Energy Policy 95 (2016) 370–377

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Exploring the relationship between agricultural electricity consumption and output: New evidence from Turkish regional data

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HIGHLIGHTS

- This study uses the recently developed Dumitrescu-Hurlin Granger causality test.
- There is unidirectional causality running from agricultural output to electricity consumption for non-coastal regions.
- Bidirectional causality runs between the analyzed variables for coastal regions.
- Electricity consumption increases agricultural output.

ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form
4 May 2016
Accepted 10 May 2016
Available online 16 May 2016

Keywords:
Electricity consumption
Agricultural output
Regional data
Dumitrescu-Hurlin causality test

ABSTRACT

This study investigates the relationship between agricultural electricity consumption and agricultural output for a panel of 12 regions of Turkey for the period 1995–2013. In order to reveal the possible heterogeneity between regions, empirical analyses are conducted for the whole panel data and two sub-groups within the panel data; namely, coastal regions and non-coastal regions. The results from several panel unit root tests indicate that electricity consumption and output are stationary process at their levels for overall panel and the two specific groups. By using the OLS with regional fixed effects, this study finds that coefficient estimate of electricity consumption on output is statistically significant and positive for overall regions, coastal regions and non-coastal regions. In addition, the results from the Dumitrescu-Hurlin Granger causality test show that there is unidirectional causality running from agricultural output to electricity consumption for non-coastal regions, and there is bidirectional causality between agricultural electricity consumption and output for overall panel and coastal regions. Findings and policy implications are further discussed.

1. Introduction

The exhaustible nature of conventional energy resources, the continuous rise in energy prices, the proliferation of energy-intensive lifestyles along with the global warming are resulting in an unprecedented resurgence of interest in the role of energy consumption on economic growth. Since the oil turmoil of 1973, until today and for the years ahead, securing energy supply will be repeatedly one of the main challenges of nations because energy is increasingly used to power growth in different sectors. In particular, the agricultural sector has increasingly become an energy consuming sector due to the process of mechanization. It uses energy both directly in the form of electricity and fuel in crop production, poultry production, animal products production (e.g., milk and eggs) and transportation of farm productions, and indirectly through use of energy-intensive inputs, most notably fertilizers, seeds and pesticides. Because of the importance of energy for nations, the investigation of energy-growth nexus has attracted much attention in both academic and political arenas.

This study differs from the existing energy-growth literature in several aspects. Although the energy-growth nexus is a much discussed topic in the literature over the last decades (Paul and Bhattacharya, 2004; Mehrara, 2007; Chontanawat et al., 2008; Apergis and Payne, 2009; Ozturk, 2010; Ozturk et al., 2010; Shahbaz et al., 2011; Eggoh et al., 2011; Belke et al., 2011; Dagher and Yacoubian, 2012; Wesseh and Zoumara, 2012; Apergis and Payne, 2012; Yildirim et al., 2012; Baranzini et al., 2013; Ocal and

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http://dx.doi.org/10.1016/j.enpol.2016.05.018
0301-4215/

Aslan, 2013; Dogan, 2014; Aslan, 2014; Nazlioglu et al., 2014; Karanfil and Li, 2015; Bloch et. al, 2015; Dogan, 2015a, 2015b; Bhattacharya et al., 2016; Tang et al., 2016), it has produced mostly confusing results due to the insufficient data and methodology problems (Ozturk, 2010; Sebri, 2015), and the investigation of energy issues in the agricultural sector has received little attention as compared to the industrial and transport sectors for many years. This might be due to two main reasons: the lower share of energy consumed in agricultural activities and the lack of data. A growing number of studies on all aspects relative to agriculture and food security of nations have recently emerged in response to the sharp increase in food prices from 2007 to 08. Nonetheless, as it will be exposed in the subsequent literature review section, there are only few studies dealing with the causal relationship between energy consumption and agriculture output. Therefore, we think that the current study provides a useful contribution. In addition, the-state-of-the-art have analyzed the relationship of agricultural energy consumption and agricultural production by using either aggregate energy consumption (or disaggregate energy consumption) at national level or aggregate energy consumption at sub-national level.

To the best of our knowledge, no study has so far focused on together regional data and the effect of electricity consumption for agricultural sector. To fill the mentioned gap in the literature and to help reach consensus about the relationship between agricultural production and energy consumption, this study employs the data on electricity consumption at agriculture sector (ELC) and agricultural output (Y) for a panel of 12 regions of Turkey to assess the linkages between Y and ELC for overall panel as well as the specific groups within the panel data. Furthermore, this is the first study that investigates the long-run estimate and the direction of causality between Y and ELC using the Turkish regional data on the analyzed variables. Moreover, this study employs several unit root tests (LLC, IPS, HT and CADF), the OLS with fixed effects and the Dumitrescu-Hurlin Granger causality test to attempt to produce economically meaningful results.

This study addresses a generally overlooked issue by undertaking a regional analysis. The use of regional data is of great utility. It helps taking into account several specificities and differences between regions which, therefore, allows drawing more accurate conclusions and crafting more sustainable policies. The agriculture sector occupies a descent status for the Turkish society. Following the common feature of development process of every country in the world, the contribution of agriculture in the total Turkish economy has seen a decrease over years. Even so, its contribution to total GDP remains significant. The share of agricultural value added made up 9% of total gross domestic product (GDP) in 2012 (World Bank, 2015). This sector is also the largest employment provider of total labor force in Turkey. The employment rate reached 24% in 2012 (World Bank, 2015). On the other hand, this sector becomes more energy-dependent; for example, the sector's energy consumption represented 6.62% of the total country's energy consumption in 2011. According to Ozturk and Yuksel (2016), energy supply is critical in the development of Turkey. The energy sources used in agricultural activities are electricity, lignite, petroleum products, natural gas and biomass, and of which electricity and petroleum products make up the majority (OeEB, 2013). The remainder of this study proceeds as follows. Section 2 reviews the existing literature according to three main strands. Section 3 describes the Turkish agriculture sector and electricity consumption. Section 4 describes the data and econometric methods. Section 5 reports the findings of this study. Last section provides the conclusions and policy implications.

2. Literature review on energy-growth nexus

An ongoing debate on the nexus between energy consumption and economic growth has provided a vast literature for over last decades. Studies have been conducted on developed and developing countries as well on energy-exporting and energy-importing countries. This explains the role played by energy as a key input to economic growth of all nations. As this paper examines the causality relationship for agricultural sector in Turkey and uses the regional data for the first time, we choose to focus on this literature review along three strands: studies that deal with the agricultural sector, studies that use within-country regional data and studies that focus on the case of Turkey.

2.1. Energy consumption and agricultural production

By examining the literature that disaggregates total energy consumption by sector, one mainly finds that the industrial and transport sectors occupy the lion's share because they are the most energy-intensive sectors. However, limited empirical studies have been undertaken on the agricultural sector despite its key role in many economies. This might be due to the small share of total electricity consumption in this sector across many countries as well as the lack of data. For instance, Ahmed and Zeshan (2014) investigate the decomposition of energy consumption in Pakistan and analyzed the behavior of change in agricultural production, energy intensity and structural changes between 1972 and 2012 using the structural vector auto-regression (SVAR) model. Among other results, the authors find that there is bi-directional causal relationship between energy consumption and the share of agriculture in total value addition. Based on Johansen's cointegration approach and VECM Granger causality, Abbas and Choudhury (2013) use the annual time series of India and Pakistan from 1972 to 2008 to conclude that the causality between Y and ELC is bi-directional in India, while it is unidirectional running from Y to ELC in Pakistan. Using the same econometric methods, Zaman et al. (2012) investigate the casual relationship between energy consumption and agricultural technology factors that regroup agricultural value added in Pakistan during the period 1975–2010. The authors recommend the government to form a policy of incentive-based supports which might be a good policy for increasing the use of energy level in agriculture. Tang and Shahbaz (2013) assess the electricity-growth nexus in Pakistan at the aggregated and disaggregated levels over the period of 1972–2010. The authors reveal that the neutrality hypothesis is supported for the agricultural sector, and no causal relationship is found between electricity consumption and real output in the agricultural sector. Sebri and Abid (2012), by using time series of Tunisia between 1980 and 2007 and Johansen's coin-tegration and VECM Granger causality, probe the cointegration and causal relationship between energy consumption, agriculture value added and trade openness. The relationship is investigated at aggregated and disaggregated components of energy consumption, namely oil and electricity. The authors find that variables are cointegrated for a long run relationship, and trade openness and energy consumption (aggregated and disaggregated) Granger cause agricultural value added. Turkekul and Unakitan (2011), upon examining the Turkish time series over the period 1970–2008 by employing cointegration and error correction (ECM) analysis, focus on determining price and income elasticities of energy (diesel and electricity) demand in agricultural sector. The authors obtain two main findings: first, energy prices Granger caused energy consumption, and unidirectional Granger causality runs between diesel and electricity consumption and agricultural production. Second, the long-run income and price elasticities are estimated as 1.47% and −0.38% for diesel and, 0.19% and −0.72% for the electricity, respectively.

2.2. Energy consumption and economic growth in Turkey

A significant number of studies relative to energy consumption-economic growth nexus have been carried out on Turkey. In the following survey, we will be limited to some of more recent empirical works. Based on VECM Granger causality, Dogan (2015a) investigates the relationship between natural gas consumption and economic growth in a multivariate model in which capital and labor are included as control variables. The empirical results suggest the presence of bidirectional Granger causality between natural gas consumption and economic growth. Arac and Hasanov (2014) use the nonlinear approach to analyze the dynamic interactions between energy consumption and economic growth through a smooth transition vector autoregressive model on annual time series between 1960 and 2010. They find that energy consumption increased with output but at declining rates, and a decrease in output has a negligible impact on energy consumption. The authors recommend that energy conserving policies should be implemented gradually rather than aggressively. Bildirici and Bakirtas (2014) employ the Autoregressive Distributed Lag (ARDL) bounds testing approach to examine the causal relationship between economic growth and disaggregated energy consumption (coal, natural gas and oil) for BRICTS group (Brazil, Russia, India, China, Turkey and South Africa) for the years of 1980–2011. In case of Turkey, they detect bidirectional causality between oil and natural gas and economic growth. Ocal and Aslan (2013) examine the interrelationship between renewable energy use and economic growth for the 1990–2010 period by using the Toda-Yamamoto causality test. The authors find that there is unidirectional Granger causality running from economic growth to renewable energy consumption, which supported the conservation hypothesis. Using the ARDL bounds test approach, Fuinhas and Marques (2012) perform a comparison analysis between Turkey and Portugal, Italy, Greece and Spain using the annual data on energy consumption and GDP from 1965 to 2009. The empirical results support the evidence of feedback hypothesis between energy and growth both in the short run and long run. These findings are also robust when the panel data framework is employed, too. Yalta (2011) finds the evidence of neutrality hypothesis between energy consumption and economic growth using a maximum entropy bootstrap on data between 1950 and 2006.

2.3. Regional data studies

Conversely to the literature based on specific country time series or panel data of a group of countries, studies on the energy consumption-economic growth nexus that rely on sub-national data are very scarce. In the subsequent survey, it is clear that most of literature employing regional data is carried out on Chinese provinces from which we review the recent studies. Based on the panel data for 28 provinces in China over the period 1995–2007, Wang et al. (2011) employ panel cointegration and panel vector error correction modeling techniques to investigate the causal relationship between CO2 emissions, energy consumption and economic growth. The results indicate that there is bidirectional causality between CO2 emissions and energy consumption and also between energy consumption and economic growth. Li and Leung (2012), by grouping the Chinese provinces into three subgroups and, namely Coastal, Central and Western, and using panel cointegration and GMM and pooled mean group estimator for causality, find that the coal consumption-GDP relationship is bidirectional in the Coastal and Central regions whereas it is unidirectional running from GDP to coal consumption in Western region. The authors notice the importance of causality analysis using sub-national data. That is, energy conservation policies should not equally implemented in Chinese regions because coal consumption does not harm economic growth in Western provinces. Following the standard Granger causality test, Akkemik et al. (2012) take into account the panel heterogeneity when analyzing the energy consumption-economic growth nexus in Chinese provinces. The empirical findings prove that the panel of provinces is not homogeneous and thus heterogeneous analysis is more adequate. Unidirectional causality from GDP to energy is held for 19 provinces while the opposite direction is obtained for the rest 14 provinces. Herrerias et al. (2013) decompose the energy consumption into different components; namely, electricity, coal, coke, and crude oil. The authors also take 1999 as a break date and carry out their analysis for two periods separately, before and after this date. Based on the VECM Granger causality test, they find that causality runs from economic growth to energy consumption in the long-run when using 1999–2009 period and find mixed results for 1995–1999 period. The case of Italian regions is explored by Magnani and Vaona (2013) and Ladu and Meleddu (2014). Magnani and Vaona (2013) focus on the link between renewable energy generation and output at the regional level in Italy from 1997 to 2007, controlling for employment and capital formation. The results indicate unidirectional causality running from renewable energy generation to output. This direction of causality is still robust under various time stability checks and econometric techniques employed by the authors. Ladu and Meleddu (2014) obtain different results as compared to those of Magnani and Vaona (2013) when using annual data for 20 Italian regions covering the period 1996–2008 and using total factor productivity as proxy to economic growth. Based on dynamic panel estimation technique, Ladu and Meleddu (2014) report that there is bidirectional causality between energy consumption and economic growth, supporting therefore the feedback hypothesis. The authors insist on the utility of using sub-national data, since they provide a first step in implementing adequate energy policies. The case of Indian states is investigated by Mandal and Madheswaran (2010). The authors explore the causal relationship between energy consumption and output growth in the Indian cement industry using data for 18 states over the period 1979–80 to 2004–05 and panel VECM. The empirical findings suggest that shocks to energy consumption affect output in the cement industry and vice versa, and thus bi-directional causality is valid between energy consumption and output. Thus, the authors recommend that energy conservation policies should be oriented toward energy-use efficiency rather than energy supply reduction.

According to the above survey of the literature, the empirical studies failed to achieve unanimous conclusion regarding the direction of the causal flow between energy consumption and economic growth, even when using the same country data. The main reason for the discrepancy in results in the previous research comes from the use of different model specifications, data characteristics, estimation techniques (cointegration methods and causality tests), and development level of the country on which a study was conducted (Sebri, 2015).

3. Agricultural output and electricity consumption in Turkey

Agriculture sector requires energy at all stages of production. A variety of energy sources such as electricity and petroleum is used by agricultural machinery and irrigation systems and water pumps. Electricity in rural areas is widely believed to be a stimulus factor for increased agricultural productivity and output through irrigation and mechanization. In addition, electricity is the source of power for irrigation in Turkey. 12.5 million hectares out of the cultivable area of 28 million hectares are classified as suitable for irrigation. Moreover, when economic considerations are included, Turkey's official estimated irrigation potential is 8.5 million hectares, of which 93% from surface water resources and 7% from groundwater. The irrigated land in Turkey is 5.29 million hectares, or 13% of the country's agricultural area (FAO, 2009).

As given in Table 1, agricultural electricity consumption in Turkey has tripled since 1995. In other words, ELC at agriculture sector increased from 1,287,535 MWh in 1995 to 4,360,331 MWh in 2010. A similar considerable increase in electricity consumption for agriculture sector is valid for coastal and non-coastal regions as well.[1] Furthermore, non-coastal regions require more ELC than coastal regions. The main reason for a high share of agricultural electricity consumption in the non-coastal regions is groundwater-irrigated agriculture. More precisely, non-coastal regions do not have supplemental surface water supply source and thus underground water has to be pumped, which needs a large amount of electricity consumption. Furthermore, the coastal regions of Turkey are likely to have a higher volume of rainfall due to their geographical location. In mountainous coastal areas, a significant part of the water finds its way to the sea without forming any large ground water reservoirs. Hence, agriculture sector in non-coastal regions are more dependent on energy due to reasons explained above. Moreover, the share of agricultural ELC is expected to be higher in non-coastal regions considering the fact that the most of agricultural production comes from non-coastal regions. Another difference between the regions is energy utilization. Table 1 indicates the difference between coastal and non-coastal regions. As compared to non-coastal regions, coastal regions have higher agricultural output for one unit of electricity consumption. Agricultural production/Electricity consumption for coastal regions is above the overall ration. Table 1 also shows a correlation between high energy consumption and agricultural production. As Turkish agriculture consumes higher energy, agricultural yields increase. Any modernization in production methods presupposes sustainable access to energy.

Energy consumption has increased due to mechanization and advanced technology applications in Turkish agriculture. Therefore, it is necessary to increase the efficiency of energy utilization in agriculture. Turkish rural development policies pay much attention on production and irrigation to foster the sustainable growth of less developed regions. Based upon this, it appears important to deepen the regional analysis studying the long run relationship between growth and energy use in order to provide clear policy implications.

4. Methods and data

Following the related research articles in the literature (Li and Leung, 2012; Akkemik et al., 2012; Ladu and Meleddu, 2014), this study investigates the relationship between electricity consumption and agricultural production in a widely used bivariate model (the fundamental reason why this study uses a bivariate model is that the data on capital, labor, trade, etc. are not available at regional level) in which electricity consumption at agriculture sector is a separate factor:

$$Y_{it} = f\,(ELC_{it})$$

where Y is the value of crop production in Turkish Liras, ELC is the electricity consumption for irrigation at agriculture sector in MWh. The annual data on Y and ELC for 12 regions of Turkey are drawn from the Turkish Statistical Institute (www. turkstat. gov. tr).[2] The data are available for 12 Nomenclature of Territorial Units for Statistics (NUTS) regions from 1995 to 2013. Both time-series data are transformed into their logarithmic forms to reduce the heteroscedasticity and interpret the coefficient estimate of ELC on Y as the elasticity of Y with respect to ELC. Although the use of multivariate model has recently been more popular in the literature, the data on other variables such as capital and labor are unfortunately not available at regional level. This study is restricted to data availability. Nevertheless, this study provides an insight for the importance of the use of electricity for agriculture sector.

4.1. Panel unit root tests

This study applies several panel unit root tests to investigate integration properties of agricultural production and electricity consumption. They are the HT panel unit root test due to Harris and Tzavalis (1999), the LLC panel unit root test due to Levin, Lin and Chu (2002), the IPS panel unit root test due to Im, Pesaran and Shin (2003), and the CADF panel unit root test due to Pesaran (2007). The HT panel unit root test uses the following OLS regression in Eq. (1):

$$x_{i,t}=\alpha_i+\beta x_{i,t-1}+\rho_i T+\varepsilon_{i,t} \quad (1)$$

where x_{it} stands for Y and ELC, ε_{it} is independent and identically distributed error term, and Δ is the lagged operator, and α and T are individual intercepts and time trends, respectively. The HT is generated to get applied to panel data with relatively short time period. The HT unit root test relies on that $\beta_i=\beta$ for all individuals (i) in each time-series cross-sectional data; in other words, β is fixed across i for each panel data. The null hypothesis that a panel data as a whole contains unit root is test against the alternative hypothesis that the panel data as a whole is stationary:

$$H_o\colon \beta = 1, \qquad H_a\colon |\beta| < 0.$$

The LLC, IPS and CADF panel unit root tests take Δx_{it} as the response variable rather than x_{it}, and thus are based on the Augmented Dickey-Fuller (ADF) method in Eq. (2):

$$\Delta x_{i,t}=\alpha_i+\beta_i x_{i,t-1}+\rho_i T+\sum_{j=1}^{ni}\theta_{ij}\,\Delta x_{i,t-j}+\varepsilon_{i,t} \quad (2)$$

where x_{it} stands for Y and ELC, ε_{it} are error terms, and Δ is the lagged operator, and α and T are individual intercepts and time trends, respectively. As it is the case in the HT test, the LLC test also assumes that β is fixed across individuals for each panel data; however, the lag order (n_i) can differ across cross-section units. The LLC unit root test proposes the null hypothesis that there is common unit root process in a panel data against the alternative hypothesis that there is no common unit root process in the panel data:

$$H_o\colon \beta = 0, \qquad H_a\colon \beta < 0.$$

If time period is short, the LLC test will have relatively lower power. In addition, the null hypothesis that there is common unit root process is rather restrictive. In contrast to the LLC test, the IPS and the CADF panel unit root tests are not restrictive too much as they permit β_i to vary across cross-section units in each time-series cross-sectional data. As different from the IPS test, the CADF test deals with cross-section dependence in panel data. To do so, Eq. (2) is augmented with the cross section averages of lagged levels and first-differences of the individual series. On the other hand, the IPS and the CADF tests are analogous to each other in terms of proposed hypotheses. Both perform the null hypothesis that all individuals within a panel data are not stationary versus the alternative hypothesis that at least one individual is stationary process:

[1] This study divides the country into 12 regions based on the NUTS. In addition, five of them are coastal regions while seven of 12 regions are non-coastal regions. The coastal regions are mostly located alongside the Mediterranean Sea, the Aegean Sea, the Black Sea and the Marmara Sea.

[2] For those who have hard time to download the data from the website, they can be provided upon request.

Table 1
Regional electricity consumption and agricultural production.

Year	Overall			Coastal Regions			Non-Coastal Regions		
	Agr. Prod. (1000 TL)	Agr. ELC (MWh)	AgPd/Elec	Agr. Prod. (1000 TL)	Agr. ELC	AgPd/Elec	Agr. Prod. (1000 TL)	Agr. ELC	AgPd/Elec
1995	2,018,129	1,287,535	157	1,317,828	560,916	248	700,301	726,619	096
2000	26,724,351	2,358,312	1133	17,378,908	969,508	1793	9,345,445	1,388,804	673
2005	88,364,969	3,239,603	2728	58,524,908	1,410,297	4150	29,840,063	1,829,306	1631
2010	165,039,291	4,360,331	3785	106,847,478	1,651,751	6469	58,191,814	2,708,580	2148

Source: The Turkish Statistical Institute (www. turkstat. gov. tr).

H_o: $\beta_i = 0$

$$H_a = \begin{cases} \beta_i < 0 & \text{for } i = 1, 2, \ldots, N_1 \\ \beta_i = 0 & \text{for } i = N_1 + 1, N_1 + 2 \ldots, N \end{cases}$$

The appropriate lag lengths for each panel unit root test are selected based on the Akaike Information Criterion (AIC). A variable (Y or ELC) is found to be stationary process in the case where we have enough evidence to reject the null hypothesis.

4.2. Long-run estimates

This study employs the ordinary least squares (OLS) with fixed effects to analyze long run estimate of electricity consumption for agricultural output. In order to estimate the long-run effect of electricity consumption on agricultural output, this study employs the following linear regression in Eq. (3):

$$Y_{it} = \beta_0 + \beta_1 ELC_{it} + \delta_i + \varepsilon_{it} \tag{3}$$

where ε_{it} is normally distributed error term, β_0 is the panel-specific mean, β_1 is the long-run marginal effect of ELC to Y. The parameter δ_i stands for unobserved regional fixed effects that cannot be observable by econometricians. The long-run elasticity of agricultural production with respect to ELC (β_1) are supposed to be unbiased since the linear regression in Eq. (3) includes regional fixed effects to account for all unobservable time-invariant differences across regions. In other words, it is attempted to obtain unbiased estimate of β_1 by handling the omitted-variable bias problem through controlling for all time-invariant differences between regions. The expected sign of the estimate of β_1 is positive for overall panel and specific groups within the panel.

4.3. Granger causality test

This study applies a panel data Granger causality test so as to reveal the direction of causality between agricultural production and electricity consumption. The knowledge of the causal direction between the analyzed variables helps the Turkish government to apply appropriate policies in regard to agricultural sector. Therefore, recently developed Dumitrescu-Hurlin causality test (Dumitrescu and Hurlin, 2012) is employed. The Dumitrescu-Hurlin test is applicable to stationary series and working well for heterogeneous panel data. This test follows the regression shown in Eq. (4):

$$y_{i,t} = \alpha_i + \sum_{i=1}^{K} \gamma_i^{(k)} y_{i,t-k} + \sum_{i=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \tag{4}$$

with $K \in \mathbb{N}^+$ and $K \in \mathbb{N}^* and \beta_i = (\beta_i^{(1)}, \ldots\ldots, \beta_i^{(K)})$ and α_i, $\gamma_i^{(k)}$, and $\beta_i^{(k)}$ indicate constant term, lag parameter and coefficient slope, respectively. The null and alternative hypotheses are defined as:

$$H_0 : \beta_i = 0, H_1 : \begin{cases} \beta_i = 0 \ \forall_i = 1, 2, \ldots\ldots\ldots N \\ \beta_i \neq 0 \ \forall_i = N_1 + 1, N_1 + 2, \ldots\ldots, N \end{cases}$$

The null hypothesis supports the existence of no homogenous Granger causality for all regions whereas the alternative hypothesis assumes that there is at least one causal relationship in the panel data. In detail, there are four possible outcomes depending on the combination of rejection decisions: unidirectional causality running from ELC to Y; unidirectional causality running from Y to ELC; bidirectional causality between Y and ELC; no causality between Y and ELC.

5. Empirical results and discussions

5.1. Panel unit root tests

In this study, four different panel data unit root tests are used to examine unit root properties of Y and ELC for overall panel as well as specific groups within the panel; namely, LLC panel unit root test due to Levin et al. (2002), IPS panel unit root test due to Im et al. (2003), HT panel unit root test due to Harris and Tzavalis (1999), and CADF panel unit root test due to Pesaran (2007).

We sequentially apply these aforementioned tests to the data on agricultural production and electricity consumption at agricultural sector for a panel of 12 regions (overall), a panel of 7 coastal regions (coastal regions), and a panel of 5 non-coastal regions (non-coastal regions). In addition, panel unit root tests are applied with an option that only individual intercept is included, and with an option that both individual intercept and trend are included so as to make the analysis more robust. The optimal lag lengths are selected based on Akaike Information Criterion (AIC). According to the t-statistics reported in Table 2, we can reject the null hypothesis of unit root for both Y and ELC in their levels for overall regions, coastal regions and non-coastal regions. In short, we have enough evidence to conclude that the time-series data are stationary process in their levels in overall regions as well as two groups within the panel.

5.2. Long-run estimates

This study uses the OLS with regional fixed effects in order to find the long-run elasticity of agricultural output with respect to electricity consumption in overall regions as well as specific groups within the panel. This study applies the Hausman test so as to test the efficiency of the use of fixed effects versus random effects. Because we have enough evidence to reject the null hypothesis that the use of random effects is efficient for overall regions and two sub-groups, the linear fixed effects regression is consistent and preferred for both overall regions and the two subsequent regions.

Table 3 shows that the coefficient on ELC is all positive and statistically significant for overall regions as well as two specific groups within the panel data. Furthermore, the elasticity of output is 1.34, 1.10 and 1.98 for overall regions, coastal regions and non-coastal regions. In other words, a 1% increase in electricity consumption stimulates agricultural production by 1.34%, 1.10% and

Table 2
results from panel unit root tests.

Variable		Level					
		Overall		Coastal regions		Non-coastal regions	
		Intercept	Intercept+ trend	Intercept	Intercept+ trend	Intercept	Intercept+ trend
Y	LLC	−3.88**	−7.04**	−2.46**	−3.46**	−3.44**	−4.49**
	IPS	−5.37**	−7.33**	−3.33**	−4.30**	−3.17**	−2.85**
	CADF	−3.57**	−3.84**	−3.17**	−3.01*	−2.79*	−3.42**
	HT	−10.60**	−8.11**	−8.29**	−7.43**	−5.92**	−3.70**
ELC	LLC	−4.90**	−7.35**	−7.31**	−7.75**	−2.26*	−2.23*
	IPS	−5.60**	−5.77**	−6.84**	−7.80**	−2.72**	−2.18*
	CADF	−2.58**	−2.93*	−2.89**	−3.26**	−3.10**	−2.95*
	HT	−15.76**	−11.62**	−14.60**	−9.41**	−1.83*	−1.98*

Note: * and ** denote the statistical significance at 5% level and 1% level, respectively. Critical values are not reported for the sake of brevity but can be provided upon request.

Table 3
Results from OLS with fixed effects.

Variable	Overall	Coastal regions	Non-coastal regions
ELC	1.34**	1.10**	1.98**
Cons	−0.42	1.05	−4.32**
Regional fixed effects	Yes	Yes	Yes
R^2	0.59	0.62	0.60
F-stat	26.70**	29.46**	26.36**
Hausman test	32.07**	9.44**	39.19**

Note: * and ** denote the statistical significance at 5% level and 1% level, respectively.

1.98% for overall regions, coastal regions and non-coastal regions, respectively, at one percent level of significance. The use of electricity significantly stimulates agricultural output but it is more effective on Y in non-coastal regions as compare to coastal regions. In short, electricity consumption is a statistically and significantly determining factor for agricultural product. This is consistent with that of the-state-of-the-art.

In regard to policy recommendations, the Turkish policy makers are strongly suggested to increase the accessibility of electricity power both in coastal and non-coastal regions as well as urban and rural areas. As a result of mechanization and advanced technology applications in Turkish agriculture, energy consumption is expected to continuously increase. Therefore, it is necessary to increase the efficiency of energy utilization in Turkish agriculture. Considering electricity energy, electricity and water use in irrigation are very much intertwined. A true solution to the problem would need to address both these issues simultaneously leading pumping and water-use efficiency. Farmers are always demanding more water than what is currently accessible to them: once pumping efficiency is improved, they can extract more and more, which may in turn aggravate the depletion of groundwater tables. As these tables drop further down, the amount of electricity required to draw water would increase. Some easy and inexpensive methods can reduce water and electricity demand by a great deal. Crop diversification is one of the rational and cost-effective methods for improving water and energy-use efficiency in agriculture. Farmers can save a lot of water and electricity by planting less-water-intensive crops or choosing to grow less-water-intensive variants of the same crop. The other methods include massive state investments to improve surface irrigation, groundwater table management, irrigation technologies, and agricultural practices (such as organic agriculture) as well as Turkish food procurement policies.

5.3. Granger causality test

The Dumitrescu-Hurlin causality test (Dumitrescu and Hurlin, 2012) is employed to explore the causality direction between Y and ELC for each of the three panel data. The related results are given in Table 4. For non-coastal regions, we cannot reject the null hypothesis that ELC does not Granger cause Y in favor of the alternative hypothesis that electricity consumption at agriculture sector Granger causes output, whereas we can reject the null hypothesis that agricultural production does not Granger cause ELC. In other words, unidirectional causality runs from Y to ELC for non-coastal regions. As different from non-coastal regions, bidirectional causality is found between ELC and Y for overall regions and coastal regions since we have a strong evidence to reject both the null hypothesis that ELC does not Granger cause Y in favor of the alternative hypothesis and the null hypothesis that Y does not Granger cause ELC in favor of the alternative hypothesis that Y Granger causes ELC. In short, this study reveals the existence of conservation hypothesis for non-coastal regions, and the presence of feedback hypothesis for coastal regions. Our findings are in line with that of Abbas and Choudhury (2013) which conclude that the causality between ELC and Y is bidirectional in India, and unidirectional causality runs from agricultural production to ELC in Pakistan. The results found by Tang and Shahbaz (2013) are also consistent with the current study. On the other hand, the finding of this paper is contrast to that of Turkekul and Unakitan (2011), and Sebri and Abid (2012) which find the evidence of unidirectional causality running from ELC to agricultural production in Turkey and Tunisia, respectively. One possible reason for the difference between the finding of this study and those of Turkekul and Unakitan (2011), and Sebri and Abid (2012) may be the use of different Granger causality test.

The evidence of bidirectional causal relationship suggests that energy consumption stimulates economic growth and likewise

Table 4
Results from Dumitrescu-Hurlin causality test.

	Overall		Coastal regions		Non-coastal regions	
Hypothesis	ELC→Y	Y→ELC	ELC→Y	Y→ELC	ELC→Y	Y→ELC
Zbar-stat	1.74*	5.73***	2.34**	4.33***	1.16	11.97***
Result	Yes	Yes	Yes	Yes	No	Yes
Conclusion	Bidirectional causality between ELC and Y.		Bidirectional causality between ELC and Y.		Unidirectional causality from Y to ELC.	

Note: *, ** and *** denote the statistical significance at 1%, 5% level and 1% level, respectively.

increases in production require electricity consumption. The evidence of one-way causality from agricultural output to electricity consumption implies that more energy is needed as the agricultural production increases. Thus, an important implication of the overall result is that agricultural output will significantly be promoted if the government improves the infrastructure and subsidies for electricity use at agriculture sector. Even though, the present use of energy inputs in agriculture is not strictly commensurate with energy consumption trends in developed countries, Turkish agricultural productivity heavily depends on proper availability and prices of energy inputs. Also electricity consumption especially for irrigation is important in terms of increasing the productivity in Turkish arable lands, accelerating the economic growth and decreasing the migration from rural to urban areas.

6. Conclusions and policy implications

This study extends the energy-growth literature by investigating agricultural electricity consumption and output for a panel of 12 regions of Turkey. This study decomposes the panel data into two sub-groups in order to show possible differences in energy use-output relationship between coastal and non-coastal regions. It is known that non-coastal regions are relatively less developed in terms of economic and industrial development. In addition, non-coastal regions are relatively more dependent on electricity consumption for water-pumps because the agriculture sector in these regions is mostly based on groundwater-irrigation. Furthermore, the Southeastern Anatolia Project, by covering the major part of non-coastal regions, has been initiated to promote agriculture sector and irrigation to remove regional heterogeneity by increasing productivity, employment and income level in those regions.

The investigation of the causal relationship between energy consumption and economic growth has important policy implications. Therefore many empirical studies have been conducted for the causality among electricity consumption and economic growth for developed and developing countries. But these empirical researches have not yielded a consensus on the causal relationship between electricity consumption and economic growth. In addition, most articles in the literature focus on the relationship between either aggregate energy consumption and aggregate output (GDP) or aggregate energy consumption and disaggregated output (i.e. agricultural output). There is no study that uses together disaggregate energy consumption and disaggregate output at sub-national level. Thus, this study investigates the long-run estimates and causal relationship between electricity consumption and agricultural output in Turkey at regional level for overall panel as well as two specific groups within the panel data. Furthermore, this study uses recently developed Dumitrescu-Hurlin Granger causality test.

This study reveals that agricultural electricity consumption and agricultural production are stationary process in their levels for overall regions, coastal regions and non-coastal regions using several panel unit root tests. In addition, the results from linear regression with fixed effects show that an increase in electricity consumption significantly stimulates agricultural output in whole sample and specific groups. By using the Dumitrescu-Hurlin Granger causality test, we have enough evidence to support unidirectional Granger causality running from Y to ELC for non-coastal regions and bidirectional Granger causality between Y and ELC for overall panel and coastal regions. Although the presence of Granger causality originally suggest that one variable can be useful in forecasting other variable over the period for which we run the model; as the past determines the future, following the literature, the evidence of Granger causality is interpreted as suggestive piece of evidence that ELC can have effects on Y, and vice versa. Regarding policy implications, an important implication of unidirectional Granger causality result is that the energy demand is strongly dependent from the economic performance of the agriculture sector for non-coastal region. An implication of bidirectional Granger causality is; in addition to that of unidirectional one, that increases in electricity consumption boost agricultural output in coastal regions. Thus, the improvements in the infrastructure and subsidies for electricity use at agriculture sector are potential contributors to agricultural output growth while adopting some conservation policies can harm agriculture sector's performance although there might be some other effective factors that we cannot observe due to lack of available data. In addition, Turkish farmers spend some agricultural income on electricity consuming products such as water pump. This is consistent with the argument made in Section 3 which claims that agriculture in non-coastal regions is mostly dependent on groundwater-irrigation. The fact that long-run coefficient estimate of ELC is statistically significant and positive; the Turkish government should encourage the use and accessibility of electricity power in agriculture sector through proper policies. According to Ozkan et al. (2004), energy in agriculture is important in terms of crop production. Moreover, energy subsidies have become a cornerstone of rural politics in Turkish agriculture due to high energy prices. Therefore, the government may decrease the price of one unit of electricity for agriculture sector or support the electricity consumption for agriculture, improve the power infrastructure, increase electricity supply investments and provide subsidies to farmers to establish their own wind and solar turbines to generate electricity. The strategic place of the agriculture sector in Turkey needs from the country to take suitable measures to sustain this sector. It is also important to note that agriculture sector plays a meaningful role in the Turkish economy according to Ari (2016). One important policy concerns the scaling down of the conventional energy consumption and enhancing the role of the renewable energy as a source of electricity generation for various agriculture activities.

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