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The Socio-Economic Impacts of Energy Policy Reform through the Lens of the Power Sector – Does Cross-Sectional Dependence Matter?

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Abstract

The reform of the power sectors is one of the widely pursued energy policy reform agenda in developing economies with core objectives around improving socio-economic outcomes. The empirical evidence, until date, however, has not quantified the reform impacts segregating the impacts of the common factors such as common drivers of reforms among reforming countries. This is the first study in the reform literature to investigate the socio-economic impacts of power sectors reforms accounting for cross-sectional dependence. We focus on the 18 non-OECD Asian economies for this purpose, which also includes member countries belonging to important economic regions of the ASEAN and the SAARC for the time-period 1990-2018. The findings from our study suggests that energy policy reform in the power sector has generated positive impacts on the economy as measured

aggregately and social welfare such as human development and income inequality. Electricity reforms have also contributed in reducing network losses and thereby induce operational efficiency improvements. Our results are robust to alternative model specifications that considers interaction effects of power sector reforms. We conclude that energy policy reform in the power sector is an enabler to achieve the interrelated sustainable development goals in developing economies.

Keywords: energy policy, electricity reforms, welfare, economy, cross-sectional dependence

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1. Introduction

Cross-sectional dependence can arise due to spatial or spillover effects, or from common factors that are unobservable (Baltagi and Pesaran, 2007). The market-based electricity markets reform initiated in the early 1990s in many developing economies is, therefore, prone to cross-sectional dependence arising from common drivers of reforms as reforms turned into bandwagon often under external pressures and through demonstration effects. For instance, about two-fifths of the 115 developing and transition economies surveyed in 1998 had corporatized their state utilities or contracted with independent power producers (IPPs);

about one-third had passed new electricity laws, established independent regulators, or restructured their power sectors; and about one-fifth had fully or partially privatized state-owned generation or distribution (ESMAP, 1999). This new paradigm for power sector reform that emerged during the 1990s was an outcome of the Washington Consensus and spread across the developing world (Foster and Rana, 2020). Power sector reforms eventually became the normal prescription of the multi-lateral donor agencies like the International Monetary Fund (IMF) and the World Bank as a foreign direct investment (FDI) was the only way to bridge the gap between investment needs and available public sector funds (Jamasb, 2006; Williams and Ghanadan, 2006; Bhattacharya, 2007). However, prior empirical studies on the impact of reforms have neglected the presence of cross-sectional dependence in the dataset owing to common reform motives, which could lead to significant size distortions including biased results and false policy inferences. The first generation panel unit root and cointegration tests developed in the 1990's, which many prior empirical studies on power sector reforms have relied on assumes cross-sectional independence (Baltagi and Pesaran, 2007). Therefore, this is the first study in the reform literature, to the best of our knowledge, to investigate the impacts of power sectors reforms accounting for cross-sectional dependence.

The study focuses on the Asian economies that are non-members of the Organization of the Economic Cooperation and Development (OECD). Non-OECD Asia is a crucial economic region in the world from an energy use and environmental sustainability perspective because these economies comprise about 34% of world primary energy demand, 60% of the population and 65% of the world's poor, and will account for more than 60% of the total increase in energy consumption between 2015 and 2040 (Sen, Nepal and Jamasb, 2018). The non-OECD Asian economies include important sub-economic regions such as the Association of Southeast Asian Nations (ASEAN) and the South Asian Association for Regional Cooperation (SAARC). The ASEAN was established in 1967 to promote economic, political, and security cooperation among its ten members which includes Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore,

Thailand, and Vietnam. Likewise, the SAARC is an economic and political organization of eight countries in South Asia established in 1985 and includes member countries including Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka. The market-based model has had limited benefits in the ASEAN and SAARC countries, largely due to sectoral heterogeneity and institutional endowments (Sen, Nepal and Jamasb, 2018). Several ASEAN economies implemented reform initiatives in their electricity industries in the mid-to-late1990s to improve productivity and attract private sector investments (Sharma, 2005). For example, Malaysia amended an electricity reform law in 2001 and established a regulator in 2002. Myanmar established a regulator in 1996 while enacting an electricity reform law in 2014. Philippines introduced an electricity reform law and established a regulator both in 2001 while Vietnam introduced an electricity reform law and established a regulator both in 2001. An early review of these reform experiences and outcomes of reforms suggests that there is a significant disparity between the expected and actual outcomes of reform in the ASEAN (Sharma, 2005).

Likewise, the SAARC region has witnessed slow progress in undertaking domestic sector reforms (Singh et al. 2018). Bangladesh enacted an electricity reform law in 2003 and established an electricity regulator in 2004. Bhutan implemented an electricity reform law in 2001 and established the electricity regulator in 2002. India established the electricity regulator in 1998 and implanted an electricity law in 2003. Sri Lanka established the electricity regulator in 2002. Political instability has affected the power sector reform process while slow progress of reform has affected the sector viability in terms of attracting power sector investment (Bhattacharya, 2007). The lack of adequate domestic electricity reform progress has also adversely affected the expansion of cross-border electricity cooperation and trade in the SAARC region (Singh et al. 2018).

The purpose of this study is to empirically revisit the electricity reform performances of the non-OECD economies focusing on the ASEAN and the SAARC regions using modern panel-data econometrics that accounts for cross-sectional dependence. Recent advances in applied econometric research pertaining to panel

data are primarily concerned with the problem of cross-section dependence and heterogeneity (Baltagi and Pesaran, 2007) and therefore we apply these techniques to assess the reform impacts in more than three decades of the reform process. By doing so, this study contributes to the literature on electricity market reforms in three major ways. First, this is the only novel empirical study questioning the importance of accounting for cross-sectional dependence in electricity reforms literature until this date. Second, there are only limited studies empirically assessing the performance of electricity reforms in the ASEAN and the SAARC countries with the inclusion of China. A notable recent study is the one by Sen, Nepal and Jamasb (2018). However, this study ignores the effects arising from not accounting for heterogeneity among the sample countries as well as the presence of cross-sectional dependence in the data. Third, our study considers broader economic and welfare impacts of reforms that are of societal relevance rather than solely confining the analysis to the technical impacts of reforms.

The remainder of the study is structured as follows. Section 2 summarizes the relevant quantitative literature on power sector reforms in developing and transition economies. Section 3 discusses the data, model specification, and methodology. Section 4 presents and discusses the results. Section 5 calculates the paper with relevant policy recommendations.

2. Review of Relevant Literature

Microeconomic and industrial organization theories provide the economic rationale for undertaking electricity reform with the key objective of maximising economic welfare. The first fundamental theorem of welfare economics holds that all competitive outcomes are Pareto efficient. Therefore, promoting competition in the generation and retail segments of the electricity supply industry (ESI) is one of the objectives of reforms. Likewise, the monopoly segments of the ESI such as electricity networks are economically regulated based on incentive regulation in line with the theory of the second-best since some distortions (or deadweight loss) arising from monopoly network characteristics cannot be eliminated. A

recent study by Jamasb, Nepal and Timilsina (2017) have summarized the literature on the microeconomic and macroeconomic impacts of reforms in developing and transition economies. The reviewed microeconomic impact dimensions include pricing, economic efficiency, and quality of service (i.e. operational efficiency) while the macroeconomic dimensions include impacts on economic welfare, economic growth and poverty reduction.

Cubbin and Stern (2004) based on ordinary least squares (OLS) and fixed effects (FE) estimation show that the regulatory law and governance is positively related to higher per capita electricity generation and capacity in a panel dataset consisting of 28 developing economies between 1980 and 2001. Using the same dataset, Cubbin and Stern (2006) show that regulatory law and governance is positively related to higher per capita electricity capacity controlling for privatization and competition based on EF and error correction models (ECM). Zhang et al. (2005) using FE estimations show that independent regulation and competition before privatisation are important for higher electricity generation and capacity in a panel of 25 developing economies from 1985-2001. Another study by Zhang et al. (2008) based on FE estimations shows that privatization and regulation on their own do not lead to obvious gains in economic performance using a panel dataset of 51 economies from 1985-2000. Nagayama (2007) based on panel dataset comprising 83 countries (both developed and developing) between 1985-2002 show that unbundling may reduce prices when coexisting with independent regulator using OLS, FE and random effects (RE) estimations. Another study by Nagayama (2009) based on a panel dataset of 78 countries shows that liberalisation models do not necessarily reduce electricity price using RE and FE estimations for the time period 1985-2003. Nagayama (2010) further shows that reforms reduced transmission and distribution losses in a panel dataset of 86 economies based on FE estimations.

Other notable global studies of reform include the one by Erdogdu (2011) which documents that the impact of the reforms process as a whole on price-cost margins and cross-subsidy levels is non-uniform based on a

panel dataset of 63 economies from the time period 1982-2009 using FE and RE estimations. Erdogdu (2013) further shows that reform progress led to a decline in R&D investments for a panel of 27 economies for the time period 1974-2008 based on FE and RE estimations. Erdogdu (2014), in another study, evidence that reform progress led to higher levels of electricity supply self-sufficiency for a panel of 55 economies for the time- period 1975-2010 based on FE and RE estimations. Nepal and Jamasb (2012), in the case of 27 transition economies for the time period 1990-2010, show that power sector reform on its own did not produce any significant impacts on T&D losses based on bias-corrected fixed effects (LSDVC) estimations. In the case of Latin America, the study by Balza, Jimenez and Mercado (2013) shows a strong and robust association between regulatory quality and electricity prices based on generalized least squares estimations for 18 countries from 1971-2010. An ESMAP (2011) study for a panel dataset of 20 countries with different power system sizes showed that vertical unbundling reduced electricity tariffs by 10% based on FE estimations while the introduction of independent power producers escalated electricity access by 50% based on FE and RE estimations.

In the context of India, Kundu and Mishra (2011) showed that some consumers groups such as the industrial sector benefited from reforms while others like the agricultural groups lost based on partial least squares estimations. Sen and Jamasb (2012) using LSDVC estimations further show that political economy factors led to adverse outcomes in the initial stages of reforms for a panel of 19 Indian states from 1991-2007. A recent study in the Chinese context by Zheng, Menezes and Nepal (2021) shows that the 2015 electricity reforms in China reduced overall average retail prices while also improving reliability at the expense of increased supply interruptions based on FE estimations.

Another strand of reform literature focuses on the impact of reforms on productivity and efficiency. Goto and Sueyoshi (2009) based on the multi-product translog cost function show for a panel of 9 distribution companies in Japan that deregulation led to improvements in productivity growth between 1983-2003. An

earlier study by Nakano and Managi (2008) for 10 electricity distribution companies in Japan between the period 1965-2003 had shown that regulatory reforms had contributed to productivity growth in the steam-power generation based on generalized methods of moment (GMM) estimations. In the case of India, Jain et al. (2010) documented that unbundling drove efficiency in electricity generation for 30 state-owned utilities between 2007-2008 based on stochastic frontier analysis. Likewise, Malik et al. (2015) show in the case of India that states unbundling before the Electricity Act of 2003 experienced improvements in operational efficiency especially 3-5 years after unbundling based on FE estimations for an unbalanced panel of 385 electricity generating units for the years 1998-2009.

In terms of the macroeconomic impact, Nepal and Jamasb (2012) and Sen and Jamasb (2012) evidenced that reforms positively affected the gross domestic product (GDP) based on the LSDVC estimations for the transition economies and India respectively. Likewise, Carvalho et al. (2016) for the transition economies also show that reforms had a positive effect on the GDP index in the Commonwealth of Independent States (CIS) and non-CIS countries based on LSDVC estimation between 1992-2007. The impact of reforms in improving welfare through the channels of electricity access is well evident in the context of Bangladesh and India. Khandker et al. (2012) show that electrification led to household gains in income and poverty reduction based on propensity score matching using cross-sectional data from Bangladesh. Khandker et al. (2014) based on cross-section data show that rural electrification helped reduce poverty even though a larger share of benefits accrued to wealthier rural households in India using probit models. In a recent study by Sedai, Nepal and Jamasb (2021), it is also shown in the context of India that an additional hour of electricity overall generates significant positive effects especially among the poor households in rural India using panel data econometrics based on FE estimations.

The only study in the non-OECD Asian context is the one by Sen, Nepal and Jamasb (2018) which shows that reforms measure such as the introduction of independent power producers, unbundling and distribution

privatization had significant positive effects in reducing income inequality based on the two-stage least squares (2SLS) and the GMM estimations for 17 non-OECD Asian economies between 1990-2013. A review of the literature based on the aforementioned studies clearly documents the sole reliance on first-generation panel data econometrics by completely disregarding the possibilities and the need to account for cross-sectional dependence. In addition, empirical quantitative studies in the non-OECD Asia region is also very limited. Therefore, our study fills these gaps.

3. Hypotheses, Data and methodology

This section details out the model specification including the hypotheses to be tested, data, and the econometric methodology applied in this study under three distinct subsections.

3.1. Hypotheses

The 'standard reform model' was pioneered in the 1980s and 1990s by OECD economies—the UK, Norway, Chile, and the US and eventually spread to developing economies. The standard model had five distinct reform steps (Joskow, 1998; Newbery, 2005; Joskow, 2008): a) electricity law enactment; b) opening electricity generation to independent power producers; c) corporatization and vertical separation of the competitive segments of the ESI from the regulated natural monopoly segments; d) establishment of independent electricity regulatory body and e) divestiture or privatization of the electricity sector. Reforms were expected to generate far-reaching implications in terms of their economic, technical, and welfare impacts. Did the theory meet the practice in the case of the Asian economies?

3.1.1. Economic Impacts

In many non-OECD countries, electricity reform was not an undertaking confined to the sector as in the OECD economies but closely tied to changes throughout the national economy (Williams and Ghanadan,

2006). The direct and indirect contributions of the power sector towards the Gross Domestic Product (GDP) of developing economies was significant. Therefore, reforms in the power sector was important in determining the speed and magnitude of economic growth for countries experiencing systemic changes since the sector also involved strategic aspects of national energy supply (Boccanfuso, 2009; Nepal and Jamasb, 2012). At the same time, improving the performance of the electricity sector was expected to reduce imported resource dependency thereby promote energy security since reforms were expected to mitigate electricity shortages, promote investment and improve energy access (Singh et al. 2018). Marketization of the electricity sector was also perceived to promote electricity sector trade in the region. Therefore, inadequate and incomplete reform progress can act as barriers to electricity trade openness (Timilsina and Toman, 2016).

Hypothesis 1 (H1): *Electricity reforms led to positive impacts on economic output in the Asian economies including a reduction in net electricity imports and increased electricity trade openness in the region.*

We estimate three separate models to test hypothesis (H1) as specified below:

$$\text{LNPGDP}_{it} = \emptyset_0 + \emptyset_1\text{IPPS}_{it} + \emptyset_2\text{REG}_{it} + \emptyset_3\text{UNBLDG}_{it} + \emptyset_4\text{CORP}_{it} + \emptyset_5\text{OPACCESS}_{it} + \emptyset_6\text{DPRV} + \emptyset_7\text{PINSTC} + \emptyset_8\text{LNPEC} + \emptyset_9\text{TRPI} + \varepsilon_{it} \quad (1)$$

$$\text{LNNI}_{it} = \varphi_0 + \varphi_1\text{IPPS}_{it} + \varphi_2\text{REG}_{it} + \varphi_3\text{UNBLDG}_{it} + \varphi_4\text{CORP}_{it} + \varphi_5\text{OPACCESS}_{it} + \varphi_6\text{DPRV} + \varphi_7\text{PINSTC} + \varphi_8\text{LNPEC} + \varphi_9\text{TRPI} + \varepsilon_{it} \quad (2)$$

$$\text{ETO}_{it} = \theta_0 + \theta_1\text{IPPS}_{it} + \theta_2\text{REG}_{it} + \theta_3\text{UNBLDG}_{it} + \theta_4\text{CORP}_{it} + \theta_5\text{OPACCESS}_{it} + \theta_6\text{DPRV} + \theta_7\text{PINSTC} + \theta_8\text{LNPEC} + \theta_9\text{TRPI} + \varepsilon_{it} \quad (3)$$

where LNPGDP is Log of Per capita GDP (US$); LNNI is Log of Net Import of Electricity and ETO is Electricity trade openness as the dependent variables. We used the reform index and individual reform measures as our Explanatory variables. IPPS is Independent Power Producers; REG is establishment of energy

regulator (regulator monopoly); UNBLDG is unbundling of vertically integrated state-owned utilities into competitive; CORP is corporatisation - formed company to commercialised electricity sector; OPACCESS is Open/Third Party Access (0/1) - make access open all parties (in term of grids); DPRV is Distribution privatisation (0/1); PINSTC is Per Capita Instal Capacity (KW/pop); LNPEC is Log of Per Capita Electricity Consumption; and TRPI Transparency index (Institution).

3.1.2. Technical Impacts

The electricity sectors in many developing economies before reforms were experiencing from chronic undercapitalization leading to supply shortages and high system losses while not being able to expand electricity access among the poor (Williams and Ghanadan, 2006). Therefore, reforms were expected to promote operational efficiency by reducing electricity losses as the soft-budget constraint under public ownership was displaced with the profit motive.

Hypothesis 2 (H2): *Electricity reforms led to a reduction in network losses among the Asian economies.*

We estimate two separate models to test hypothesis (H2) as specified below:

$$\mathrm{LNPDL}_{it} = \alpha_0 + \alpha_1 \mathrm{IPPS}_{it} + \alpha_2 \mathrm{REG}_{it} + \alpha_3 \mathrm{UNBLDG}_{it} + \alpha_4 \mathrm{CORP}_{it} + \alpha_5 \mathrm{OPACCESS}_{it} + \alpha_6 \mathrm{DPRV} + \alpha_7 \mathrm{LNPEG} + \alpha_8 \mathrm{TRPI} + \varepsilon_{it} \quad (4)$$

$$\mathrm{LNPTDL}_{it} = \beta_0 + \beta_1 \mathrm{IPPS}_{it} + \beta_2 \mathrm{REG}_{it} + \beta_3 \mathrm{UNBLDG}_{it} + \beta_4 \mathrm{CORP}_{it} + \beta_5 \mathrm{OPACCESS}_{it} + \beta_6 \mathrm{DPRV} + \beta_7 \mathrm{LNPEG} + \beta_8 \mathrm{TRPI} + \varepsilon_{it} \quad (5)$$

where LNPDL is Log of Per Capita Distribution losses; and LNPTDL is Log of Per Capita Transmission and Distribution losses as the dependent variables. Following Sen, Nepal, and Jamasb (2018), the main explanatory variables include: IPPS is Independent Power Producers; REG is establishment of energy regulator (regulator monopoly); UNBLDG is unbundling of vertically integrated state-owned utilities into competitive; CORP is corporatisation - formed company to commercialised electricity sector; OPACCESS

is Open/Third Party Access (0/1) - make access open all parties (in term of grids); DPRV is Distribution privatisation (0/1); DPRV is Distribution privatisation (0/1); LNPEG is Log of Per Capita Electricity Generation; and TRPI Transparency index (Institution).

3.1.3. Welfare Impacts

Electricity is one of the essential factor inputs in economic production implying that economic growth is constrained due to lack of infrastructure and reliable supply of electricity (Stern and Kander, 2012). Therefore, any reforms that remove the electricity supply constraints are expected to generate positive impacts on economic welfare and growth while reducing poverty through the channels of electricity access.

Hypothesis 3 (H3): *Electricity reforms led to welfare improvements in the Asian region.*

We estimate three separate models to test hypothesis (H3) as specified below:

$$\mathrm{LNPEC}_{it} = \gamma_0 + \gamma_1 \mathrm{IPPS}_{it} + \gamma_2 \mathrm{REG}_{it} + \gamma_3 \mathrm{UNBLDG}_{it} + \gamma_4 \mathrm{CORP}_{it} + \gamma_5 \mathrm{OPACCESS}_{it} + \gamma_6 \mathrm{DPRV} + \gamma_7 \mathrm{LNEA} + \gamma_8 \mathrm{TRPI} + \gamma_9 \mathrm{LNPEC} + \varepsilon_{it} \quad (6)$$

$$\mathrm{HDI}_{it} = \delta_0 + \delta_1 \mathrm{IPPS}_{it} + \delta_2 \mathrm{REG}_{it} + \delta_3 \mathrm{UNBLDG}_{it} + \delta_4 \mathrm{CORP}_{it} + \delta_5 \mathrm{OPACCESS}_{it} + \delta_6 \mathrm{DPRV} + \delta_7 \mathrm{LNEA} + \delta_8 \mathrm{TRPI} + \delta_9 \mathrm{LNPEC} + \varepsilon_{it} \quad (7)$$

$$\mathrm{GINI}_{it} = \vartheta_0 + \vartheta_1 \mathrm{IPPS}_{it} + \vartheta_2 \mathrm{REG}_{it} + \vartheta_3 \mathrm{UNBLDG}_{it} + \vartheta_4 \mathrm{CORP}_{it} + \vartheta_5 \mathrm{OPACCESS}_{it} + \vartheta_6 \mathrm{DPRV} + \vartheta_7 \mathrm{LNEA} + \vartheta_8 \mathrm{TRPI} + \vartheta_9 \mathrm{LNPEC} + \varepsilon_{it} \quad (8)$$

where LNPEC is Log of Per Capita Electricity Consumption; HDI is Human Development Index covers social wellbeing in a wider sense, a representation of standard of living, and life expectancy in a society and GINI is GINI coefficient Score (0 to 1) (Income Inequality) - covers the welfare impact via changes in income distribution as the dependent variables. The explanatory variables are; IPPS is Independent Power Producers; REG is establishment of energy regulator (regulator monopoly); UNBLDG is unbundling of vertically integrated state-owned utilities into competitive; CORP is corporatisation - formed company to

commercialised electricity sector; OPACCESS is Open/Third Party Access (0/1) - make access open all parties (in term of grids); DPRV is Distribution privatisation (0/1; LNEA is Log of Per Capita Electricity Access; TRPI Transparency index (Institution) and LNPEC is Log of Per Capita Electricity Consumption.

3.2. Data

The reform measures were constructed through a comprehensive country-specific survey of reforms by the authors to capture the status and progress of electricity reforms in the Asia region. Most of the dependent and independent variables were standardized by undertaking log transformations. Other data used in this study are sourced from recognised sources and therefore limiting standardisation problems. These include the World Bank World Development Indicators, Energy Information Administration, the Human Development Reports of the United Nations Development Programme (UNDP), and the Corruption Perceptions Index of the Transparency International. Table 1 contains the variables' names and the units of measurement.

(Insert Table1 here)

Table 2 summarizes the status and progress of electricity reforms for the countries in our sample. Only the Philippines and Singapore have implemented all reform steps as prescribed under the '*standard model of reform*'.

(Insert Table 2 here)

3.3. Methodology

This section outlines the methodology employed to test for cross-sectional dependence, panel unit root tests, two-stage least squares estimations and panel corrected standard errors as below.

3.3.1. Cross-sectional dependence

The relationship between countries due to common factors explains the cross-sectional dependence (CSD), which affects the validity of the outputs of the analysis. If CSD is not put into consideration when common factors are present, this may invalidate our findings. Therefore, the presence of the CSD should be estimated in panel data since it is likely that the cross-sections are related with common factors. For this reason, we applied two types of CSD tests. The Pesaran (2021) test following statistic expression:

$$y_{it} = \alpha_i + \beta_i x_{it} + \varepsilon_{it} \quad (1)$$

Note that the "i" is equal to one (1), the cross-section member is being represented by N, the "t" is equal to one (1), and T represents the time, and x_{it} is a (k×1) matrix of the concerned regressors. While α_i is the intermediary, and the coefficients of the slope, β_i are varies across all panels.

Given the eq (1), we can construct the CD test as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \rho_{ij} \right) \rightarrow N(0,1) \quad (2)$$

Note that ρ_{ij} represent the formed pair's connection of the OLS residuals, ε_{it}, link to the eq (1).

$$\rho_{ij} = \rho_{ij} = \frac{\sum_{t=1}^{T} \varepsilon_{it}\, \varepsilon_{ij}}{\left(\sum_{t=1}^{T} \varepsilon^2{}_{it}\right)^{1/2} \left(\sum_{t=1}^{T} \varepsilon^2{}_{jt}\right)^{1/2}} \quad (3)$$

3.3.2. Panel unit-root test

Pesaran's (2021) cross-sectional dependence has been adopted to identify cross-sectional dependency or not among the varying countries and panel dataset. This estimation follows Pesaran's (2007) cross-section dependency test known as the CADF test. CADF analysis is a modern test known as the second-generation panel unit root test that shows the results of entire panel figures while testing each country in the panel. CADF test is dependable because it can be used under constraint conditions such as T>N and T. Usually, the

CADF test are estimated by comparing CADF critical table values, and therefore the hypothesis of the unit root test is constructed below:

$$y_{it} = (1 - \emptyset_i)\mu_i + \emptyset_i y_{it-1} + \mu_i \qquad i = 1,2 \dots N \; ve \; t = 1,2 \dots T \tag{5}$$

$$\varepsilon_i = \gamma_i f_t + \varepsilon_{it} \tag{6}$$

where f_t refer to the unobservable common effects of each country in the panel, while ε_{it} show the error term of each country. Given this, we construct the unit root hypothesis below:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \gamma_i f_t + \varepsilon_{it} \quad i = 1,2 \dots N \; and \; t = 1,2 \dots T \tag{7}$$

$$H_0 = \beta_i = 0 \; for \; all \; i \; (series \; not \; stationary)$$

$$H_0 = \beta_i < 0, i = 1,2 \dots N_1, \beta_i = 0 \; i = N_1 + 1, N_2 + 2..N. (series \; stationary)$$

Further, the mean average of the countries of unit root test statistics will be calculated. Cross-sectionally Augmented IPS (CIPS) of unit root test statistics for the whole panel can be achieved (Pesaran, 2007). CIPS statistics are constructed below:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \tag{8}$$

We also employ a first generation of the unit-root test, which is the IPS test. The coefficient of the IPS test varies cross-section units, where the null conjecture is said not to be stationary for all panels. At the same time, the alternative hypothesis shows that it is not that all processes are stationary, but at least one individual process is stationary. This process follows separate ADF regressions with (8) estimating coefficients from different lag orders in all the cross-sections. Therefore, the mean average of each t-statistics is formed from ADF estimation as below:

$$t = \frac{1}{N}\sum_{i=1}^{N} t_{\rho i} \tag{9}$$

Alternatively, it can be re-written by adjusting to form the expected test statistic. Following IPS test, which is developed based on the mean and variance of the t_ρ series.

$$z(t) = \frac{\sqrt{N}(t - E(t_\rho))}{\sqrt{Var(t_\rho)}} \tag{10}$$

Note that the z-statistic is calculated on an asymptotic theorem of normal distribution. Therefore, the estimated values of the mean and the variance are tabulated in Im et al. (2003).

3.3.3. Two-stage least square (2SLS)

To achieve our objectives, we used a two-stage least square (2SLS) through instrumental variable techniques, where Z is the matric of instruments and y and X are the dependent and explanatory variables, respectively. Hence the coefficients calculated in two-stage least squares are as shown in Eq 1 below:

$$b_{2SLS} = (X'Z(Z'Z)^{-1}Z'X)^{-1}X'Z(Z'Z)^{-1}Zy \tag{11}$$

Therefore, the estimated covariance matrix of these coefficients becomes

$$\hat{\Sigma}_{2SLS} = s^2(X'Z(Z'Z)Z'X)^{-1} \tag{12}$$

Where s^2 $s^2$is the estimated residual variance (square of the standard error of the regression).

3.3.4. Panel corrected standard error (PCSE)

Beck and Katz (1995) developed the PCSE model to overcome the shortcoming posed by Time Series Cross-Section (TCSC) model using OLS procedures. It would be recalled that OLS has been criticized for the presence of nonspherical error for its inability to provide consistent estimates. Advancing from this limitation

PCSE model provides accurate estimation, given the contemporaneously correlated or heteroskedastic panel errors. Therefore, we express the following equation:

$$y_{it} = \theta y_{it-1} + x_{it}\beta + \varepsilon_{it} \quad (13)$$

Where the error in equation (13) are partially independent, while the variance-covariance matrix of the errors will form:

$$\Omega = \Sigma \otimes I_T \quad (14)$$

Where Σ shows the N x N matrix of error variances and contemporaneous covariances and $\otimes$ signified the Kronecker product.

Since Σ signified the T x N matrix of the OLS residuals; E'E/T suggests a consistent estimate of Σ[1]. Therefore, PCSE can form by taking the square root of the diagonal of:

$$(X'X)^{-1}X'\left(\frac{E'E}{T} \otimes I_T\right)X(X'X)^{-1} \quad (15)$$

4. Results and discussions

In this section, we present the results from the cross sectional dependence test as well as the results from the estimated models to examine the economic, technical and welfare impacts of reforms.

4.1. Pre-regression analysis

[1] If divided by T will yields a consistent estimate, we could also divided by X — K. Since there is no acceptable theory signifying better in small samples (Not necessary to be in large samples). The tradition is that we divide same by T - K, however, there is acceptable theory to back this procedure. Assuming division by T - K give unbiased results, and dividing by T give estimate with lower mean squared error. We argument that gives the higher estimates of variability. But this is not necessarily an improvement if dividing by T yields the correct estimate of variability. While, the simulation with K — 2 show better explanation. Therefore, PCSEs is superior if calculated by dividing by T to OLS standard errors. No evidence of any further improvement if divided by T — A'. Hence, we can conclude that the acceptable values of N and K (say more than 20 and less than five), the difference between the two methods of computing PCSEs will be under 15 percent.

Table 3 shows descriptive statistics of the variables selected, and the results confirm that LNNI (17.1922) has the highest mean value, suggesting that selected nations mostly import electricity. While, DPRV (0.245211) is the least mean value, indicating that the states are weak in implementing electricity policy involving distribution privatization. The import of electricity (17.1922) is higher than GDP (7.486467) and the electricity trade openness (0.126798), suggesting that these states are more engaged in the import of electricity. Therefore, insecurity in electricity supply due to greater reliance on electricity imports cannot be ruled out. Furthermore, the transmission and distribution losses (4.291116) is higher HDI (0.586146), suggesting that these economies experience more losses than they contribute to the human development.

(Insert Table 3 here)

Table 4 describes the analysis on the cross-sectional dependence and CIPS test, and the results confirm cross-sectional dependency in most of the selected variables, except for regulator (REG), unbundling (UNBLDG), corporatization (CORP), distribution privatization (DPRV), PINSTC, LNNI, LNPTDL, HDI and GINI. As a result, we applied the Pesaran (2007) CIPS test, which accounts for the cross-sectional dependency. The results show that all variables reject the null hypothesis of no cross-sectional dependence, except for LNPGDP, COPRS LNPEC, ETO, LNPEG, LNPDL, and LNEA. Therefore, we took the different value of the variables as stationary and significant, except for OPACCESS and OPACCESS. This suggests that we accept the null hypothesis of no cross-sectional dependence but stationary.

(Insert Table 4 here)

4.2. Main results

Table 5 shows the economic impact of electricity reform. The results show that independent power producer (IPPS) is positive and significant, suggesting that independent power producer or production has increased the per capita GDP in the selected sample of countries. Hence, a 1% percent increase in independent power production will directly increase the per capita GDP by 0.385 in the selected states. This is not surprising since electricity is the blood-bag for the production sectors; therefore, an increase in the number of independent power producers or producers will increase the production capacities and, consequently, per capita GDP. Similarly, installed capacity has significant positive effects in promoting the per capita GDP, suggesting that capital investments in electricity generation promotes economic growth. This follows the general assertion that increase in investments boosts aggregate demand. However, we find that unbundling of vertically integrated state-owned utilities into competitive segments (UNBLDG), Per Capita Electricity Consumption (LNPEC), and Transparency index (TRPI) are negatively related to per capita GDP.

In column 2, we used alternative measure of economic variable which is also a proxy variable to capture electricity security in the region based on the net import of electricity (LNNI). The coefficient of independent power producer (IPPS) is negative and significant at a 1% level of significance, suggesting that the involvement of independent power producers expectedly have decreased the net import of electricity. Similarly, we find that the installed capacity and capacity additions have contributed to a decrease in net electricity imports. The impact of corruption as captured the transparency index on net electricity imports is negative, indicating that a higher perceived level of corruption (i.e. low transparency index score) translates into higher net electricity imports and vice versa. However, the establishment of regulators, corporatization, and open access to all parties is positively influencing net electricity imports. This is likely to happen because these policies formed a basis for the safety of the electricity sector, which, therefore, encourage foreign players to invest or import electricity.

In the third column 3, we used an alternative measure of welfare – electricity trade openness (ETO). The independent power producer (IPPS) coefficient is positive and significant at a 1% significance level, suggesting that independent power producers promote electricity trade openness in the selected states. This is possible since the privatization of the sector allows individual or independent producers to participate, hence increasing production capacity. As the available electricity increases, also trading of electricity will increase, enabling export and import of electricity. Similarly, installed capacity and transparency index are positively related to electricity trade openness, suggesting installed capacity and transparency index are also factors for promoting electricity trade openness. A lower perceived level of corruption (i.e. a higher transparency index score) imply more trade openness. These findings support the assertion that investment in new capacities and good governance and lower corruption encourages electricity trade openness in the region. However, corporatization and distribution privatization are negative, which shows that corporatization and distribution privatization force a reduction in the electricity trade openness.

(Insert Table 5 here)

Table 6 examines the technical impact. The independent power producer (IPPS) coefficient is negative and significant at 10% significance level, suggesting that independent power producer reduces the per capita transmission and distribution losses (LNPTDL). This finding coincides with our assertion that allowing an individual or private electricity producer will reduce the transmission and distribution loss because more expertise and effort are put in place by private individuals as the 'soft budget' constraints under public ownership is replaced by the profit motive. Similarly, the unbundling of vertically integrated state-owned utilities into competitive (UNBLDG) and open access to all parties are also reducing per capita transmission and distribution losses. However, the establishment of energy regulators and distribution privatization is positively related to transmission and distribution loss, indicating that the establishment of energy regulators and distribution privatization increases the transmission and distribution losses. Power grids in many Asian

countries are old and the inability of electricity regulation and distribution privatization in incentivising and modernizing the grids have translated into higher losses.

(Insert Table 6 here)

Table 7 examines the welfare impact through the channels of electricity access. The coefficient of independent power producer (IPPS) is negative and significant at 1% level, suggesting that the introduction of independent power producer (IPPS) reduced per capita electricity consumption. Increasing network losses coupled with less reliance on grid based electricity consumption in the wake of increasing electricity production from the IPPs might explain such result. In the absence of wholesale competition and lack of open access in the majority of countries in the sample; increased power production from the IPPs might not have translated into an effective market demand. Similarly, unbundling of vertically integrated state-owned utilities into competitive is also negative, indicating that separation of vertically integrated state-owned utilities into competitive and monopoly segments is also reducing the per capita electricity consumption. However, we find that establishing an energy regulator and open access to all parties promoted electricity consumption. Increasing access to electricity has been successful in prompting electricity consumption in the region.

In column 2, the alternative measure – human development index (HDI) and independent power producer (IPPS) are positively related, indicating that independent power producer (IPPS) has helped to promote human development. Similarly, we find that corporatization, open access to all parties, distribution privatization, transparency, and electricity consumption also contributed to human development. However, the unbundling of vertically integrated state-owned utilities into competitive and monopoly segments decreased human development.

Column 3 used income inequality as a measure. We find that the independent power producer (IPPS) coefficient is positive and significant at a 1% level, suggesting that the introduction of independent power producer (IPPS) promoted income equality. This follows the assertion that privatization or independent

ownership fostered competition in the market resulting in not only efficient but also fairer outcomes. The more competitive the market becomes, the lesser the electricity price, where the low-income holder can stand to buy electricity. On the other hand, the privatization or independent ownership of electricity enables new business owners to enter the market to increase their income. Similarly, unbundling vertically integrated state-owned utilities into competitive and open access to all parties is positively related to income equality. However, the establishment of energy regulators, distribution privatization, and electricity consumption is negatively related to income equality, indicating that establishment of the energy regulator, distribution privatization, and electricity consumption further increased income inequality in the states.

(Insert Table 7 here)

4.3. Robustness analysis

For robustness check, we applied the panel corrected standard error model to enable us to check for autocorrelation and heterodaskisticity, which may impede the reliability of our results in Tables 5, 6, and 7. Secondly, we also used the moderating term of institutional quality to ascertain how institutional quality affects the interaction of electricity policy on people's economic, technical, and welfare. We found that the interaction term of institutional quality*electricity policy has influenced the positive relationship between electricity policy on economic impact as reported in Table 8. This is not quantitatively different from the main finding in Table 5. Similarly, we find that the interaction term has not changed the findings in Table 9, whereas electricity policy negatively technical effects. This is also consistent with the main results in Table 6. Lastly, we found that the moderating term of electricity policy* institutional quality has contributed to the positive effect of the welfare of people. Overall, the institutional quality has not changed the contribution of electricity on economic, technical, and warfare impact. We are convinced that our model is fit as there are no reports of autocorrelation and heterodaskicity.

(Insert Table 8 here)

(Insert Table 9 here)

(Insert Table 10 here)

5. Conclusion and policy implications

We examined the role of electricity policies through the realms of power sector reforms in meeting the target of the general populace in terms of economic, technical, and welfare impacts. Given the complicity of cross-sectional dependency within the selected countries, we tailored our research using the cross-sectional estimation of two-least square regression and robust with the panel corrected standard error. Both the main and robustness analysis show a positive relationship between the electricity policies, economy, and welfare. This suggests that the electricity policy has helped to improve the economy and the welfare of people. However, we found a negative relationship between the electricity policy and technical, suggesting that electricity has helped reduce technical-related issues.

Drawing from our findings, major policy recommendations are provided below. First, the electricity policies have become an important tool that Asian economies have relied on to push for economic prosperity. Therefore, the policy actors should responsibly utilize the benefits attached to the electricity reforms to prosper the economy and the welfare of its populace. Secondly, the finding shows that electricity could help reduce the technical issues that impede successful electricity usage. Therefore, electricity reform should be the tool that the government and policymakers in the region can use to foster electricity usage and performance. Third, our results show that electricity reforms can be a catalyst to achieve the distinct but interrelated sustainable development goals (SDGs) in the Asian region. For instance, the introduction of the

independent power producers have contributed to economic growth (SDG 8), human development and also mitigated income inequality (SDG 10). Our results also show that the importance of institutional strengthening such as no corruption in improving the electricity market reform outcomes such as electricity trade openness and reducing electricity distribution losses.

Nonetheless, the mixed and varying impacts of reforms across the economic, technical and welfare dimensions is clear. Policymakers, therefore, cannot rely on a '*one size fits all*' approach to implementing electricity market reforms as occurred in the early 1990s but rather should design country specific policies. We also do not capture the environmental impacts of reforms since which future studies can consider by also controlling for the effects of other global policy drivers in combating climate change.

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