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Electricity consumption-growth nexus: Evidence from panel data for transition countries

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ABSTRACT

This paper investigates the long-run relationship and causality issues between electricity consumption and economic growth in 15 Transition countries (Albania, Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic and Ukraine) by using the Pedroni panel cointegration method for the 1990–2006 period. Results suggest that the Pedroni panel cointegration tests do not confirm a long-term equilibrium relationship between electricity consumption per capita and real GDP per capita. Moreover, since no cointegration was found, error-correction mechanisms plus causality tests cannot be run for further steps in the long-term to investigate the causality between electricity consumption and economic growth. Overall, it can be said that the electricity consumption related policies have no effect or relation on the level of real output in the long run for these countries. As a conclusion, the literature has conflicting results and there is no consensus either on the existence or the direction of causality between electricity consumption and economic growth. Thus, the findings of this study have important policy implications and it shows that this issue still deserves further attention in future research.

1. Introduction

Whether the economic development takes precedence over energy consumption or energy itself is a stimulus for economic development has motivated curiosity and interest among economists and policy analysts over the past decade to investigate the relationship and direction of causality between energy consumption and economic variables such as GNP, GDP, income, employment or energy prices. This is because the direction of causality has significant policy implications (Jumbe, 2004:62). If a unidirectional causality running from economic growth to energy consumption or if there is no causality in either direction, this signifies a less energy dependent economy such that energy conservation policies (e.g. electricity rationing) would not affect economic growth. However, if the causality runs from energy consumption to GDP, this signifies an energy dependent economy such that energy is a stimulus for GDP growth, implying that shortage of energy may negatively affect economic growth or may cause poor economic performance.

Recently, most of the empirical literature on the subject investigated the relationship between electricity consumption and economic growth by testing for the existence and direction of causality between these two variables. The most recent studies about the subject are as follows: for 4 ASEAN countries (Asafu-Adjaye, 2000; Yoo, 2006), for a group of 17 African countries (Wolde-Rufael, 2006), for China (Yuan et al., 2007), for Fiji Islands (Narayan and Singh, 2007), for 12 OPEC countries (Squalli, 2007), for 10 Asian countries (Chen et al., 2007), for the G7 countries (Narayan et al., 2007), and for 30 OECD countries (Narayan and Prasad, 2008).[2]

A general observation from these studies is that the literature has conflicting results and there is no consensus either on the existence or on the direction of causality between electricity consumption and economic growth. In other words, while some studies find causality running from economic growth to electricity consumption, others find causality running from electricity consumption to economic growth and even some studies found no causality between these variables. These conflicting results may arise due to the different data sets, different countries' characteristics and different econometric methodologies used. However, the conclusions derived from most of these studies show that the causality is running from electricity consumption to income (GDP). Consequently, we may conclude that energy is a limiting factor to economic growth and, hence, shocks to energy supply will have a negative impact on economic growth.

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[2] See Payne (2009) and Ozturk (2009) for a detailed literature survey on electricity consumption-growth nexus.

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The reasons we selected these 15 countries are because they are transition countries and all these countries are from the European continent. To our knowledge, this is the first study that considers a large group of transition countries for a test of the long-run relationship and causal relationship between electricity consumption and real GDP. Thus, the main goal of this paper is to add to this group of studies by examining any causal effects between electricity consumption and real GDP. In order to examine this issue for 15 Transition countries for the 1990–2006 period, we employed the Pedroni panel cointegration method in this study.

The rest of the paper is organized as follows: the next section presents the model and data description. The third section discusses the methodology and the fourth section reports the empirical findings of the study. The last section concludes the paper.

2. Model Specification and Data

To investigate the causality between electricity consumption and economic growth in Transition countries we employed panel cointegration and panel causality methods. Following the empirical literature, the log-linear functional specification of long-run relationship between the real GDP and the electricity consumption may be may specified as[3]:

$$GDP_{it} = \alpha_{0i} + \alpha_{1i}EC_{it} + \varepsilon_{it} \quad (1)$$

where GDP_{it} is the real GDP, per capita PPP (constant 2005 international $); EC_{it}, is the electric power consumption (kWh per capita)[4], and ε_{it} is the error term. All variables are employed with their natural logarithms form to reduce heteroscedasticity and to obtain the growth rate of the relevant variables by their differenced logarithms.

The annual time series data are obtained from the World Development Indicators (WDI) produced by World Bank for the 1990–2006 period at a form of balanced panel data. The sample includes 15 European Transition countries namely: Albania, Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Macedonia (FYR), Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic and Ukraine.

The reasons we selected these 15 countries are because they are transition countries and all these countries are from the European continent. Table 1 presents the figures for the average economic growth rates and electricity consumption for these 15 countries between 1990–2006. Overall, these figures indicate that there is no certain relation between electricity consumption and economic growth rates in these countries for the selected period.

Table 1
The average growth rates of GDP per capita and electricity consumption per capita for Transition countries.

Countries	Variables	1990–94	1995–99	2000–04	2005	2006
Albania	g_{GDP}	−3.7	4.3	3.8	4.7	4.3
	g_{EC}	2.4	11.3	0.0	−0.5	−22.5
Belarus	g_{GDP}	−6.4	5.3	5.8	9.5	10.0
	g_{EC}	−7.1	1.5	1.0	2.0	3.5
Bulgaria	g_{GDP}	−2.6	−1.4	4.6	6.5	6.6
	g_{EC}	−4.3	−3.1	1.1	4.5	4.5
Czech Republic	g_{GDP}	−2.1	0.8	2.6	5.9	6.2
	g_{EC}	−1.5	0.1	1.8	1.9	2.6
Estonia	g_{GDP}	−6.5	4.9	6.1	9.0	10.1
	g_{EC}	−6.2	0.9	3.4	1.5	5.5
Latvia	g_{GDP}	−10.1	5.2	6.4	10.6	12.1
	g_{EC}	−11.0	1.0	4.1	5.8	6.2
Lithuania	g_{GDP}	−11.3	3.9	6.4	8.3	8.0
	g_{EC}	−9.5	1.2	4.5	−1.3	4.1
Macedonia	g_{GDP}	−5.0	1.7	0.4	3.9	3.8
	g_{EC}	−0.3	0.4	1.6	7.1	2.3
Moldova	g_{GDP}	−18.1	−2.0	6.5	8.5	5.9
	g_{EC}	−9.9	−6.4	8.0	8.0	6.0
Poland	g_{GDP}	0.6	4.4	2.5	3.6	6.1
	g_{EC}	−1.8	0.7	1.1	0.6	4.2
Romania	g_{GDP}	−3.1	−1.5	5.4	4.3	7.8
	g_{EC}	−5.4	−3.7	2.7	2.6	3.0
Russian Fed.	g_{GDP}	−8.7	−0.1	5.1	6.7	7.6
	g_{EC}	−5.0	−0.3	1.6	2.5	5.7
Serbia	g_{GDP}	−15.6	0.5	4.0	6.3	5.9
	g_{EC}	−6.1	1.3	0.3	−8.2	3.0
Slovak Republic	g_{GDP}	−4.3	3.4	3.6	6.3	8.1
	g_{EC}	−3.9	0.4	0.5	−3.4	4.3
Ukraine	g_{GDP}	−12.1	−2.4	7.6	3.4	7.7
	g_{EC}	−6.4	−3.6	2.5	3.0	4.6

Notes: g_{GDP} is the average growth rates of real GDP per capita (constant 2005 international $); and g_{EC} is the growth rate of electricity consumption per capita (kWh).

3. Methodology

This paper employs the most recent heterogeneous panel data techniques for a group of 15 European transition countries. Recent literature on panel data econometrics widely emphasized that traditional unit root, cointegration and causality tests have low power performance when the time series sample size is small. An increasing finite sample performance may be realized by using either longer time horizons or pooling time series and cross sections (using panel data). Choi (2001) and Im et al. (2003) among others demonstrate that the power of unit root tests using panel data is substantially improved over univariate testing procedures. Pedroni (1997, 1999, 2004) also reports the power improvement of the panel cointegration approach. In addition, using panel data may provide more useful information on the nature of the economic system of equations for a group of countries, rather than individually analyzing a single equation for each country (Jun, 2004).

In this study heterogeneous panel data techniques have been employed to eliminate the problems associated with the low power of the traditional tests for 15 European Transition countries which have a short data span and some differences in economic conditions and degrees of development. Following the Engle and Granger (1987) two-step procedure, we will investigate the causal relationship between electricity consumption and economic growth. Firstly, we will define the order of integration in series and explore the long-run relationship between the variables by using heterogeneous panel unit root tests and heterogeneous cointegration tests, respectively. Secondly, we test the causal relationships by using the error-correction based causality models.

3.1. Panel Integration Analysis

We employ two recently developed heterogeneous panel unit root tests to check whether the variables in our model are stationary or nonstationary. These tests are the Fisher ADF (Choi, 2001) and IPS (Im et al., 2003) that take heterogeneity into account using individual effects and individual linear trends.

Choi (2001) considers the model as:

$$y_{it} = d_{it} + x_{it}(i = 1,\ldots,N; t = 1,\ldots,T_i) \quad (2)$$

where $d_{it} = \beta_{i0} + \beta_{i1} + \ldots + \beta_{im_i}t^{m_i}$, $x_{it} = \alpha_i x_{i(t-1)} + u_{it}$ and u_{it} is integrated of order zero. Choi allows each time series y_{it} to have a

[3] The main reason of using only two variables (per capita GDP and electricity consumption per capita) in our study was due to the recent studies about this subject. In analyzing the literature, it can be seen that most of the studies are using only GDP and electricity consumption variables in their models (See Payne, 2009; Table 1 for details). However, when we add also “labor force” variable to our model in Eq. (1), the panel integration and panel cointegration test results did not change. In other words, no cointegration is found between these variables. These results are available upon request.

[4] When the real GDP, PPP (constant 2005 international $) and the electricity consumption (kWh) are employed, results from the panel integration and panel cointegration tests are similar. These results are available upon request.

different sample size and a different specification of nonstochastic and stochastic components depending on i. The null hypothesis is that all the individual series in the panel are nonstationary (H_0:$\alpha_i=1$ for all i) and against the alternative of some the time series stationary (H_1:$|\alpha_i|<1$ for some i's). Choi proposed a Fisher-type test as:

$$Z = \frac{1}{\sqrt{N}}\sum_1^N \Phi^{-1}(p_i) \quad (3)$$

where Φ is the standard normal cumulative distribution function. Since $0\leq p_i\leq 1$, $\Phi^{-1}(p_i)$is a $N(0,1)$ random variable and $T_i\rightarrow\infty$ for all i, $Z\Rightarrow N(0,1)$.

Im et al. (2003) also developed a unit root test for dynamic heterogeneous panels based on the mean of individual unit root statistics. Im et al. propose a standardized t-bar test based on the ADF statistics averaged across the groups. The stochastic process, y_{it}, is generated by the first-order autoregressive process:

$$y_{it} = (1-\phi_i)\mu_i + \phi_i y_{i,t-1} + \varepsilon_{it}\ i = 1,...N;\ t = 1,...T \quad (4)$$

where initial values, y_{i0}, are given. In the testing the null hypothesis of unit roots, $\phi_i=1$ for all i. Eq. (4) can be expressed:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \varepsilon_{it}, \quad (5)$$

The null hypothesis is that each individual series in the panel has a unit root and alternative hypothesis that allows for α_i to differ across groups:

$$H_0 : \beta_i = 0 \text{ for all } i \quad (6)$$

$$H_1 : \beta_i < 0,\ i = 1,2,...,N_1,\ \beta_i = 0, i = N_1+1, N_1+2,....,N \quad (7)$$

The modified standardized t_{IPS} statistic below is distributed as $N(0,1)$ when $T\rightarrow\infty$ followed $N\rightarrow\infty$ sequentially:

$$t_{IPS} = \frac{\sqrt{N}\left(\overline{t} - \frac{1}{N}\sum_{i=1}^N E[t_{iT}|\beta_i = 0]\right)}{\sqrt{\frac{1}{N}\sum_{i=1}^N var[t_{iT}|\beta_i = 0]}} \quad (8)$$

3.2. Panel Cointegration Analysis

For the 15 European transition countries, heterogeneity may arise because of differences in economic conditions and degree of development in each country. To ensure broad applicability of any panel cointegration test, it will be important to allow for as much heterogeneity as possible among the individual members of the panel. Pedroni (1997, 1999, 2004) developed a residual-based panel cointegration method that also allows a lot of heterogeneity through individual effects, slope coefficients and individual linear trends across countries. Pedroni (2004) considers the following type of regression:

$$y_{it} = \alpha_i + \delta_i t + \beta_i X_{it} + e_{it} \quad (9)$$

for a time series panel of observables y_{it} and X_{it} for members i = 1,...,N over time periods t = 1,...T. The variables y_{it} and X_{it} are assumed to be integrated of order one, denoted $I(1)$. The parameters α_i and δ_i allow for the possibility of individual effects and individual linear trends, respectively. The slope coefficients β_i are also permitted to vary by individual, so in general the cointegrating vectors may be heterogeneous across members of the panel.

Pedroni (1999) derived the asymptotic distributions and explored the small sample performances of seven different statistics to test panel data cointegration. Pedroni's tests can be classified into two categories: The first four test statistics are based on pooling along ADF what is often referred to as the "within" dimension (called 'panel' hereafter). These tests are the panel v, panel ρ, panel PP and panel ADF statistics. These statistics pool the autoregressive coefficients across different members for the unit root tests on the estimated residuals. The last three test statistics are based on the "between" dimension (called 'group' hereafter). These tests are group ρ, group PP, and group ADF statistics. These statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country in the panel.

All seven tests are conducted on the estimated residuals from a model based on the regression in Eq. (9). Following, Pedroni (1999), heterogeneous panel and heterogeneous group mean panel cointegration statistics are calculated as follows:

$$\text{Panel } v\text{-statistic}: Z_v = \left(\sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\hat{e}_{it-1}^2\right)^{-1} \quad (10.a)$$

$$\text{Panel } \rho\text{-statistic}: Z_\rho = \left(\sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\hat{e}_{it-1}^2\right)^{-1} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\left(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_i\right) \quad (10.b)$$

$$\text{Panel } PP\text{-statistic}: Z_t = \left(\hat{\sigma}^2 \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\hat{e}_{it-1}^2\right)^{-1/2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\left(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_i\right) \quad (10.c)$$

$$\text{Panel } ADF\text{-statistic}: Z_t^* = \left(\hat{s}^{*2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\hat{e}_{it-1}^{*2}\right)^{-1/2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2}\hat{e}_{it-1}^{*}\Delta\hat{e}_{it}^{*} \quad (10.d)$$

$$\text{Group } \rho\text{-statistic}: \tilde{Z}_\rho = \sum_{i=1}^N \left(\sum_{t=1}^T \hat{e}_{it-1}^2\right)^{-1} \sum_{t=1}^T \left(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_i\right) \quad (10.e)$$

$$\text{Group } PP - \text{statistic}: \tilde{Z}_t = \sum_{i=1}^N \left(\hat{\sigma}^2 \sum_{t=1}^T \hat{e}_{it-1}^2\right)^{-1/2} \sum_{t=1}^T \left(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_i\right) \quad (10.f)$$

$$\text{Group } ADF\text{-statistic}: \tilde{Z}_t^* = \sum_{i=1}^N \left(\sum_{t=1}^T \hat{s}_i^2 \hat{e}_{it-1}^{*2}\right)^{-1/2} \sum_{t=1}^T \left(\hat{e}_{it-1}^*\Delta\hat{e}_{it}^*\right) \quad (10.g)$$

Where, $\hat{e}_{it}$ is the estimated residual from Eq. (9) and $\hat{L}_{11i}^2$ is the estimated long-run covariance matrix for $\Delta\hat{e}_{it}$. The other terms are properly defined in Pedroni (1999) with the appropriate lag length determined by the Newey–West method. The panel statistics and group statistics depend on the null hypothesis, H_0:$\hat{\rho}_i=1$ for all i, against the alternative hypotheses H_1: $\hat{\rho}_i=\hat{\rho}<1$ and H_1: $\hat{\rho}_i<1$ for all i, respectively. Where $\hat{\rho}_i$ is the estimated autoregressive coefficient of the residuals in the ith unit. All seven tests are distributed as being standard normal asymptotically. For the panel v-statistics large positive values indicate rejections, whereas large negative values for the remaining test statistics indicate rejection of no cointegration. The critical values are also tabulated by Pedroni (1999).

3.3. Panel Causality Analysis

Panel cointegration method tests whether the existence or absences of long-run relationship between the electricity consumption per capita and the real GDP per capita for the 15 transition countries. It doesn't indicate the direction of causality. Once the variables are cointegrated, the next step is to implement the Granger causality test. We use a panel-based error-correction model to account for the long-run relationship using the two-step procedure from Engle and Granger (1987). The first step is the estimation of the long-run model for Eq. (9) in order to obtain the estimated residuals e_{it}. The second step is to estimate the error-correction based Granger causality models. As opposed to the conventional Granger causality method, the error-correction based causality test allows for the inclusion of the lagged error-correction term derived from the cointegration equation. By including the lagged error-correction term, the long-run information that is lost through differencing is reintroduced in a statistically acceptable way (see Narayan and Smyth, 2008, and Odhiambo, 2007, 2009). Thus, the following models may be employed to explore the causal relationships between variables:

$$\Delta GDP_{it} = \alpha_{1j} + \sum_{k=1}^{m} \alpha_{11ik}\Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik}\Delta EC_{it-k} + \psi_{1i}ECT_{it-1} + u_{1it} \tag{11.a}$$

$$\Delta EC_{it} = \alpha_{2j} + \sum_{k=1}^{m} \alpha_{21ik}\Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik}\Delta EC_{it-k} + \psi_{2i}ECT_{it-1} + u_{2it} \tag{11.b}$$

We must use an instrument variable estimator because of the correlation between the error term and the lagged dependent variables in the dynamic panel data model. We, therefore, can employ the lagged dependent variables as instruments. Rejecting the null hypotheses indicates that EC does Granger cause GDP and GDP does Granger cause EC, respectively. Using Eqs. (11.a) and (11.b), Granger causality can be examined in three ways: 1) Short-run or weak Granger causalities are detected by testing $H_0{:}\alpha_{12ik}=0$ and $H_0{:}\alpha_{21ik}=0$ for all i and k in Eqs. (11.a) and (11.b), respectively. 2) Another possible source of causation is the ECT in equations. The coefficients on the ECT's represent how fast deviations from the long-run equilibrium are eliminated following changes in each variable. Thus, long-run causalities are examined by testing $H_0{:}\psi_{1i}=0$ and $H_0{:}\psi_{2i}=0$ for all i in Eqs. (11.a) and (11.b), respectively. 3) Strong Granger causalities are detected by testing $H_0{:}\alpha_{12ik}=\psi_{1i}=0$ and $H_0{:}\alpha_{21ik}=\psi_{2i}=0$ for all i and k in Eqs. (11.a) and (11.b), respectively (See, Lee and Chang, 2008).

4. Empirical Results

Table 2 presents the results derived from the two heterogeneous panel unit root tests for the order of panel integration. The number of lagged first differences included in the ordinary least squares (OLS) regression is based on the Modified Schwarz Information Criterion (MSIC) proposed by Ng and Perron (2001). This criterion improves the methods of Schwarz Information Criterion (SIC) particularly when there are negative moving average errors. For these panel unit root tests that assume the null hypothesis of each individual series is nonstationary. Both panel unit root tests have the same results: The null hypothesis of unit roots cannot be rejected for GDP and EC series at levels but it is strongly rejected at the 1% significance level at their first difference. So, we conclude that the real GDP per capita and the electricity consumption per capita series are $I(1)$.

We can apply the Pedroni panel cointegration tests for only the electricity consumption per capita and the real GDP per capita in order to determine if there is a long-run relationship between these two variables. Maximum lags in the panel cointegration model based on SIC that is 2. Table 3 presents the heterogeneous panel cointegration test results. Results from seven different statistics for panel data cointegration are mixed. While the group ρ and the panel ρ statistics accept the null hypothesis of no cointegration, the others reject the null hypothesis of no cointegration against the alternative of cointegration.

Table 2
Heterogeneous panel unit root test results.

Variables	ADF − Choi Z-Stat		IPS W-Stat	
	Levels	Differences	Levels	Differences
GDP	−0.5562	−5.2457[a]	−0.8614	−7.3173[a]
EC	1.2778	−4.2086[a]	0.9908	−4.1599[a]

Note: Automatic selection of lags based on Modified Schwarz Information Criterion (MSIC), 0 to 3.
[a] Indicates significance at the at 1% level.

Table 3
Pedroni panel cointegration test.

Panel weighted statistics (probability)	
Panel *v*-statistic	2.7720 (0.0028)
Panel ρ-statistic	0.0508 (0.5203)
Panel *PP*-statistic	−3.3790 (0.0004)
Panel *ADF*-statistic	−3.7628 (0.0001)
Group statistics (probability)	
Group ρ-statistic	0.9719 (0.8345)
Group PP-statistic	−6.0823 (0.0000)
Group ADF-statistic	−4.9022 (0.0000)

Note: number of countries $(N)=15$ and periods $(T)=17$.
Maximum lags on Schwarz information criterion (SIC) is 2.

The small sample size properties for the seven statistics have also been re-investigated by Pedroni (2004) via Monte Carlo simulations. In terms of power, for smaller samples ($N=20$) the group ρ statistic is the most powerful, followed by the panel ρ and panel *ADF* statistics ones. The calculated test statistics must be smaller than the tabulated critical value to accept the null hypothesis of the absence of cointegration. We, therefore, concluded that there is no long-run relationship between the electricity consumption per capita and real GDP per capita.

Since the cointegrating relationship have not been determined we cannot apply the next step, which is to estimate a VEC model. Therefore, the overall empirical results show that error-correction modeling plus Granger causality tests cannot be run for additional steps in the long-term period.

5. Conclusion

There is a growing literature that examines the causality relationship between electricity consumption and economic growth. The bulk of this literature focuses on developing, developed and emerging countries. However, to our knowledge, there is no study that investigates this issue for a large group of transition countries in the energy economics literature.

Our goal was to examine if there is any long-run relationship and causality between electricity consumption and growth for the selected 15 European Transition countries in this study. By using the Pedroni panel cointegration tests for the 1990–2006 period, the empirical results do not confirm long-term equilibrium relationship between the electricity consumption per capita and the real GDP per capita. Thus, since no cointegration was found, error-correction mechanisms plus causality tests cannot be run for further steps in the long-term to investigate the causality between electricity consumption and economic growth. Overall, it can be said that the electricity consumption related policies have no effect or relation on the level of real output in the long run for these countries.

As a conclusion, the literature has conflicting results and there is no consensus either on the existence or the direction of causality between electricity consumption and economic growth. Thus, the findings of this study have important policy implications for energy economics, it provides a basis for discussion on the appropriate design and implementation of environmental and energy policies and it shows that this issue still deserves further attention in future research.

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