Analysis of regional electricity demand for Turkey

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ABSTRACT
Electricity sectors have experienced a transformation towards more liberalized and decentralized structure since the 1980s. This transformation process increases the importance of regional-level analysis. This study analyses the factors affecting regional electricity demand. As a case study, analysis is performed for Turkey by employing a dynamic spatial lag panel data model. The model allows for the inclusion of spatial interaction effects into the analysis which are important but mostly ignored in the literature. Findings show evidence of spatial spillover effects. Therefore, the paper concludes that one should consider spatial spillover effects of economic factors and regional energy policies.

INTRODUCTION
Various factors are driving increasing electricity demand globally, including economic growth, population increase, industrialization, urbanization and improvement in living standards. Between 1971 and 2013, world per capita electricity consumption increased from approximately 1200 to 3104 kWh/capita, an average annual rate of 2.3% (The World Bank, World Development Indicators, 2016).

Some countries have undergone a parallel set of liberalization and technology development processes including improvement of distributed generation technologies mostly based on renewable energy resources. This can lead to decentralization of electricity-generation activities which in turn increases the importance of regional-level analysis and planning for the energy sector (Cormio, Dicorato, Minoia, & Trovato, 2003). From the 1960s, governmental development plans have sought to promote regional development and reduce regional disparities. As energy plays a key role in a region's development process there have also been region-specific policies and support programmes that have affected regional electricity provision, for example, special incentives for regions with priority for development. Regional-level analysis is also important for the effectiveness of these regional policies and support programmes.

In contrast to previous studies using regional-level data for total electricity demand analysis (e.g., Atakhanova & Howie, 2007; Diabi, 1998; Hsiao, Mountain, Chan, & Tsui, 1989), this study...
considers spatial interdependencies among provinces and regions resulting from socio-economic
relations, such as relocation of economic activity or migration, and spillover effects of policy
measures by using a spatial panel data model (Blázquez Gomez, Filippini, & Heimsch, 2013). Because some socio-economic factors (such as living standards of households and social norms) within individual regions, and particular policies implemented in particular regions can also affect nearby regions by spatial interactions. An illustration of this is a policy leading to an increase
in the adoption of new energy-efficient appliances in one region also causing an increase in the
adoption of these appliances in neighbouring regions through learning from success, peer effects
or imitating neighbours (Blázquez Gomez et al., 2013).

This paper addresses the following two questions: What are the factors affecting regional
electricity demand? Do spatial interactions play an important role in determining the electricity
consumption of a region? It presents findings from Turkey’s electricity market, which has under-
gone substantial liberalization since 1980, although as of 2016 it remains in transition towards
full liberalization. The study analyses factors determining regional electricity demand for Turkey
using panel data and considering regional heterogeneity, i.e., differences among regions. This
analysis is important for producing future energy policies, determining future energy requirements
and investments, and regulating the activities in the sector. The results demonstrate that different
factors become important based on the regional level and period under investigation. More
generally, this study found income, electricity price, urbanization ratio and cooling requirements
as important factors in addition to their spatial spillover effects.

PREVIOUS ELECTRICITY DEMAND STUDIES

In industrialized societies, as households and firms demand electricity for lighting, cooling, pro-
duction of goods and services, and other needs provided only through the use of electrical devices,
one needs to distinguish between short- and long-run effects of factors determining electricity
demand by employing a dynamic model. In the short run, size of stock and the efficiency of
electrical devices are fixed, but in the long run, they can change as a result of economic and
 technological developments. Since Houthakker’s (1951) pioneering work, many studies have
focused on electricity demand estimation. For total electricity demand analysis, among studies
employing regional-level data, only Ohtsuka, Oga, and Kakamu (2010) and Ohtsuka and Kakamu
(2013) include spatial effects in their analysis; however, they only forecast electricity demand by
employing a spatial autoregressive-ARMA model without considering other factors. For Turkey,
Sözen, Çakir, and Yucesu (2010) and Yaylaci, Ismaila, Uşkay, and Düzgün (2011) analyse spatial
effects in energy indicators, but not in the context of an economic model which enables the
examination of various factors’ effects. In addition, other studies using economic models mostly
employ time-series data.¹

Unlike the previous literature, this study uses panel data while incorporating economic fac-
tors, spatial interaction effects and regional heterogeneity into the analysis of electricity demand
for Turkey. Therefore, this study starts the analysis by employing the following dynamic spatial
Durbin panel data (DSDPD) model to distinguish between short- and long-run effects and to
obtain direct and indirect (spillover) effects of economic factors determined based on economic
theory and the previous literature:

\[
\ln pcec = \alpha_1 \ln ppee + \alpha_2 \ln ppee_{-1} + \alpha_3 \ln ppee_{-1} + X_\alpha_4 + WX_\alpha_5 + D_\mu + \mu + \epsilon
\]

(1)

where \(X = (\ln pcegdp, \ln rep, uratio, hdd, cdd)\). \(\ln ppee\), \(\ln pcegdp\), and \(\ln rep\) are natural logarithms of per
capita electricity consumption (\(ppee\)), per capita gross domestic product (\(pcegdp\)), and real electricity
price (\(rep\)). \(uratio\), \(hdd\) and \(cdd\) are the urbanization ratio, and heating and cooling degree-days,
respectively. \(\mu\) and \(\alpha_i\) are province-/region-specific fixed effects and the spatial lag coefficient. \(W\)
is a spatial weight matrix.
One expects positive effects of income, urbanization and weather variables, whereas a negative effect of electricity price, theoretically, is expected. Detailed information is available for the estimation of equation (1) and selection of the weight matrix and appropriate model from the author upon request. Short- and long-run direct and indirect effects are calculated to obtain the marginal effects of explanatory variables as coefficient estimates include feedback effects. See also Elhorst (2014) for further information on the estimation.

OVERVIEW OF REGIONAL ELECTRICITY DEMAND IN TURKEY

For analysis, three different datasets are used for Turkey: annual balanced panel data on (1) provinces between 1990 and 2001, (2) 26 regions (NUTS-2 level) between 1990 and 2001, and (3) 26 regions between 2004 and 2011. Because of the unavailability of province-level data for some variables, the period is restricted to between 1990 and 2001. Datasets include pcec, pegdp, per capita gross value added, rep, uratio, hdd and cdd. Data sources are given in Table 1.

The results of Moran’s I statistic show evidence of spatial interdependency calculated using a binary contiguity (queen) weight matrix for different years (Table 2). Although there are regional differences in per-capita electricity consumption levels, similar values are observed in neighbouring provinces (Figure 1) and regions (Figures 2 and 3), thus Figures 1–3 also support the evidence of spatial interdependence.

Table 1. Data sources.

| Data                                             | Sources |
|--------------------------------------------------|---------|
| Total and sectoral net electricity consumption (kWh), Sectoral electricity end-use prices (P) (TL/kWh) | Electricity Distribution Company, Electricity Transmission Company of Turkey |
| Population^a, gross domestic product (GDP) (TL), gross value added (GVA) (TL) for 2004–11, urban population^b, surface area (km^2) | Statistical Institution of Turkey Database |
| Average daily temperature^b                       | Meteorological Service of Turkey |
| Regional consumer price index (RCPI) (2003 = 100), Istanbul Chamber of Commerce wholesale price index (ITO-WPI) (general, 1968 = 100) | Electronic Data Delivery System of the Central Bank of Turkey |

^aUsed for the calculation of uratio, which is the ratio of the urban population to the total population.
^bUsed for the calculation of hdd and cdd according to the following formulae:

\[
HDD_i = \begin{cases} 
(18^\circ C - T_{mi}) & \text{and if } T_{mi} \leq 15 \text{ and } i = 1, \ldots, 365; \\
0 & \text{if } T_{mi} < 15, \text{ and } i = 1, \ldots, 365; \text{ and }
\end{cases}
\]

\[
CDD_i = \begin{cases} 
(T_{mi} - 22^\circ C) & \text{and if } T_{mi} < 22 \text{ and } i = 1, \ldots, 365, \text{ where } T_{mi} \text{ is average daily temperature.} \\
0 & \text{if } T_{mi} \leq 22, \text{ and } i = 1, \ldots, 365, \text{ where } T_{mi} \text{ is average daily temperature.}
\end{cases}
\]

Table 2. Moran’s I statistic for pcec.

| Level   | Year | Moran’s I | z-value |
|---------|------|-----------|---------|
| NUTS-3  | 1990 | 0.3071*** | 4.4060  |
|         | 2001 | 0.2521*** | 3.6987  |
| NUTS-2  | 1990 | 0.4002*** | 3.4478  |
|         | 2001 | 0.4141*** | 3.5141  |
|         | 2004 | 0.4192*** | 3.5838  |
|         | 2008 | 0.4378*** | 3.7527  |
|         | 2011 | 0.4547*** | 3.8234  |

***Statistical significance at the 1% level.
ESTIMATION RESULTS OF ELECTRICITY DEMAND MODEL

The model given in equation (1) was estimated by employing three different datasets. However, as most of the coefficients on $WX$ and $Wnpcee$, are not statistically significant, the model given in equation (1) was subsequently estimated by restricting coefficients of these variables to be equal to zero. Likelihood ratio (LR) tests (Table 3) indicate that restrictions are valid. Thus, interpretations are based on the results obtained by using these restricted models, i.e., a spatial lag model. The estimation results (Table 3) were then used to calculate the direct and indirect effects estimates (Table 4). Based on the time period and classification level of a region, the results show that different variables affect regional electricity demand statistically significantly, with theoretically consistent signs (Table 5). This is, for example, illustrated in dataset 1 where the findings show statistically significant negative short- and long-run direct effects and indirect effects of $lnrep$: this implies spillover effects of pricing policies among provinces.

The total effects, i.e., the sum of direct and indirect effects, give elasticity estimates for income and price (Table 6). The results indicate that both short- and long-run electricity demand is income and price inelastic (Table 6). These results are in line with findings of some previous studies (Diabi, 1998; Erdogdu, 2007) employing dynamic models.

DISCUSSION

As electricity demand is inelastic with respect to income and price, one can conclude that electricity is a necessity and pricing policies alone cannot be so effective to ensure supply and demand balance, but in the long run pricing policies become much more effective. Price was only found to be an important factor at the province level. Results show that based on regional disaggregation level,
one can obtain different results. Therefore, policy-makers should be careful about the regional disaggregation level while making regional-level policies.

In addition, the importance of spatial spillover effects increases in the long run (Table 6). For example, at the province level, a 1% increase in electricity prices leads to a 0.126% decline in electricity consumption in the short run. A total of 85% of this decline is due to a direct effect.
and 15% results from spatial spillover effects. But in the long run, a 1% rise in electricity prices decreases electricity consumption by 0.51%. A total of 59% of this total decline comes from the direct effect and 41% from the indirect effect. The ignorance of spatial contagion becomes much more important in the long run for the determination of policy impact. A similar argument is valid for income elasticity at different regional levels over the period 1990–2001. For generation, transmission and distribution capacity expansions, one needs to consider that economic growth in one region can also lead to electricity consumption growth in nearby regions due to socio-economic interactions, which is important to project future regional investment requirements correctly.

Figure 3. Electricity consumption per capita across regions of Turkey. Source: Author’s own elaboration based on the Jenks natural breaks algorithm.
Table 4. Direct and indirect effects estimates.

|                | 1 (Direct) | 2 (Indirect) | 3 (Total) | 4 (Direct) | 5 (Indirect) | 6 (Total) |
|----------------|------------|--------------|-----------|------------|--------------|-----------|
| Short-run      |            |              |           |            |              |           |
| uratio         | 1.144***   | 0.206***     | 0.000     | 0.000      | 0.000        | 0.000     |
|                | (4.839)    | (3.816)      | (0.943)   | (0.870)    | (0.943)      | (0.870)   |
| hdd            | 0.000      | 0.000        | 0.000     | 0.000      | 0.000        | 0.000     |
|                | (1.010)    | (0.962)      | (0.279)   | (0.225)    | (1.010)      | (0.962)   |
| cdd            | 0.000      | 0.000        | 1.284***  | 0.387***   | -0.250       | -0.107    |
|                | (0.105)    | (0.058)      | (3.338)   | (2.797)    | (1.111)      | (1.111)   |
| lnpcgdp        | 0.199***   | 0.036***     | 0.209***  | 0.063***   | 0.435***     | 0.170***  |
|                | (6.068)    | (4.113)      | (4.125)   | (3.172)    | (3.831)      | (2.991)   |
| lnrep          | -0.107***  | -0.020**     | -0.067    | -0.021     | 0.106        | 0.043     |
|                | (-2.889)   | (-2.351)     | (-1.439)  | (-1.264)   | (1.418)      | (1.241)   |
| Long-run       |            |              |           |            |              |           |
| uratio         | 3.177***   | 2.135***     | 0.000     | 0.000      | 0.001***     | 0.0015    |
|                | (5.266)    | (3.354)      | (0.934)   | (0.757)    | (3.335)      | (0.471)   |
| hdd            | 0.000      | 0.000        | 0.000     | 0.000      | 0.000        | 0.000     |
|                | (1.006)    | (0.914)      | (0.258)   | (0.136)    | (1.371)      | (0.327)   |
| cdd            | 0.000      | 0.000        | 2.871***  | 2.855**    | -0.614       | -1.168    |
|                | (0.096)    | (0.024)      | (3.610)   | (2.359)    | (-1.146)     | (-0.300)  |
| lnpcgdp        | 0.556***   | 0.377***     | 0.470***  | 0.474**    | 1.006***     | 1.482     |
|                | (6.211)    | (3.226)      | (4.251)   | (2.415)    | (4.138)      | (0.842)   |
| lnrep          | -0.300***  | -0.210**     | -0.154    | -0.170     | 0.246        | 0.365     |
|                | (-2.752)   | (-1.906)     | (-1.390)  | (-0.996)   | (1.409)      | (0.483)   |

Note: See the notes to Table 3. \( t \)-values are given in parentheses.

Table 5. Summary of the results.

|                | 1 (Direct) | 2 (Indirect) | 3 (Total) | 4 (Direct) | 5 (Indirect) | 6 (Total) |
|----------------|------------|--------------|-----------|------------|--------------|-----------|
| Short-run      |            |              |           |            |              |           |
| uratio         |            |              |           |            |              |           |
| lnpcgdp        |            |              |           |            |              |           |
| Positive       | uratio     | uratio       | uratio    | cdd lnpcgdp| cdd lnpcgdp  | uratio    |
| Long-run       | lnrep      | lnrep        | lnrep     | lnrep      | lnrep        | lnrep    |
| Negative       | lnrep      | lnrep        | lnrep     | lnrep      | lnrep        | lnrep    |

Note: See the notes to Table 3.
Table 6. Elasticity estimates.

|                | (1)               | (2)               | (3)               |
|----------------|-------------------|-------------------|-------------------|
|                | Direct | Indirect | Total | Direct | Indirect | Total | Direct | Indirect | Total |
| Short-run      | $E_Y$   | 0.199*** [84.3%] | 0.036*** [15.7%] | 0.236*** | 0.063*** [23.2%] | 0.272*** | 0.435*** [71.9%] | 0.170*** [28.1%] | 0.605*** |
|                | $E_p$   | -0.107*** [84.9%] | -0.020*** [15.1%] | -0.126*** | -0.067 [75.3%] | -0.089 | 0.106 [71.1%] | 0.043 [28.9%] | 0.149 |
| Long-run       | $E_Y$   | 0.556*** [59.7%] | 0.377*** [40.3%] | 0.932*** | 0.470*** [49.8%] | 0.944*** | 1.006*** [40.4%] | 1.482 [59.6%] | 2.488 |
|                | $E_p$   | -0.300*** [58.8%] | -0.210* [41.2%] | -0.510** | -0.154 [47.5%] | -0.170 [52.5%] | -0.324 | 0.246 [40.3%] | 0.365 [59.7%] | 0.611 |

Note: See the notes to Table 3. $E_Y$ and $E_p$ are the income and price elasticity of electricity demand, respectively. Numbers in brackets are the percentage of direct and indirect effects out of the total effects.
CONCLUSIONS

This study examined factors affecting regional electricity demand by accounting for spatial interdependencies. The findings showed evidence of statistically significant spatial spillover effects as well as direct effects of economic factors. Energy policy related to only one province/region or a change in the economic factor in only one region can affect other provinces/regions through socio-economic interactions, such as labour movements across nearby provinces/regions. This can be illustrated by the example of workers working in one region but who are resident in nearby regions – income earned at one region can be spent in nearby regions. Therefore, although there is a tendency in policy-making to consider the direct effects of economic factors and regional policies, it is necessary to broaden this out also to consider the indirect effects when making regional energy policies. Moreover, as results show that pricing policies alone cannot be so effective, these policies should be supported by energy-efficiency programmes and generation-capacity expansion considering diversification across energy resources.

Furthermore, the results of the study can be used for the purpose of regional-level forecasting which is important for planning future investments. To this must be added a note of caution, as this study did not account for regional potentials for energy saving that resulted from energy-efficiency applications and for decentralized production based on renewable energy resources. In addition, a similar analysis can also be performed for other countries or by employing cross-country data to understand factors affecting electricity demand. A final limitation of this study is that due to official data unavailability, the analysis could be only performed at the province level for the period between 1990 and 2001. It would therefore be desirable in a future study to perform further analysis for the period after 2001 at the province level, and in particular to test the expectation that at a higher level of regional disaggregation one can expect more evidence of spatial effects.

NOTES

1. See Maden and Baykul (2012) for a detailed discussion on the previous literature.
2. \( \text{pcgdp} \) and per capita gross value added are used as a proxy for income per capita as they show the level of economic activity.
3. Data arrangements and calculations are available from the author upon request.
4. Estimation results for the DSDPD model are available from the author upon request.

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