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Estimating Rural Premium and Financial Crisis Effect on the Nexuses between Food, Energy, and Water Consumption on Urban-Rural Income Gap in South–Eastern Asian Countries Using Pooled Regression Analysis

Khambai Khamjalas[1*]

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ABSTRACT

Poverty and inequality reduction and access to affordable clean energy and clean water are among the global sustainable development goals. Yet, researchers have overlooked how food, energy, and water (FEW) resources can be instrumental in reducing the urban-rural income gap. In this article, ordinary least squares regression analysis was used to estimate rural premium and financial crisis effect on the nexuses between food, energy, and water consumption on urban-rural income gap using a sample of data pooled from three Asian countries: China, India, and Indonesia over 2000 to 2019. No significant urban or crisis effect on the poverty rate was established. However, a significant crisis effect on the poverty gap was established, but not on the urban premium. A significant positive interaction between food insecurity and water was established. Water supply improves agricultural production, improves food security, and reduces poverty by raising income. However, modern clean energy is associated with rising income inequality. Modern energy technologies benefit a few wealthier individuals investing in the energy and agriculture sectors. Therefore, improved water access, particularly to support food production and affordability, and efficient utilization of clean fuels and technologies among all individuals, regardless of socio-economic class, are crucial to escaping poverty and achieving prosperity.

INTRODUCTION

Ensuring equity in food, water, and energy resource distribution for a rapidly growing population remains a fundamental development challenge in South Asian countries. The population of Asia is the largest among all the continents in the world. China (1.43 billion people) and India (1.37 billion) were the world's most populous countries, with 19% and 18% of the global population in 2019, respectively. The US and Indonesia are the third and fourth most populous countries, with 329 million and 271 million people in 2019, respectively. The population of Asia is expected to increase from 4.7 billion in 2023 to 5.3 billion in 2055, still ranking first, followed by Africa at 2.7 billion, while other continents trail below a million. India is projected to surpass China as the world's most populous country around 2027 (United Nations [UN], 2019). The UN (2019) anticipates that India could remain the world's most populous country, with about 1.5 billion people, followed by China with about 1.1 billion. The 2023 estimates, as of October, indicate that the population of Asia is 4.753 billion, equivalent to 59.1% of the total world population (8.045). Southern Asia leads with about 2.027 billion, followed by Eastern Asia (1.662), South-Eastern Asia (0.686 billion), Western Asia (0.298), and Central Asia (0.078). The Asian urban population is estimated at 52.6 % (2.500 billion). By 2025, Asia will account for about 61.4 % of the world's population, with a 53.8 % (2.590 billion) urban population (Worldometer, 2023). Given its rising population, the region faces mounting challenges in meeting the growing demand for food, water, and energy for a rapidly growing population. Consequently, Asia's high population has contributed to income inequality between the rural households with adequate access to food, energy, and water, given their high incomes.

Food insecurity is a common problem worldwide, particularly in developing countries, often caused by rising population and natural disasters such as drought, flood, and epidemics. The 2021 Global Hunger Index (GHI) report indicated that despite the overall decline in GHI (score between 0: hunger and 100: worst) from series levels in 2006 (25.1) and 2012 (20.4) to moderate in level in 2021 (17.9) there is evident continental and intercountry disparity (Grebmer *et al*., 2021). Africa, South of the Sahara regions, ranks highly (30.5 in 2012 Vs. 27.1 in 2021), followed by South Asia (29.2 in 2012 Vs. 26.1 in 2021), West Asia and North Africa (14.1 in 2012 Vs. 12.7 in 2021), Latin America and the Caribbean (8.5 in 2012 Vs. 8.7 in 2021), East and South-east Asia (11.0 in 2012 Vs. 8.5 in 2021), and lastly Europe and Central Asia (7.5 in 2012 Vs. 6.5 in 2021). Despite the low GHI ranking (< 9.9) among South-east Asian Countries, there are countries with moderate (10.0 – 19.9) and serious (20.0 – 34.9) indices in 2021. Timor-Leste (32.4) leads in terms of GHI, followed by Laos (19.5), Cambodia (17.0), Indonesia (18.0), the Philippines (16.8), and Vietnam (13.6). Malaysia (12.8), and lastly Thailand [11.7] (Grebmer *et al*., 2021; Our World in Data, n.d.). Drivers of food insecurity include climate change through severe high drought sporadic rainfall patterns (Mbow *et al.* 2020).

[1] School of Economics and Trade, Hunan University, Yuelu District, Changsha 410006, P.R. China
[*] Corresponding author's e-mail: baibay1980@gmail.com

There has been a remarkable rise in access to electricity globally over the past decades. The United Nations report 2019 indicated that the global electricity access rate rose from 75% percent in 2000 to 90% in 2019 (United Nations Statistics Division [UN], 2021). The efforts align with the SDG7 7.1.1 target of universal access to electricity by 2030. Yet, electrification progress has indicated regional discrimination. Central and Southern Asia and Sub-Saharan Africa registered the largest access deficit in 2019. In Central and Southern Asia, the access rate rose significantly from 59% in 2000 to 95% in 2019, whereas Sub-Saharan Africa rose from 24% to 46% over the same period. Besides, there is also evident urban-rural discrimination in access to electricity. The UN (2021) estimated that 97 million people in urban zones and 471 million in rural remained unelectrified in Central and Southern Asia and Sub-Saharan Africa.

In addition, there is global inequality in access to clean fuels and technologies (liquid petroleum gas, natural gas, and biogas). In 2019, 66% of the global population had access to clean cooking fuels and technologies, leaving about 2.6 billion households, mostly from Asia and Africa, reliant on inefficient and polluting cooking methods. While the global annual increase in the number of people with clean cooking access from 2015 to 2019 was remarkably high at 82.5%, regional inequality is evident. Central and Southern Asia registered a 23.6% increase, 12.8% in Eastern and South-Eastern Asia, 27.2% in Sub-Saharan Africa, and 8.6% in Western and Northern Africa. Besides, urban-rural discrimination also exists. Generally, the urban population is the leading consumer of clean energy. However, the annual growth rate of access to clean energy in rural areas has registered an impressive growth since 2000 (about 0.1%), growing faster, reaching 2% in 2019. Contrarily, urban areas seem to be in a decelerating face since 2011, with improvements in clean cooking access stagnating in urban areas, registering a growth of less than 0.5% since 2011 (UN, 2021). The exponential growth in access to clean energy in rural areas could potentially help lower income inequality since energy is a resource that can be used in economic activities such as in the food and beverages, hotel, or hospitality sectors.

Generally, there is a remarkable electrification effort globally. The extent to which such a global agenda is welfare-oriented remained unexplored by existing empirical literature since the ultimate drive is to minimize climate change effects by minimizing carbon emissions. Since FEW are essential resources for socio-economic development, uneven distribution of the resources could further widen income inequality between the rural and urban settings. Interestingly, between 2010-2019, the growth in access to clean fuels and technologies was dominated by the most populous countries, Brazil, China, India, Indonesia, and Pakistan, registering a combined growth rate of 2% (UN, 2021). Therefore, the current study examined how improved access to FEW resources influences the rural income gap in South-East Asian Countries.

LITERATURE REVIEW

Literature was reviewed based on the study's objectives, investigating the relationship between food, energy, and water supply and household incomes.

Water Access, Food Availability, and Incomes

Increasing water productivity is vital in improving sustainable agriculture food security since water is useful in crop, tree, livestock, and fish production. Agriculture accounts for 72% of global freshwater withdrawal from the world's rivers, lakes, and groundwater aquifers yearly (Center for Strategic & International Studies, 2019). Most farming worldwide is carried out as mixed crop-livestock farming, covering about 2.5 billion hectares of land (n.d.). As a result, Agriculture is a source of farm income sales of products like meat, milk and hides, livestock, and crop produce to a majority of households, especially in the humid and sub-humid regions of South-East and East Asia, which have registered the greatest increase in irrigated mixed farming systems (Food and Agriculture Organization [FAO], n.d.). Major constraints in livestock production, especially in arid and semi-arid areas, are feed shortage, animal diseases, and low productivity, especially during the dry season. Common coping strategies to feed scarcity among pastoralists in arid and semi-arid areas are conserving crop residues and hay, purchasing roughages, reducing herd size, and renting grazing land (Duguma & Janssens, 2021). Such remedies often lead to losses since dry roughages are not nutritious and may reduce animals' live weight. Reducing herd size is often associated with a throwaway price since holding large herd in dry seasons could lead to huge losses from animal mortality (Roche *et al*., 2021).

Improved water access improves livestock production and health through increased fodder and legume feed production, livestock watering, and sustainable pasture grazing management, hence increasing earnings from livestock sales through increased live weight while reducing animal mortality (Mbow *et al*., 2020; Mayberry *et al*., 202; Ndlovu *et al*., 2020). Monjardino *et al*. (2020) established that maintaining a high-quality legume crop in the mixed crop-livestock system increases farm income and reduces financial risk from integrating more resilient livestock and higher crop revenue among traditional mixed smallholder farms in South-East Asia. Hashmi *et al*. (2021) established that while Pakistan has the world's largest integrated irrigation system, water scarcity has constrained farmers to shift cultivation from water-intensive crops like rice, wheat, cotton, and sugarcane to other crops and vegetables, which require less water, thus increasing pressure in the food market. Such a shift threatens the diversification in agriculture, reducing the incomes of households with limited access to water for irrigation due to financial constraints in collecting water from a distant source by ferrying using vehicles. Thus, providing public or institutional water supply is essential in ensuring sustainability in agricultural production. Increased irrigation improved the productivity of crops by maintaining health and vigorously growing crops through optimized water, nutrients, and agronomic management (Descheemaeker *et al.*, 2013).

Lastly, aquaculture is predominately reliant on water. According to the FAO (2021), in 2020, the total global aquaculture production comprised 122.6 million tonnes of aquatic animals, with 87.5 million tonnes used for human consumption. The largest producing region is Asia, accounting for over 88.4% of the total fisheries and aquaculture production of aquatic animals in 2020, substantially higher than Africa (2.57), Americas (5.00), Europe (3.74), and Oceania (0.26). Due to its high population, China (mainland) has produced more farmed aquatic animals than the rest of the world Since 1991. Its share in world aquaculture production was 64.13% for aquatic animals in 2020, followed by India (11.16), Indonesia (6.75), Vietnam (5.95), Bangladesh (3.34), and the rest of Asia (8.67). Thus, increased water supply increases water usage in aquaculture, especially in Asian countries like Indonesia and China, which are leading world fish producers.

Domestic aquaculture increases the incomes of smallholder fish farmers supply while providing domestic consumption (Tran *et al.*, 2017). Generally, improving agricultural water productivity creates synergies in crop and livestock production. It could consequently increase earning from sales of the produce, raising the incomes of most households who would have trailed below poverty lines. Fitton *et al.* (2019) established that approximately 11% and 10% of current crops and grasslands could decline due to a reduction in water availability and may lose their productive capacity, particularly in Africa, the Middle East, China, Europe, and Asia. Thus, improving water access in these regions is critical in improving agricultural productivity and, hence, the incomes of households. Aquaculture's benefits include food sources, livelihood improvement through sales of aquatic life, and nutrition and health (Ahmed & Thompson, 2019; Mills *et al.*, 2019; Dinesh, 2016).

Energy and Income Inequality

There is a lack of consensus on the relationship between clean fuel and income inequality. Generally, the benefits of access to clean energy sources are realized through employment opportunities, economic growth, education, industrialization, and improved healthcare outcomes (Acheampong, Dzator Shahbaz, 2021). Access to electricity improves the livelihoods of households through incomes from investments and employment opportunities; improves food production through cultivation, harvesting, processing, preservation, and transportation; and improves water productivity through processes such as water desalination, filtering, treatment, distribution, harvesting, recycling (Biggs *et al.*, 2015; Nilsson, Griggs, & Visbeck, 2016).

In China, Ma *et al.* (2021) established that increased per capita energy consumption leads to declining energy poverty alleviation and inequality reduction in rural households. Huang *et al.* (2020) outline that labour migration from rural to urban areas is a structural change and footpaths of the negative effect of energy supply on income inequality. According to the authors, low-carbon policies have the greatest impact on employment across all energy. Thus, labor will migrate from rural to urban areas for better jobs. The reduced rural population brings new opportunities for the modernization of agriculture, increasing the income of rural residents. The income gap among urban residents will widen in the short run due to the labor demand and education level differentials. In the end, equitable development of resources between urban and rural areas is achieved.

Using panel data for 166 countries to investigate from 1990 to 2017, Acheampong, Dzator, and Shahbaz (2021) established that access to electricity reduces global income inequality, while access to modern and clean energy increases global income inequality. Further, the authors revealed that rural and urban electrification reduced income inequality; however, the elasticity of urban electrification exceeds rural electrification. Thus, there could be heterogenous effects of access to clean energy on income inequality in urban and rural settings – which was controlled for in this study to minimize the bias in the regression results.

Other studies have shown that access to clean energy increases income inequality. Using panel data from 46 countries in Sub-Saharan Africa from 1990 to 2017, Sarkodie and Adams (2020) established that access to electricity widens income inequality. According to the authors, access to electricity widens the income gap between the rich and the poor since modern energy technologies tend to benefit the wealthier in terms of better investment opportunities, such as in the energy and agriculture sectors. Besides, there is no clear direction of the causality effect between income inequality and renewable energy consumption. Uzar (2020) established that a declining income inequality will enhance renewable energy consumption. Xu and Zhong (2023) established that high-income inequality increases energy consumption.

The lack of consensus on whether income inequality implies that the findings could be contextual based on region, methodology, and variables used. In this study, data is pooled from three Asian countries to estimate how FEW nexuses influence can influence income inequality while controlling for the 2008/09 financial crisis and socio-economic class of rural and urban settings.

METHODOLOGY

Study Design

The study adopts a panel study design. The study used a convenient sample of three Asian countries, China, India, and Indonesia since the data on the rural and urban settings on all the study variables were missing. The two outcome measures were poverty rates and poverty gap. The predictors were FEW resource metrics: food insecurity, access to electricity, access to clean fuels and technologies for cooking, and improved water access. A binary predictor was created to delimit 1 for if urban and zero otherwise to establish the urban premium. Lastly, existing empirical evidence indicates that countries with high populations have been associated with greater income inequality (Krieger & Meierrieks, 2019). The data were collected from different sources, comprising the World Bank's (WB) World Development Index Database (WDI), the Food and Agriculture Organisation (FAO), and Our World in Data (OWID) databases. The data was collected for three countries (China, India, and Indonesia) between 2000 and 2019. The study variables' operationalization and data source are summarized in Table 1.

Table 1: Variables, Units, And Sources

Code	Name	Description	Units	Source
Pv_rate	Poverty rate	Poverty headcount ratio (% of the population living below $2.15)	%	World Bank. (n.d.-a)
Pv_gap	poverty gap	The ratio by which the mean income of the poor falls below the poverty line ($2.15)	%	World Bank. (n.d.-a)
Foodins	prevalence of severe food insecurity food insecurity	China and India: Food Insecurity Experience Scale (FIES). This indicator measures the proportion of people uncertain of having or unable to acquire enough food because they have insufficient money or other resources. Indonesia; Prevalence of undernourishment (% of population)	%	FAO (2019)
Elcacc	Access to electricity	% of the cohort (urban/rural) population who have success with electricity	%	World Bank. (n.d.-b)
Cleanf	Access to clean fuels and technologies for cooking	% of the cohort population who have access to clean fuels and technologies for cooking	%	World Bank. (n.d.-b)
Impwacc	Improved water access	People using at least a basic improved drinking water source includes piped water on premises (piped household water connection located inside the user's dwelling, plot, or yard, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection).	%	OWID, (n.d.-c).
Pop	Population size	Annual population size		OWID

Notes. foodins by urban and rural areas were incomplete and were imputed using MA (3) and empirical studies depicting the rural-urban gap on food insecurity.

Data Analysis

The study used pooled ordinary least square (OLS) regression analysis to examine the urban premium and financial crisis effect on poverty rate and poverty gap and the nexuses between food, energy, and water consumption on urban-rural income gap in south-eastern Asia. The data was pooled across rural and urban settings in three Asian countries: China, India, and Indonesia from 2000 to 2019. Therefore, a rural-urban setting premium is captured by using an urban dummy. A rural dummy variable, labeled rural which takes the value "0" for each i^{th} observation in a rural setting and takes the value "1" for the urban setting. A crisis dummy variable, labeled crisis will be created that takes the value "0" for each i^{th} observation for the years between 2000 and 2010 and takes the value "1" for each observation i^{th} from the year 2010 to 2019. Let Y_i be the welfare measure i, the study seeks to fit two OLS linear regression models in the form represented in Equation 1.

Where Y_i are predict income inequality and poverty

$$Y_{isct} = \alpha + \sum_{i=1}^{4} \beta_i \Delta X_{icst} + \sum_{i=k=1}^{4} \tau_i \Delta X_{icst} \Delta X_{kcst} + \varphi_i crs + \omega_i urbn + \theta_i crs * urbn + \pi_i \Delta lnpop_{isct} + \varepsilon_i \quad (1)$$

index, $X_{(i,k)}$ is a vector of FEW resources' measures; Δ is the differential operator whose order is dependent on the stationarity of the data; α is the interaction effect between treatment and time, β_s are the regression coefficients of each of the four FEW metrics, namely, the prevalence of severe food insecurity, access to electricity, clean fuels and technologies for cooking, and water; τ denotes the interaction effect of the FEW resources that help identify the nexus between FEW in influencing in urban and rural income gap; φ is the crisis effect (crs), ω is the urban (urbn) premium/loss; θ is the interaction effect crisis and urban setting (crs*urbn); Δlnpop is natural of population size, π_i is the population effect; i is the observation index, s is the observation index, c is the country index, and t is the time index; and ε_i is the error term capturing the variation in outcome measures not accounted for by the model.

RESULTS

The OLS regression analysis was done to estimate rural premium and financial crisis effect on the nexuses between food, energy, and water consumption on the urban-rural income gap using a sample of data pooled from three Asian countries: China, India, and Indonesia. To ensure the robustness and validity of the findings, the diagnostic tests are first reported as follows.

Diagnostics Tests

Four diagnostic tests, stationary, multicollinearity, heteroscedasticity, and normality tests, were examined to ensure that the reported regression results do not bias the regression estimates.

Stationary Test

The stationarity test was done using a Fisher-type Augmented Dickey-Fuller unit-root test since it does not require strongly balanced data (Choi, 2001)). It tests the null hypothesis that all panels contain a unit root against an alternative hypothesis that at least one panel is stationary.

The stationary test was done separately since the data was panel data stacked by urban-rural setting. All the variables provide sufficient evidence that the urban first differenced data is stationary at a 10% significance level. Besides, all the variables provide sufficient evidence that the rural first differenced data is stationary at a 10% significance level. Therefore, the first differenced series of continuous data was used in regression analysis (Table 2).

Table 2: Stationarity Test for Urban and Rural Data

Variable	Urban				Rural			
	Level		First difference		Level		First difference	
	Inverse Chi-squared	p-value	Inverse Chi-squared	p-value	Inverse Chi-squared	p-value	Inverse Chi-squared	p-value
Poverty rate	5.17	0.522	26.11***	0.000	0.791	0.992	16.66*	0.011
poverty gap	6.82	0.338	23.78***	0.001	2.69	0.846	24.04***	0.001
food insecurity	21.88***	0.001	10.98*	0.089	21.82***	0.001	10.64***	0.100
Access to electricity	12.67**	0.049	43.93***	0.000	6.85	0.335	29.86***	0.000
Access to clean fuels and technologies for cooking	42.11***	0.000	23.08***	0.001	37.67***	0.000	11.59***	0.072
Improved water access	38.88	0.000	16.63**	0.011	73.67***	0.000	11.27*	0.080
Population growth	8.8	0.185	11.35*	0.078	9.92	0.128	16.93**	0.010

*Notes: The reported statistics are based on the inverse-normal transformations. The drift option was specified since all the series' means are nonzero. Two lags in the ADF regressions and cross-sectional means were removed using demean; degrees of freedom = 6. Significant codes: *** $p < .001$; ** $p < .01$; * $p < .05$.*

Multicollinearity

The multicollinearity of the predictors (excluding the interaction terms) was examined using the variance inflation factor and Tolerance factor. Since the average VIF is less than 5, multicollinearity is not a severe problem in the regression results. See Table 3.

Table 3: Variance Inflation Factors of The Predictor Variables

Variable	Variance inflation factor	Tolerance factor
lnimpwacc_d1	10.73	0.093
lnpop_d1	9.52	0.105
urban	7.52	0.133
urbanpostcrisis	3.17	0.315
postcrisis	2.47	0.404
lncleanf_d1	2.32	0.431
lnfoodins_d1	1.39	0.719
lnelcacc_d1	1.08	0.927
Mean VIF	4.78	

Heteroskedasticity Test

The results provide strong evidence of violation constant variance at a 5% significance level in the poverty rates, based on the Breusch-Pagan test for heteroskedasticity, $\chi^2(1) = 32.3$, $p = .001$ and the poverty gap model, $\chi^2(1) = 20.14$, $p < .001$ (Table 4).

Thus, clustered standard errors by country are used to correct for heteroscedasticity.

Table 4: Breusch-Pagan / Cook-Weisberg Test for Heteroskedasticity

Model	**Degrees of freedom**	**Chi-square Statistic**	**p-value**
Poverty rate model	1	32.30	0.000
Poverty gap model	1	20.14	0.000

Normality Test

The residuals for the poverty rates and poverty gap models (without interaction terms) are approximately normally distributed, indicating that the models substantially satisfy the linearity assumption (Figure 1).

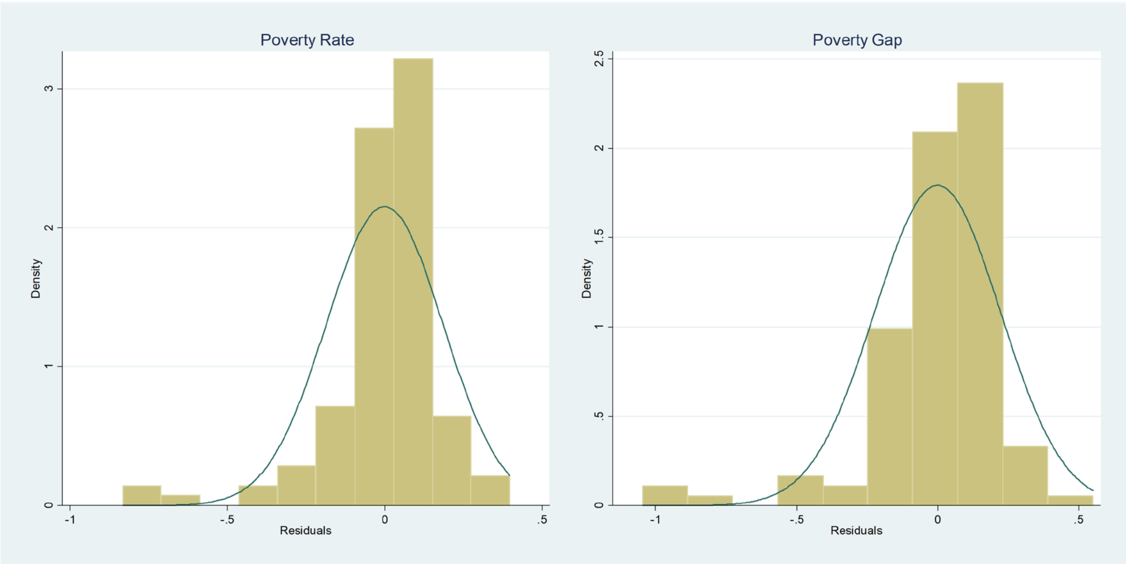

Figure 1: Histogram of the Residuals for The Poverty Rates and Poverty Gap Models

Correlation Analysis

The correlation analysis of the study variables based on the first differenced variables was done by setting (rural and urban) and aggregately using the pooled data. The correlation between poverty rate vs. food insecurity and electricity access is not statistically significant in all three panels at a 10% significance level ($p > .1$). Besides, the correlation between the poverty gap vs. improved water access and clean fuel access is not statistically significant in all the three panels at a 10% significance level ($p > .1$) However, poverty rates seem to be positive and statistically significantly correlated with improved water access ($r = .305$, $p < .1$) and clean fuel access ($r = 0.299$, $p < .1$) in urban areas only at a 10% significance level (Table 5). (See Figure 2– 5) (Table 5).

Table 5: Correlation Analysis Between First Differenced Poverty Gap and Rate Vs. Food Insecurity

Correlation pairs		**Aggregate**	**Rural**	**Urban**
Food insecurity	Poverty rate	0.058	0.101	0.006
	Poverty gap	0.075	0.031	0.111
Water access	Poverty rate	-0.001	-0.1335	0.306*
	Poverty gap	-0.048	-0.138	0.194
Clean fuel access	Poverty rate	0.186*	0.171	0.299*
	Poverty gap	0.141	0.149	0.241
Electricity Access	Poverty rate	0.143	0.169	0.174
	Poverty gap	0.148	0.187	0.152

*Notes. *** p<0.01, ** p < 0.05, * p < 0.1*

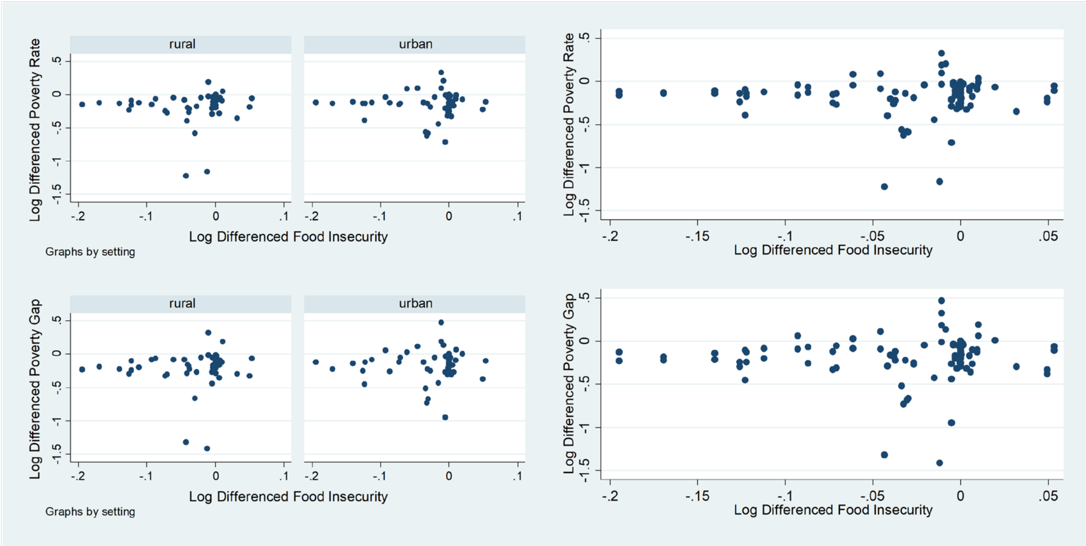

Figure 2: Correlation Analysis Between First Differenced Poverty Rate and Gap Vs Food Insecurity

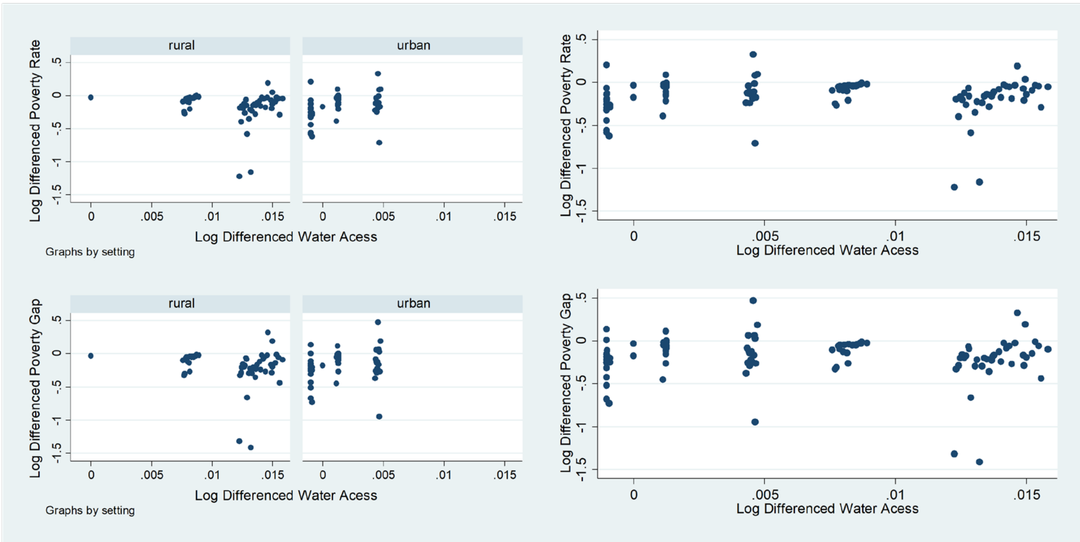

Figure 3: Correlation Analysis Between First Differenced Poverty Rate and Gap vs. Improved Water Access

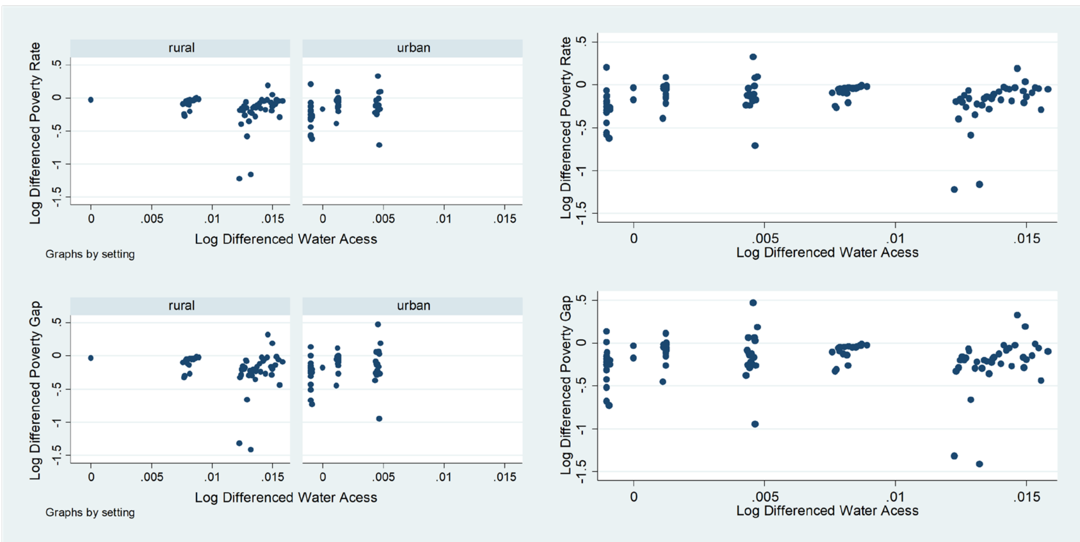

Figure 4: Correlation Analysis Between First Differenced Poverty Rate and Gap vs. Clean Fuel

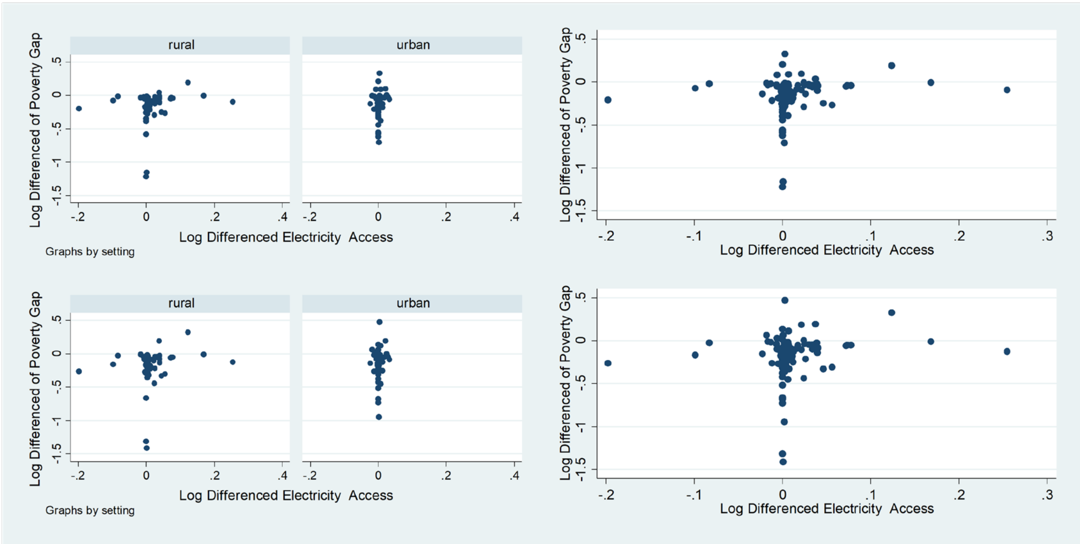

Figure 5: Correlation Analysis Between First Differenced Poverty Rate and Gap vs. Electricity Access

REGRESSION RESULTS

The regression results indicate no significant urban premium effect on poverty rates (β= 0.006, p > .05). Access to clean fuels and technologies for cooking is the only resource that contributes to increasing poverty rates at a 10% significance level (β=1.508,p<.1) and poverty gap (β=1.741,p<.05) at a 5% significance level. Thus, a 1% increase in clean fuels and technologies increases the poverty rate and gap by 1.508% and 1.741%, respectively.

The results show no significant urban (-0.160) and crisis (-0.156) effect on poverty rate. However, a significant negative crisis effect at a 10% significance level (β= -0.245, p<.1) on poverty gap was established but not urban premium (β= -0.226, p >.1). Further, a significant interaction between food insecurity and water (β= -176.1, p < .05) and between clean fuel and cooking technologies and electricity (β= 12.59, p > .05) on poverty gap was established (See Table 6).

Table 6: The OLS Regression Results Predicting the Urban Premium and Crisis Effect on the Nexuses between FEW Resources and Poverty Rates and Poverty Gaps

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Ln Poverty rates_D1	**Ln Poverty rates_D1**	**Ln Poverty rates_D1**	**Ln Poverty Gap_D1**	**Ln Poverty Gap_D1**	**Ln Poverty Gap_D1**
lnfoodins_d1		0.0455	0.660		0.0627	0.408
		(0.411)	(0.850)		(0.430)	(1.159)
lncleanf_d1		0.199	1.508*		0.277	1.741**
		(0.242)	(0.509)		(0.215)	(0.365)
lnelecacc_d1		0.537	1.203		0.705	0.535
		(0.299)	(1.077)		(0.491)	(1.114)
lnimpwacc_d1		10.14	11.67		4.833	4.640
		(8.140)	(9.168)		(8.893)	(12.27)
foodins_fuel			2.761			8.982
			(6.991)			(7.804)
foodins_electricity			-1.582			1.248
			(13.04)			(13.66)
foodins_water			-111.6			-176.1**
			(40.43)			(32.48)
fuel_electricity			9.261			12.59*
			(4.046)			(3.210)
fuel_water			-111.4			-114.9
			(53.56)			(51.61)

electricity_water			-220.8			-177.7
			(184.2)			(177.4)
urban	0.006	-0.160	-0.212	0.022	-0.165	-0.226
	(0.005)	(0.082)	(0.139)	(0.014)	(0.069)	(0.132)
postcrisis		-0.156	-0.212		-0.176	-0.245*
		(0.101)	(0.0892)		(0.0920)	(0.0801)
urbanpostcrisis		0.134	0.229		0.135	0.235
		(0.107)	(0.106)		(0.0864)	(0.0904)
lnpop_d1		6.656*	5.989		5.895*	5.092
		(1.619)	(2.659)		(1.847)	(3.069)
Constant	-0.160	-0.199*	-0.187**	-0.188	-0.168*	-0.144
	(0.064)	(0.052)	(0.043)	(0.066)	(0.057)	(0.071)
Observations	114	114	114	114	114	114
R-squared	0.000	0.217	0.251	0.002	0.183	0.217

*Notes. Robust standard errors are in parentheses. The clustered standard errors were done in urban and rural settings. All the series were first differenced (D1) since all the series were first stationary at first difference.; Significant codes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

DISCUSSION

The study used pooled OLS regression analysis to examine the urban premium and financial crisis effect on poverty rate and poverty gap, the nexuses between food, energy, and water consumption on the urban-rural income gap in South-eastern Asia. Using sample data pooled across a rural and urban setting in three Asian countries, China, India, and Indonesia, from 2000 to 2019, the regression results indicate that access to clean fuels and technologies for cooking is the only resource that contributes to increasing poverty rates and gaps. The correlation analysis indicates that poverty rates are positive and statistically significantly correlated with improved clean fuel access in urban areas but not rural areas. While clean energy has been rising globally, its benefits and impacts may vary across rural and urban areas due to economic barriers to accessing clean energy services. Clean fuels and cooking technologies, including solar, electric, biogas, natural gas, liquefied petroleum gas (LPG), and alcohol fuels, including ethanol, are more abundant in urban areas (UN, 2021). Comparatively, while rural areas have seen a substantial increase in cleaner gaseous fuels, biomass fuels, such as charcoal, are the dominant form of cooking energy. Such trends could be influenced by the fact that clean energy could be expensive to rural households, where most have lower incomes and larger families than those in urban areas. Thus, rural households might otherwise opt for firewood collected for free in the neighborhood; poor households are also likely to have low access to energy. As a result, clean energy supply creates a negative feedback loop in urban areas.

The high abundance in urban areas and a greater social stratification means that the elasticity of poverty rates is highly responsive to clean energy supply. Ma and Liao (2018) established that the income effect is positive for cleaner fuels (LPG and electricity) but negative for biomass fuels like coal. Adopting cleaner fuels as primary cooking fuel was income elastic among rural households but inelastic for urban households, whereas the substitution of dirty fuels is all income inelastic. Thus, rural households may not be responsive since most rely on biomass. Other studies have suggested reverse causality, from income inequality to access to clean fuels. Using data from 14 Latin American and Caribbean countries, Murshed (2023) established that increasing income inequality aggravates the urban-rural inequality in clean cooking fuel accessibility by improving and reducing urban and rural clean cooking fuel access rates, respectively. In another study, Acheampong, Dzator, and Shahbaz (2021) revealed that rural and urban electrification reduced income inequality. However, the elasticity of urban electrification exceeds rural electrification. Thus, the greater social stratification means that the elasticity of poverty rates is highly responsive to clean energy supply.

In addition, most high-income earners rely on clean energy; hence, their consumption and utilization levels in income-generating activities such as in the hotel or hospitability and industry sector can go up. However, most low-income earners in urban areas rely on clean fuels for household cooking (UN, 2021). The same also applies to rural households who might heavily rely on clean fuels for home usage and not for income generation. Thus, raising clean energy could increase the proportion of the population living below the poverty line, usually taken as half the median household income of the total population, as a few households earn relatively more than the majority if the households. The assertion is consistent with the stronger evidence that a 1% increase in clean fuels and technologies increases the poverty gap by 1.741%. To mitigate such tradeoff, affordability of clean fuels and cooking technologies and enhancing income-generating activities that utilize clean energy in rural and urban low-income households should be a top priority in achieving SDG 7.

The results also indicated a significant positive interaction between food insecurity and water. The finding implies that the positive impact of food insecurity on poverty gaps is lessened by increasing water access. The finding is consistent with the expectation that agricultural production relies heavily on water. Water supply is essential for agriculture, as it affects the productivity and sustainability of crop and livestock systems. For instance, Fitton *et al*. (2019) established that approximately 11% and 10% of current crops and grasslands could decline due to reduced water availability and may lose their productive capacity, particularly in Africa, the Middle East, China, Europe, and Asia.

Water supply also minimizes annual crop and livestock losses, reducing poverty gaps and improving food security (Ndlovu, Prinsloo & Le Roux, 2020). Irrigated cropping systems can benefit from improved water productivity by maintaining healthy, vigorously growing crops through optimized water, nutrient, and agronomic management (Descheemaeker *et al*., 2013). Irrigation also reduces the risk of crop failure due to droughts and allows for multiple cropping seasons (Organisation for Economic Co-operation and Development, n.d.).

Likewise, water supply supports livestock production, an important income source and nutrition for many poor households. Water availability and quality affect animals' health, growth, and reproduction. Livestock water productivity can be increased through sustainable grazing or feeding management from planted crops and pasture and livestock watering availability, leading to reduced animal mortality, which is a common problem among pastoralists who live in arid and semi-arid areas (Descheemaeker *et al*., 2013; Gusha, 2019; Otte *et al*., 2019). Livestock also provide manure, which can fertilize crops and improve soil quality. Conversely, crop residues as animal feed, animal traction for land preparation, and crop-livestock rotations for pest and disease control create synergies between crops and animals, improving agriculture's efficiency and sustainability (Baiyeri *et al*., 2019). Thus, water scarcity negatively impacts poverty gaps propagated through reduced crop and livestock production.

The finding is also consistent with empirical evidence. For instance, Monjardino *et al*. (2020) established that maintaining a high-quality legume crop in the mixed crop-livestock system increases farm income and reduces financial risk from integrating a more resilient livestock and higher crop revenue among traditional mixed smallholder farms in South East Asia. Besides, aquaculture improves livelihoods through selling aquatic life (Ahmed & Thompson, 2019; Mills *et al*., 2019; Dinesh, 2016). Thus, increasing population access to basic improved drinking water sources includes piped water, public taps, wells or boreholes, and springs, increasing water available for crop production, livestock keeping, and aquaculture. The increasing incomes, in turn, lessen poverty gaps as low incoming earners' incomes rise.

The results also indicated a significant positive interaction between clean fuel and cooking technologies and electricity on the poverty gap. The finding implies that clean energy widens poverty gaps. The study finding is consistent with existing empirical evidence of Sarkodie and Adams (2020) that established that rising access to clean energy has increased income inequality in Sub-Saharan Africa. According to Sarkodie and Adams (2020), access to electricity increases the income gap between the rich and the poor. Modern energy technologies benefit the wealthier in terms of better investment opportunities, such as in the energy and agriculture sectors. Besides, Xu and Zhong (2023) established that high-income inequality increases energy consumption, implying a tentative positive correlation between access to clean energy. While Huang *et al*. (2020) argue that clean energy supplies reduce income inequality through structural unemployment, where labour migrates from rural to urban areas until an equilibrium is attained, it might occur in the long run since existing rural households might not get the requisite skills to take up new jobs created the energy sector. Thus, a rising energy supply can keep increasing the incomes of a few individuals, whereas the majority who live in urban areas remain unemployed or unemployed.

Lastly, the results indicated that poverty gaps were generally lower in the post-global financial crisis of 2008-2009. The finding can be associated with structural changes in employment and investments that the financial crisis might have shaped due to the housing market bubbles in the real estate sector (Bartmann, 2017). The shock might have shifted investments to more resilient sectors like energy and food supplies. Besides, lending institutions' moral hazard might have made banks minimize market risks by financing more resilient sectors dealing with FEW resources since they are the basic life-supporting needs. Other confounders include rising education skills (Lee & Lee, 2018), declining unemployment rates, and labour unions that push for equity in wage distribution through their collective bargaining power (Dosi *et al*., 2018), and welfare policies such as progressive taxation (Oishi, Kushlev, & Schimmack, 2018) that have been established to lower income inequality.

CONCLUSIONS

In this study, OLS regression analysis was done to estimate rural premium and financial crisis effect on the nexuses between food, energy, and water consumption on urban-rural income gap using a sample of data pooled from three Asian countries: China, India, and Indonesia. The results revealed increased clean energy (fuel and electricity) has contributed to rising poverty gaps. To mitigate the tradeoff between clean energy supply and poverty supply, especially in rural areas, a holistic and inclusive approach is needed to ensure that clean fuels and technologies for cooking contribute to sustainable development for all. Besides, supplying affordable clean fuels and technologies and enhancing income-generating activities that utilize clean energy in rural and urban low-income households should be a top priority in achieving SDG 7.

Improved water access is crucial in increasing crop and livestock production and lowering poverty gaps. Water supply improves agricultural production, improving food security and reducing poverty by raising income from crops, livestock, and fish farming, especially among low-income households heavily reliant on agriculture. Thus, equitable access to water resources, regardless of the socio-economic class in the society, particularly to support food production, is instrumental in reducing poverty and hunger.

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