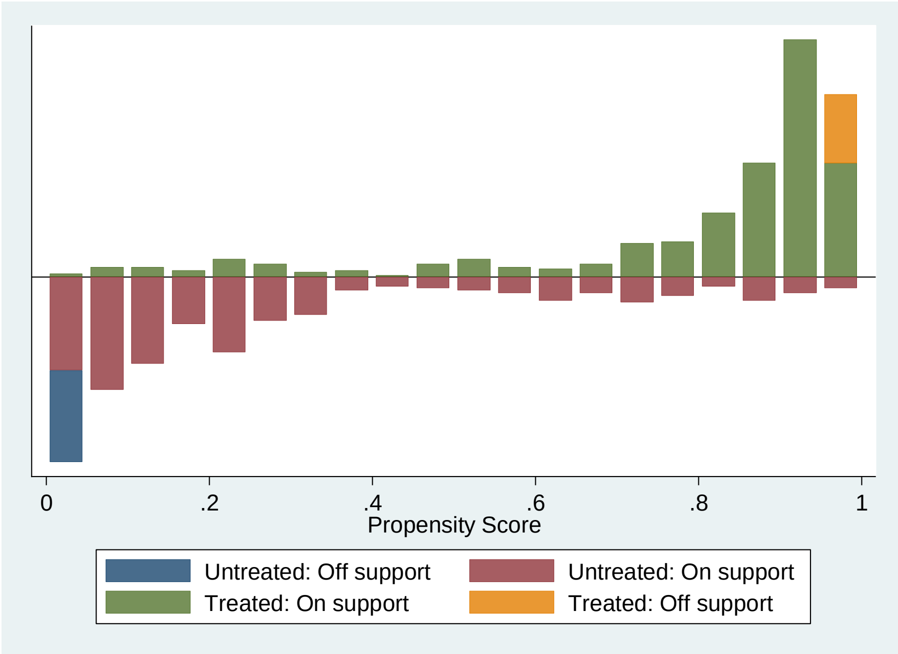

Figure 6 Distribution of propensity score

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

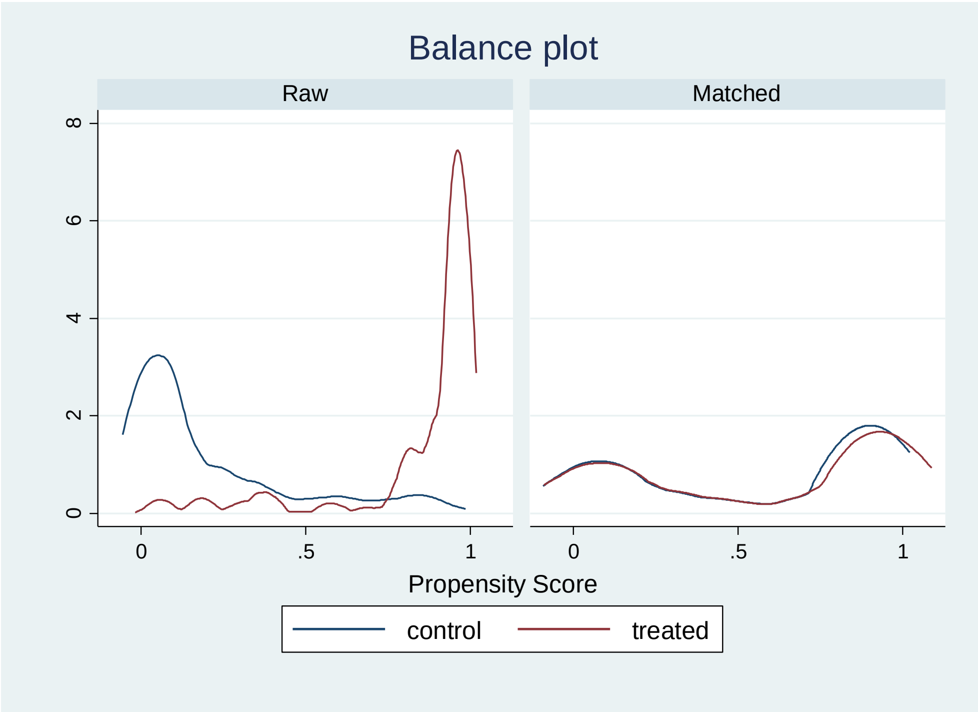

Figure 7 Comparison of propensity score before and after matching

3.4 Robustness analysis

To test the robustness of the analysis, we conducted some heterogeneous effects of biomass use for cooking on early child development in subgroups of the sample. For this purpose, Table 5-7 presents PSM outcome that shows the negative impact of biomass on early childhood development stratified for subgroups of 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. As to the two sub-samples, we used children aged 36-48 and 49-59 as two separate samples. Similarly, Table 7 shows disaggregated analysis of sub-samples stratified over the mother's education, again this showed the robustness of our earlier findings.

Table 5 Average treatment effect of the treated of using three stones 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	-0.106***	0.065	4.27	500	347
Nearest Neighbor	ECD	-0.0927	0.076	1.37	500	347

Table 6 Average treatment effect of the treated of stratified for 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	-0.0912	0.043	2.10	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

Table 7 Average treatment effect of the treated of stratified for Mother education

Mothers 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.

3.5 Sensititivity to hidden bias

According to Table 8 showing the MH bound test findings, we can generally reject the basic hypothesis that a concealed bias causes an 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 MH-bound 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

Early childhood development refers to the physical, cognitive, social, and emotional growth and development. 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 United Nations (UN) recognizes the importance of ECD and has incorporated it into the Sustainable Development Goals (SDGs), specifically SDG 4: Quality Education. In Kiribati, we examined the prevalence and disparities of reported child development delays. This is the first study on the impact of adopting biomass fuels for cooking on early child development. We analyzed the effect of biomass usage on child development using propensity score matching. The paper is based on a comprehensive data set of MICS 2018-19. The findings show that after matching covariates through the PSM method and reducing bias, biomass adoption has a significant effect on early child development. In addition, the results from both the logit model and PSM model show that the likelihood of child development being on track reduces significantly in case the child belongs to a household that consumes biomass fuel for cooking. We examined biomass fuel’s impact on early childhood development and its four domains for robustness analysis. This analysis also shows a negative role of biomass fuel consumption on child development as well as in all four domains including literacy-numeracy, socio-emotional, learning and physical. Based on the findings from the empirical analysis, the present study recommends the following policy suggestions.

The provision of small gas tubes at affordable prices/subsidized 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 the use of clean fuel. 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 early child development and transition to clean fuel for cooking, church-based interventions for child development through fuel choice and other factors are 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 of 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 even though these results were obtained using observational data, the selection bias was reduced, if not eliminated, by using the PSM method and other tests to make sure 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 couldn't account for.

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