THE EFFECT OF ECONOMIC VOLATILITY ON ELECTRICITY DEMAND: PANEL DATA ANALYSIS FOR TURKEY

by

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Outline

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Introduction

- Increased uncertainty affects decision behavior of economic agents based on the precautionary savings motive, theories of investment under uncertainty and real options (Robays, 2012).
- As electricity demand is also an economic decision, we expect significant effect of economic uncertainty on the electricity demand
- our aims: (1) to examine the effect of volatility associated with some important economic variables on electricity demand, (2) to analyze the determinants of electricity demand, (3) to obtain the price and income elasticities.
- ***For the first time, we analyze the determinants of electricity consumption of Turkey's provinces by focusing on common uncertainty factors:*** exchange rate volatility, industrial production volatility, stock market volatility, oil price volatility
- annual balanced panel data on 65 provinces of Turkey between the years 1990 and 2001.

Introduction

Understanding the determinants of electricity demand are essential

- electricity demand forecasting,
- investment planning,
- the regulation of the sector,
- the formulation of policies on demand management,
- restructuring of electricity sector,
- the determination of the social, economic, and environmental impacts of policies.

Introduction

How does the uncertainty affect economic decisions ?

Past theoretical works have defined two channels based on (Plante and Traum, 2012);

- **Precautionary savings motive:** higher uncertainty→ consumption↓; savings ↑→ investment ↑

  for example, Sandmo (1970)
- **Real options effect:** "if an investment is irreversible, increased uncertainty raises the option value of waiting to invest" (Guo and Kliesen, 2005: 679)→ investment↓/delay

for example, Henry (1974), Bernanke (1983), Brennan and Schwartz (1985), Majd and Pindyck (1987), Brennan (1990), Gibson and Schwartz (1990), Triantis and Hodder (1990), Aguerrevere (2009), and Bloom (2009)

Effects of Uncertainty on Economic Activity

- Many theoretical and empirical studies that include the different types of uncertainty into their models (Akarsu, 2013: 80) and generally show the ***investment, growth, trade, production, consumption, employment, inflation, welfare, and trade effects*** of various volatilities/uncertainties

for example, Ramey and Ramey (1995), Boyd and Caporale (1996), Ferderer (1996), Grier and Perry (2000), Bloom (2009), Elder and Serletis (2010), Arratibel et al. (2011), Bahmani-Oskooee and Xi (2011-2012), Berument et al. (2011), Knotek and Khan (2011), Beetsma and Giuliodori (2012), Chen and Hsu (2012), Huang et al. (2012), Plante and Traum (2012), Pourshahabi et al. (2012), and Demir (2013)

- Few energy studies analyze the effect of economic uncertainty: Molls (2000), Radchenko (2005), Kellogg (2010), Görmüş (2012), Pourshahabi et al. (2012), and Romano and Scandurra (2012). ***For the energy demand, the only study is by Pourshahabi et al. (2012) that incorporates the volatility into their petroleum consumption model and found negative and significant effect of oil price volatility on the petroleum consumption for OECD countries over the period from 1980 to 2008.***

Literature Review on Electricity Demand

- Houthakker (1951): pioneering study
- Between years 1951 and 2008, more than 450 studies for the electricity demand estimation (Dahl (2011))
- Our focus is on the aggregate electricity demand based on the arguments suggested by Pouris (1989) in order to obtain unbiased elasticity estimates for the total economy.
- For Turkey, there are only few studies analyzing the total electricity demand.
- We conclude that based on the explanatory variables, time period and method employed, studies find different results for elasticity estimates.
- Our study aims to contribute to the literature by including volatility as a factor determining the electricity demand and by employing panel data for Turkey.

Total Electricity Demand Studies for Turkey

Author	**Data**	**Method/ Model**	**Variables**	**Income Elasticities**		**Own Price Elasticities**	
				Short-run	**Long-run**	**Short-run**	**Long-run**
Soysal (1986)	1963-1981 TS	Multiple linear regression OLS	GNP at constant prices, corrected electricity price, time	1.839		-0.0683	
Bakırtaş et al. (2000)	1962-1999 TS	Linear ECM	per capita real income	0.667	3.134		
Akan and Tak (2003)	1970-2000 TS	ECM	Income, price	0.630	1.8098	-	-0.2212
Erdoğdu (2007)	1984:Q1-2004:Q4 TS	PAM	real electricity prices, real GDP per capita	0.057	0.414	-0.04	-0.29
Maden and Baykul (2012)	1970-2009 TS	Cointegration model, ECM	per capita GDP, electricity price	0.168	0.928	-1.440	-6.85

Source: Author’s own elaboration. Note: OLS: Ordinary Least Squares; PAM: Partial Adjustment Model; ECM: Error Correction Model.

Model

Distinction between long run and short run effects of economic factors

- ✓ In the short run, as stocks of electrical appliances, equipment, and machines, and other factors of production are fixed, only the factors that lead to changes in utilization rate of fixed electrical equipment stock determine the electricity demand;

- ✓ In the long run, size of stock and efficiency of electrical appliances, equipment, and machines can change as a result of change in the economic and technological factors.

- ✓ "This recognition actually calls for a dynamic model, where the difference between the short run and the long run is tackled explicitly" (Olsen and Roland, 1988: 16).

Model

Dynamic panel data model;

$$\ln\ pcec = \alpha_1 \ln\ pcec_{-1} + X\alpha_2 + D_\mu \mu + \varepsilon \tag{1}$$

Where X = (lnpcgdp lnrep uratio hdd cdd h),

lnpcec, lnpcgdp, and lnrep: natural logarithms of per capita electricity consumption, per capita gross domestic product, real electricity price;

uratio: urbanization ratio;

hdd and cdd: heating and cooling degree days, respectively;

h: one of the volatility variables.

Formulation of the Model

- Static electricity consumption model (desired level of electricity consumption):

$$\ln pcec^* = \beta * \ln pcgdp + \gamma * \ln rep + \theta * uratio + \upsilon * hdd$$
$$+ \varphi * cdd + \lambda * h + D_{\mu}\mu_{*} + u \qquad (2)$$

- Partial adjustment mechanism in (3) to consider adjustment lags of current electricity consumption to the long-run equilibrium level after a shock. π : adjustment speed.

$$\ln pcec - \ln pcec_{-1} = \pi(\ln pcec^* - \ln pcec_{-1}) \qquad (3)$$

- Replace lnpcec* in equation (3) with lnpcec* in equation (2) and solve for lnpcec.

Data

- annual balanced panel data on 65 provinces of Turkey between the years 1990 and 2001

- total electricity consumption (kWh), sectoral electricity consumption (kWh) and sectoral electricity end-use prices (TL/kWh) from Turkish Electricity Distribution Company (Co. Inc.)

- Population, GDP and urban population data of provinces from TURKSTAT Database

- İstanbul Chamber of Commerce (İTO) wholesale price index (general, 1968=100) used for deflation of GDP and electricity end-use prices from Electronic Data Delivery System of CBRT.

Data

- Average daily temperatures for each province from Turkish State Meteorological Service for calculation of hdd and cdd variables

$$HDD_i = \begin{cases} 18°C - T_{mi} & \text{if } T_{mi} \leq 15°C \\ 0 & \text{if } T_{mi} > 15°C \end{cases}, \text{ i=1,...,365}$$

$$CDD_i = \begin{cases} T_{mi} - 22°C & \text{if } T_{mi} > 22°C \\ 0 & \text{if } T_{mi} \leq 22°C \end{cases}, \text{ i=1,...,365}$$

where, $T_{m\,i}$ is the average daily temperature.

- Volatilities are proxied by the quarterly, monthly and weekly averages of conditional variances of growth of real exchange rate calculated using PPI, growth of real exchange rate calculated using CPI, industrial production index growth, crude oil price growth, nominal exchange rate growth and İstanbul Stock Exchange-100 index growth obtained from the estimation of GARCH models.

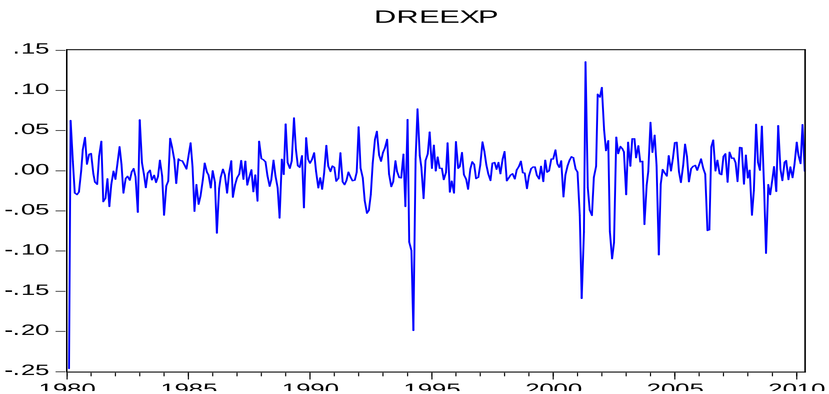
Volatility Modelling

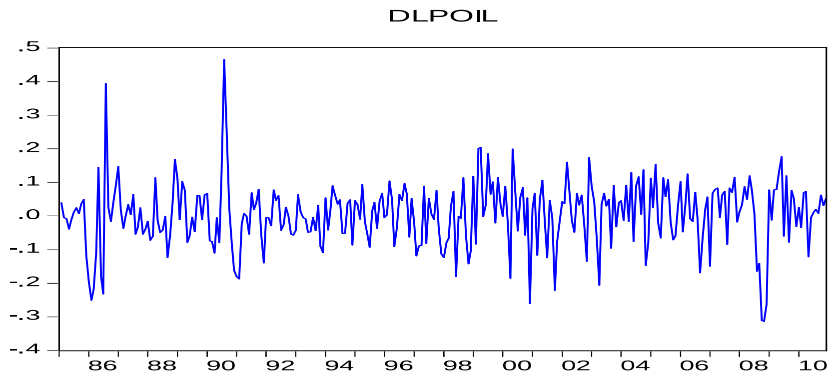
- apply ARCH/GARCH models to time series of various economic variables:
- ✓ real exchange rate calculated using PPI (REEXP),
- ✓ real exchange rate calculated using CPI (REEXC),
- ✓ industrial production index (IPI),
- ✓ crude oil spot price (Brent) (POIL),
- ✓ nominal exchange rate (NEXCR) and
- ✓ İstanbul Stock Exchange-100 index (BIST100).
- Conditional variances as proxy for volatility.

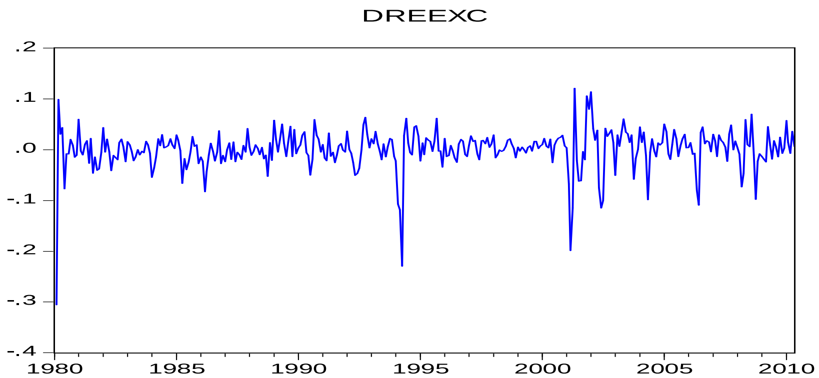
Summary Statistics and Data Sources

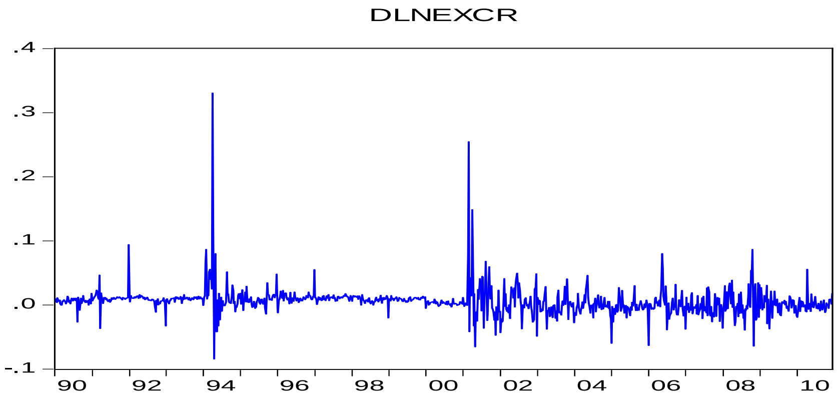
Series	REEXP	REEXC	IPI	POIL	NEXCR	BIST100
Frequency	Monthly	Monthly	Quarterly	Monthly	Weekly	Monthly
Time Period	1980M01-2010M05	1980M01-2010M05	1980Q1-2006Q4	1985M01-2010M12	1990W01-2010W50	1987M11-2011-M01
Observations	365	365	108	312	1094	279
Mean	122.9652	126.8274	78.13333	32.75679	0.341101	14536.56
Median	117.0000	122.2000	75.05000	21.59500	0.279353	5451.840
Maximum	188.5000	194.1000	142.6000	133.1800	0.774285	68787.18
Minimum	81.50000	78.00000	28.70000	9.410000	0.001172	3.798640
Std. Dev.	20.54930	26.22609	30.08493	24.06677	0.295582	18450.11
Skewness	0.321468	0.572513	0.236922	1.709039	0.055700	1.185302
Kurtosis	2.093298	2.570342	2.132144	5.473339	1.206166	3.206786
Jarque-Bera	18.78952	22.74699	4.399661	231.4087	147.2455	65.82682
Probability	0.000083	0.000011	0.110822	0.000000	0.000000	0.000000
Sum	44882.30	46292.00	8438.400	10220.12	373.1640	4055699.
Sum Sq. Dev.	153707.6	250362.1	96846.04	180134.1	95.49405	9.46E+10
Data Source	CBRT EDDS	CBRT EDDS	CBRT EDDS	IEA Database	Author's own calculation	CBRT EDDS

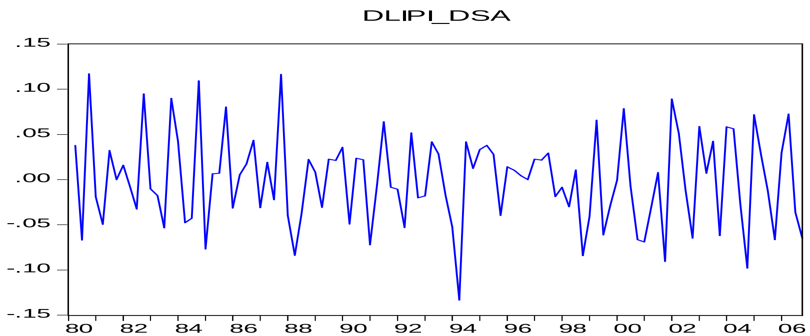
Periods of extremely high volatility followed by periods of tranquility

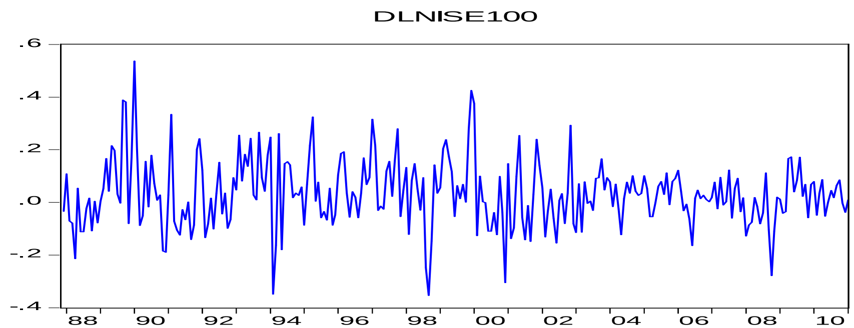












Volatility Modelling

- Proxies for the volatilities of important economic variables are obtained from the estimations of various univariate fixed parameter GARCH models: ARCH (q), GARCH (q, p), Threshold GARCH, EGARCH, Power ARCH, and Component ARCH models.
- 1st step of ARCH modeling: specification of an adequate conditional mean equation of the series assuming constant variance. For this purpose, we employ ARMA (r, s) models. Model selection is based on Box-Jenkins (1970, 1976) methodology and besides, we follow general to specific modeling approach.

$$y_t = \mu + \sum_{i=1}^{r} y_{t-i} + \sum_{j=1}^{s} \varepsilon_{t-j} + \varepsilon_t$$

Volatility Modelling

- After specifying our mean equation and diagnostic checking, the last step will be to estimate our ARMA(r,s)-GARCH(q,p) model from which volatility measurement will be obtained and we modify the mean equation, accordingly.

- GARCH(1, 1) model with t distribution for DREEXP
- GARCH(1, 1) model with GED for DREEXC
- EGARCH(1, 1) model for DLIPI_DSA
- GARCH(1, 1) model with normally distributed errors for DLPOIL
- EGARCH (1, 1) model with GED for DLNEXCR
- EGARCH (1, 2) model for DLNISE100

- In all model estimations, the log-likelihood function is maximized by Marquardt optimization algorithm under the different conditional distribution assumptions for the errors.

(G)ARCH Model Estimation Results

Conditional Mean Equation

	DREEXP	DREEXC	DLIPIDSA	DLPOIL	DLNEXCR	DLNBIST100
AR(1)	0.230113 (0.0001)				0.993616 (0.0000)	
AR(2)			0.598382 (0.0000)			
AR(12)		0.125547 (0.0216)				-0.875395 (0.0000)
SAR(4)			0.916468 (0.0000)			
SAR(12)	-0.122031 (0.0018)					
MA(1)		0.300046 (0.0000)	-0.172331 (0.0000)	0.171013 (0.0073)	-0.752584 (0.0000)	0.074298 (0.0036)
MA(2)			-0.800682 (0.0000)		-0.106047 (0.0000)	
MA(12)						0.896482 (0.0000)
SMA(4)			-0.619995 (0.0000)			
SMA(12)		-0.235231 (0.0006)				

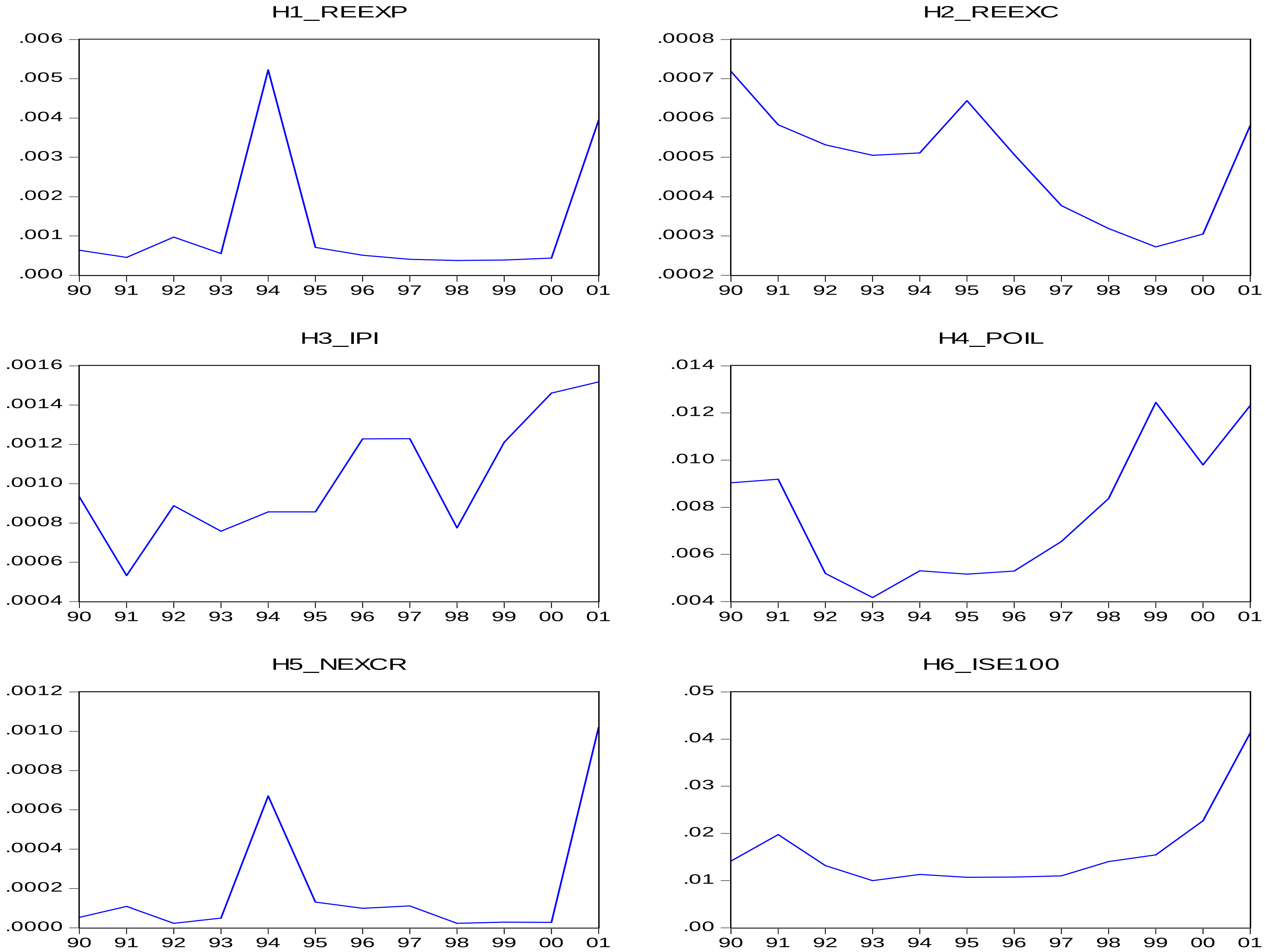
(Logarithm of) Conditional Variance Equation ((ln)h_t)

	DREEXP	DREEXC	DLIPIDSA	DLPOIL	DLNEXCR	DLNBIST100
ε_{t-1}^{2}	0.448902 (0.0225)	0.073846 (0.0479)		0.232340 (0.0013)		
h_{t-1}	0.540496 (0.0000)	0.891018 (0.0000)		0.650589 (0.0000)		
$\varepsilon_{t-1} / h_{t-1}^{0.5}$			-0.375057 (0.0016)		0.056596 (0.0982)	-0.047712 (0.0027)
$\left\lvert \varepsilon_{t-1} / h_{t-1}^{0.5} \right\rvert$			-1.169904 (0.0000)		0.394638 (0.0000)	0.465468 (0.0002)
$\ln(h_{t-1})$			0.497562 (0.0000)		0.961388 (0.0000)	0.058192 (0.0889)
$\ln(h_{t-2})$						0.921956 (0.0000)
t-dist. dof	3.305008 (0.0001)					
GED Parameter		1.082459 (0.0000)			0.799967 (0.0000)	
L.L.	810.120	825.7731	201.9997	325.973	3622.711	240.9664
AIC	-770.12	-767.773	-178	-311.973	-3484.71	-192.966
SIC	-692.90	-655.728	-146.618	-285.794	-3140	-106.962

(G)ARCH Model Diagnostic Test Results

	DREEXP	DREEXC	DLIPIDSA	DLPOIL	DLNEXCR	DLNBIST100
Q(6)	4.6663 (0.323)	7.1750 (0.067)	2.7679 (0.096)	6.9779 (0.222)	2.7148 (0.438)	5.1779 (0.159)
Q(12)	6.4511 (0.776)	10.109 (0.342)	5.7937 (0.564)	16.164 (0.135)	7.2410 (0.612)	13.770 (0.131)
$Q^2(6)$	2.0240 (0.731)	3.2774 (0.351)	2.4267 (0.119)	5.6800 (0.339)	1.7194 (0.633)	6.7418 (0.081)
$Q^2(12)$	6.3104 (0.789)	16.756 (0.053)	5.4628 (0.604)	16.162 (0.135)	3.3966 (0.946)	10.877 (0.284)
ARCH(1)	0.207 (0.649)	0.132 (0.716)	0.165 (0.685)	0.019 (0.890)	0.000 (0.993)	1.506 (0.219)
ARCH(2)	0.476 (0.788)	0.285 (0.867)	0.342 (0.843)	0.626 (0.731)	0.232 (0.890)	2.522 (0.283)
ARCH(4)	1.849 (0.764)	1.282 (0.864)	2.389 (0.665)	1.653 (0.799)	0.795 (0.939)	6.058 (0.195)
Skewness	-0.452759	-0.521381	-0.328273	-0.314116	1.793850	0.011742
Kurtosis	5.396742	5.075700	2.950175	3.056065	27.12132	3.258332
JB test	96.003 (0.000)	79.139 (0.000)	1.825 (0.402)	5.155 (0.076)	27059.2 (0.000)	0.746 (0.689)
Leverage Effects	1.835 (0.042)	1.263 (0.239)	0.399 (0.959)	0.529 (0.895)	0.742 (0.913)	0.102 (0.749)

- ✓ Ljung-Box statistics of the standardized and the squared standardized residuals for model of each series indicates that there is *no evidence of autocorrelation* in standardized and the squared standardized residuals.
- ✓ ARCH-LM test for the standardized residuals support the result obtained by checking autocorrelation in squared standardized residuals that there is *no remaining GARCH effects* in the models.
- ✓ There is *significant seasonality* in the conditional means and *non-explosion conditions* for conditional mean (sums of AR coefficients are less than one) and (log)conditional variance are *satisfied*.
- ✓ The leverage effects test indicate the *absence of remaining asymmetry*



H1_REEXP
.006
.005
.004
.003
.002
.001
.000
90 91 92 93 94 95 96 97 98 99 00 01
H2_REEXC
.0008
.0007
.0006
.0005
.0004
.0003
.0002
90 91 92 93 94 95 96 97 98 99 00 01
H3_IPI
.0016
.0014
.0012
.0010
.0008
.0006
.0004
90 91 92 93 94 95 96 97 98 99 00 01
H4_POIL
.014
.012
.010
.008
.006
.004
90 91 92 93 94 95 96 97 98 99 00 01
H5_NEXCR
.0012
.0010
.0008
.0006
.0004
.0002
.0000
90 91 92 93 94 95 96 97 98 99 00 01
H6_ISE100
.05
.04
.03
.02
.01
.00
90 91 92 93 94 95 96 97 98 99 00 01

- Compare the volatilities calculated between 1990 and 2001 to be employed for the panel application on the provinces of Turkey.
- Each volatility measure can capture different economic events, more clearly.
- In 2001, most of the volatilities rapidly increase as a result of economic crisis in Turkey reflecting the period of high uncertainty.
- Other economic crises such as 1994 crisis seem to be better reflected in the volatility measures based on real and nominal exchange rates.
- Increase in stock market volatility for year 1991 can be due to Gulf crisis between 1990 and 1991.
- The source of the sharp increases in oil price volatility in 1999 and 2001 may be related to the concerns about year 2000 problem (millennium bug) in 1999 and September 11, 2001 Terrorist attack on World Trade Centre in New York (Henriques and Sadorsky, 2011).

Estimation of the Dynamic Panel Data Model

- ➢ restrict each cross-section to have the same long-run&short run slope coefficients and error variances, but not put any other constraints on intercepts across cross-sections.
- ✓ Blundell and Bond (1998) "system" GMM estimation which is found to be more stable and efficient compared to Arellano and Bond (1991) "difference" GMM estimation
- ✓ two-step system GMM to ensure consistency and asymptotic efficiency of estimators
- ✓ Downward bias in the two-step standard errors are corrected by Windmeijer (2005) finite-sample correction.
- ✓ Number of moments is determined by downward testing procedure proposed by Andrews and Lu (2001).
- ✓ We take the following variables as exogenous: real electricity prices (lnrep) as they are under the regulation of government, urbanization ratio (uratio), temperature variables (hdd and cdd); and volatility variables.

Estimation of the Dynamic Panel Data Model

- ✓ estimate a system of equations composed of level equation and differenced equation.
- ✓ In the differenced equation, second lag of lnpcec is used as instrument for differenced lagged lnpcec and Δlnpcgdp is instrumented by lnpcgdp_{-2}.
- ✓ For the level variables in level equation, lags of own first differences are employed as instruments.
- ✓ However, we account for the possibility of correlation between fixed effects and lnpcec_{-1}, lnpcgdp, lnrep, uratio, hdd and cdd variables by excluding them from the levels equation.
- ✓ We use one instrument for each time period, variable and lag distance.

Estimation Results of Electricity Demand Model for Turkey (Panel data on 65 provinces over the period from 1990 to 2001)

lnpcec	**Blundell and Bond (1998) System GMM Estimation Results of Dynamic Model**					
	h1_reexp[1]	h2_reexc[1]	h3_ipi	h4_poil	h5_nexcr[1]	h6_ise100[1]
$lnpcec_{-1}$	0.575***	0.575***	0.548***	0.49747***	0.575***	0.575***
lnpcgdp	0.428***	0.428***	0.379***	0.34815***	0.428***	0.428***
lnrep	-0.591*	-0.591*	-0.174***	-0.1160***	-0.591*	-0.591*
uratio	1.381**	1.381**	1.5979**	3.07413***	1.381**	1.381**
hdd	0.00001	0.00001	9.96E-07	1.39E-05	0.00001	0.00001
cdd	-2.72E-06	-2.72E-06	-3.2E-05	-3.4E-05	-2.72E-06	-2.72E-06
h	-0.70909	-16.40724	74.73***	-2.27714	-6.590933	-0.4175889

[1]The series are cross sectional demeaned.

Diagnostic Test Results						
	h1_reexp	h2_reexc	h3_ipi	h4_poil	h5_nexcr	h6_ise100
Hansen J Test Statistic	45.13 (0.142)	45.13 (0.142)	44.25 (0.163)	56.42 (0.189)	45.13 (0.142)	45.13 (0.142)
AB Test – 1	-3.20 (0.001)***	-3.19 (0.001)***	-3.76 (0.000) ***	-3.37 (0.001) ***	-3.20 (0.001)***	-3.20 (0.001)***
AB Test - 2	-0.15 (0.884)	-0.15 (0.882)	-0.02 (0.985)	0.36 (0.717)	-0.15 (0.883)	-0.14 (0.885)
AB Test - 3	1.73 (0.084)*	1.75 (0.081)*	1.71 (0.086) *	1.81 (0.070) *	1.73 (0.084)*	1.73 (0.083)*
Instruments #	44	44	44	56	44	44
Pesaran CD test	-2.08 (0.038)**	-2.14 (0.032)**	1.28 (0.200)	1.55 (0.121)	-1.98 (0.047)**	-1.70 (0.090)*

Models are correctly specified according to the diagnostic tests. Arellano-Bond and Hansen tests indicate the absence of second and third order autocorrelation and that overidentifying restrictions are valid.

Empirical Results

- ✓ Previous dynamic aggregate electricity demand studies: short run and long run income (price) elasticity of electricity demand lie between 0.02 and 2.24 (-0.03 and -1.67) and 0.203 and 5.39 (-0.003 and -6.849), respectively from the findings of previous studies
- ✓ Short run income elasticity is estimated to be between 0.35 and 0.43 within range of previous study's findings, whereas short run price elasticity is found to be between -0.11 and -0.59 again in the interval of the elasticity estimates obtained by previous works. All the elasticity estimates are significant with theoretically congruent signs. From the results, we can conclude that electricity demand is inelastic with respect to income and price in the short run.
- ✓ Besides, urbanization ratio and the only one volatility measure, namely, conditional variance of industrial production index growth are observed to affect electricity demand, significantly and positively.

Short run and Long run Coefficient Estimates

Variables	Short-run	Long-run
lnpcgdp	0.379028*** (0.000)	0.83798*** (0.000)
lnrep	-0.17413*** (0.000)	-0.38498*** (0.0016)
uratio	1.597967** (0.038)	3.532895*** (0.0048)
hdd	9.96E-07 (0.957)	2.20E-06 (0.9566)
cdd	-3.2E-05 (0.710)	-7E-05 (0.715)
h3_ipi	74.73137*** (0.001)	165.2212*** (0.0027)

Notes: P-values are provided in parentheses. *, **, *** shows the statistical significance of coefficient at 10%, 5% and 1% significance levels.

Empirical Results

- ✓ 45.2% deviations of logarithm of actual consumption from logarithm of desired consumption is eliminated in a year.
- ✓ In the long run, also, electricity demand is income and price inelastic. But, long run elasticity estimates are larger than short run's. Our results are supported by the past studies based on panel and time series data employing partial adjustment model. For example, Hsiao et al. (1989), Diabi (1998), Erdoğdu (2007), and Bhargava et al. (2009) have found that electricity demand is inelastic with respect to income and price in the short run. However, in the long run, findings of Hsiao et al. (1989) and Bhargava et al. (2009) indicate that electricity demand is income elastic, whereas, price inelastic.

Conclusion

- determinants of electricity demand and the effect of economic volatility on the electricity demand
- volatility modeling and panel data techniques.
- panel data application for the provinces of Turkey
- As a proxy for economic volatility, we use the conditional variance of various economic variables which are all obtained from the estimation of suitable GARCH models for each time series.
- The dynamic electricity demand model is estimated by System GMM proposed by Blundell and Bond (1998).
- Results show that among the various volatility measures associated with different economic variables, only industrial production volatility has a significant and positive effect on the electricity demand.

Conclusion

- Also, other factors significantly affect the electricity demand with theoretically consistent signs except the weather variables.
- electricity demand is income and price inelastic in the long run and the short run implying that electricity is a normal good and a necessity, but more responsive to price and income changes in the long run due to the time lag for the capital stock adjustment.
- policies depend on electricity prices alone are not so much effective, especially in the short run to decrease electricity demand.
- low income elasticity may be the reflection of low energy intensity showing efficient use of energy.

Conclusion

- We suggest that generation capacity expansion and pricing policies should be supported by the diversification across energy resources, restructuring of the industrial sector to the less-energy intensive structure and extensive energy efficiency programs.
- Lastly, as industrial production volatility affects the electricity demand positively, policy makers should employ volatility decreasing measures in order to ensure supply and demand balance in the electricity sector.

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Thank you for your attention

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