Gülsüm Akarsu
Corresponding author

Ondokuz Mayıs University,
Faculty of Economic
and Administrative Sciences,
Kurupelit-Samsun,
Turkey

✉ gulsum.akarsu@omu.edu.tr

Burcu Berke

Niğde Ömer Halisdemir University,
Faculty of Economic
and Administrative Sciences,
Niğde,
Turkey

✉ burcuberke@ohu.edu.tr

Convergence of Electricity Consumption in Turkey: Spatial Panel Data Analysis

Summary: The issue of convergence has been discussed in many theoretical and empirical studies. Because per capita electricity consumption is considered as an indication of economic development, this study aims to determine the presence of "absolute and conditional beta (β) convergence" of per capita total electricity consumption across the provinces of Turkey between 1986 and 2013. This work is the first investigation of electricity consumption convergence in Turkey. Based on the annual balanced panel data and the spatial panel data model, our findings indicate absolute β convergence of per capita electricity consumption across the provinces of Turkey. We conclude that regional policies are successful in reducing regional disparities in per capita electricity consumption among the provinces of Turkey. However, other indicators of economic development should be examined to determine the overall convergence.

Key words: Convergence, Electricity consumption per capita, Spatial panel data model, Turkey.

JEL: C50, Q41, R10.

Similarly to other developing countries, Turkey has experienced regional disparities in electricity consumption resulting from differences in the population density and in the level and composition of regional economic activity, despite the implementation of regional development policies and projects to diminish regional differences (Gülsüm Akarsu 2017).

The main aim of this study is to determine the presence of absolute and conditional *β* convergence of *per capita* electricity consumption across the provinces of Turkey between 1986 and 2013 by applying a spatial panel data model. One of the fundamental issues in economics is whether there is a difference in *per capita* income between countries and regions (Paul Cashin and Ratna Sahay 1996). The concept of convergence has been widely discussed in the literature on growth and has gradually been extended to the literature on energy (Brantley Liddle 2009). Because *per capita* electricity consumption is regarded as an indicator of economic development, it is important to analyze the regional disparities related to electricity demand and, subsequently, the existence of convergence across regions in relation to electricity consumption. The current studies in the literature focus mostly on the convergence of electricity consumption across countries rather than within a country. However, across countries,

there are many factors that can mislead to evidence of convergence, such as the implementation of energy-efficient technologies in high-income countries and the continued application of inefficient technologies in low-income countries. On the other hand, a higher rate of technology spillover can be expected within a country compared with that across countries. In addition, some studies, such as Harald Badinger, Werner Müller, and Gabriele Tondl (2004), incorporate a spatial dimension into the convergence analysis. Discarding space from regional convergence can produce biased results. Therefore, this study uses spatial panel data techniques.

The paper is organized as follows. After this brief introduction, the development of the concept of convergence is discussed in Section 1, and the literature on convergence of electricity consumption is reviewed in Section 2. In Section 3, the models used to test the convergence hypotheses in the analysis are introduced. In Section 4, spatial panel data analysis is applied to determine whether there is evidence of convergence in electricity consumption across the provinces of Turkey in the period of 1986-2013. The last section provides a summary of the findings, presents the conclusion, and provides policy recommendations related to the demand side of the electricity sector.

1. Concept of Convergence

As discussed by William J. Baumol (1986), Robert J. Barro and Xavier Sala-i-Martin (1991) and N. Gregory Mankiw, David Romer, and David N. Weil (1992), based on certain assumptions (e.g., diminishing marginal returns to capital, common consumption, and saving behavior), the *per capita* incomes of non-developed and developed countries gradually converge to the same steady-state level (Cashin and Sahay 1996). The concept of conditional convergence (Barro and Sala-i-Martin 1992; Mankiw, Romer, and Weil 1992) based on the neoclassical growth theory (assumptions of the model of Robert M. Solow (1956), such as diminishing returns to capital and exogenous technological development) argues that, controlling for the initial factor levels, the *per capita* income of non-developed countries will, over time, reach the level of and grow faster than wealthy countries.

In the literature, Oded Galor (1996) discussed three major convergence hypotheses: absolute (unconditional), conditional, and convergence clubs. Whereas absolute convergence is the convergence of income *per capita* in the economy toward a steady state, this form of convergence is described as conditional if it is dependent on other factors. In other words, steady-state convergence still emerges but not necessarily at the same long-term levels; instead, it is linked to the unique characteristics (e.g., factor intensity or institutions) of each country. On the other hand, convergence clubs emerge from the presence of multiple and locally stable steady-state balance and thus refers to the convergence of economies with similar characteristics (Philippe Monfort 2008; M. Simona Andreano, Lucio Laureti, and Paolo Postiglione 2013).

The rate of convergence is defined as the difference between the *per capita* income of countries and their steady-state values. Barro and Sala-i-Martin (1991) focused on the concepts of β and sigma (σ) convergence, arguing that β convergence means: "non-developed regions are more inclined to achieve greater growth rates and that there is a negative relation between growth rates and initial income levels" (Barro

and Sala-i-Martin 1991). On the other hand, σ convergence refers to a decrease in the dispersion of regional *per capita* income over time (Efthymios G. Tsionas 2010).

Therefore, there are two types of convergence: β and σ. The first denotes that non-developed countries grow faster than developed countries, and the second analyzes the distribution behavior of income *per capita* over a period of time (Barro and Sala-i-Martin 1991). In other words, whereas β convergence indicates the convergence of relatively non-developed regions with higher growth rates, σ convergence emphasizes that the dispersion of regional income *per capita* decreases over a period of time (Tsionas 2010). β convergence is more popular because σ convergence is criticized for disregarding the geographical aspect of such dispersions. In addition, the β convergence approach is more convincing because of its ability to theoretically determine the speed of convergence (Sergio J. Rey and Mark V. Janikas 2005; Andreano, Laureti, and Postiglione 2013).

Two different concepts related to β convergence are proposed: absolute and conditional β convergence. Under the assumption of diminishing returns, Solow (1956) showed that non-developed countries have higher growth rates and reach the levels of prosperous economies in terms of income and/or income *per capita*. Independent of initial conditions, for all economies converging toward a steady state *per capita* income and growth rates correspond to the absolute version of β convergence. On the other hand, *per capita* income varies from economy to economy and can change in response to long-term determinants, such as factor intensity (e.g., physical capital, human capital, social capital, energy, materials, and labor endowments) or institutions. According to conditional β convergence, independent of the initial conditions, countries with similar structural characteristics converge toward one another (Monfort 2008).

These convergences are macro in nature and explain how income *per capita* converges and diverges across economies. This type of convergence has three basic sources: spillover of technology, the neoclassical growth model, and globalization (Farhad Rassekh 1998).

In terms of technology, some economists advocate convergence, and others support divergence. For example, whereas Thorstein Veblen (1915) argued that the transfer of technology from developed to non-developed economies contributes to convergence, Alexander Gerschenkron (1952) and Moses Abramovitz (1986) suggested that a reverse technology transfer contributes to faster growth. On the other hand, Baumol (1994) stated that technological development provides countries with external profits (Rassekh 1998).

In the scope of the neoclassical growth model, economies eventually converge to a stable value (steady-state balance) with regard to income *per capita*. However, the marginal efficiency of the capital is high when the capital/labor ratio is low compared with the steady-state capital/labor ratio of the economy at the beginning of the period. Economies such as these grow faster than others (Solow 1956). On the other hand, the convergence resulting from globalization indicates that the role of foreign trade in the convergence process should be examined. Although there are different views on this issue (Matthew J. Slaughter 1997), foreign trade facilitates the convergence of income *per capita* levels of countries (Dan Ben-David 1996).

Barro and Sala-i-Martin (1992) used the following model to measure absolute β convergence:

$$g_i = \alpha + \beta q_i + \varepsilon_i, \qquad (1)$$

where g_i is the average growth rate of the *per capita* GDP for country i; α is a constant term; $q_i = ln(y_{i0})$ is the logarithm of the initial *per capita* GDP; $\beta = -(1 - e^{-\lambda t})/T$; λ is the convergence coefficient; T is the time interval; ε is an error term.

If a statistically significant negative relationship exists between the growth rate of the *per capita* GDP and its initial level, then, β is negative and significantly different from zero; this is referred to as absolute β convergence. However, this convergence is not complete because it disregards other variables. This is where conditional convergence, which includes other explanatory variables, becomes important (Andreano, Laureti, and Postiglione 2013). The following equation is used in convergence studies:

$$\Delta \ln(y_{i,t}) = \alpha + \beta \ln(y_{i,t-1}) + \gamma Z_{i,t} + u_{i,t}, \qquad (2)$$

where $\Delta \ln(y_{i,t})$ is the *per capita* GDP growth rate in region i at time t; $Z_{i,t}$ refers to all other factors affecting the growth rate; u is an error term. According to this equation, if the β coefficient, which represents the relationship between the growth rate and the level of initial income *per capita* $\ln(y_{i,t-1})$, is negative and statistically significant, then convergence exists. If the γ value is limited to zero, then there is absolute convergence. However, the presence of conditional convergence can be claimed if the value is not statistically zero (Monfort 2008).

2. Literature Review on Convergence of Electricity Consumption

Initial studies in the literature on energy focused on the estimation of electricity demand and the causality between energy or electricity consumption and growth.

Whereas several studies have examined electricity demand and the relationship between energy consumption and growth, the convergence of energy and electricity consumption is rarely addressed (Hassan Mohammadi and Rati Ram 2012). Compared with electricity consumption, the literature on convergence related to energy and the environment is slightly more developed. For example, the convergence of carbon dioxide emissions (Joseph Aldy 2006; Roberto Ezcurra 2007b) and the convergence of energy intensity have been investigated (Anil Markandya, Suzette Pedroso-Galinato, and Dalia Streimikiene 2006; Ezcurra 2007a; Ming Meng, James E. Payne, and Junsoo Lee 2013). Among these studies, Meng, Payne, and Lee (2013) found significant convergence of *per capita* energy consumption across 25 OECD countries.

Whereas convergence analysis shows that the basic variable of economic development is income *per capita*, electricity consumption *per capita* is an alternative indicator of prosperity (Adolfo Maza and Jos Villaverde 2008). The convergence of electricity consumption in this context has been investigated (Maza and Villaverde 2008; Liddle 2009; Mohammadi and Ram 2012; Surender Kumar 2014; Young Se Kim 2015; Lei Zhang et al. 2016; Djula Borozan 2017). In the growth literature, convergence is related to "whether non-developed or developing countries have caught up with developed countries in terms of *per capita* income"; however, in the energy

literature, studies investigate "whether *per capita* electricity consumption is converging between countries or regions" (Maza and Villaverde 2008).

Maza and Villaverde (2008) carried out initial β and σ convergence analyses of location-based electricity consumption and found strong evidence of β convergence of electricity consumption. However, they also stated that the differences between countries are permanent in the long-term. Liddle (2009) tested the convergence of electricity intensity and examined the convergence of electricity consumption at both the aggregate level and by sector (production, commercial, and residential); the findings indicated that the convergence rate differs among the three sectors and that the convergence rate of electricity intensity in residential and commercial sectors is higher. Mohammadi and Ram (2012) analyzed the convergence of *per capita* energy and electricity consumption. On a global scale, they found that when energy consumption convergence is weak, convergence in electricity consumption is stronger. In contrast to previous studies, Kim (2015) analyzed the convergence of both electricity intensity and *per capita* electricity consumption, as well as the relationship between convergence of *per capita* electricity consumption and convergence of *per capita* income by considering country heterogeneity and examining the presence of club convergence. The findings showed overall convergence of electricity intensity and club convergence of *per capita* electricity consumption. Kim (2015) also reported similar clustering patterns for *per capita* income and electricity consumption.

Some studies have also been done at the regional level. Kumar (2014) showed evidence of β and σ convergence across the Indian states in the period between 1990 and 2012. In this study, urbanization, literacy rate, and industrialization level were used as control variables. Moreover, Kumar (2014) examined the impacts of income and electricity consumption disparities on electricity consumption growth and found significant effects for some of the states studied. Zhang et al. (2016) also investigated the presence of convergence in Chinese provinces from 2000 to 2014 by using a spatial panel data model; conditional β convergence was found for both *per capita* GDP and *per capita* electricity consumption. Another regional study, Borozan (2017), used panel unit root tests to examine the hypothesis of *per capita* electricity consumption convergence, considering sectoral disaggregation, across Croatian regions over the period 2001 to 2013. Different results were obtained for different sectors and with use of different panel unit root tests. Most of the studies in the literature analyzed the electricity consumption convergence across countries. The present work aims to investigate the presence of convergence across the provinces of Turkey, i.e., within the borders of a country.

3. Empirical Approach

3.1 Model

The analysis uses two different models to test for the existence of β convergence. The model of Maza and Villaverde (2008) is first applied:

$$\Delta lnE_{i,t} = \delta_i + \beta lnE_{i,t-1} + \varepsilon_{i,t}, \tag{3}$$

where $\Delta lnE_{i,t}$ is the growth of the *per capita* electricity consumption in year t and province i; $lnE_{i,t-1}$ is the natural logarithm of the *per capita* electricity consumption in the previous year; δ_i is the constant effect of province I; ε is an error term. As explained in the section on convergence, absolute convergence requires the β coefficient to be both negative and significant (Maza and Villaverde 2008). As indicated, unconditional or absolute β convergence is present when only the initial value of variable exists in the model. However, it is possible to test for conditional convergence if other variables have been included in the model. Because countries or regions can converge toward different values in energy or electricity consumption, conditional convergence is difficult to explain. In other words, it is difficult to choose conditional variables that affect the change in energy or electricity consumption (Mohammadi and Ram 2012). The literature uses the urbanization ratio, which can be calculated as the ratio of the urban population to the total population, as a structural factor that affects electricity consumption (Asami Miketa and Peter Mulder 2005). By including this variable, the model can be rewritten as follows:

$$\Delta lnE_{i,t} = \delta_i + \beta lnE_{i,t-1} + \phi URB_{i,t} + \varepsilon_{i,t}. \tag{4}$$

The coefficient of the urbanization ratio (ϕ) is expected to be positive, indicating that urbanization increases electricity consumption growth (Mohammadi and Ram 2012) by ensuring better access to electricity and electrical appliances, as previously stated in Pernille Holtedahl and Frederick L. Joutz (2004) and Rigoberto Ariel Yépez-García, Todd M. Johnson, and Luis Alberto Andrés (2011).

3.2 Methodology

In recent years, the role of space in regional convergence has emerged as an alternative to cross-section and panel data analyses (Rey and Janikas 2005). For instance, some studies, such as Badinger, Müller, and Tondl (2004), incorporate a spatial dimension into the convergence analysis. Disregarding space in convergence analysis can lead to misleading results (Badinger, Müller, and Tondl 2004) because regional data require the consideration of spatial dependency, and regional differences require the existence of spatial heterogeneity (Monfort 2008). As indicated by Jihai Yu and Lung-Fei Lee (2012), the assumption of independent economies, i.e., closed economies in the neoclassical growth theory, leads to invalid inferences resulting from the technological spillover across the regions that cause spatial dependency. Because of the socioeconomic interactions (e.g., migration or labor movements) among regions and the spillover of policy measures and technology across regions, these spatial interactions are also expected to have significant effects on the electricity consumption through different channels, for example, social learning. Thus, a model that accounts for these interactions is needed. Akarsu (2017) provided a detailed explanation for why the spatial dependency should be considered in analyzing the electricity consumption in Turkey at the regional level. Thus, the following spatial Durbin panel data models (SDM) are used to allow for two types of spatial effects in our study: endogenous interaction effects ($\rho W \Delta lnE_{i,t}$) and exogenous interaction effects ($\theta W lnE_{i,t-1}, \xi W URB_{i,t}$) in our study:

$$\Delta lnE_{i,t} = \rho W \Delta lnE_{i,t} + \delta lnE_{i,t-1} + \theta W lnE_{i,t-1} + \mu_i + \varepsilon_{i,t}, \tag{5}$$

$$\Delta lnE_{i,t} = \rho W \Delta lnE_{i,t} + \delta lnE_{i,t-1} + \phi URB_{i,t} + \theta W lnE_{i,t-1} + \xi W URB_{i,t} + \mu_i + \varepsilon_{i,t}, \tag{6}$$

where $i = 1,\ldots, N$ and $t = 1,\ldots, T$ are subscripts for provinces and time periods; $\Delta lnE_{i,t}$, $lnE_{i,t-1}$, $URB_{i,t}$ and $\varepsilon_{i,t}$ are the growth of the *per capita* electricity consumption in year t and province i, the logarithm of the *per capita* electricity consumption in the previous year (t-1), the urbanization ratio of province i in year t, and an error term, respectively; μ_i and ρ are province-specific fixed effects and the spatial lag coefficient, respectively. In the models given in Equations (5) and (6), by including the endogenous interaction effects, one allows for the dependence of the *per capita* electricity consumption growth of province i on that of province j. On the other hand, exogenous interaction effects capture the dependency of the *per capita* electricity consumption growth of province i on the urbanization ratio and the previous year logarithm of the *per capita* electricity consumption of region j. The convergence rate β is obtained by using the expression: $\delta = -(1 - e^{-\beta})$. W denotes the $N \times N$ spatial weight matrix, which is assumed to be constant over time. For the robustness check, we apply the following weight matrices: the binary (queen) contiguity weight matrix, in which the off-diagonal elements take the value of one if the two provinces share a common border and zero otherwise; weight matrices based on the nearest 2, 3, and 4 neighbors; the weight matrix, which is based on power distance weights given by ($w_{ij} = d_{ij}^{-1}$), where d_{ij} is the distance between the ith and j^{th} provinces. The maximum likelihood (MLH) estimation method is used. To correct for the bias in the parameter estimates, the procedure proposed by Lee and Yu (2010) is applied. Detailed information on the estimation and model selection procedure is provided in J. Paul Elhorst (2014). The models given in Equations (5) and (6) are simplified to the spatial lag model (SAR) and spatial error model (SEM) by imposing the following restrictions: H_{01} and H_{02} for Equation (5), and H_{03} and H_{04} for Equation (6):

$$\begin{aligned} &H_{01}: \theta = 0; \\ &H_{02}: \theta + \rho \times \delta = 0. \end{aligned} \tag{7}$$

$$\begin{aligned} &H_{03}: \theta = 0 \text{ and } \xi = 0; \\ &H_{04}: \theta + \rho \times \delta = 0 \text{ and } \xi + \rho \times \phi = 0. \end{aligned} \tag{8}$$

These hypotheses were tested by using the likelihood ratio (LR) and Wald tests. If both hypotheses are rejected, then the analysis is continued by using SDM. To select between the SAR and SEM models, LM tests developed by Luc Anselin (1988) and robust LM tests proposed by Anselin et al. (1996) are applied. Finally, according to the arguments proposed by James LeSage and Robert Kelley Pace (2009), to obtain the marginal effects of the factors, the direct and indirect (spillover) effects of the exogenous variables are calculated.

4. Data and Empirical Results

4.1 Data

This study used annual balanced panel data on the provinces of Turkey over the period 1986 to 2013. The data set includes only total electricity consumption, population, and urban population based on the available information at the provincial level for the period. The data on total electricity consumption (measured in MWh) are obtained from the Electricity Distribution Company of Turkey (TEDAŞ 2015)[1]; the data on population and urban population are from the Statistical Institution of Turkey (TURKSTAT 2015)[2] database. The data are rearranged before the analysis. The gaps in total and urban population are interpolated. After 1989, new provinces emerged because some towns gained provincial status; thus, the data values of these new provinces are added to those of the provinces with which they were previously affiliated. Therefore, the data include observations on 65 provinces over 27 years (Table 1). The urbanization ratio (*URB*) is calculated as the ratio of the urban population to the total population, and the *per capita* electricity consumption is obtained based on the population data of each province over time. The natural logarithm of *per capita* electricity consumption (*lnE*) is taken, and the growth of *per capita* electricity consumption is obtained by taking the first difference of lnE, ΔlnE.

Tables 1 and 2 present the descriptive statistics and pairwise correlations for all variables. The pairwise correlations between the explanatory variables in the model are close to 0.5, indicating that there is no problem of high collinearity.

Table 1 Summary Statistics (Total Number of Observations: 1755 with *N* = 65, *T* = 27)

Variable		Mean	SD	Min	Max
ΔlnE	Overall	0.06417	0.103331	-0.5413	0.651605
	Between		0.017013	0.035704	0.108213
	Within		0.101942	-0.51974	0.677715
lnE_{-1}	Overall	-0.10644	0.856232	-2.85703	2.147630
	Between		0.670962	-1.51146	1.492351
	Within		0.538161	-1.52558	1.418875
URB	Overall	0.562104	0.146706	0.245093	1
	Between		0.119774	0.324509	0.925841
	Within		0.085962	0.346805	1.166589

Notes: Within (between) variation can be defined as variation over time (across provinces). Overall variance is decomposed as within and between variance. SD is the abbreviation for standard deviation. The minimum and maximum values for the panel data are given for overall (x_{it}), between ($\bar{x}_i$) and within ($x_{it} - \bar{x}_i + \bar{x}$). *N* shows the number of provinces. *T* is the time series dimension for each province. Calculations are done by using STATA 11.

Source: Authors' calculations.

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[1] **Turkey Electricity Distribution Company (TEDAŞ).** 2015. https://www.tedas.gov.tr/ (accessed June 29, 2015).

[2] **Statistical Institution of Turkey (TURKSTAT).** 2015. Regional Statistics. https://biruni.tuik.gov.tr/bolgeselistatistik/sorguSayfa.do?target=tablo (accessed June 29, 2015).

Table 2   Correlation Matrix

Variable	ΔlnE	lnE_{-1}	URB
ΔlnE	1		
lnE_{-1}	-0.1675	1	
URB	-0.1300	0.5960	1

Notes: Calculations are done by using STATA 11.

Source: Authors' calculations.

Figure 1 shows the regional differences in the growth rate of the *per capita* electricity consumption at the provincial level in Turkey in the chosen years between 1987 and 2013; the darker areas indicate higher growth rates. As shown in the figure, neighboring provinces have similar *per capita* electricity consumption growth rates in each year, indicating spatial interdependence resulting from the socioeconomic interactions among the provinces. In Table 3, the Moran's I statistics for the given years are calculated by using the binary contiguity (queen) weight matrix. According to the results, although there is no evidence of spatial dependency before 2010, the statistics show that there are highly significant spatial interactions among the provinces in the electricity consumption growth of Turkey. In the next section, these spatial effects are considered in the analysis.
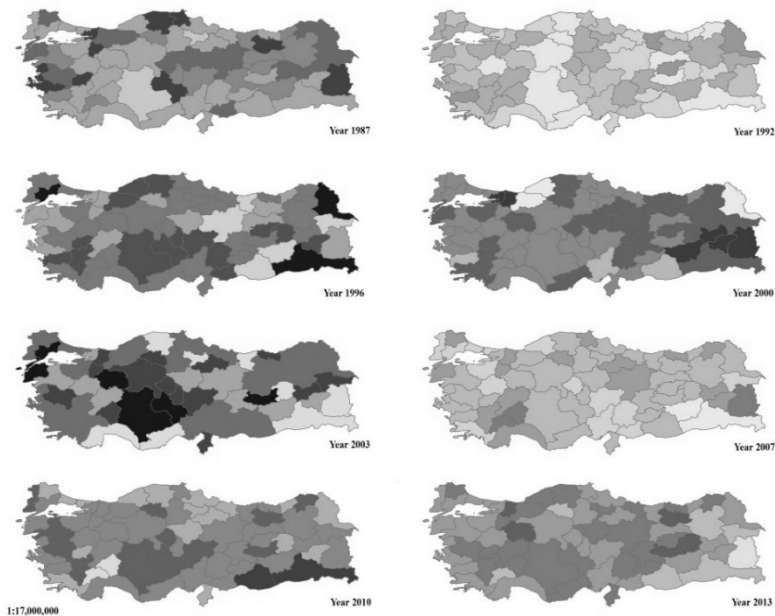
Source: Elaborated by authors based on data obtained from TEDAŞ (2015) and TURKSTAT(2015).

Figure 1   Regional per capita Electricity Consumption Growth at NUTS-3 Level for Turkey

Table 3 Moran's I Statistics for per capita Electricity Consumption Growth

Year	Moran's I	E(I)	SD(I)	z-value	p-value
1987	0.0196	-0.0156	0.0775	0.4574	0.312540
1992	-0.0892	-0.0156	0.0783	-0.9389	0.175590
1996	-0.0314	-0.0156	0.0761	-0.2092	0.431770
2000	0.0853	-0.0156	0.0784	1.3504	0.095360
2003	-0.0332	-0.0156	0.0755	-0.2335	0.420860
2007	-0.0152	-0.0156	0.0572	-0.2834	0.383350
2010	0.0924	-0.0156	0.0712	1.5188	0.064640
2013	0.1871	-0.0156	0.0738	2.7432	0.006660

Notes: Calculations are done by using GeoDa.

4.2 Empirical Results

In this section, the existence of conditional and absolute β convergence is analyzed by applying the models presented in Section 3.2. To test the absolute convergence hypothesis, the model is first analyzed, excluding the urbanization ratio and by using Equation (5). Then, the model is estimated, including the urbanization ratio as an explanatory variable. To determine the existence and types of spatial interaction effects, LM and robust LM tests are carried out. Table 4 shows the results.

Table 4 LM Test and Estimation Results for the Model without Spatial Effects Considering Different Types of Fixed Effects

Variables	Pooled OLS	Province FE	Province and time-period FE	Pooled OLS	Province FE	Province and time-period FE
lnE_{-1}	-0.020***	-0.036***	-0.158***	-0.017***	-0.047***	-0.157***
	(-7.1141)	(-8.0481)	(-13.018)	(-4.762)	(-6.496)	(-12.969)
URB				-0.033	0.091**	-0.061
				(-1.599)	(2.002)	(-1.152)
Intercept	0.062***			0.081***		
	(25.3018)			(6.6995)		
σ^2	0.0104	0.0100	0.0085	0.01040	0.01000	0.00850
R^2	0.0281	0.0614	0.1994	0.02950	0.06350	0.20000
LL	1520	1550	1690	1520	1551.40	1689.70
LM-SAR	65.107***	63.732***	1.771	63.591***	66.783***	1.822
	[0.000]	[0.000]	[0.183]	[0.000]	[0.000]	[0.177]
Robust LM-SAR	17.069***	90.561***	1.237	15.676***	88.581***	0.675
	[0.000]	[0.000]	[0.266]	[0.000]	[0.000]	[0.411]
LM-SEM	77.268***	86.776***	2.632	75.451***	91.424***	2.4632
	[0.000]	[0.000]	[0.105]	[0.000]	[0.000]	[0.117]
Robust LM-SEM	29.230***	113.61***	2.098	27.536***	113.22***	1.3167
	[0.000]	[0.000]	[0.147]	[0.000]	[0.000]	[0.251]

Notes: Estimations are done by using the MATLAB codes provided by Professor Elhorst. *, **, *** indicate the statistical significance of the test statistic at 10%, 5% and 1% significance levels. t values are given in parentheses. p-values are given in square brackets.

The estimations associated with the weight matrix based on power distance weights result in higher maximized log-likelihood values and lower residual variance estimates. Table 4 shows only the test results obtained by using this weight matrix. In Table 4, the estimation results are also presented, considering the different types of fixed effects and ignoring any spatial interaction effects. Estimations are done by using the OLS estimation method. The test results differ by the type of fixed effect. Tests based on the panel data model with province and time period fixed effects show no evidence of spatial effects. This model corresponds to a SEM with a spatial weight matrix that has the elements of ($1/N$) and includes the diagonals. For the other cases, the tests indicate that there are spatial effects. However, we cannot decide between the two models based on these tests; therefore, the type of interaction effects needs to be considered.

Table 5 Wald and LR Test Results for the Model Selection

Hypothesis	Model	Wald tests	LR tests
H_{01}: $\theta = 0$	SAR	115.7234*** [0.000]	116.7131*** [0.000]
H_{02}: $\theta + \rho \times \delta = 0$	SEM	71.4589*** [0.000]	90.4510*** [0.000]
H_{03}: $\theta = 0$ and $\xi = 0$	SAR	111.7333*** [0.000]	112.9115*** [0.003]
H_{04}: $\theta + \rho \times \delta = 0$ and $\xi + \rho \times \phi = 0$	SEM	70.4763*** [0.000]	86.6643*** [0.000]

Notes: Estimations are done by using the MATLAB codes provided by Professor Elhorst. *, **, *** indicate the statistical significance of the test statistic at 10%, 5% and 1% significance levels. *p*-values are given in square brackets.

Source: Authors' calculations.

Furthermore, for the model selection, the spatial Durbin panel data model with province fixed effects is estimated by using the MLH estimation method to simultaneously account for heterogeneity across provinces and spatial interactions. Wald and LR tests are done to test the restrictions given in Equations (7) and (8). Table 5 presents the test results for both models in Equations (5) and (6). The results indicate that the spatial Durbin panel data model cannot be reduced to the SAR or SEM models. For comparison, the estimation results of the SDM, SAR, and SEM models are presented in Table 6. In the SDM and SAR models, the coefficient estimates contain feedback effects. Therefore, there is a need to distinguish between direct and indirect (spillover) effects, as shown in Table 6.

The findings support the evidence of absolute *β* convergence in *per capita* electricity consumption across provinces. Convergence rates of 0.17, 0.16, 0.06, and 0.018 are obtained from the estimations of the panel data model with province and time period fixed effects, SDM, SEM, and SAR model, respectively. For comparison, the results of the panel data model with province and time period fixed effects are included. As previously mentioned, this model corresponds to a SEM model with a spatial weight matrix that has the elements of ($1/N$), including the diagonals.

Table 6 Estimation Results for the Model with Province Fixed Effects and Direct and Indirect Effects

Variables	SDM	SAR	SEM	SDM	SAR	SEM
$W\Delta lnE_{i,t}$	0.34***	0.29***		0.33***	0.29***	
	(8.34)	(6.79)		(8.14)	(7.09)	
lnE_{-1}	-0.15***	-0.03***	-0.06***	-0.15***	-0.05***	-0.07***
	(-12.58)	(-6.48)	(-8.71)	(-12.33)	(-6.09)	(-8.34)
URB				-0.03	0.12**	0.13***
				(-0.52)	(2.56)	(2.56)
$WlnE_{-1}$	0.137***			0.15***		
	(10.74)			(9.19)		
W*URB				-0.11		
				(-1.09)		
$W\varepsilon$			0.38***			0.38***
			(9.49)			(9.49)
lnE_{-1}-DE	-0.15***	-0.02***		-0.15***	-0.03***	
	(-12.09)	(-6.19)		(-12.56)	(-8.48)	
lnE_{-1}-IE	0.12***	-0.03***		0.15***	-0.01***	
	(9.46)	(-5.63)		(7.41)	(-5.69)	
lnE_{-1}-TE	-0.02***	-0.05***		0.004	-0.04***	
	(-3.66)	(-6.22)		(0.22)	(-8.91)	
URB-DE				-0.03	0.07***	
				(-0.64)	(11.91)	
URB-IE				-0.17	0.03***	
				(-1.33)	(7.51)	
URB-TE				-0.20	0.10***	
				(-1.66)	(16.46)	
σ^2	0.0093	0.0100	0.0094	0.0093	0.0100	0.0094
R^2	0.1590	0.0971	0.0504	0.1599	0.1012	0.0544
LL	1631.9	1573.6	1586.7	1633.4	1576.9	1590.1

Notes: Estimations are done by using the MATLAB codes provided by Professor Elhorst. *, **, *** indicate the statistical significance of the test statistic at 10%, 5%, and 1% significance levels. *t* values are given in parentheses. DE - direct effect; IE - indirect effect; TE - total effects; LL - log-likelihood.

Source: Authors' calculations.

Next, the model is estimated by including the urbanization ratio as an explanatory variable. However, because this model tests for the conditional convergence hypothesis, the estimation results show that different conclusions are obtained from different models. These indicate that the urbanization ratio has a statistically significant and positive effect on the electricity consumption growth based on the estimation results of SEM and SAR model; however, the urbanization ratio has an insignificant effect based on SDM estimation. The negative coefficients on the lagged logarithm of the *per capita* electricity consumption indicate that there is conditional convergence of the *per capita* electricity consumption across the provinces for the SEM and SAR model. The convergence rates obtained from estimations of the SEM and SAR model are 0.07 and 0.025, respectively, which are higher than those for the absolute β convergence based on the same models. In conclusion, based on the model selection procedure, the results favor SDM. The findings obtained by using SDM show only evidence of absolute β convergence of *per capita* electricity consumption. The annual

convergence rate is found to be 0.16, which shows that it takes 4.33 years to eliminate one half of the initial gap in *per capita* electricity consumption.

5. Conclusion

The determinants of energy consumption and the causal relationship between energy consumption and growth are heavily represented in the literature. However, the convergence of carbon dioxide emissions and energy and electricity intensities are rarely considered (Mohammadi and Ram 2012). To the best of our knowledge, this is the first study to examine the convergence of *per capita* electricity consumption in Turkey by using spatial econometric techniques.

In summary, the present work investigates the existence of absolute and conditional convergence in the *per capita* electricity consumption of Turkey by using spatial panel data models and panel data on the provinces of Turkey during the period 1986 to 2013. As the role of space is very essential in regional growth analysis, spatial econometrics is applied to consider the impacts of proximity to neighboring regions and other dependencies (Monfort 2008). The urbanization ratio is included as an explanatory factor for regional differences in electricity consumption growth. The results show that different conclusions are reached based on the model applied to determine conditional convergence. Previous studies have also found evidence of conditional convergence at the regional level in different countries by using different methods (e.g., Kumar 2014; Zhang et al. 2016). Regarding absolute convergence, the estimation results obtained from the different models show the existence of absolute β convergence (decreased differences in *per capita* electricity consumption) across the provinces; however, the convergence rates differ based on the model applied. Overall, regional policies are successful in decreasing regional disparities in *per capita* electricity consumption. However, in future studies, other indicators of development can be analyzed. Further, similarly to Borozan (2017), the electricity consumption can be disaggregated into industrial and residential consumption, which can show different patterns across regions.

In terms of policy implications, developing countries, such as Turkey, experience rapid economic changes. On a global scale, the energy policies of developed countries implemented after the first oil shock aim to increase efficiency, i.e., by reducing the intensity of electrical energy. In Turkey, policy makers should focus on introducing regulations aimed at changing electricity consumption habits, subsidizing those that apply efficient technologies and continuing the auto-production of electricity based on renewables, particularly in regions with high consumption levels, to decrease the environmental degradation and external dependency on fossil fuels resulting from the use of imported coal, natural gas, and petroleum-based energy sources.

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