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ENERGY SUPPLY SECURITY AND RENEWABLE ENERGY FOR TURKEY

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Abstract: *Energy is viewed as a fundamental building block for practically all financial exercises. The aim of presented study is to investigate the relationship between the Energy security index of energy intensity and some indicator parameters for different perspectives of energy policy. Lineer and non-lineer models are framed out to explore the relationship between the parameters and sensitivity analyzes are conducted on these models. In the study the Energy Security Index of energy intensity (ESS) is used as the target variables for the models. Fossil Energy consumption (FEC), Total renewable Energy Consumption (REN), Hydro-power Energy Consumption (HEC), Carbon dioxide emissions (CO2) are used to indicate the total and the renewable energy consumption. The parameters Population (POP), Human Development Index of Turkey (HDI), Average Democracy Index for main energy suppliers of Turkey (DI) are dedicated to socio-development side of Energy security. The parameters Petrol Prices (PP), Gas prices (GP) are used to indicate the cost side of energy security.*

Keywords: *Energy Security, Energy Intensity, Neural Networks, Linear Regression, Sensitivity Analysis.*

1. INTRODUCTION

Since it is imperative, energy creates numerous security dangers, which may influence life undesirably. The fate of future generations may be jeopardized in the case of unexpected energy cuts and some natural dangers brought about by overconsumption of fossil fuels (Erdal *et al.* 2015). The world's flourishing and welfare relies upon having access to reliable and secure supplies of energy at reasonable costs be it oil, gasoline, or electricity (Balat, 2010).

Energy security has an expansive definition spanning a broad scope, despite the fact that security indicates distinctive ideas as to, military, social, economic, political and environmental fields. Because it is a very intricate idea, energy security has numerous implications. However, it is frequently utilized to show the

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steadiness of a nation's energy supply (Von Hippel et al. 2011). The security of energy supply is a frequently emerging idea in national energy policies. Furthermore, it is also a commonly discussed concept at the European as well as overall levels (Chevalier, 2006). Energy security by and large alludes to guaranteeing satisfactory and solid energy supplies at sensible costs all the while keeping in mind the end goal of maintaining financial development (Hogan et al., 2007).

Energy issues are closely related to economic development, scientific research and development, socio-cultural issues, environmental protection and international politics. Currently the most important issue which researchers, energy industry figures and policy makers are facing is to establish and provide a global energy system which is more secure, sustainable and affordable. It is necessary to explore new ideas about the structures, processes and policies that are needed to ensure technology integration in order to establish the most suitable and efficient ways to build a better energy system (Ozkan *et al.*, 2015).

Economic stability and development necessitate secure, reliable and affordable energy supply. The increasing potential of energy depletion and the rise of electricity prices from conventional energy sources necessitate a set of policy, regulatory and fiscal reforms which are being adopted to provide energy efficiency, renewable energy technologies, such as wind, solar, geo-thermal and biomass etc; sustainable transport technologies, such as hybrid vehicles, high speed rail and rapid bus transit systems.

Energy efficiency, high-technology power generation and RES have been promoted for the transition from an uncertain, unsafe and unreliable energy supply to a safe, sustainable, secure one. As a result, Turkey must prepare a strong energy policy that secures a stable supply and reinforces technical development as a contributor to the national growth strategy (Ozkan *et al.*, 2015).

The economy of Turkey is basically dependent on imported energy resources for 80% of its total domestic energy consumption per year, the highest percentage of any major industrialized nations. Thus, reducing dependency and import expenditures are always main issues in the energy policy of Turkey.

1.2. Data Collection and used Parameters

The current study concentrates to analyze the relationships between "Energy security index of Energy intensity (ESS)" and some other important variables that present different concerns like renewable energy consumption, socio-economic development and market prices of energy sources. The data set was collected from different sources in and the energy intensity index is calculated for each year between 1965-2013, all the data is restructured in a year base. In the analysis Fossil Energy consumptions (FEC), Renewable energy consumptions (REN),

Hydroelectricity consumption (HEC), Human development index (HDI), Democracy Index (DI), Carbon dioxide emissions (CO2), Population (POP), Human Development Index of Turkey (HDI), Average Democracy Index for main energy suppliers of Turkey (DI), Petrol Prices (PP) and Gas prices (GP) are used as the explanatory variables for ESS.

Since the usage of Renewable energy is very important for a sustainable energy policy renewable energy consumption amounts are included in analysis in detail in addition to Fossil energy consumption amounts (FEC). The parameters which are used to present the renewable energy side are Renewable energy consumption amounts (REN) and Hydro-electric energy Consumption (HEC). For Turkey the amount of Hydro-power supply in energy production has a very important ratio and this technology have been used over 60 years for electricity generation.

Two different indexes are used to include the socio-economic changeability with in the analysis. The HDI is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living (HDI, 2014). Sub indicators and variables like education level, average age of marriage, literacy rate,..etc. are used to calculate the HDI. Therefore the HDI of Turkey could be considered as an indicator of social development. The Democracy index (DI) is calculated by using 60 indicators grouped in five different categories measuring pluralism, civil liberties, and political culture (The Economist, 2012). Petrol and gas pricecs are maliyet parameters that are mostly important on energy consumption.

The population could be interpreted as the main driver of any type of energy consumption in a direct or indirect way. Like Population the Carbon dioxide emissions coldbe interpreted as the output of any kind of human activity and fossil fuel consumption.

1.3. The Energy Security Index (ESS)

Different definitions and formulations are used in the literature to indicate different sides of energy security. In this study, the Energy intensity index is used to examine the affordability and accessibility of the energy security and named as ESS. *ESS* index is used as a measure of "accessibility" and "affordability" dimensions of the security of supply (ref gir)? and generally formulated as the fraction of Industrial energy consumption (IEC) to Gross domestic product (GDP) for the index year (i) (Frondel and Schmidt, 2008):

$$ESS = \frac{\Sigma_i IEC_i}{\Sigma_i GDP_i} \tag{1}$$

2. METHODOLOGY AND DATA RESULTS

In the study linear correlation analysis are used to present the bilateral relationships between the variables. A different methodology is used to investigate the multilateral relationships between target variable (ESS) and multilevel input parameters while keeping the interaction effect of each input parameter to other inputs.

First an accurate model is developed to predict the ESS and then sensitivity analysis are conducted on this model to understand the most important parameter of the accurate model. For statistical and linear inference Multistep linear regression analysis is used. Multi Layer Perceptron artificial Neural Network Models (MLP-ANN) is developed to include the non-linear relationship between inputs and the output. In ANN models the sensitivity analysis are developed and In Regression models the Standardized Beta coefficients are used as to investigate the most important variable for the models.

2.1. Correlation Analysis of ESS

The current study concentrates to analyze the relationships between Energy security index of Energy intensity (ESS) and some other variables and indicators. For this purpose, a well known parametric Pearson Correlation analysis is performed to suggest pairwise relations of the parameters and to measure how variables are related (Myers and Well, 2003). Pearson Correlation test results are given Table 1.

Table 1
Pearson Correlation Test Result

	ESS	*CO2*	*POP*	*PP*	*GP*	*REN*	*HDI*	*DI*	*HEC*	*FEC*
ESS	1.000	-.683**	-.637**	-.734**	-.784**	-.489**	-.569**	.446**	-.618**	-.691**
CO2	-.683**	1.000	.975**	.514**	.654**	.644**	.962**	-0.009	.942**	.998**
POP	-.637**	.975**	1.000	.477**	.610**	.537**	.971**	0.110	.948**	.963**
PP	-.734**	.514**	.477**	1.000	.969**	.585**	.370**	-.341*	.423**	.525**
GP	-.784**	.654**	.610**	.969**	1.000	.619**	.524**	-.317*	.542**	.665**
REN	-.489**	.644**	.537**	.585**	.619**	1.000	.519**	-0.189	.621**	.669**
HDI	-.569**	.962**	.971**	.370**	.524**	.519**	1.000	0.108	.926**	.955**
DI	.446**	-0.009	0.110	-.341*	-.317*	-0.189	0.108	1.000	0.104	-0.041
HEC	-.618**	.942**	.948**	.423**	.542**	.621**	.926**	0.104	1.000	.940**
FEC	-.691**	.998**	.963**	.525**	.665**	.669**	.955**	-0.041	.940**	1.000

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

As shown in Table 1, the correlation coefficients between ESS and the other variables are found statistically significant. All the variables are found highly and medium negatively correlated with ESS except the DI. The highest correlations

are observed between ESS and the energy price variables (PP and GP). The lowest negative correlation is between Renewable energy consumption.

There are very high correlation relationships between some variables. As expected the PP and GP, FEC and CO2, FEC and HEC and POP are very highly correlated. These high correlations could be interpreted as the precaution of high multi-collinearity problem before linear regression model.

2.2. Linear Regression Analysis

Linear regression models are developed to investigate the interactions of input parameters within a regression equation to predict the dependent variables (ESS). The main aims are to gain acceptable level of accuracy while obtaining the stability of regression coefficients (especially very important when the dependent parameters are highly inter-correlated) and to observe the unit difference level of these coefficients while the others are staying in constant line (Erdal *et al.* 2015). Especially if all the inputs (dependent variables) have been standardized before the model development phase then the unit difference level could show the relative importance of each input in the model. These standardized coefficients are called as Beta coefficients and can be shown in Table 2.

In the presented work the backward type of multilevel regression model is used. In the backward process, initially all the variables are located in the equation and then the irrelevant variables are removed sequentially. The first variable to be removed is chosen as the one with the smallest partial correlation with the dependent variable. Upon satisfaction of the elimination criterion, the variable is removed. Next variable to be removed is again chosen as the one with the smallest partial criterion among the remaining variables in the equation. When the variables meeting the removal criterion finish, the procedure is ended. On the other hand the VIF and Tolerance values and the change in the correlation values (zero-partial and part correlation levels) are observed to prevent from multi-collinearity situation (Erdal *et al.* 2015).

The backward Model take the final form at the 6^{th} step with an accuracy of Adjusted R^2= 0.767. Finally, the parameters GP, REN, DI and HEC is found statistically significant contributors. The VIF indexes are below 10 indicating there is not any collinearity problem in regression coefficients. The standardized Beta coefficients indicate that the HEC and GP are the most important variables in the model, the REN and DI have close weights. The Durbin Watson statistics of model residuals are 1.264 indicating that the residuals are not strongly correlated serially.As a general rule of thumb, the residuals are uncorrelated is the Durbin-Watson statistic is approximately 2. A value close to 0 indicates strong positive correlation, while a value of 4 indicates strong negative correlation.

Table 2
Regression coefficients and Collinearity diagnosis

Model		*Unstandardized Coefficients*		*Standard. Coefficients*	*t*	*Sig.*	*Correlations Statistics*			*Collinearity*	
		B	*Std. Error*	*Beta*			*Zero-order*	*Partial*	*Part*	*Tol.*	*VIF*
Model 1	(Constant)	-18,118	10,557		-1,716	,094					
(Adjusted	CO2	-,192	,187	-3,506	-1,027	,311	-,683	-,162	-,073	,000	2290,551
R^2 = 0.756)	POP	2,498E-07	,000	,662	,804	,426	-,637	,128	,057	,008	133,031
	PP	-,010	,083	-,063	-,123	,903	-,734	-,020	-,009	,020	51,111
	GP	-,845	1,027	-,478	-,823	,416	-,784	-,131	-,059	,015	66,144
	REN	1,671	,979	,261	1,707	,096	-,489	,264	,122	,218	4,594
	HDI	14,181	20,694	,279	,685	,497	-,569	,109	,049	,031	32,464
	DI	6,151	1,709	,376	3,599	,001	,446	,499	,257	,468	2,138
	HEC	-,961	,450	-,725	-2,134	,039	-,618	-,323	-,152	,044	22,696
	FC	,441	,515	2,778	,856	,397	-,691	,136	,061	,000	2070,350
Model 6	(Constant)	-7,460	7,139		-1,045	,302					
(Adjusted	GP	-,934	,174	-,528	-5,369	,000	-,784	-,629	-,374	,502	1,991
R^2 =0.767)	REN	1,444	,639	,226	2,260	,029	-,489	,322	,158	,488	2,050
	DI	6,127	1,301	,374	4,709	,000	,446	,579	,328	,770	1,299
	HEC	-,677	,132	-,511	-5,138	,000	-,618	-,612	-,358	,491	2,036

2.3. Neural Network

ANN is a computing system based on the operating mechanism of biological neural networks (Dorf, 1997). During the process of neural network training or learning, a data set including inputs and desired outputs are provided to the network model. The neural network is constructed by fitting itself to the training data to predict (to learn) the unknown outputs by using training data. Usually, a portion of data called validation data is reserved to confirm the prediction accuracy performance of the trained model.

In the presented study nine input parameters are used to predict the ESS. 25 ANN Models are developed and the best 10 models are selected for further sensitivity analyses. In models hidden layers node number are restricted between three to eleven, different activation and output functions are used in different ANN architectures. Before developing the ANN models the data was split into three parts as a training (70%), testing (15%) and validation (15%). Goodness of fit statistics and the details of the ANN models are given in Table 3.

Table 3
Summary of active networks

Networks /input/hidden layers node /output	*Performance (r)*			*Error*				
	Train.	*Test*	*Valid.*	*Train.*	*Test*	*Valid.*	*Hidden activation*	*Output activation*
MLP 9-6-1	0,86	0,98	0,96	3,46	0,70	1,37	Tanh	Identity
MLP 9-10-1	0,87	0,98	0,98	3,24	0,97	1,70	Identity	Logistic
MLP 9-7-1	0,92	0,96	0,97	1,95	1,01	2,86	Exponential	Identity
MLP 9-12-1	0,87	0,98	0,96	3,09	1,17	2,62	Tanh	Tanh
MLP 9-12-1	0,85	0,98	0,97	3,52	1,13	1,29	Exponential	Logistic
MLP 9-5-1	0,87	0,98	0,99	3,23	1,38	1,22	Identity	Exponential
MLP 9-11-1	0,88	0,96	0,97	2,91	1,56	1,26	Identity	Exponential
MLP 9-11-1	0,87	0,97	0,97	3,15	1,63	1,52	Logistic	Exponential
MLP 9-13-1	0,93	0,96	0,97	1,83	1,15	3,68	Exponential	Identity
MLP 9-6-1	0,92	0,97	0,95	1,98	0,91	2,57	Tanh	Identity

As seen in Table 3, the testing and validation parts' correlation coefficients not differ from each other indicating that there is not any over-training problem in models. Validation performances of all models are sufficiently good.

ANNs has a major weakness caused its black box structure when compared to traditional statistical approaches like regression analysis. ANNs are called "black-boxes" by many researchers due to the implicit behavior of input and output relationship. Input variables are often entered into the network, and an output value is generated without gaining any understanding of the interrelationships

between the variables. Without information regarding the relative importance of parameters and contributory behavior of inputs on outputs ANNs utility is limited. To fix this deficiency, many sensitivity analysis methods are developed by ANN applicators. Sensitivity analysis is the study of how the variation or uncertainty in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input to a model (Cacuci *et al.*, 2005). Sensitivity analyses give information about the relative importance of the variables used in a neural network.

In sensitivity analysis, *ANN* tests how the neural network responses (predictions) and, hence, the error rates would increase or decrease if each of the input variables were to undergo a change. In this process, the data set is submitted to the network repeatedly, with each variable in turn replaced with its mean value calculated from the training sample, and the resulting network error is recorded. If an important variable changed in this fashion, the error will increase a great deal; if an unimportant variable is removed, the error will not increase very much.

The result of the sensitive analyses of selected ANN models are given in Table 4. Since the ANN attribute random weights in a very high changeable scale order before taking average the sensitivity scores are normalized to obtain 100 percent for each model.

Table 4
The result of sensitive analyses of ESS

Network Architechture Input Num.-hidden layer node-output	*Normalized Sensitivity coefficients of the Input Variables*								
	POP	*CO2*	*HEC*	*FEC*	*GP*	*DI*	*PP*	*HDI*	*REN*
MLP 9-6-1	10,01	10,35	12,15	10,41	11,26	13,84	12,19	9,84	9,95
MLP 9-10-1	9,75	10,39	12,04	10,53	10,99	14,81	12,20	9,59	9,70
MLP 9-7-1	78,82	6,38	5,56	5,12	2,36	0,53	0,35	0,62	0,26
MLP 9-12-1	9,72	10,08	12,13	10,01	10,71	16,34	11,19	10,29	9,54
MLP 9-12-1	10,36	10,54	11,57	10,64	10,73	13,85	11,89	10,21	10,21
MLP 9-5-1	9,19	10,75	12,28	10,74	11,58	15,06	11,88	9,13	9,39
MLP 9-11-1	19,65	11,24	14,01	10,82	11,63	9,83	7,52	8,19	7,10
MLP 9-11-1	9,21	10,12	11,68	10,50	11,59	16,50	11,82	9,19	9,39
MLP 9-13-1	77,33	3,26	10,39	2,10	2,41	1,48	1,28	1,19	0,56
MLP 9-6-1	51,31	17,15	8,46	12,49	5,44	1,46	1,42	1,61	0,66
Average	28,54	10,03	11,03	9,34	8,87	10,37	8,17	6,99	6,68

In ANN model process there is not any feature selection process, therefore ANN use all inputs to minimize the error function and to obtain high accuracy. Because of this new ANN models are developed by using only the significant pre-

determined parameters of the regression models. The normalized sensitivity scores of the selected models are given in Table 5.

Table 5
The result of sensitive analyses of ESS

Network Architechture Input Num.-hidden layer node- output	*Normalized sensitivity coefficients İnput parameters*			
	GP	*DI*	*REN*	*HEC*
MLP 4-7-1	44,56	36,76	9,00	9,68
2. MLP 4-10-1	25,89	45,61	13,48	15,02
3. MLP 4-8-1	34,08	34,87	18,70	12,34
4. MLP 4-8-1	25,93	43,25	13,43	17,39
5. MLP 4-5-1	27,35	44,23	13,15	15,28
6. MLP 4-8-1	57,09	28,25	8,83	5,83
7. MLP 4-4-1	26,87	41,51	15,38	16,24
8. MLP 4-9-1	27,68	47,52	11,52	13,29
9. MLP 4-9-1	67,22	19,81	8,33	4,63
10. MLP 4-9-1	36,18	35,43	18,73	9,66
Average	37,87	37,65	12,72	11,75

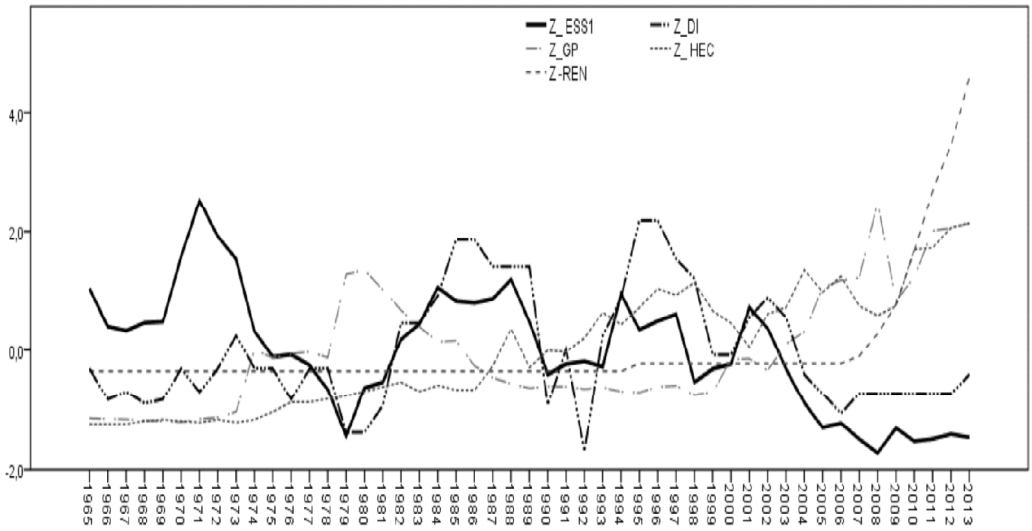
3. DISCUSSION AND CONCLUSION

At the beginning of the 21st century, the European Union had three goals related to energy policy. Reduction in energy intensityis the first and only prerequisite for fall in energy consumption. As known the Turkey has a governmental policy which mainly aims to include in the EU since 1960s. Therefore EU energy security policies should be considered as a road map for Turkey. On the other hand, national energy security is clearly more evident for countries that do not have abundant resources, like Turkey. Unfortunately, there is not a clear policy and stabile regulations instituted by the Turkey government aims to improve energy security in the sense that energy sources could be available, accessible, affordable and acceptable.

All the variables are found statistically significant correlated with ESS in correlation analysis. In linear regression model 4 variables are found significant (in order GP, REN, DI and HEC). When all the inputs are used in ANN models, the most sensitive variable is found POP with %25 normalized sensitivity coefficient, all the other variables have similar sensitivity coefficients between 11% and 6%.

When only the 4 variables which are found significant in regression models are used in ANN models, the most contributor variables are found as GP and DI with 37% normalized sensitivity coefficients. The normalized coefficients of REN and HEC are found %12 and 11%, respectively. The Z scores of these variables is presented in Fig. 1.

Figure 1: Normalized time series of the variables



As seen in Fig. 1 there are sharp decreasing trends in ESS between the years 1971- 1979 and 2000- 2013 while GP has slight and sharp increases in these years. As known there was an important oil energy crisis between 1970-1980 such as OPEC oil export embargo (1973) and Iranian revolution (1979) so the decreasing trend in the affordability and accessibility (EES) is normal for this period. The decrease after 2000s is related with the non-industrial economic growth of Turkey. As known heat money flow takes its peak in these years depending upon governmental privatization and the debt taken for public investments. While the increase rate of the industrial energy consumption increases smoothly for this term, the Gross domestic product increases sharply so that the ESS has a decreasing trend (Erdal *et al.* 2015).

Hydropower electricity consumption (HEC), the most important renewable energy source of Turkey, has a slight upward trend within overall years. But especially after the year 2001 the upward trend of the HEC becomes significant. But as explained, for these years the ESS has a decreasing trend. So it is normal to find that the relationship between the HEC and ESS is negative. The REN which is the residual energy consumption after the HEC is subtracted, comes with zero until 2007 and then has a very high increasing trend up to today. But the important fact is that the affordability of ESS is closely related with REN and HEC.

Affordability and accessibility side of energy security is found negatively first order related with GP by both ANN and Regression analysis. This is probably because of that Turkey has 97% import dependence on Gas energy. So while the Gas prices' (energy cost) increasing this situation is normally negatively effecting the affordability of energy security.

An important consequence of this study is that the close relationship between ESS and political stability is quantitatively approved in a statistical way. The Democracy index of the import countries is a positive significant contributor for the affordability and accessibility ESS. This means that the political stability is very important for accessibility and affordability. The direction of the relationship is expectedly positive.

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