Is the Single-Buyer Model a Barrier to Clean Energy? Empirical Evidence on Decarbonization and Renewable Energy Supply in 63 Developing Countries

Selahattin Murat Sirin **Amro M. Elshurafa** **Sarah Abuouf**

KAPSARC
King Khalid International Airport
Riyadh 13415, Saudi Arabia

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Outline

Introduction (1/2)

It has been more than two decades since Lovei (2000) described the Single-Buyer Model (SBM) as "a dangerous path" for electricity market reforms in developing countries. The author argued that:

- SBM has potential advantages in simplifying regulatory/operational aspects compared to Wholesale Electricity Market (WEM).
- However, the SBM could lead to substantial downsides, particularly in environments with weak governance.
- It can lead to worse welfare outcomes: Large contingent liabilities for governments; Lack of incentives for operational efficiencies; Room for political interference

Introduction (2/2)

Despite criticisms, SBM remains the most common electricity market structure worldwide (IFC, 2024).

Many developing economies have slowed or halted electricity market reforms due to economic challenges, financial problems, and market turmoil.

Some advanced economies still resort to government-driven support mechanisms, such as auctions, feed-in tariffs, or capacity mechanisms to incentivize investments.

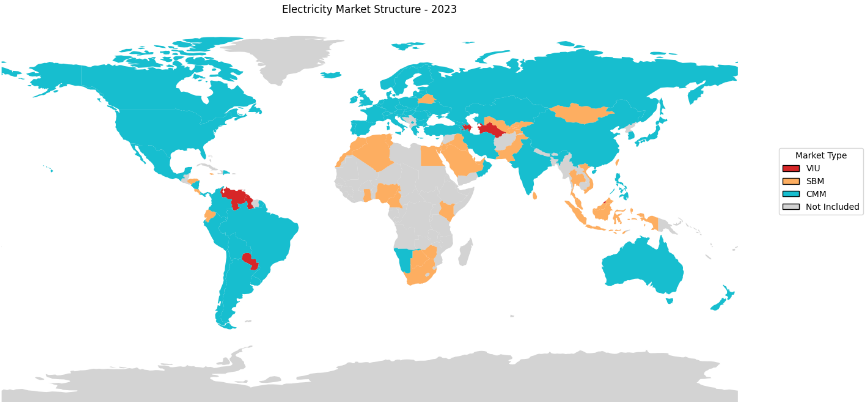
Research Question: Has the competitive market outperformed in renewable energy generation and carbon emission intensity?

This paper compares decarbonization and renewable energy performance of SBM and WEM in 63 emerging and developing countries.

Power Market Structures

Structure	Type	Ownership/Operation	Description
Vertically Integrated Utility (VIU)	1a	State-owned	A single company holds monopolistic control over energy production, transmission, and supply, leaving customers without the option to choose their supplier. Although private generators or mini-grids may exist, they operate solely for self-consumption and are not permitted to supply power to the national grid.
	1b	Majority Private Owned	A single company retains monopolistic rights to produce, transmit, and supply energy, but with a diversified ownership structure where the state holds less than a majority stake. Private captive generators or mini-grids may operate independently, yet they are restricted from supplying the national grid.
Single-Buyer Model (SBM)	2a	Owns/controls generation assets	A single entity is designated as the sole buyer of electricity in the country, granting it ownership and control over generation assets. The central buyer acquires power from IPPs through Power Purchase Agreements (PPAs). The structure includes cases where transmission and generation remain under a state-owned entity, while distribution and supply functions are unbundled into a separate company.
	2b	Does not own/control generation assets	The entity does not own or control any generation assets. Multiple generators operate independently, entering Power Purchase Agreements (PPAs) with the central buyer.
Wholesale competition (WEM)	3a	Bilateral Trading	Independent Power Producers (IPPs) are permitted to engage in bilateral contracts with distribution companies or large customers with prices set through direct negotiation between generation firms and eligible customers. A complementary balancing market, managed by the system operator, may also be in place to address any imbalances in the system.
	3b	Bilateral trading with bid-based power exchange	Electricity trade takes place through both bilateral contracts and a bid-based voluntary power exchange. Prices are established in the power exchange via the auction process.
	3c	Bilateral trading with cost-based power pool	Electricity trade is facilitated through both bilateral contracts and a cost-based power pool. Generators submit their supply curves based on audited cost parameters—such as heat rates, minimum loads, and fuel costs—allowing the system operator to determine each generator's direct marginal operating costs.
	3d	Gross pool settlement design	All available power is supplied through auctions managed by the system or market operator, with bilateral trades outside the pool generally prohibited. All transactions are cleared on a gross basis through the market operator. No direct contractual agreements exist between individual sellers and buyers; instead, all trades are settled at spot prices.

Power Market Structures in 2023



Pros and Cons of the Single-Buyer Model

	Pros	Cons
System Operations & Capacity Management	• Centralized procurement facilitates streamlined planning and dispatch • Avoids complex third-party transmission access agreements, which can be costly or impractical in less developed markets	• Government-driven capacity decisions may lead to excessive and inefficient expansions due to political interests or regulatory capture • Limits cross-border trade as state-owned single buyers lack incentives for optimal trade, especially with neighbors under liberalized models • Less flexibility in adapting new technologies
Economic & Financial Incentives	• Ensures stable returns for investors through long-term PPAs with take-or-pay clauses, reducing market risk in high-risk environments • Easier to implement with less-developed capital markets • Less transaction costs for agents compared to WEM • Limited opportunities for market manipulation • Can internalize network externalities	• Does not reflect the spatial and temporal value of energy demand; therefore, hard to implement demand response programs • Limited competition could cause economic inefficiencies and higher costs • Power Purchase Agreements (PPAs) create contingent liabilities for governments, risking creditworthiness, especially in demand shortfalls • Less incentives for efficient operations at the distribution level • Less incentives for innovation and applied R&D
Regulation & Governance	• Establishes a unified wholesale price, aiding in straightforward price regulation and reducing market complexities • Centralization allows for easier implementation of policy objectives, aligning system operations with national energy strategies	• Centralized dispatch decisions and government control can lead to preferential treatment, operational inefficiencies, and political pressure • Can lead to regulatory capture and information asymmetries • May delay full market competition, as governments retain control over wholesale electricity trading

Source: Compiled through literature review

Change in emissions and renewable energy share (2010-22)

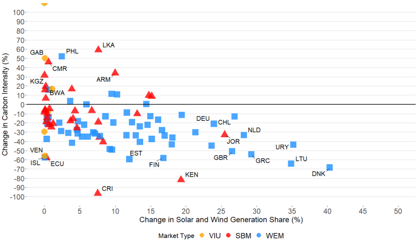


Figure: All countries

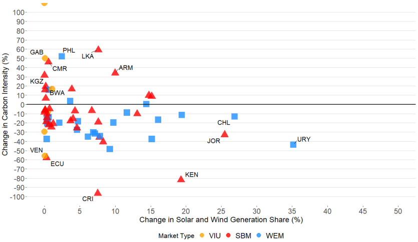


Figure: wo Major Economies

Major economies (G7, EU27, China, India, Australia, and New Zealand) are not included in the second graph. Source: The World Bank and EnerData

Hypotheses

H1: The competitive electricity market model outperforms the single-buyer model in renewable energy share in electricity generation in developing countries.

H2: The competitive electricity market model outperforms the single-buyer model in reducing carbon intensity of the power sector in developing countries.

Empirical Strategy

Propensity Score Matching

- Compare SBM vs. WEM using matched samples from 2010

Panel Data Regression (Fixed Effects)

- Exploit Paris Agreement ratification (post-2015) as an exogenous shock

Period: 2010 –2022

Data Sources

- **Global Power Market Structures Database** (Akcura, 2024)
- **Regulatory Indicators for Sustainable Energy (RISE) Database**
  - Renewable energy policy framework scores; Scale: 0–100
- **World Bank (WDI)**, **Enerdata**
  - GDP per capita, population, inflation, etc.
  - Energy capacity by technology
  - Governance indicators

Descriptive Statistics

Variable	Type	Unit	Mean	SD	Min	Max
Solar + Wind in Generation	Dependent	%	2.60	5.38	0.00	43.80
Carbon Intensity	Dependent	tCO_2/MWh	0.54	0.49	0.00	3.95
Thermal Capacity	Technical	MW	17618.11	27706.83	6.10	189772.14
Hydro Capacity	Technical	MW	5549.73	13662.54	0.00	109798.00
Nuclear Capacity	Technical	MW	1133.61	4519.14	0.00	30313.18
Other Capacity	Technical	MW	1196.62	3564.24	0.00	47309.00
RISE-RE Score	Economic	Score	36.6	21.90	0.00	90.73
GDP per Capita	Economic	USD	22210.65	21806.41	2324.02	132468.93
Population	Economic	Million	40.07	56.29	74.39	275.50
Rural Population Share	Economic	%	35.01	20.26	0.00	81.80
Governance	Economic	Score	46.25	21.65	1.90	100.00
Inflation (GDP Deflator)	Economic	%	8.67	26.83	-30.20	604.95

Propensity Score Matching: Setting

Model	Method	Covariates	Group Size
1	PSM-NN*	Hydro Capacity; Thermal Capacity; Nuclear Capacity; Other Capacity; RISE-RE Score	WEM: 14; SBM: 14
2	PSM-NN*	Population; Inflation (%); Governance Score; Rural Population (%)	WEM: 10; SBM: 10
3	PSM-NN*	All	WEM: 3; SBM: 3
4	PSM-Full	Hydro Capacity; Thermal Capacity; Nuclear Capacity; Other Capacity; RISE-RE Score	WEM: 20; SBM: 14
5	PSM-Full	Population; Inflation (%); Governance Score; Rural Population (%)	WEM: 18; SBM: 10
6	PSM-Full	All	WEM: 3; SBM: 4

*NN: Nearest neighbor matching

Notes: Capacity values are normalized with respect to total installed capacity.

Propensity Score Matching: Results (1)

Model	Dependent Variable	Variable	Coefficient	Significance
1	Renewable Energy Share	WEM	0.021	Insignificant
2	Renewable Energy Share	WEM	2.159	Insignificant
3	Renewable Energy Share	WEM	-2.310	Insignificant
4	Renewable Energy Share	WEM	0.390	Insignificant
5	Renewable Energy Share	WEM	3.207	Insignificant
6	Renewable Energy Share	WEM	-2.519	Insignificant

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Notes: Table shows linear regression model results that use datasets after NN and Full Matching. The coefficients are estimated using linear regression model with time-fixed effects. Heteroskedasticity- and autocorrelation-consistent (HAC) standard errors are estimated using R statistical program *sandwich* package.

Propensity Score Matching: Results (2)

Model	Dependent Variable	Variable	Coefficient	Significance
1	Carbon Intensity	WEM	0.113	Insignificant
2	Carbon Intensity	WEM	-0.456*	Significant
3	Carbon Intensity	WEM	0.073	Insignificant
4	Carbon Intensity	WEM	-0.103	Insignificant
5	Carbon Intensity	WEM	-0.403	Insignificant
6	Carbon Intensity	WEM	-0.030	Insignificant

*$p<0.1$; **$p<0.05$; ***$p<0.01$

Notes: Table shows linear regression model results that use datasets after NN and Full Matching. The coefficients are estimated using linear regression model with time-fixed effects. Heteroskedasticity- and autocorrelation-consistent (HAC) standard errors are estimated using R statistical program *sandwich* package.

Fixed-Effects Panel: Setting

Regression Setup:

$$Y_{it} = \alpha_i + \gamma_t + \beta^{\text{Market}}(\text{Paris}_t \times \text{Market}_{it}) + \delta X_{it} + \epsilon_{it}$$

- Y_{it}: Renewable Energy Share or Carbon Intensity
- α_i, γ_t: Country and Year Fixed Effects
- X_{it}: Technical/Economic controls (capacity mix, RISE scores, population, GDP, etc.)

Fixed Effects: Results (1/2)

Dependent Variable:	Renewable Energy Share in Generation			
Model:	Model 1	Model 2	Model 3	Model 4
SBM	-0.0358	-2.100*	-0.6126	-2.583**
	(2.140)	(1.114)	(2.098)	(1.109)
WEM	2.701	-1.440	1.415	-2.442
	(4.101)	(2.214)	(4.046)	(2.283)
SBM $\times$ Paris	2.165***	1.897	1.316	1.493
	(0.8007)	(1.155)	(0.8299)	(1.351)
WEM $\times$ Paris	4.462***	3.522*	3.412**	2.926
	(1.565)	(1.900)	(1.495)	(2.007)

Clustered standard errors in parentheses; L1: First Lag
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: The analysis is conducted in R statistical program with *fixest package* (Bergé, 2018).

Fixed Effects: Results (2/2)

Dependent Variable:	Carbon Intensity (ln)			
Model:	Model 1	Model 2	Model 3	Model 4
SBM	-0.0632	-0.1960	-0.1215	-0.1591
	(0.1577)	(0.1522)	(0.1533)	(0.1621)
WEM	0.0256	-0.1933	-0.1714	-0.2259
	(0.2629)	(0.1849)	(0.2913)	(0.2035)
SBM × Paris	0.5352	0.8248	0.4815	0.6083
	(0.4989)	(0.6938)	(0.3507)	(0.4482)
WEM × Paris	0.3716	0.6701	0.2884	0.4807
	(0.4921)	(0.7042)	(0.2983)	(0.4522)

Clustered standard errors in parentheses; *L1: First Lag*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: The analysis is conducted in R statistical program with *fixest package* (Bergé, 2018).

Robustness Check: Fixed Effects (1/2)

Dependent Variable:	Renewable Energy Share in Generation			
Model:	Model 1	Model 2	Model 3	Model 4
SBM	-0.0125	-2.085*	-0.6339	-2.600**
	(2.058)	(1.093)	(2.031)	(1.100)
WEM	2.636	-1.244	1.375	-2.267
	(3.912)	(2.084)	(3.884)	(2.168)
SBM × Paris	0.6349***	0.7105**	0.4551***	0.5882
	(0.1686)	(0.3118)	(0.1701)	(0.3733)
WEM × Paris	1.141***	1.103**	0.9087***	0.9210*
	(0.3016)	(0.4726)	(0.2884)	(0.5105)

Clustered standard errors in parentheses; *L1: First Lag*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: The analysis is conducted in R statistical program with *fixest package* (Bergé, 2018).

Robustness Check: Fixed Effects (2/2)

Dependent Variable:	Carbon Intensity (ln)			
Model:	Model 1	Model 2	Model 3	Model 4
SBM	-0.0052	-0.1255	-0.0702	-0.1057
	(0.1507)	(0.1431)	(0.1329)	(0.1491)
WEM	0.0528	-0.1401	-0.1535	-0.1902
	(0.2567)	(0.1836)	(0.2677)	(0.1859)
SBM × Paris	0.0986	0.1977	0.0939	0.1497
	(0.0904)	(0.1608)	(0.0669)	(0.1084)
WEM × Paris	0.0751	0.1722	0.0631	0.1285
	(0.0879)	(0.1623)	(0.0553)	(0.1079)

Clustered standard errors in parentheses; *L1: First Lag*
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: The analysis is conducted in R statistical program with *fixest package* (Bergé, 2018).

Discussion (1/3)

- Neither market structure alone guarantees strong gains in renewables share or emission reduction.
- Differences among developing countries are largely driven by:
  - Regulatory/policy frameworks (e.g., feed-in tariffs, auctions)
  - Grid constraints and integration capacity
  - Availability of finance and governance quality
  - Macroeconomic conditions (small electricity markets, low demand growth)

Discussion (2/3)

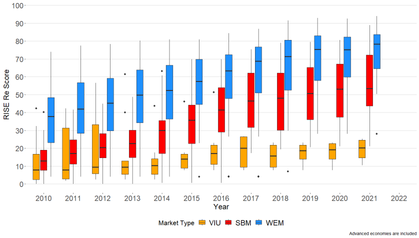


Figure: All countries

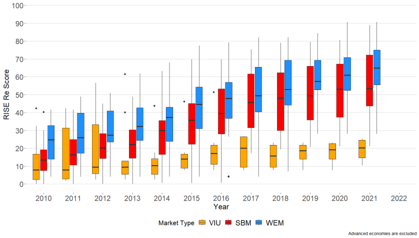


Figure: wo Major Economies

Notes: Figures show RISE Renewable Energy (RISE-RE) scores for all countries and developing countries respectively. Major economies (G7, EU27, China, India, Australia, and New Zealand) are not included in the second graph. Source: ESMAP.

Discussion (3/3)

- Competitive energy-only markets have major issues, the “hybrid” approach is increasingly visible:
  - Long-term PPAs or auctions to de-risk renewables
  - Short-term wholesale markets to encourage efficient dispatch
- Countries with Single-Buyer Model can (and do) implement robust RE policies and perform as well as many WEMs in attracting renewables.

Conclusions

- **Main Findings:** No statistically significant difference in renewables share and carbon intensity between SBM and WEM in developing countries (2010–2022).
- The ability to incentivize renewables depends heavily on:
  - Policy and regulatory frameworks
  - Access to finance
  - Grid infrastructure
  - Broader governance environment
- **Policy Implication:** One-size-fits-all liberalization is not a silver bullet for decarbonization. Focus on tailored regulatory frameworks, de-risking mechanisms, and robust institutions.

Questions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