

Total Factor Productivity and Energy Consumption in Non- OECD Asia

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Outline

- Introduction
- Literature Review
- Data and Descriptive statistics
- Methodology
- Results and Discussion
- Conclusion and Policy Recommendations



Introduction

- Solow (1957) introduced TFP concept.
- TFP help businesses and policy makers to steer economy towards sustainable growth (Santos et al., 2021).
- The Non-OECD Asia has increasing energy demand but slow productivity growth (BP Statistical Review of World Energy, 2021).
- Share of renewable and non-renewable energy consumption has increased by 3% and 13% in Asia.



Literature

- Review of energy consumption and growth nexus (Ozturk, 2010; Smyth and Narayan, 2015).
- Few studies have examined the relationship between energy consumption and TFP growth (Hasanov et al., 2019; Rath et al., 2019; Moghaddasi & Pour, 2016).
- The non-renewable energy consumption decreased the TFP growth (Rath et al., 2019; Tugcu and Tiwari., 2016).
- Divisia index and Malmquist index has been used as a measure of TFP growth (Bjurek, 1996; Star & Hall, 1976).



Gaps

- The existing literature does not have consensus view on the TFP growth calculation.
- No study used the Stochastic frontier analysis (SFA) approach to calculate the TFP series in the existing energy economics literature.

Research Question

How TFP growth affect energy consumption at aggregate and disaggregate level (i.e., non-renewable and renewable energy consumption) of non-OECD Asia?



Contributions of the study

- TFP calculation: SFA approach.
- Effect of TFP on aggregate and disaggregate energy consumption in non-OECD Asia.
- Address endogeneity issue by employing IV Mediation analysis approach introduced by Dippel et al (2019).



Data and Descriptive Statistics

- Non-OECD Asia (SAARC and ASEAN).
- Sample size: 1982-2019.
- Data Source: PWT 10.0, US EIA.
- Energy consumption and GDP are in per capita form.

Variable	Obs	Mean	Std. Dev.	Min	Max
<i>Ln(gdp)</i>	532	8.699	1.179	6.683	11.549
<i>Ln(e)</i>	532	-17.817	1.653	-21.213	-14.245
<i>Ln(nre)</i>	532	-18.059	1.734	-21.658	-14.25
<i>Ln(re)</i>	500	-20.662	1.646	-27.456	-16.374
<i>Ln(em)</i>	532	-13.82	1.693	-18.946	-10.068
<i>Ln(K)</i>	532	12.929	1.861	8.217	17.38
<i>Ln(L)</i>	532	2.396	2.125	-2.639	6.21



Total Factor Productivity (TFP) decomposition: Stochastic Frontier Analysis

We follow Kumbhakar and Wang (2005) to estimate TFP of non-OECD Asia. The decomposition of TFP is as follow:

1. Technical change (TC)

$$\frac{\partial \ln f(t, K, L, \gamma)}{\partial t}$$

2. Technical efficiency (TE)

$$-u$$

3. Return to scale (scale)

$$(RTS - 1) \cdot [\lambda_K \cdot g_K + \lambda_L \cdot g_L]$$

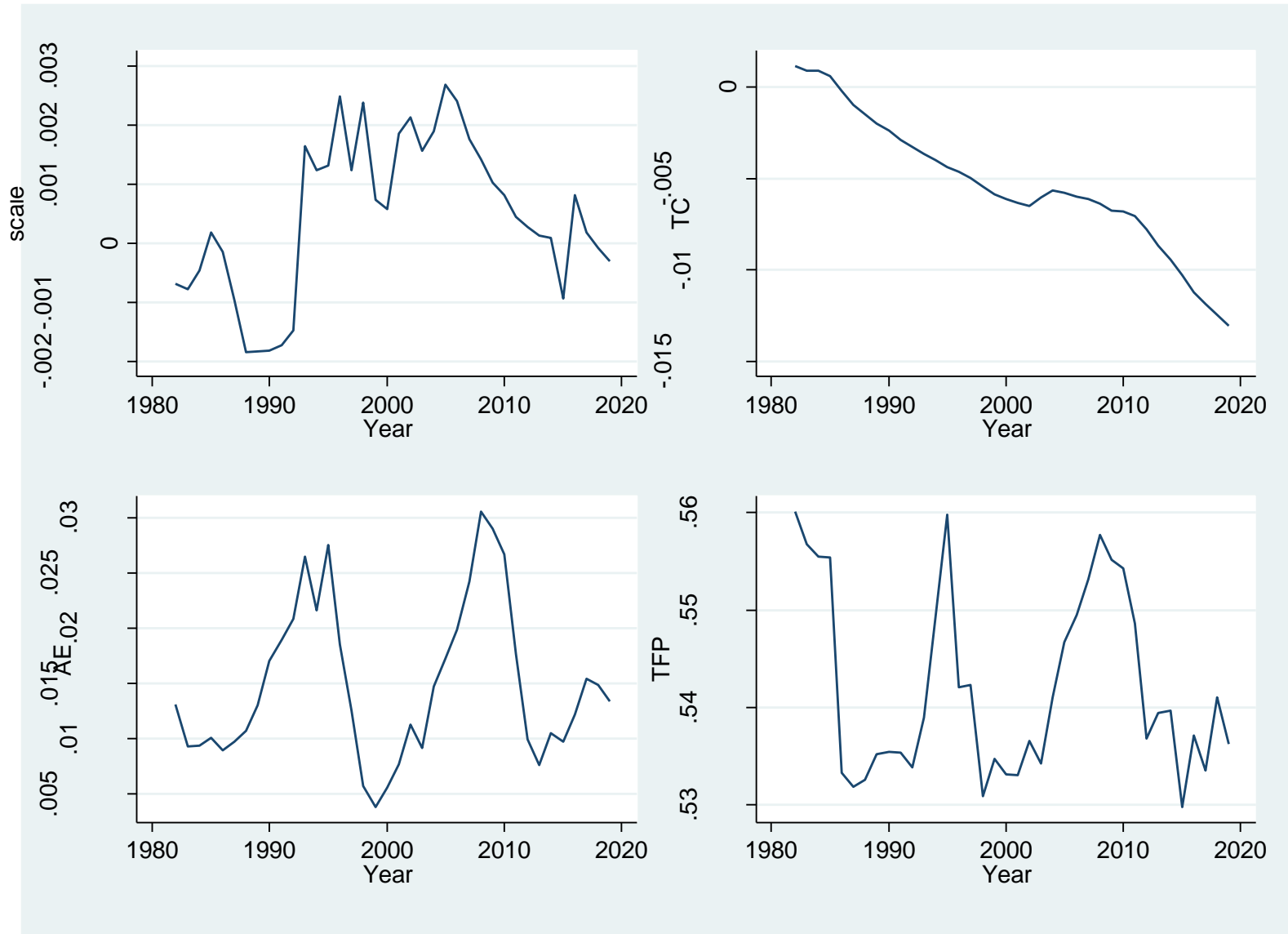
4. Allocative efficiency (AE)

$$[(\lambda_K - S_K) \cdot g_K + (\lambda_L - S_L) \cdot g_L]$$

$$TFP = TC + TE + scale + AE$$



TFP Decomposition



Methodology

Model 1:

$$\ln(e)_{it} = a_0 + a_1 \ln(TFP)_{it} + a_2 \ln(gdp)_{it} + e_{it}$$

Model 2:

$$\ln(nre)_{it} = b_0 + b_1 \ln(TFP)_{it} + b_2 \ln(gdp)_{it} + u_{it}$$

Model 3:

$$\ln(re)_{it} = c_0 + c_1 \ln(TFP)_{it} + c_2 \ln(gdp)_{it} + \varepsilon_{it}$$



Estimation Procedure

- Cross-Sectional dependence test
- Slope Heterogeneity test
- Unit root tests
- CS-ARDL test
- Robustness test 1: Changing dependent variable
- Robustness test 2: Changing independent variable
- Robustness test 3: Alternative method
- Heterogeneity Analysis
- IV Mediation analysis



CS-ARDL Panel data estimation test

- This method use to identify short and long run relationship between TFP and energy consumption.
- Address panel data problems of CSD and slope heterogeneity.
- Address endogeneity issue.

$$\Delta \text{Ln}(e)_{i,t} = \alpha_0 + \sum_{k=1}^p \gamma_{it} \Delta \text{Ln}(e)_{i,t-k} + \sum_{k=0}^p \alpha_{it} Z_{i,t-k} + \sum_{k=0}^1 \bar{W}_{i,t-k} + \varepsilon_{it}$$



Cross-Sectional Dependence test results

Variable	Pesaran (2004)	p-value	Pesaran (2015)	p-value
<i>Ln(gdp)</i>	45.040*	0.000	42.228*	0.000
<i>Ln(e)</i>	49.350*	0.000	49.825*	0.000
<i>Ln(TFP)</i>	6.790*	0.000	6.844*	0.000
<i>Ln(nre)</i>	49.810*	0.000	50.323*	0.000
<i>Ln(re)</i>	27.070*	0.000	19.789*	0.000
<i>Ln(em)</i>	50.180*	0.000	50.177*	0.000

** is the 5% significance level and * is the 1% significance level



Slope Homogeneity results

Tests	Statistics	p-value
DV: $\ln(e)$		
$\bar{\Delta}$	36.881*	0.000
$\bar{\Delta}_{adj}$	38.990*	0.000
Δ_{HAC}	10.163*	0.000
$\Delta_{HAC adj}$	10.799*	0.000
DV: $\ln(nre)$		
$\bar{\Delta}$	32.542*	0.000
$\bar{\Delta}_{adj}$	34.403*	0.000
Δ_{HAC}	6.745*	0.000
$\Delta_{HAC adj}$	7.167*	0.000
DV: $\ln(re)$		
$\bar{\Delta}$	29.206*	0.000
$\bar{\Delta}_{adj}$	30.993*	0.000
Δ_{HAC}	10.467*	0.000
$\Delta_{HAC adj}$	11.172*	0.000

Note: DV is the dependent variable. * is the 1% level of significance.



Panel Unit root results

Variable	CADF		CIPS		CADF		CIPS		
	(Level)		(Level)		(First difference)		(First difference)		
	Intercept	Trend	Intercept	Trend	Intercept	Trend	Intercept	Trend	
$\ln(gdp)$	-1.86	-1.84	-1.67	-1.56	-3.07*	-3.86*	-3.89*	-4.60*	I (1)
$\ln(e)$	-2.07	-2.46	-1.92	-2.22	-3.81*	-4.08*	-5.26*	-5.55*	I (1)
$\ln(TFP)$	-1.89	-2.53	-1.98	-2.40	-3.59*	-3.62*	-5.37*	-5.47*	I (1)
$\ln(nre)$	-1.76	-1.88	-1.61	-1.85	-3.97*	-4.33*	-5.55*	-5.89*	I (1)
$\ln(em)$	-2.24	-2.25	-2.02	-2.10	-4.21*	-4.51*	-5.43*	-5.67*	I (1)

* is the 1% level of significance.



Benchmark Results: CS-ARDL

Variables	DV: $\Delta \ln(e)$	DV: $\Delta \ln(nre)$	DV: $\Delta \ln(re)$
Long run			
$\ln(TFP)$	➡ -0.512** (0.023)	➡ -0.431*** (0.085)	➡ -1.015 (0.317)
$\ln(gdp)$	0.807* (0.001)	0.900* (0.000)	0.091 (0.864)
Short run			
Error correction	-0.996* (0.000)	-1.026* (0.000)	-1.051* (0.000)
$\Delta \ln(TFP)$	➡ -0.495** (0.025)	➡ -0.436*** (0.080)	➡ -1.207 (0.286)
$\Delta \ln(gdp)$	0.722* (0.003)	0.807* (0.001)	-0.023 (0.963)
CD statistics	-2.71	-2.94	-2.11
Root MSE	0.09	0.08	0.20
N	504	504	465

Note: DV is the dependent variable. P-value is in parenthesis.

*p<0.01, ** p<0.05, ***p<0.1



Robustness test 1 Results

Variables	DV: $\Delta \ln(em)$
Long run	
$\ln(TFP)$	➔ -0.422*** (0.054)
$\ln(gdp)$	1.047* (0.000)
Short run	
Error correction	-1.068* (0.000)
$\Delta \ln(TFP)$	➔ -0.391*** (0.060)
$\Delta \ln(gdp)$	1.071* (0.000)
CD statistics	-2.19
Root MSE	0.08
N	504

Note: DV is the dependent variable. P-value is in parenthesis.

*p<0.01, ** p<0.05, ***p<0.1



Robustness test 2 Results

Variables	DV: $\Delta \ln(e)$	DV: $\Delta \ln(nre)$	DV: $\Delta \ln(re)$
Long run			
$\ln(TFP)$	➔ -0.239* (0.002)	➔ -0.257* (0.001)	0.069 (0.622)
$\ln(gdp)$	0.798* (0.003)	0.668* (0.001)	-0.269 (0.532)
Short run			
Error correction	-1.165* (0.000)	-1.181* (0.000)	-1.092* (0.000)
$\Delta \ln(TFP)$	➔ -0.277* (0.003)	➔ -0.300* (0.003)	-0.011 (0.941)
$\Delta \ln(gdp)$	0.836* (0.005)	0.724* (0.002)	-0.411 (0.400)
CD statistics	-2.61	-2.67	-2.39
Root MSE	0.08	0.08	0.19
N	504	504	465

Note: DV is the dependent variable. P-value is in parenthesis.

*p<0.01, ** p<0.05, ***p<0.1



Robustness test 3 Results: DCCEMG

Variables	DV: $\Delta \ln(e)$	DV: $\Delta \ln(nre)$	DV: $\Delta \ln(re)$
$\Delta \ln(TFP)$	➔ -0.483** (0.067)	➔ -0.470*** (0.085)	-1.293 (0.215)
$\Delta \ln(gdp)$	0.724* (0.009)	0.747* (0.001)	0.488 (0.291)
CD statistics	-2.57	-2.79	-2.69
Root MSE	0.09	0.08	0.20
N	504	504	465

Note: DV is the dependent variable. P-value is in parenthesis.

*p<0.01, ** p<0.05, ***p<0.1



Regional Heterogeneity analysis

	DV: $\Delta \ln(e)$		DV: $\Delta \ln(nre)$		DV: $\Delta \ln(re)$	
	ASEAN	SAARC	ASEAN	SAARC	ASEAN	SAARC
Long run						
$\ln(TFP)$	➡ -0.527** (0.037)	➡ 0.018 (0.671)	➡ -0.532* (0.009)	➡ -0.028*** (0.083)	0.922 (0.337)	0.071 (0.236)
$\ln(gdp)$	0.819* (0.003)	0.179 (0.674)	0.977* (0.000)	0.427 (0.171)	-0.167 (0.847)	1.760** (0.043)
Short run						
Error correction	-0.896* (0.000)	-1.087* (0.000)	-0.924* (0.000)	-1.088* (0.000)	-1.030* (0.000)	-1.164* (0.000)
$\Delta \ln(TFP)$	➡ -0.397* (0.010)	➡ 0.020 (0.618)	➡ -0.401* (0.003)	➡ -0.030** (0.050)	0.898 (0.333)	0.076 (0.263)
$\Delta \ln(gdp)$	0.620* (0.005)	0.221 (0.596)	0.791* (0.001)	0.376 (0.278)	-0.407 (0.645)	2.110** (0.036)
CD statistics	-3.14	-2.83	-2.99	-2.88	-2.00	-2.25
Root MSE	0.07	0.06	0.08	0.07	0.19	0.21
N	288	216	288	216	249	216

Note: DV is the dependent variable. P-value is in parenthesis.

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.1$



IV Mediation analysis

Linear IV mediation analysis	DV: $\ln(e)$	DV: $\ln(nre)$
Total effect	-2.425** (0.039)	-2.857** (0.040)
Direct effect	-2.43e-07 (0.610)	0.093 (0.134)
Indirect effect	-2.425** (0.039)	-2.950** (0.040)
% effect mediated by lee	100	103.26
Weak identification tests	14.531	14.531

Note: DV is the dependent variable. P-value is in parenthesis.

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.1$



Conclusion and Policy Recommendations

- TFP is main driver of economic growth.
- Impact of TFP on aggregate and disaggregate energy consumption.
- CS-ARDL shows negative impact of TFP on energy consumption and non-renewable energy consumption.
- Robustness test results postulates that benchmark results are robust.
- Efficient use of energy and prioritize TFP.



Thank You
For Your Attention!

Any Questions

