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New Insight into the Finance-Energy Nexus: Disaggregated Evidence from Turkish Sectors

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Abstract: Seeing that reshaped energy economics literature has adopted some new variables in energy demand function, the number of papers looking into the relationship between financial development and energy consumption at the aggregate level has been increasing over the last few years. This paper, however, proposes a new framework using disaggregated data and investigates the nexus between financial development and sectoral energy consumption in Turkey. To this end, panel time series regression and causality techniques are adopted over the period 1989–2011. Empirical results confirm that financial development does have a significant impact on energy consumption, even with disaggregated data. It is also proved that the magnitude of financial development is larger in energy-intensive industries than in less energy-intensive ones.

Keywords: financial development; energy consumption; Turkey

JEL Classification: C23; G20; Q43

1. Introduction

Subsequent to the oil crisis in the 1970s, energy economics has become one of the most popular research areas, which is broadly expanded in the context of the energy-growth nexus. Undoubtedly, energy economics with social and economic dimensions is followed closely by both scholars and policymakers. In the second decade of the 21st century, augmented energy demand functions have added some new variables in order to measure these social and economic impacts employing trade, urbanization, and financial development.

Papers studying the impact that financial development has on energy consumption are focused at the aggregate level. Some papers, however, suggest that a transition process that causes a gradual shift from agriculture, or from manufacturing to services, may exhibit some structural changes in the sectoral output composition of developing economies. Compared with a less energy-intensive industry, financial development is expected to create more energy demand in an energy-intensive industry. In a similar manner to aggregated analyses, one should anticipate financial development to have a significant impact at the disaggregated level. Given these assumptions, the primary hypothesis suggested herein is "the impact of financial development may affect energy consumption even at the disaggregate level". As these impacts are expected to differ across the energy intensity of related industries, the second hypothesis is "financial development affects energy-intensive industries more than less energy-intensive industries".

Departing from the hypotheses above, the goal of this paper is to investigate the impacts of financial development on sectoral energy consumption in Turkey. To this end, the relevant disaggregated relationship has been tested within a panel data framework over the period 1989–2011. We hope that the existing study will contribute to the empirical literature in several ways. First, previous studies on this issue have analyzed the nexus at the aggregate level and no micro-level analysis with disaggregated data has been carried out before to the best of our knowledge. The present study is therefore going to fill this gap. Second, Levine and Zervos (1998) [1] argue that the impact of financial development on economic growth might differ across the source of financial development. There exist a few studies in the finance-energy literature in which the source of financial development has been separated (see, for example, Sadorsky, 2010 [2]; Sadorsky, 2011 [3], Coban and Topcu 2013 [4]). Previous papers in the case of Turkey (Ozturk and Acaravci, 2013 [5]; Zeren and Koc, 2014 [6]) merely use bank-related variables as well. Thus, the existing study will be the first to measure the impact of financial development using both banking and stock market variables in the case of Turkey. Third, recent developments in panel data econometrics allow researchers to use new approaches, taking heterogeneity into account and obtaining cross-sectional results as well as pooled panel results. As a convenient framework for the latest trends, the empirical basis of this study depends on panel time series regression and causality methods.

The rest of the paper is structured as follows: Section 2 explains the theoretical relationship and reviews the related literature, Section 3 describes the data and model, Section 4 presents methods and empirical results, Section 5 discusses policy implications, and Section 6 provides concluding remarks.

2. Financial Development and Energy Consumption: Theory and Literature

2.1. Regression Approach

As is widely known, the theoretical background of the relationship between financial development and energy consumption depends on two pivots. One of them is the financial development-energy consumption nexus. A great number of studies on this issue have revealed that financial development affects growth via capital accumulation and technological innovation (see: Roubini and Salai-Martin, 1992 [7]; Bencivenga and Smith, 1993 [8]; King and Levine, 1993 [9,10]; Miller, 1998 [11]; Chortareas et al., 2015 [12]). The second one is the economic growth-energy consumption nexus, which is well documented (see the surveys by Ozturk, 2010 [13]; Payne, 2010 [14,15]). Considering these two, the financial development-energy consumption literature is derived given the implicit role of economic growth. The first attempt to provide a theoretical reason for why financial development affects energy consumption was made by Sadorsky (2010, 2011) [2,3]. According to this framework, financial development affects energy consumption through the direct effect, business effect, and wealth effect channels (see Table 1 for the extension).

Table 1. How financial development affects energy consumption.

Channels	Reflection of the Effects
Direct effect	When there is improved financial development, consumers can borrow money more easily and cheaply in order to buy durable consumer goods that consume energy.
Business effect	Improved financial development helps businesses access financial capital easily and cheaply. Additionally, stock market development can also affect businesses by providing them an additional funding source. This allows businesses to expand their present business potential and increase energy demand.
Wealth effect	Increased stock market activity usually affects the confidence of consumers and businesses by creating wealth. Increased economic confidence may expand the economy and promote energy demand.

Source: Sadorsky (2011) [3] (p. 1000); Coban and Topcu (2013) [4] (p. 82).

There is an extensive literature estimating the magnitude of financial development on energy consumption. The bulk of these studies use banking-related variables and almost all of these studies find a positive impact of financial development on energy consumption (see, for example, Shahbaz and

Lean, 2012 [16]; Islam et al., 2013 [17]; Aslan et al., 2014 [18]; Tang and Tan, 2014 [19]; among others). In addition to those, only a few of the studies include stock market variables as well as banking variables in order to measure the separate effects. The results of these studies are mixed and differ across country groups, time periods, and empirical techniques (see, for example, Sadorsky, 2010, 2011 [2,3]; Coban and Topcu, 2013 [4]).

2.2. Causality Approach

Unlike the energy-growth literature, there is no clear definition of causality hypotheses in the finance-energy literature as it internalizes causality in a more indirect sense. It is thus possible to construct energy-led finance hypotheses under four lines: *Growth hypothesis* indicates uni-directional causality from energy consumption to financial development. Energy conservation policies are expected to have some impacts on the financial sector in an economy where the growth hypothesis is valid. *Conservation hypothesis* suggests uni-directional causality from financial development to energy consumption. This hypothesis defines a situation in which the financial system plays a vital role in energy consumption. In such an economy, it has to be kept in mind that the precondition of implementing energy-saving projects is the financial sector. *Feedback hypothesis* means there is a reciprocal relationship between financial development and energy consumption. Energy conservation policies, in order to improve energy efficiency, may affect the financial sector, which, in turn, affects energy consumption. The *neutrality hypothesis* postulates that financial development and energy consumption are independent. In an economy where the neutrality hypothesis holds, developments in the financial system and policies targeting energy efficiency will not have a significant impact on each other.

As far as we know, the literature on the finance-energy nexus provides a large number of studies including single-country cases and a limited number of multi-country studies. Some of these papers report the existence of the growth hypothesis (see, for example, Pao and Tsai, 2011 [20]; Chitioui, 2012 [21]; Ozturk and Acaravcı, 2013 [5]; among others), some studies favor the conservation hypothesis (see, for example, Kakar et al., 2011 [22]; Al-mulali and Lee, 2013 [23]; Shahbaz et al., 2013 [24]; among others) while some support the feedback hypothesis (Al-mulali and Sab, 2012 [25]; Shahbaz et al., 2013 [26]; Sbia et al. 2014 [27]; among others). As mentioned in the introduction, however, all of these papers deal with the impact of financial development on energy consumption at the aggregate level. Thus, one rational way to compare the disaggregated evidence with previous studies is to focus on the energy-growth literature at the micro level. Table 2 overviews these studies.

Table 2. Literature of growth-sectoral energy consumption nexus based on causality.

Authors	Countries	Period	Method	Findings
Bowden and Payne (2009) [28]	USA	1949–2006	Toda-Yamamoto	Trade and residential; G↔E Industry; E→G Transportation; ∅
Tsani (2010) [29]	Greece	1960–2006	Toda-Yamamoto	Industry and residential; G↔E Transportation; ∅
Zaman et al. (2011) [30]	Pakistan	1972–2008	ECM	Industry and transportation; ∅ Energy; G→E
Abid and Sebri (2012) [31]	Tunisia	1980–2007	VECM	Industry; G→E Transportation; G↔E Residential; G↔E (short term) G→E (long term)
Gross (2012) [32]	USA	1970–2007	ECM	Trade; G→E Transportation; G↔E Industry; E→G

Table 2. *Cont.*

Authors	Countries	Period	Method	Findings
Hamit-Haggar (2012) [33]	Canada	1990–2007	VECM	Industry; G→E
Zhang and Xu (2012) [34]	China	1995–2008	VECM	Industry; G→E (short term) G↔E (long term) Transportation; G→E Services; G↔E Residential; G→E
Abbas and Choudhury (2013) [35]	India and Pakistan	1972–2008	ECM	Agriculture; G↔E (India) G→E (Pakistan)
Saunoris and Sheridan (2013) [36]	USA	1970–2009	ECM	Industry; E→G (short term) G→E (long term) Trade and residential; G→E
Tang and Shahbaz (2013) [37]	Pakistan	1972–2010	VECM	Industry and services; E→G Agriculture; ∅

E→G implies uni-directional causality from energy consumption to growth; G→E implies uni-directional causality from growth to energy consumption; G↔E implies bi-directional causality between energy consumption and growth; ∅ implies no causality between energy consumption and growth.

3. Model and Data

In line with theory and the empirical literature (see, for example, Sadorsky, 2010, 2011 [2,3]; Xu 2012 [38], Khan et al., 2014 [39]; Tang and Tan, 2014 [19]), energy consumption in this study is described as a function of income (y), prices (p), and financial development (fd):

$$e = f\ (y, p, f\ d). \tag{1}$$

The Turkish Republic Ministry of Energy and Natural Resources calculates total energy consumption as a sum of five sectors. Therefore, micro-level energy consumption data includes the following sectors: (i) industrial; (ii) transportation; (iii) residential and services; (iv) agriculture; and (v) non-energy[1]. The panel data augmented form of function (1) is presented in Equation (2) below:

$$e_{i,t} = \beta_{1i} y_{it} + \beta_{2i} p_{it} + \beta_{3i} f d_{it} + v_i + \varepsilon_{it} \tag{2}$$

where v denotes the sector-specific variable and ϵ denotes the random error term. The time dimension consists of annual observations from 1989 to 2011. Energy consumption (e) is measured as energy use in kg of oil equivalent per capita and attained from the Turkish Republic Ministry of Energy and Natural Resources statistics [40]. On the right-hand side, income (y) is measured by real GDP per capita (PPP, constant 2005 US$). Consistent with the literature, energy prices are proxied using real oil prices. Dubai and Brent oil prices[2] are converted into real terms by the consumer price index (CPI, 2005 = 100)[3]. Data for income and the consumer price index are available from the World Bank World Development Indicators database. Oil price data are gathered from British Petroleum's Statistical Review of World Energy database [41].

1 Based on the definition by International Energy Agency (IEA) (http://www.iea.org/), non-energy use covers the fuels that are used as raw materials in the different sectors and are not consumed as a fuel or transformed into another fuel.
2 The reason why two different price measures are used in the model is that it is not easy to find a proxy for Turkey. Although Brent is commonly used in European countries, a large volume of Turkey's imports come directly from Middle Eastern countries. Therefore, it might be useful to compare the results in order to find which proxy would be better in the case of Turkey.
3 Presenting the time series plots of each variables will make the study insufficiently long. The figures, therefore, are not presented here. However, they are available upon request.

Given the baseline proposed by Levine and Zervos (1998) [1], financial development (*fd*) is divided into two parts as described in function (3):

$$fd = f\ (fdbank,\ fdstock) \tag{3}$$

where *fdbank* represents the banking sector development and *fdstock* represents the stock market development.

$$fdbank = f\ (dbagdp,\ fdgdp,\ prcdbofgdp,\ llgdp) \tag{4}$$

where banking sector (*fdbank*) is proxied using four bank-related variables: deposit money bank assets to GDP (*dbagdp*), financial system deposits to GDP (*fdgdp*), private credit by deposit money banks and other financial institutions to GDP (*pcrdbofgdp*), and liquid liabilities as a share of GDP (*llgdp*).

$$fdstock = f\ (stvaltraded,\ stturnover,\ stmktcap) \tag{5}$$

where stock market development (*fdstock*), on the other hand, is represented by three proxies: stock market value traded to GDP (*stvaltraded*), stock market turnover ratio (*stturnover*), and stock market capitilization to GDP (*stmktcap*).

The dataset for the financial development variables is obtained from the World Bank Financial Development and Structure database [42]. Empirical estimations have been carried out using Eviews and Stata software.

4. Methodology and Results

4.1. Principle Component Analysis (PCA)

Within an equation, modeling a few related set of variables might stimulate multicollinearity problem. In order to solve this, measuring the aggregated impact could become more consistent rather than observing them separately. Following previous studies (see, for example, Saci and Holden, 2008 [43]; Huang, 2010 [44]; Tang and Tan, 2014 [19]) we construct two indexes in order to represent banking and stock market development. Thus, the method of principle component analysis (PCA) is used to extract these indexes.

PCA is a well-known linear technique for dimensionality reduction. It reduces the dimensionality of a dataset consisting of a larger number of interrelated variables, while retaining as much as possible the variation present in the original dataset (Lu et al., 2008 [45]). The individual contribution of each financial development variable is standardized by the variance of the related principal component. Table 3 shows weights obtained from the PCA method. These coefficients are weighted with existing variables so as to construct new variables. Therefore, these new variables will be used as financial development proxies for the rest of the analyses.

Table 3. Weights obtained from PCA.

Banking Sector Indicators	Weight	Stock Market Indicators	Weight
dbagdp	0.258512	stvaltraded	0.427832
fdgdp	0.254248	stturnover	0.196701
pcrdofgdp	0.228623	stmktcap	0.375467
llgdp	0.258616		

All outputs of PCA are not reported. They are available upon request.

4.2. Unit Root

Among the panel data literature, commonly used unit root tests by Levin et al. (2002) [46] (hereinafter, LLC) and Im et al. (2003) [47] (hereinafter, IPS) are used. Table 4 shows the LLC and IPS test results. As can be seen from the table, the null hypothesis indicating the existence of a unit root cannot be rejected in levels for each variable. The first difference results, however, show that all variables are stationary. Thus, the results presented in Table 4 prove that all variables in the system are integrated of I (1).

Table 4. Unit root results.

Variable	LLC	IPS
e	1.047 [0.14]	−0.421 [0.33]
y	0.834 [0.79]	−0.899 [0.18]
pdubai	1.099 [0.86]	1.630 [0.94]
pbrent	0.675 [0.75]	1.120 [0.88]
fdbank	−0.757 [0.22]	0.625 [0.73]
fdstock	−0.781 [0.20]	−0.590 [0.27]
Δ*e*	−6.437 [0.00]	−6.475 [0.00]
Δ*y*	−8.181 [0.00]	−7.034 [0.00]
Δ*pdubai*	−9.750 [0.00]	−7.684 [0.00]
Δ*pbrent*	−8.660 [0.00]	−6.921 [0.00]
Δ*fdbank*	−2.007 [0.02]	−2.546 [0.00]
Δ*fdstock*	−2.030 [0.02]	−2.906 [0.00]

Δ is the first difference operator. Tests are run including a trend. Newey-West bandwidth selection with Bartlett kernel is used for the LLC test. The maximum lag lengths are set to 2 and Schwarz Bayesian Criterion is used to determine the optimal lag length. Figures in the brackets are *p*-values.

4.3. Cointegration

A commonly used cointegration technique for panel data is Pedroni's (1999) [48] cointegration test[4]. Table 5 reports the results obtained using Pedroni's test. The results of the majority of within-group as well as between-group cointegration tests indicates the rejection of the null hypothesis. Thus, the null hypothesis of no cointegration is rejected, indicating the presence of cointegration.

Table 5. Pedroni's cointegration results.

Dimension	Test	Equation (6)	Equation (7)	Equation (8)	Equation (9)
Within-group cointegration tests	Panel-v	0.506 [0.30]	−0.537 [0.70]	0.486 [0.31]	−0.553 [0.71]
	Panel-rho	−0.247 [0.40]	−0.336 [0.36]	−0.233 [0.40]	−0.324 [0.37]
	Panel-pp	−2.742 [0.00]	−2.906 [0.00]	−2.671 [0.00]	−2.833 [0.00]
	Panel-adf	−2.636 [0.00]	−3.062 [0.00]	−2.824 [0.00]	−2.979 [0.00]
Between-group cointegration tests	Grup-rho	0.993 [0.83]	0.917 [0.82]	0.999 [0.84]	0.922 [0.82]
	Grup-pp	−1.628 [0.05]	−1.795 [0.03]	−1.530 [0.06]	−1.694 [0.04]
	Grup-adf	−1.768 [0.03]	−2.241 [0.01]	−1.962 [0.02]	−2.095 [0.01]

The tests are carried out with two lags. The panel v-statistic is a right-tailed test while the remaining tests are left-tailed. Figures in the brackets are *p*-values.

4.4. Regression

Having proved the long-run relationship among variables, long-run coefficients can be estimated. To this end, the Mean Group (MG) estimator developed by Pesaran and Smith (1995) [53] is used. The

[4] Previous studies show that estimating slope coefficients with panel time series estimators is robust to cointegration and cross-section dependence (see, for example, Chudik et al., 2011 [49]; Kapetanios et al., 2011 [50]; Pesaran and Tosetti, 2011 [51]; Sadorsky, 2014 [52]). Therefore, cointegration among the variables is tested only using the Pedroni (1999) [48] method.

advantage of this estimation over OLS, fixed effects, and random effects is that MG handles models with heterogeneous slope coefficients. Therefore, results for each cross-section will also be obtained. The linear models estimated using MG are specified as follows:

$$e_{i,t} = \alpha_{1i}y_{it} + \alpha_{2i}pdubai_{i,t} + \alpha_{3i}fd_i bank_{i,t} + v_i + \varepsilon_{i,t} \quad (6)$$

$$e_{i,t} = ß_{1i}y_{it} + ß_{2i}pbrent_{i,t} + ß_{3i}fd_i bank_{i,t} + \Omega_i + \varepsilon_{i,t} \quad (7)$$

$$e_{i,t} = \chi_{1i}y_{it} + \chi_{2i}pdubai_{i,t} + \chi_{3i}fd_i stock_{i,t} + \phi_i + \varepsilon_{i,t} \quad (8)$$

$$e_{i,t} = \delta_{1i}y_{it} + \delta_{2i}pbrent_{i,t} + \delta_{3i}fdstock_{i,t} + \gamma_i + \varepsilon_{i,t} \quad (9)$$

Results reported in Table 6 reveal for the pooled panel that the estimated coefficients on the income variable are statistically significant and positive, and the impact range falls between 0.877 and 0.904 with regard to each specification. If prices are proxied using Dubai, the negative impact of energy prices on energy consumption falls between 0.079 and 0.088. While the estimation is also carried out using Brent prices, there is still not much difference in the results. Note that neither Dubai nor Brent prices have a significant impact on energy consumption. The estimated coefficients on *fdbank* and *fdstock* variables are both positive and statistically significant for each specification. The impact range of developments stemming from the banking sector on energy consumption is between 0.253 and 0.259, while it is between 0.431 and 0.435 for the developments stemming from the stock market.

Table 6. MG results based on linear model.

Unit	Variable	Equation (6)	Equation (7)	Equation (8)	Equation (9)
Pooled Panel	*y*	0.877 [0.00]	0.883 [0.00]	0.891 [0.01]	0.904 [0.00]
	pdubai	−0.088 [0.12]		−0.079 [0.11]	
	pbrent		−0.084 [0.12]		−0.079 [0.10]
	fdbank	0.259 [0.01]	0.253 [0.01]		
	fdstock			0.435 [0.00]	0.431 [0.00]
	cons	−4.823 [0.14]	−5.186 [0.16]	−5.936 [0.15]	−6.403 [0.16]
Industrial	*y*	1.210 [0.00]	1.218 [0.00]	1.257 [0.00]	1.267 [0.00]
	pdubai	−0.019 [0.83]		−0.012 [0.90]	
	pbrent		−0.038 [0.65]		−0.014 [0.87]
	fdbank	0.197 [0.20]	0.179 [0.26]		
	fdstock			0.515 [0.23]	0.486 [0.26]
	cons	−7.385 [0.38]	−7.416 [0.00]	−8.233 [0.00]	−8.309 [0.00]
Transportation	*y*	0.845 [0.03]	0.874 [0.02]	0.868 [0.04]	0.904 [0.03]
	pdubai	0.031 [0.70]		0.031 [0.72]	
	pbrent		0.019 [0.80]		0.017 [0.82]
	fdbank	0.341 [0.09]	0.369 [0.06]		
	fdstock			0.395 [0.03]	0.417 [0.02]
	cons	−6.104 [0.10]	−6.411 [0.70]	−6.513 [0.13]	−6.958 [0.09]
Residential and Services	*y*	0.800 [0.00]	0.810 [0.00]	0.800 [0.01]	0.812 [0.00]
	pdubai	−0.106 [0.12]		−0.089 [0.25]	
	pbrent		−0.102 [0.10]		−0.089 [0.20]
	fdbank	0.199 [0.13]	0.182 [0.16]		
	fdstock			0.437 [0.28]	0.433 [0.21]
	cons	−2.050 [0.48]	−2.210 [0.44]	−2.053 [0.50]	−2.254 [0.46]
Agriculture	*y*	0.671 [0.04]	0.650 [0.05]	0.681 [0.05]	0.653 [0.06]
	pdubai	−0.135 [0.23]		−0.104 [0.39]	
	pbrent		−0.148 [0.13]		−0.125 [0.25]
	fdbank	0.020 [0.28]	0.020 [0.29]		
	fdstock			0.090 [0.83]	0.073 [0.86]
	cons	−0.483 [0.88]	−0.766 [0.81]	−0.283 [0.93]	0.706 [0.84]

Table 6. *Cont.*

Unit	Variable	Equation (6)	Equation (7)	Equation (8)	Equation (9)
Non-Energy use	*y*	3.157 [0.00]	3.162 [0.00]	3.155 [0.00]	3.159 [0.00]
	pdubai	−0.256 [0.12]		−0.239 [0.15]	
	pbrent		−0.231 [0.12]		−0.217 [0.15]
	fdbank	0.237 [0.50]	0.204 [0.55]		
	fdstock			0.419 [0.23]	0.420 [0.31]
	cons	−26.25 [0.00]	−26.16 [0.00]	−26.23 [0.00]	−26.11 [0.00]
Diagnostic Tests	*RMSE*	0.0744	0.0740	0.0769	0.0765
	Wald	48.12 [0.00]	48.79 [0.00]	43.85 [0.00]	44.52 [0.00]
	Obs	115	115	115	115
	CD-test	−0.31 [0.75]	−0.35 [0.72]	−0.36 [0.71]	−0.39 [0.69]
	CIPS-test	−4.091 [0.00]	−4.093 [0.00]	−3.905 [0.00]	−3.930 [0.00]

Parameter estimates are calculated as sample averages. Wald is a chi-squared test for all slope coefficients equal to zero. CD-test is a test for cross-section dependence while CIPS is for unit root. Tests are carried out including a time trend. Figures in the brackets are *p*-values.

(i) Results for industry prove that the estimated coefficient on income variable is statistically significant and positive in each specification, and ranges between 1.210 and 1.267. No matter how oil prices are represented, prices are found to affect energy consumption negatively, but the coefficients are statistically insignificant. Neither for the specifications estimated with *fdbank*, nor for the specifications estimated with *fdstock*, does financial development have a significant impact on energy consumption; (ii) Transportation results show that income affects energy consumption significantly and positively, ranging in value between 0.845 and 0.904. Prices, regardless of measurement, do not affect energy consumption significantly. The estimated coefficients on financial development variables are significant in each specification. While the impact range of the banking sector ranges between 0.341 and 0.369; it ranges between 0.395 and 0.417 in the specification with stock market; (iii) Results for residential services indicate that the estimated coefficients on income variable in each specification is significant and positive, and the impact range falls between 0.800 and 0.812. Estimations for prices using both proxies prove that the impact of prices on energy consumption is negative, as expected, but insignificant. From either the banking side or the stock market, financial development does not significantly affect energy consumption; (iv) Agricultural results suggest that income significantly affects energy consumption, ranging in value between 0.650 and 0.681. In any specification with either energy price proxies or with financial development proxies, prices and financial development are found to affect energy consumption insignificantly; (v) Results for the non-energy sector suggest that the estimated coefficient on the income variable is statistically significant and positive in each case, and ranges between 3.155 and 3.162. As in the agricultural case, prices and financial development do not significantly affect energy consumption, regardless of how prices or financial development are measured. Diagnostics based on linear models do not imply a model specification problem in each separate specification. Cross-sectional dependence (CD-test) and the unit root (Cross-sectionally Augmented IPS-CIPS, hereinafter, CIPS) results reveal that each model presents cross-section dependence and non-stationary residuals. The Root Mean Squared Error (hereafter, RMSE) is low enough in each specification stating the higher estimation power of the models with heterogeneous slope coefficients.

Coban and Topcu (2013) [4] show that a transition process that causes a gradual shift from agriculture, or likewise from manufacturing to services, may produce some structural changes in the sectoral output composition of developing economies. One might expect financial development to affect energy consumption nonlinearly in developing counties like Turkey. In addition to the linear analysis, we also estimate curvilinear models using MG. The nonlinear models are specified as follows:

$$e_{i,t} = \alpha_{1i} y_{it} + \alpha_{2i} pdubai_{i,t} + \alpha_{3i} fd_i bank_{i,t} + \alpha_{4i} fd_i banksq_{i,t} + v_i + \varepsilon_{i,t} \quad (10)$$

$$e_{i,t} = ß_{1i}y_{it} + ß_{2i}pbrent_{i,t} + ß_{3i}fd_ibank_{i,t} + ß_{4i}fd_ibanksq_{i,t} + \Omega_i + \varepsilon_{i,t} \quad (11)$$

$$e_{i,t} = \chi_{1i}y_{it} + \chi_{2i}pdubai_{i,t} + \chi_{3i}fd_istock_{i,t} + \chi_{4i}fd_istocksq_{i,t} + \phi_i + \varepsilon_{i,t} \quad (12)$$

$$e_{i,t} = \delta_{1i}y_{it} + \delta_{2i}pbrent_{i,t} + \delta_{3i}fdstock_{i,t} + \delta_{4i}fdstocksq_{i,t} + \gamma_i + \varepsilon_{i,t} \quad (13)$$

where the terms *fdbanksq* and *fdstocksq* represent the squared terms of financial development in order to test the curvilinear relationship between financial development and energy consumption.

Test results based on nonlinear specifications are reported in Table 7. Findings[5] reveal for the pooled panel that the estimated coefficients of the banking sector and stock market variables are insignificant. (i) Results for industry prove that financial development exhibits an inverted U-shaped pattern of energy consumption, regardless of how financial development is measured. Inflection points[6] for curvilinear relationships are calculated at 3.40 for banking and 1.20 for the stock market; (ii) There is no nonlinear relation found in the case of transportation; (iii) Results for residential services indicate that the impact of financial development on energy consumption displays a U-shaped pattern either with the banking index or with the stock market index. In addition, inflection points for the curvilinear relationship are calculated at 2.55 once the impact of financial development is measured using the banking index, or 1.01 for the stock market index; (iv) Agricultural results provide support for a curvilinear relationship and the impact that financial development has on energy consumption is U-shaped. Inflection points are calculated at 3.08 in the regressions with the banking index and 1.12 in the regressions with the stock market index; (v) Finally, we find no nonlinear relation in the case of non-energy use. When it comes to diagnostics, results based on the nonlinear models indicate that each specification is reasonable. There is no evidence of cross-sectional dependence and non-stationary residuals in addition to the lower RMSE values in all specifications.

Table 7. MG results based on nonlinear model.

Unit	Variable	Equation (10)	Equation (11)	Equation (12)	Equation (13)
Pooled Panel	*y*	0.843 [0.00]	0.850 [0.00]	0.840 [0.00]	0.846 [0.00]
	pdubai	−0.042 [0.18]		−0.067 [0.17]	
	pbrent		−0.067 [0.11]		−0.072 [0.09]
	fdbank	−0.702 [0.57]	−0.696 [0.56]		
	fdbanksq	0.127 [0.51]	0.125 [0.51]		
	fdstock			−4.294 [0.44]	−4.270 [0.44]
	fdstocksq			1.938 [0.42]	1.902 [0.42]
	cons	−5.575 [0.24]	−5.460 [0.24]	−4.903 [0.33]	−4.959 [0.32]
Industrial	*y*	1.021 [0.00]	0.995 [0.00]	1.024 [0.00]	0.999 [0.00]
	pdubai	−0.040 [0.59]		−0.029 [0.69]	
	pbrent		−0.014 [0.83]		−0.005 [0.93]
	fdbank	3.350 [0.00]	3.242 [0.00]		
	fdbanksq	−0.492 [0.00]	−0.483 [0.00]		
	fdstock			13.65 [0.00]	13.46 [0.00]
	fdstocksq			−5.650 [0.00]	−5.624 [0.00]
	cons	−9.265 [0.01]	−8.774 [0.02]	−11.84 [0.00]	−11.42 [0.00]

[5] As the main focus is on the impact of financial development on energy consumption in these models, the impacts of the control variables have been excluded.

[6] Inflection points are calculated using a vertex formula (−b/2a; given the parabola $ax^2 + bx + c$). Because there are no substantial volatilities across the regression results in which Dubai or Brent prices are proxied, results based on the specifications with Dubai prices will be reported for the calculation of inflection points in the rest of the paper.

Table 7. *Cont.*

Unit	Variable	Equation (10)	Equation (11)	Equation (12)	Equation (13)
Transportation	*y*	0.826 [0.01]	0.840 [0.01]	0.818 [0.01]	0.831 [0.01]
	pdubai	0.028 [0.75]		0.030 [0.73]	
	pbrent		0.014 [0.86]		0.016 [0.84]
	fdbank	0.250 [0.84]	0.307 [0.80]		
	fdbanksq	−0.036 [0.82]	−0.041 [0.80]		
	fdstock			0.683 [0.88]	0.780 [0.86]
	fdstocksq			−0.291 [0.86]	−0.300 [0.86]
	cons	−2.775 [0.53]	−3.034 [0.49]	−2.679 [0.58]	−2.902 [0.55]
Residential and Services	*y*	0.993 [0.00]	1.001 [0.00]	0.991 [0.00]	0.999 [0.00]
	pdubai	−0.068 [0.25]		−0.076 [0.20]	
	pbrent		−0.067 [0.21]		−0.073 [0.16]
	fdbank	−1.560 [0.06]	−1.540 [0.06]		
	fdbanksq	0.305 [0.00]	0.302 [0.00]		
	fdstock			−8.859 [0.00]	−8.791 [0.00]
	fdstocksq			4.385 [0.00]	4.356 [0.00]
	cons	−1.339 [0.65]	−1.435 [0.62]	1.184 [0.71]	1.085 [0.73]
Agriculture	*y*	0.477 [0.18]	0.513 [0.14]	0.479 [0.18]	0.514 [0.14]
	pdubai	−0.071 [0.46]		−0.084 [0.38]	
	pbrent		−0.092 [0.28]		−0.102 [0.23]
	fdbank	−3.198 [0.01]	−3.073 [0.02]		
	fdbanksq	0.518 [0.00]	0.505 [0.00]		
	fdstock			−14.39 [0.00]	−14.11 [0.00]
	fdstocksq			6.412 [0.00]	6.346 [0.00]
	cons	4.147 [0.38]	3.567 [0.44]	7.257 [0.16]	6.727 [0.19]
Non-Energy Use	*y*	2.979 [0.00]	2.985 [0.00]	2.949 [0.00]	2.954 [0.00]
	pdubai	−0.226 [0.18]		−0.228 [0.17]	
	pbrent		−0.203 [0.18]		−0.205 [0.17]
	fdbank	−1.632 [0.49]	−1.652 [0.48]		
	fdbanksq	0.249 [0.42]	0.248 [0.42]		
	fdstock			−8.084 [0.33]	−8.027 [0.34]
	fdstocksq			3.398 [0.29]	3.334 [0.30]
	cons	−21.32 [0.01]	−21.25 [0.01]	−18.93 [0.03]	−18.92 [0.03]
Diagnostic Tests	*RMSE*	0.0677	0.0675	0.0675	0.0673
	Wald	35.37 [0.00]	43.85 [0.00]	36.21 [0.00]	45.45 [0.00]
	Obs	115	115	115	115
	CD-test	−0.09 [0.93]	−0.12 [0.90]	−0.14 [0.88]	−0.17 [0.86]
	CIPS-test	−4.279 [0.00]	−4.293 [0.00]	−4.290 [0.00]	−4.296 [0.00]

Parameter estimates are calculated as sample averages. Wald is a chi-squared test for all slope coefficients equal to zero. CD-test is a test for cross-section dependence while CIPS is for unit root. Tests are carried out including a time trend. Figures in brackets are *p*-values.

4.5. Causality

Recent developments in panel data econometrics have proved that standard causality tests do not perform well under the existence of the heterogeneity. Considering these developments, Dumitrescu and Hurlin (2012) [54] (hereafter, DH) propose a simple Granger (1969) [55] non-causality test in heterogeneous panel data models with fixed coefficients.

The DH procedure has a number of advantages. First, the tests have very good properties, even in samples with very small values of T and N. Second, the test statistics based on the cross-sectional average of individual Wald statistics can be used without estimating any particular panel regression. Third, the method can be employed in unbalanced panels and/or panels with different lag order k for each individual.

Table 8 shows DH causality results. Results for first lag show no causal relationship between energy consumption and financial development in the pooled panel. This finding is exactly the same for all cross-sectional units[7]. For second lag, financial development, regardless of its source, causes changes in energy consumption in the pooled panel. The only significant result for cross-sectional units belongs to the industry sector, in which banking sector and stock market development are found as a source of energy consumption. When it comes to the third lag, pooled panel results indicate bi-directional causality between financial development and energy consumption. Cross-sectional results, on the other hand, show that financial development stemming from either the banking sector or stock market causes changes in energy consumption in the cases of industry, transportation, and residential services.

Table 8. Causality results.

Lag Length	Sectors	*fdbank*→*e*	*e*→*fdbank*	*fdstock*→*e*	*e*→*fdstock*
k = 1	Pooled panel	0.741 [0.68]	0.718 [0.66]	0.801 [0.75]	0.604 [0.53]
	Industry	3.024 [0.08]	0.637 [0.42]	3.338 [0.06]	0.487 [0.48]
	Transportation	0.215 [0.64]	0.792 [0.37]	0.131 [0.71]	0.869 [0.35]
	Residential and services	0.242 [0.62]	0.786 [0.37]	0.301 [0.58]	0.491 [0.48]
	Agriculture	0.207 [0.64]	1.686 [0.19]	0.182 [0.66]	1.164 [0.28]
	Non-energy use	0.015 [0.89]	0.007 [0.93]	0.052 [0.81]	0.009 [0.92]
k = 2	Pooled panel	2.722 [0.09]	1.494 [0.25]	2.818 [0.06]	1.281 [0.11]
	Industry	7.606 [0.02]	1.674 [0.43]	7.681 [0.02]	1.474 [0.47]
	Transportation	1.683 [0.43]	1.085 [0.58]	1.539 [0.46]	1.073 [0.58]
	Residential and services	3.728 [0.15]	1.861 [0.39]	4.357 [0.11]	1.331 [0.51]
	Agriculture	0.314 [0.85]	2.164 [0.33]	0.213 [0.89]	1.539 [0.46]
	Non-energy use	0.277 [0.87]	0.688 [0.70]	0.299 [0.86]	0.990 [0.60]
k = 3	Pooled panel	5.750 [0.00]	2.289 [0.05]	6.029 [0.00]	1.876 [0.00]
	Industry	7.863 [0.04]	1.797 [0.61]	7.959 [0.04]	1.604 [0.65]
	Transportation	9.583 [0.02]	1.150 [0.76]	10.46 [0.01]	1.034 [0.79]
	Residential and services	8.104 [0.04]	1.991 [0.57]	8.479 [0.03]	1.387 [0.71]
	Agriculture	0.325 [0.95]	4.089 [0.25]	0 267 [0.96]	3.214 [0.35]
	Non-energy use	2.878 [0.41]	2.317 [0.49]	2.971 [0.39]	2.151 [0.54]

Figures are reported using Wald statistics. Figures in the brackets are *p*-values.

5. Discussion and Policy Implications

The empirical results reported herein can be used for an extensive discussion addressing how consistent existing results are with the relevant theories and previous literature. For each model/specification, the positive and significant coefficients on income indicate the validity of the hypothesis "energy consumption rises with increases in income," not only at the aggregate level but also at the disaggregated level[8]. In non-energy use industry, in particular, the coefficients on income in all specifications are dramatically greater than those of other sectors. A possible reason for this finding could be the production structure of the industry, which is pretty homogeneous. For the pooled panel, although the impact of prices on energy consumption is negative, which is consistent with theory, it is not statistically significant, regardless of the proxy. This finding might explain why energy consumption is heavily influenced by income. Sadorsky (2011) [3], for instance, finds for Central and Eastern European countries that income does not have a significant impact on energy consumption. Income, therefore, seems to be more important in determining energy demand in Turkey over this particular period of time. Furthermore, the negative and insignificant impact of energy prices on energy consumption is also in line with Xu (2012) [38], who finds a downward sloping but insignificant

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7 Results for industry sector seem to exhibit significant uni-directional causality from financial development—no matter how it is measured—to energy consumption in the first lag. However, this result is not valid as the null indicating "no causality for any of the cross-section units of the panel" cannot be rejected.

8 At least in this case.

energy demand equation in China. Note that the impact of energy prices on the transportation sector's energy consumption is also insignificant in each specification. However, the estimated coefficients are positive even if they are close to zero. This could be evidence of a fully rigid price elasticity in the transportation industry, where fuel is considered a necessary input.

Results for the pooled panel reveal that both banking and stock market developments have a significant positive impact on energy consumption in Turkey. The magnitude of stock market development, however, is larger than that of banking development. This finding points out the efficiency of the wealth effect. It is also totally consistent with Sadorsky (2010) [2], who reports the positive impact of stock market development on energy use in emerging economies. Findings obtained from nonlinear models indicate that the impact of financial development (no matter what the source is) on energy consumption in the industry sector is an inverted U-shaped curve. This result suggests that access to financial capital easily and less expensively leads to more manufacturing and an increase in energy consumption; a gradual shift later on from manufacturing to services leads to a drop in energy consumption. Both banking sector and stock market development affects energy consumption positively in the transportation sector via the direct effect channel in addition to the business effect channel. Results for residential services and the agricultural industry show that the impact of financial development on energy consumption displays a U-shaped pattern. This might be very hard to explain at first glance. Indeed, it goes with the results of the industry sector. In the early stages of financial development, the utilization of production factors in manufacturing leads to a decrease in energy consumption in other dominant industries. Expansion in the potential of manufacturing leads to factor mobilization from manufacturing to services. Expanded business potential is expected to lead to an increase in energy consumption in these industries[9]. The only sector in which financial development does not significantly affect energy consumption in any specification/model is non-energy use. This makes sense given the relative unimportance of the non-energy use industry in the sectoral composition of energy consumption.

Overall, the results indicate that development in the financial system is expected to affect production and energy consumption in the industry sector initially, and then shift to other sectors. Furthermore, inflection points reveal that financial development leads to an increase in energy consumption in the residential and service sectors before the agricultural industry. This finding, which points out that residential services benefit from financial development earlier than the agricultural industry, is very robust to the source of financial development.

Causality analyses in the field of energy economics are expected to provide some preliminary information to policymakers on whether energy conservation policies would be in conflict with economic targets. Disaggregated evidence obtained from causality analysis indicates the existence of the conservation hypothesis in three sectors, namely (i) industrial; (ii) transportation; and (iii) residential services. In these sectors energy conservation policies could be implemented without a significantly adverse impact on the financial system. This finding clearly shows that policymakers could aim at decreasing energy intensity regardless of any economic or financial consequences. Moreover, tending towards alternative resources and investing in technologies that help to increase the use of renewable energy sources is expected not to have a harmful impact on the financial system. In short, the negative environmental impacts of using fossil fuels in these sectors, in particular transportation, can be kept down without considering any financial restriction.

Causality results suggest that the neutrality hypothesis is valid in the case of agricultural and non-energy use sectors. Given a gradual shift from agriculture to services, changing sectoral composition could make sense of why financial development and agricultural energy consumption is interdependent. No causality in the case of non-energy use sector, on the other

[9] One might wonder why this would be the case in the agricultural industry. Although the basic idea is conceptually the same, the adoption of modern techniques in the agriculture sector with advanced technology can be a proper way of explaining how an efficient agricultural industry benefits from financial markets as financial development proceeds.

hand, might be explained given the relative unimportance of this sector in the sectoral composition of energy consumption.

This study provides some macro level evidence as well as disaggregated findings. Financial development that occurs in the current period affects energy consumption during the two subsequent periods, while the opposite holds true for the following three periods. Thus, energy conservation policies at the aggregate level might deteriorate the financial sector after a certain period of time. Policymakers therefore have to keep in mind that policies increasing energy efficiency might eventually affect economic activity. Under such a long-term condition, growth can only be promoted via a well-functioning banking system and stock market, and thus the demand for energy will be enhanced.

When it comes to cross-sectional results in terms of lag lengths, the findings are of interest. It should be emphasized that financial development that occurs in a certain period of time initially affects energy demand in the industrial sector, and then transportation and residential services. For agricultural and non-energy use sectors, the only interpretation one could make is that the impact[10] of financial development needs at least four periods[11] to exist on energy consumption. At the aggregate level, financial development primarily affects energy consumption, which in turn affects financial development.

Although there are a limited number of studies on the finance-energy nexus in the case of Turkey, it is possible to compare the results of the existing study with those provided by the relevant literature. Findings obtained from the pooled panel show the validity of the feedback hypothesis between financial development and energy consumption. While this result is totally consistent with the results of Zeren and Koc (2014) [6], it is partially consistent with the results of Ozturk and Acaravci (2013) [5] that report uni-directional causality from energy consumption to financial development in the short term. In terms of the energy-growth literature, this study supports the bulk of the literature that reports bi-directional causality between energy consumption and growth (see, for example, Akan et al., 2010 [56]; Erdal et al., 2008 [57]; Kaplan et al., 2011 [58]). In addition, it is also possible to compare the results of this study with the papers on energy-growth nexus at the disaggregated level. The findings of this study do not support those of Jobert and Karanfil (2007) [59], who suggest the existence of the neutrality hypothesis either in pooled panel or in the industry sector. From an international energy-growth perspective, on the other hand, the findings of this study are consistent with the results of Tang and Shahbaz (2013) [37], who report the validity of the neutrality hypothesis in Pakistan's agricultural sector. Similarly, the results are consistent with those of Zhang and Xu (2012) [34], who find support for the conservation hypothesis in industry, residential, transportation, and services in China.

6. Conclusions

The goal of this study is to investigate the relationship between financial development and energy consumption in Turkey at the sector level. To this end, heterogeneous panel time series techniques are adopted over the period 1989–2011. Regression results show that financial development affects energy consumption positively in the pooled panel and in the transportation sector. However, the impact of financial development on energy consumption in the industry sector displays an inverted U-shaped pattern, while it displays a U-shaped pattern in the residential services and agricultural sectors. In terms of causality, the findings indicate a feedback relationship in the pooled panel. Cross-sectional results, on the other hand, show uni-directional causality from financial development to energy consumption in the case of (i) industrial; (ii) transportation; and (iii) residential services. The variation across lag lengths obtained from the cross-sectional results shows that financial development occurring

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[10] Of course, if there is.

[11] In the case of this study, four periods correspond to a year. Therefore, the impact of financial development takes at least a year to affect energy consumption in these sectors.

in a certain period of time initially affects the demand for energy in the industrial sector, which is followed by the transportation sector and residential services. Once the results are evaluated in terms of the hypotheses suggested herein, the empirical results confirm that financial development affects energy consumption at the sector level and that financial development affects energy-intensive industries much more than less energy-intensive industries. Another finding is that the impact that financial development has on energy consumption does not vary across financial development proxies. Furthermore, the magnitude of energy prices on energy consumption is very robust to oil price proxy.

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