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The Vector Auto Regression Analysis of the Link between Renewable Energy Consumption and Economic Development for Turkey and Kazakhstan

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ABSTRACT

The relationship between the use of renewable energy and economic growth has gotten a lot of attention in the literature. Regarding the Granger causality and nature of this relationship, there are various points of view. This empirical analysis uses data from 1990 to 2021 using a vector auto regression method to examine the relationship between economic growth and electricity costs and the consumption of renewable energy on electricity generation. This is accomplished by employing two case study nations - Turkey and Kazakhstan - that are in various parts of the world and have varying degrees of economic development but have recently made a concerted effort to encourage the use of renewable energy sources. The results of this study demonstrate that, over the long term, income and power prices have a considerable impact on the usage of renewable energy during the time under review.

Keywords: Renewable Energy Consumption, Economic Growth, Turkey, Kazakhstan
JEL Classifications: A12, O44, Q43, Q44

1. INTRODUCTION

It is commonly known that energy use and economic expansion are related (Belke et al., 2011; Chen et al., 2020). Energy security is essential for industry, building new infrastructure, moving people around, and raising living standards (Gasser, 2020; Darke et al., 2022). The link between the use of renewable energy and economic expansion is less clear, though. A multitude of factors connected to raising the standard of living for their inhabitants encourage interest in renewable energy in nations of diverse economic power. The goal of developed nations is to promote the growth of renewable energy sources in order to improve energy supply security and combat climate change (Gökgöz and Güvercin, 2018; Inês et al., 2020; Lowitzsch et al., 2020; Li et al., 2022), whereas developing and underdeveloped nations are interested in renewable energy in order to support goals for economic development, modernize their energy industries, and promote energy sustainability (Cantarero, 2020; Shimbar and Ebrahimi, 2020; Karatayev et al., 2022).

It is reasonable to wonder whether the relationship between renewable energy consumption and economic development is universal despite national differences, given that different countries have different motivations for and aims for the development of renewable energy. Choosing a case study group of nations with different levels of economic development, access to energy, and geopolitical variables is one way to shed light on this subject. Such a group is exemplified by Kazakhstan and Turkey. These nations were picked because they are diverse and, in contrast to many others, have the information needed. In other words, the sample countries vary in terms of their political systems for renewable energy as well as their phases of economic growth. The single country study allows for consideration of whether nations with various geographic, economic, and political circumstances respond differently to an increase in the consumption of renewable energy.

For the case study countries over the past few years, economic growth and renewable energy use have both increased, albeit at different rates. The World Bank database shows that in 2021, Turkey's economy grew by 11.4%, and renewable energy consumption increased by 9.3%. In 2021, Kazakhstan's economy grew by 4.3%, and the country's use of renewable energy increased by 0.9% (WB, 2022). In contrast, the growth rate of renewable energy sources worldwide over the first 10 years of the twenty-first century was 1.4%. The case study nations' goals for the expansion of renewable energy also vary. Increasing the share of renewable energy sources in electricity production to 75% is necessary for Turkey to reach its 35% absolute emission reduction target by 2030 (Bulut and Muratoglu, 2018; Alkan et al., 2020; Shan et al., 2021), whereas Kazakhstan has set a target of producing 50% of its electricity from renewable sources by 2050 (Karatayev et al., 2016; Koshim et al., 2018; Karatayev and Hall, 2020).

Several studies have shown a favorable correlation between economic growth and overall energy demand (Wang et al., 2018; Muhammad, 2019; Mohsin et al., 2021). The more general correlation between economic growth and the development of renewable energy has gotten less attention, and to yet, no empirical study on this relationship has been done in the set of Turkey and Kazakhstan (Smagulova et al., 2015; Moldabekova et al., 2022). This study aims to explore the relationship between the use of renewable energy and economic development in the case study countries using a novel technique compared to another research. In this paper, section 2 will discuss and review related studies in the literature. Section 3 will describe the data and the methods used in this paper. Section 4 will present the empirical findings and discussion, and section 5 will provide the conclusions and discuss policy implications.

2. REVIEW OF THE EXISTING LITERATURE

A suitable statistical technique is necessary for an empirical research into the relationship between economic growth and RE. Examining the relationship between renewable energy usage and elements relevant to economic development has been successful when using the VAR model approach (Apergis and Payne, 2010; 2014; Menegaki, 2011; Ohler and Fetters, 2014; Sadorsky, 2009a; 2011; Silva et al., 2012). Sadorsky (2011) used the VAR model to analyse the relationship among renewable energy consumption, income, oil prices, and oil consumption. Sadorsky (2011) suggested that positive shocks to income increase renewable energy consumption. Sadorsky (2009a) employs a VAR approach to analyse the relationships among RE consumption, income, oil prices, and CO_2 emissions by performing panel unit root and cointegration tests. Sadorsky (2009a) pointed out that increases in income and CO_2 emissions are major drivers for increases in renewable energy consumption for long run. Silva et al. (2012) analysed how an increasing share of renewable energy sources on electricity generation affects economic growth and carbon emissions using structural VAR approach for Denmark, Portugal, Spain, and United States. Their findings show that the increasing renewable energy share had economic costs in terms of GDP per capita and there is an evident decrease of CO_2 emissions per capita.

Many studies have examined the association between the use of renewable energy and various macroeconomic factors (such as income, oil prices, capital, and labor) at the national or regional level (Apergis and Payne, 2010; Sadorsky, 2009b, 2011; Salim and Rafiq, 2012). According to these studies, rising income is correlated favourably with rising consumption of renewable energy. Given that the cost of renewable energy is typically higher than the cost of energy obtained from fossil fuels and that people must be able to afford renewable energy in order to use it, this makes obvious sense. Sadorsky (2009b) provided two empirical panel VAR models of income and consumption of renewable energy for 18 emerging nations. Increases in income have a beneficial effect on the consumption of renewable energy, according to the findings of the first empirical model that looked at this relationship. The second model looked at the connections between income, pricing for electricity, and the utilization of renewable energy. According to this finding, the consumption of renewable energy is more susceptible to fluctuations in the price of renewable energy than the overall demand for power.

For a panel of 20 OECD nations, Apergis and Payne (2010) employed panel VAR techniques to analyze the relationship between renewable energy usage and economic development. An aggregate production function connecting output to labor, capital, and renewable energy is used in the theoretical framework. They discover evidence of both short- and long-term Granger causation between the use of renewable energy and economic growth. Salim and Rafiq (2012) used panel data and time series analyses to examine the effects of income, pollutant emissions, and oil prices on the usage of renewable energy in six emerging nations (Brazil, China, India, Indonesia, Philippines, and Turkey). These findings imply that there are two-way causal relationships between renewable energy and both income and pollution emissions. Our findings demonstrate that, over the long term, income strongly influences the use of renewable energy, while oil prices appear to have a less significant and detrimental effect in these nations. Ohler and Fetters (2014) studied the causal relationship between economic growth and electricity generation from renewable sources across 20 OECD countries. They found evidence of a bidirectional short run relationship between aggregate renewable electricity generation and GDP. Apergis and Payne (2014) observed Central American countries from 1980 to 2006 using the panel VAR approach. Their findings imply evidence of a bidirectional Granger correlation between renewable energy consumption and economic growth over the long run. They define renewable energy consumption as total renewable power consumption in millions of kilowatt-hours.

In contrast to bidirectional results, several studies report a unidirectional relationship between renewable energy consumption and economic growth. Payne (2011) investigates the relationship between biomass consumption and GDP in the US, and finds a positive unidirectional relationship from biomass to GDP. Menyah and Wolde-Rufael (2010) studied the relationships between renewable energy consumption, CO_2 emissions, nuclear consumption, and real GDP for the United States using the VAR model. They report that there are unidirectional Granger causality relations from nuclear energy consumption to CO_2 emissions and from GDP to renewable energy but no Granger causality from renewable energy consumption to CO_2 emissions. Menegaki (2011) studied the causal relationship between economic growth and renewable energy for 27 European countries in a VAR panel framework. Menegaki (2011) results do not confirm Granger causality between renewable energy consumption and GDP.

To summarize the literature review, there has been an increase in research on the link between renewable energy consumption and economic growth, but the direction of Granger causality between these three variables, both globally and within individual case countries, is not well established in the current research. Also, the data from the previous 3 years, a time of considerable increase for renewable energy that justifies inclusion in predicting models, is not present in the available research.

3. DATA AND METHODOLOGY

3.1. Data

Annual data was collected on RE consumption (rep), electricity price (ep), and income (gdp), from World Bank online database, International Energy Agency (IEA), and US International Energy Statistics (IEA) database.

Data on RE consumption was derived from the IEA database and measured in billion kilowatt-hours. RE is the electricity generated from wind, solar, geothermal, biomass, hydropower, tidal, and wave sources. This paper uses electricity price, as opposed to oil price, because of it has a strong penetration of the RE sources.

GDP per capita, taken from the World Bank online database and measured in current US dollars, represents economic growth. A key economic growth indicator, GDP was used as a proxy of income in the studies detailed above. Economic growth measured in terms of GDP (real or per capita), or growth rate of GDP, uses different econometric methodologies, countries, and time periods.

The electricity price variable was taken from the World Bank databases and it is current fuel price index numbers 2021=100. This study analyses additional channel of Granger causality by presenting electricity prices. Although electricity prices have been neglected in many previous studies, this paper examines the electricity price as a proxy because of its effects on both energy consumption and economic growth. Furthermore, an increase in prices is anticipated to lead to a decrease in energy demand.

Selection of the variables for this study is based on comparability with the variables collected in previous research, and so the data collected on these variables in the more recent period of this study can easily be compared with data collected in the more distant past.

3.2. Methodology

Model estimation of the relationship between renewable energy consumption and economic growth is based on the standard VAR technique (Caruso et al., 2020; Piłatowska et al., 2020; Jiang et al., 2020). This approach is used because there is no need to assume exogeneity assumptions about which variables are response variables/explanatory variables since all variables in VAR are treated as endogenous, thereby, reflecting the realities of interdependence (Gamtessa and Olani, 2018; Smagulova et al., 2022; Kelesbayev et al., 2022). This model permits for a much richer data structure that can capture complex dynamic properties in the data. Furthermore, the model is well suited to forecast the effects of specific policy actions or of significant changes in the economy. For Granger causality test, a VAR model was selected rather than a VECM model as the VECM model is only defined when the time-series are cointegrated and when this is the case the series need to be integrated of the same order. Furthermore, a VAR model is preferred rather than using a VECM model for causality testing.

These features make the VAR the ideal choice of methodology to analyse the macroeconomic responses in case countries to RE consumption. The standard VAR model is specified as:

$$Y_t = \Gamma(\mathrm{L})Y_{t-1} + \varepsilon_t$$

where Y_t is a vector of stationary variables {ΔREN, ΔEP, ΔGDP} with ΔREN= renewable consumption; ΔGDP= economic growth as per capita; ΔEP=change in electricity prices and ε_t = vector of error terms.is the lag operator which is calculated below:

$$\Gamma(\mathrm{L}) = \Gamma_1 L^1 + \Gamma_2 L^2 + \ldots + \Gamma_p L^p$$

The model also makes provisions for the error terms and shocks to calculate the impulse response functions (IRF) and the forecast error variance decompositions (FEVD). IRF and FEVD show that the dynamic responses and size of total effect respectively. The estimation of interaction between RE consumption, economic growth and electricity price are based on the IRFs and the FEVDs after estimating the VAR model. The IRFs usually show the effects of shocks on the adjustment path of the variables. The FEVDs measure the contribution of each type of shock to the forecast error variance. Both computations are useful in assessing how shocks to economic variables reverberate through a system.

4. EMPIRICAL RESULTS

All variables were expressed in natural logarithms for estimating the VAR, and logarithmical differences were used because this guarantees all variables are stationary. VAR estimation strategies, which require the model identification by using the stationarity test, lag selection, causal ordering, and restrictions for measuring the impulse response functions and forecast error variance decomposition are presented below.

4.1. Impulse Response Function Analysis

The analyses examined the relationship between renewable energy consumption, economic growth, and electricity price using impulse response function (IRF) methodology. Impulse response functions are only valid if the VAR is stable. Therefore, some steps must be taken to ensure that the VAR is stable while IRFs are used to interpret the results. The IRF demonstrates how a residual shock to one of the innovations in the model affects the contemporaneous and future values of all endogenous variables. Significance was determined by 95% confidence intervals. The error bands were obtained by using a Monte Carlo simulation procedure with 1000 replications. Analytically calculated standard errors were employed to construct confidence intervals that were provided to gauge the significance of each impulse response. The IRF indicates how long, and to what extent, renewable energy consumption reacts to an unanticipated change in income or electricity price.

The IRF table presented in Table 1 shows that renewable energy consumption in case countries responded negatively and significantly to a 10% deviation in economic growth by 0.2% (negatively) in the short run and, 0.06% (positively) in the long run. This indicates that income shocks among other variables affect case countries' renewable energy consumption within the period under consideration. This means that economic growth in the sample countries respond positively and significantly to renewable energy consumption shocks. Furthermore, renewable energy consumption in the case countries responded positively and significantly to a 10% deviation in prices by 0.09% in the short run and, 0.05 (negatively) in the long run.

4.2. Variance Decomposition

This study's analyses applied the advanced generalized forecast error variance decomposition to investigate the relationships among renewable energy consumption, income and electricity price, as well as to gauge the influences of the variables on each other for the short and long run. The variance decomposition reports are presented below in Table 2.

The variance decomposition indicates that in the short run approximately 1.3% of the fluctuations in case study countries' economic growth are explained by a 39% deviation in renewable energy consumption shock. In the long run, in this case, ten years, a 100% deviation in renewable energy consumption shocks accounts for about 7% of the fluctuations in economic growth in case countries' economies. Furthermore, 0.2% of the fluctuations electricity prices are explained by a 2% deviation in renewable energy consumption shock for short run and a 100% deviation for about 5.6% of the fluctuations in electricity prices for the long run. As a result, economic growth significantly affects renewable energy consumption in sample countries both in the short run and long run. Likewise, electricity prices in sample countries are found to have significant effects on renewable energy consumption during the period under consideration. This strand of the result is in line with a priori expectations. This outcome is also consistent with the literature on the relationship between economic growth and renewable energy consumption.

Generally, the present study shows that barring any country level response, changes in renewable energy consumption

Table 1: Impulse response function

Step	RE consumption response to GDP impulse			GDP response to RE consumption impulse		
	IRF	Lower*	Upper*	IRF	Lower*	Upper*
0	0	0	0	0.129837	0.041622	0.218052
1	−0.021632	−0.063027	0.019763	−0.155564	−0.270597	−0.040532
2	0.040584	−0.014034	0.095201	0.013535	−0.107074	0.134145
3	−0.025187	−0.078152	0.027778	0.070993	−0.063262	0.205248
4	0.00415	−0.042702	0.051002	−0.056148	−0.180937	0.06864
5	0.009342	−0.03387	0.052554	0.025267	−0.059429	0.109963
6	−0.016782	−0.053222	0.019658	0.00568	−0.082561	0.093922
7	0.012847	−0.018325	0.044018	−0.026774	−0.10865	0.055103
8	−0.001571	−0.028398	0.025256	0.020374	−0.037378	0.078126
9	−0.006052	−0.029513	0.017408	−0.002498	−0.044919	0.039924
10	0.00697	−0.012225	0.026164	−0.00701	−0.053275	0.039256
Step	**RE consumption response to price impulse**			**Price response to RE consumption impulse**		
	IRF	**Lower***	**Upper***	**IRF**	**Lower***	**Upper***
0	0	0	0	0.000646	−0.030654	0.031946
1	0.00973	−0.041043	0.060504	−0.034834	−0.064462	−0.005206
2	−0.03622	−0.106353	0.033914	0.011393	−0.018633	0.041418
3	0.024402	−0.027108	0.075913	0.017364	−0.013523	0.048251
4	0.004931	−0.030296	0.040159	−0.009334	−0.033847	0.01518
5	−0.016644	−0.051474	0.018186	0.000057	−0.020569	0.020683
6	0.014873	−0.021251	0.050998	0.000853	−0.016769	0.018474
7	−0.006975	−0.034516	0.020566	−0.003537	−0.01881	0.011736
8	−0.003459	−0.02586	0.018943	0.003204	−0.007783	0.014191
9	0.008274	−0.013356	0.029905	0.000627	−0.007485	0.008739
10	−0.00557	−0.022887	0.011747	−0.001856	−0.009575	0.005863

*95% lower and upper bounds. IRF: Impulse response functions, GDP: Gross domestic product

Table 2: Variance decomposition

Step	RE consumption response to GDP impulse			GDP response to RE consumption impulse		
	FEVD	Lower*	Upper*	FEVD	Lower*	Upper*
0	0	0	0	0	0	0
1	0	0	0	0.359297	0.013927	0.704667
2	0.013606	−0.039131	0.066342	0.454295	0.081983	0.826606
3	0.05345	−0.094369	0.20127	0.453227	0.081536	0.824917
4	0.066252	−0.111242	0.243745	0.475294	0.099743	0.850845
5	0.062214	−0.106638	0.231066	0.491207	0.089595	0.892818
6	0.06205	−0.111837	0.235937	0.489189	0.081451	0.896927
7	0.067427	−0.123816	0.258671	0.486876	0.081447	0.892306
8	0.070319	−0.126972	0.267609	0.490213	0.077361	0.903064
9	0.069973	−0.126466	0.266411	0.491456	0.073618	0.909293
10	0.070507	−0.128206	0.26922	0.491059	0.07384	0.908278
Step	**RE consumption response to price impulse**			**Price response to RE consumption impulse**		
	FEVD	**Lower***	**Upper***	**FEVD**	**Lower***	**Upper***
0	0	0	0	0	0	0
1	0	0	0	0.000086	−0.008263	0.008436
2	0.002753	−0.02596	0.031465	0.193485	−0.090817	0.477787
3	0.035547	−0.109357	0.180451	0.190556	−0.076611	0.457722
4	0.048243	−0.13047	0.226955	0.213567	−0.075414	0.502547
5	0.045567	−0.119104	0.210239	0.21828	−0.080995	0.517554
6	0.05008	−0.125819	0.225979	0.216683	−0.082071	0.515436
7	0.054289	−0.13638	0.244959	0.216089	−0.081811	0.513988
8	0.054823	−0.137006	0.246652	0.217155	−0.085225	0.519534
9	0.054766	−0.136561	0.246093	0.218058	−0.086876	0.522992
10	0.056024	−0.13899	0.251038	0.218054	−0.087023	0.523131

*95% lower and upper bounds. IRF: Impulse response functions, FEVD: Forecast error variance decompositions GDP: Gross domestic product

Table 3: Granger causality test

Granger causality wald tests			
Equation	**Excluded**	χ^2	P $>\chi^2$
Turkey			
RE consumption	GDP	11.435	0.022
RE consumption	Electricity price	3.8749	0.423
RE consumption	All	12.801	0.119
GDP	RE consumption	19.495	0.001
GDP	Electricity price	17.067	0.002
GDP	All	27.886	0.000
Electricity price	RE consumption	93.067	0.000
Electricity price	GDP	34.292	0.000
Electricity price	All	109.51	0.000
Kazakhstan			
RE consumption	GDP	47.803	0.000
RE consumption	Electricity price	14.694	0.005
RE consumption	All	49.931	0.000
GDP	RE consumption	24.957	0.000
GDP	Electricity price	20.436	0.000
GDP	All	39.161	0.000
Electricity price	RE consumption	3.5722	0.467
Electricity price	GDP	5.0131	0.286
Electricity price	All	12.546	0.128

GDP: Gross domestic product

are transmitted to sample countries' economies. The claim that macroeconomic activities respond to renewable energy consumption is further confirmed by the VAR Granger causality test in Table 3, which suggests that renewable energy consumption causes economic growth in sample countries. Table 3 shows there was a bidirectional Granger causality running from renewable energy consumption to income and from income to renewable energy consumption for all countries. There are positive relationships between RE consumption and economic growth. The results further demonstrate that economic welfare enhancement translate to more renewable deployment for the sample countries. The level of these impacts in various countries is also different as these countries respond differently to changes in renewable energy consumption.

Although there is no Granger causality from renewable energy consumption to electricity price, there is Granger causality running from electricity price to renewable energy consumption for Turkey. This study found the unidirectional relationship between renewable energy consumption and electricity prices. Similarly, there is unidirectional Granger causality relationship between renewable energy consumption and electricity prices for Kazakhstan. While there is Granger causality for the relationship between renewable energy consumption and electricity prices, there is no Granger causality from electricity price to renewable energy consumption.

5. CONCLUSIONS

Using a conventional vector auto regression methodology, this study examined the dynamic connection between renewable energy use, income, and electricity price for the case study countries. The study makes use of data from Kazakhstan and Turkey. The forecasting in the case study countries was crucial for the completion of the research. In this regard, the goal of this article is to analyse how a growing percentage of renewable sources of power generation affects income and pricing. This study investigated the dynamic relationship between renewable energy use, income, and electricity price for the case study countries using a typical vector auto regression methodology. The study uses information from Turkey and Kazakhstan. For the research to be completed, the forecasting in the case study countries was essential. In this regard, the objective of this article is to examine the impact that a rising share of renewable energy sources has on revenue and cost.

The findings of this study have possible policy ramifications for the example countries since they emphasize the value of expanding the consumption of renewable energy within the case study countries' energy portfolios. Consequently, it appears that a new market in the energy sector is emerging, one that has the potential to significantly alter the current traditional energy markets, if not in the short term, then at least in the medium or long term. Addressing this, it appears from the analysis that the slow growth rates seen in the market for renewable energy in the past are good predictors of the trends that such markets will likewise follow in the future with effective policies. The fact that income variables have a significant impact on the advancement of renewable sources is one of the key policy implications of these findings. Particularly, the development or expansion of investments in renewable energy for the objectives of future development should be the emphasis of the energy and economic policies of the case study countries. This study has demonstrated that the income effect is favorable and that it has policy implications for the nation's economy and politics. These results demonstrate the merits of government policies promoting the use of renewable energy through the implementation of renewable energy markets and renewable energy portfolio standards, not only to improve security and environmental concerns but also from a macroeconomic perspective.

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