RENEWABLE ENERGY PERFORMANCE OF TURKEY

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ABSTRACT

Turkey has to evaluate its own renewable energy opportunities in order to reduce greenhouse gas emissions in accordance with the Kyoto protocol, which Turkey attended in 2009, and to reduce its rapidly increasing dependency on foreign energy sources. In this study, the performance which Turkey has exhibited in usage of renewable energy resources in recent years was examined. For this purpose, the renewable energy share of total energy consumption of 30 developed and developing countries was expressed as "renewable energy performance." Activity evaluation was performed by using data envelopment analysis method. 30 countries whose data are completely available were used as decision unit. Efficiency changes in between 2000-2009 were investigated with window analyses. Some recommendations are offered to determine deficiencies of Turkey which must be prioritized in renewable energy sub-sectors in order to increase the renewable energy performance of Turkey and to increase the share of renewable energy in total energy consumption.

Keywords: Renewable Energy, Efficiency, Data envelopment analysis

TÜRKİYE'NİN YENİLENEBİLİR ENERJİ PERFORMANSI

ÖZET

Türkiye, sera gazı emisyonlarını azaltmak için 2009 yılında imzaladığı Kyoto Protokolünün gereklerini yerine getirebilmek ve enerjide dışa bağımlılığını azaltmak için yenilenebilir enerji kaynaklarını değerlendirmek zorundadır. Bu çalışmada son yıllarda hızla gelişen yenilenebilir enerji kullanım performansı değerlendirilmiştir. Bu amaç doğrultusunda 30 gelişmiş veya gelişmekte olan ülkenin toplam enerji tüketimi içerisindeki yenilenebilir enerji payı yenilenebilir enerji performansı olarak değerlendirmeye alınmıştır. Çalışmada window analizi kullanılmış ve 2000-2009 yılları arasındaki etkinlik değişimleri belirlenmiştir. Çalışma sonucunda Türkiye'nin toplam enerji tüketimi içerisindeki yenilenebilir enerji payını artırmak için yenilenebilir enerji alt sektörlerindeki öncelikleri hakkında yorumlar sunulmuştur.

Anahtar Kelimeler: Yenilenebilir Enerji, Etkinlik, Veri Zarflama Metodu

1. INTRODUCTION

The Turkish Republic, as it targets of the year 2023, the 100th anniversary of foundation in many sectors, considers its strategies in energy and environment within the scope of this 2023 vision. Turkey's fundamental strategy is to become energy independent, to use renewable energy resources maximally, and to increase the diversification in energy supply including nuclear energy in electrical energy production composition by 2020. This wise redesign of energy sector structure is based on these three fundamental aims and will accordingly minimize the dependency on foreign energy sources and reduce environmental effects. Increasing the resources used in energy supply and diversifying technology and infrastructure are of high importance for reducing the dependency on foreign energy, which is currently at 73%. The most important one of these goals is the maximum utilization of renewable energy resources.

As of 2008, Turkey's total installed power and total production were 41.813,40 MW, and 198.418 GWh, respectively[1]. Thermal power plants, hydroelectric power plants, and geothermal and wind power plants constitute 66%, 33.06%, and 0.94% of the installed capacity in Turkey, respectively. The share of natural gas-fired thermal power plants among all thermal power plants is 32%, whereas the share of lignite and hard coal-fired thermal power plants is 20.42% (Fig.1.).

Installed power and production have shown a yearly increase of 4% and 8%, respectively, since 2003. Furthermore, as compared to 2007, installed power increased by 2.4% and production increased by 3.58% in 2008.

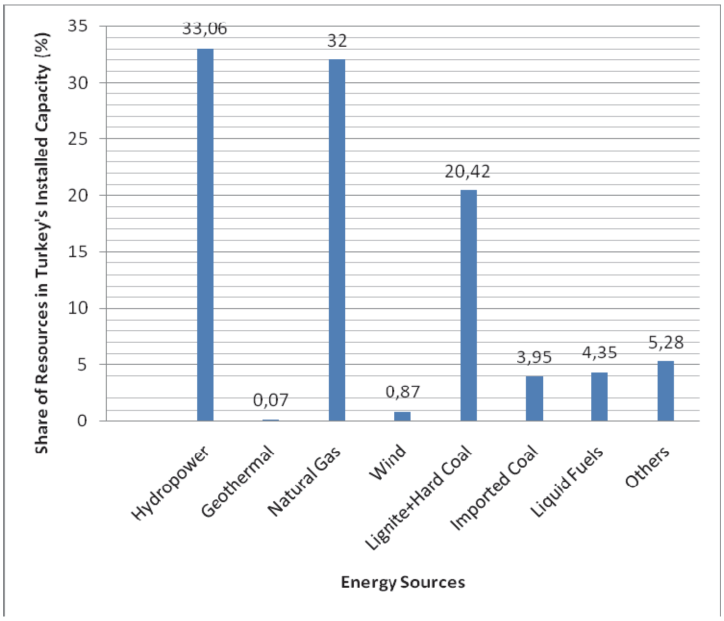

Figure.1. Share of primary energy sources in Turkey's installed capacity

Energy production in Turkey is primarily based on thermal power plants which mainly use natural gas and lignite. The second highest means of energy production is hydroelectric power plants. Today, hydroelectric power plants are one of the most important renewable and sustainable energy resources. Within total renewable energy resources of Turkey hydroelectric power plants, wind, geothermal, biomass, and others have a share of 92%, 3.6%, 3.5%, 0.6%, and 0.3% respectively.

Renewable energy laws have been passed in recent years with the aim of promoting and increasing the use of renewable energy. The most important of them is the one related to solar power, which aimed to increase electricity generation from solar power plants which have already been used at a very small scale. Although Turkey is located within hot climate belt, has an annual mean solar radiation of 3.6 kWh/m^2day and a total annual radiation period of 2610 h, Turkey cannot take advantage of solar power in electricity generation yet.

In this study, the renewable energy usage efficiency of Turkey was investigated by using data envelopment method to compare Turkey's status with respect to other countries since 2000. Window analysis was preferred for determining the development of activities throughout years.

2. MATERIAL AND METHOD

2.1. SOURCE DATA

EUROSTAT data was used in this study. The input variables and output variables selected for the performance evaluation are presented in Table 1.

Table 1. Energy indicators used in the analysis

Variable	Input (I) /Output (O)
Biomass and Waste Electricity Net Generation (kWh*10^6)	I
Geothermal Electricity Net Generation (kWh*10^6)	I
Hydroelectricity Net Generation (kWh*10^6)	I
Solar, Tide and Wave Electricity Net Generation (kWh*10^6)	I
Wind Electricity Net Generation (kWh*10^6)	I
Share of electricity production from renewable sources	O

2.2. METHODOLOGY

2.2.1. DATA ENVELOPMENT ANALYSIS

Data Envelopment Analysis (DEA), which was developed by Charnes, Cooper, and Rhodes (CCR)[2], is a nonparametric technique based on Farrell's[3] efficiency measurement opinion. The fundamental idea of Farrell is based on one input and one output, whereas the DEA method of Charnes, Cooper, and Rhodes focuses on the case where organizations (i.e. decision making units, (DMUs)) use multiple inputs to produce simultaneous multiple outputs. A DMU is a concrete or intangible system whose performance is evaluated and responsible for transforming inputs into outputs. Nations, banks, hospitals, schools, airports, tax offices, libraries, universities or their departments and also environment and energy organizations are some of the examples to which DEA has been applied[4-9]. DEA is an advantageous system that can be applied to not-for-profit organizations participating in public programs.

DEA can be considered as a powerful new methodology since it is used for organizing and analyzing data to identify best practice frontiers. The fundamentals of DEA are based on the identification of the most efficient decision making unit/s among all DMUs. The pareto-optimal unit which is the most efficient DMU is accepted as the standard for comparison for all other DMUs. DEA determines the efficiency frontier using linear programming technique. While efficient companies' DMUs lie on the frontier, inefficient companies' DMUs lie below the frontier (Fig.2).Since the methodology of DEA is directed towards frontiers rather than central tendencies, it has a greater advantage over all other measurement techniques having similar efficiency. DEA surrounds the data with a piecewise linear surface from the top, while parametric methods fit a regression line passing through the center of the data. DEA does not examine the averages and estimation of parameters related to parametric approaches but rather it focuses on each individual observation.

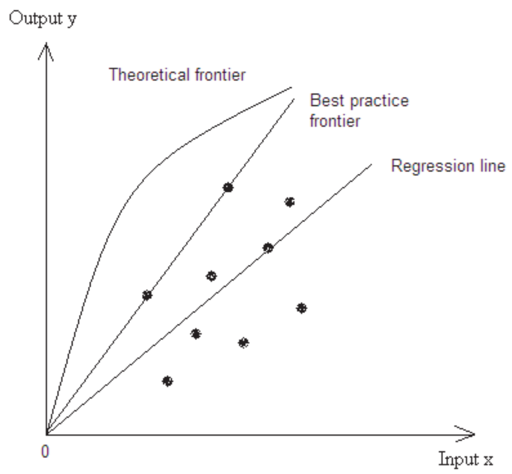

Figure 2. Comparison of Theoretical frontier, DEA and Regression line.

DEA aims to quantify the distance to the efficiency frontier for every DMU. Performance measurement is shown in the form of an efficiency score.

Relative efficiencies of the current set of units are examined and then DEA exhibits the change of inputs and outputs in order to maximize the efficiency of the DMU which is targeted. For each inefficient DMU, DEA advises a benchmark at the level of its individual combination of inputs and outputs. There are two main criteria for classifying DEA models: type of scale effects and model orientation. The criterion of scale effects determines the assumptions concerning the scale effects accepted in the model (constant returns to scale (CRS) or variable returns to scale (VRS)). The criterion of model orientation shows if the objective is the minimization of input(s), such as cost of production, or the maximization of a particular output, such as profit. Output-oriented CCR (CRS) model was used in this study. When this model is used, one can determine the efficiency scores by keeping inputs constant and assessing to what extent outputs should be increased to obtain a DMU which is considered as efficient.

CCR (CRS) output-oriented model has the dual form as follows:

$$\max \quad h_o = \phi + \varepsilon . \sum_{r=1}^{s} S_r^+ + \varepsilon . \sum_{i=1}^{m} S_i^-$$

$$\textit{Subject to}$$

$$\phi . y_{ro} - \sum_{j=1}^{n} \lambda_j y_{rj} + S_r^+ = 0$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} + S_i^- = x_{io}$$

$$\lambda_j, S_i^-, S_r^+ \geq 0$$

$$j = 1,\ldots, n, \; i = 1,\ldots, m, \; r = 1,\ldots, s$$

The subscript o indicates the assessed DMU, and h_o represents the efficiency score of DMUo. xij, yrj denote the input i and output r of DMUj, respectively. ε is an arbitrary “non-Archimedean” number which is small. S_i^-, S_r^+ are the slacks in the ith and the rth input and output while n, m and s are the number of DMUs, inputs, and outputs, respectively. Output augmentation is performed through the variable ϕ, from the dual CCR model. When ϕ is greater than 1.0 (or 100) and/or the slacks are not zero, the investigated DMU is inefficient. ϕ for all outputs must be proportionally increased to improve and shift the DMU towards the frontier and individual slacks should be adjusted successively.

2.2.2 WINDOW ANALYSIS

Several DEA applications use cross-sectional data and each DMU unit is observed once in each study. When multi-period data exist, a panel data analysis which focuses on the changes in efficiency over time must be performed combining with the individual efficiency of each DMU. Additionally, longitudinal analysis technique compares cross-sectional performance series across the number of time periods. Since this approach treats the performance of a DMU in each time period as independent from its performance in the former period, there is variability in the analysis. This approach does not enable us to ascertain trends in performance or to observe persistence of efficiency or inefficiency. Window analysis approach corrects some of these problems. DEA can be performed over time using a moving average analogue (of time series), and the DMU in each different time period can be considered a distinct DMU. In particular, the performance of a DMU in a specific period is compared to its performance in other periods and to the performance of the other DMUs [10, 11]. The results table of normal DEA analyses is called as "static table", whereas the results table of the window analyses is named "dynamic table". A window analysis application uses the following concepts and formulas:

n= number of DMUs,

k= number of periods

w= number of windows

p= length of windows

The number of DMUs (the number of nations, n) used in the study is 29. Number of periods (k) is 10 (the years 2000-2009). Since there is a possibility of nations being dependent on the previous two years, the window length (p) is 3. In this application,

# of windows: $w = k - p + 1 = 10 - 3 + 1 = 8$.

# of DMUs in each window: w*p = 8 * 3 = 24.

# of different DMUs : n p w = 29 * 3 * 8 = 696.

Table 3 exhibits the underlying framework of the window analysis. Due to the first window, Turkey is represented within the constraints of DEA model as though it was a different DMU in during the three-year (2000, 2001, and 2002) sample set of 29 DMUs. Accordingly, if a nation is evaluated for its efficiency in 2000, its performance data of the years 2000, 2001 and 2002 are included in the constraint sets in parallel with similar performance data obtained from the other nations for years 2001 and 2002. Therefore; results of the first window, columns 2000, 2001 and 2002, consist of 24 scores which correspond to each row of nations. An analysis is performed on the second three-year (2001, 2002 and 2003) set of observations for the 29 DMUs after the window is shifted one period. In case of there are more periods, the shifting process continues by shifting the window forward one period at a time.

2. RESULTS AND DISCUSSION

DEA and Window analyses of Turkey and 29 other countries whose data are completely available and their activity changes throughout years are given in Table 2 and Table 3 for Turkey and selected countries, respectively. The rate of increase of outputs with constant inputs was evaluated in the analyses considered with output direction. Therefore, renewable energy inputs and the countries which have a share of renewable energy in maximum total production were actively determined. These countries are Iceland and Norway. It was observed in these analyses that Turkey tended to increase its activity at a small rate. While Turkey had an activity score of 2.34 in 2000, it reached 2.80 in 2001 after a three years evaluation. After each three year development period, Turkey reached the score of 3.65 in 2009. This activity score is considerably low. Turkey has to increase the current hydroelectric capacity and evaluate solar power to increase renewable energy share in total energy production in order to reach it's energy goals. There has been increased resistance to foundation of both river and reservoir type hydroelectric power plants in recent years. Both renewable energy encouragement laws passed by political will following Turkey's evaluation of the important role of renewable energy power plants in its fundamental energy policies and the efforts of

Turkey to follow a path in line with the fundamental energy policies of European Union (EU) countries mean that renewable energy activity should increase in the years to come.

3. CONCLUSIONS

This study is expected to be helpful in the exhibition of renewable energy efficiency of Turkey among selected countries. Comparison of Turkey's renewable-energy-specific position among EU states and other developed countries within the EU accession process will inform the policies which will ensure the regulation of energy inputs and outputs in a manner consistent with Turkey's current goals.

To be considered as an efficient country, Turkey should strive to achieve 97% like Norway and Iceland. Since the study may direct new policies for reviewing its energy-specific status and for eliminating its deficiencies within the EU accession process, it can be considered as a highly significant project. In conclusion, this study will enable Turkish policymakers to define their future energy-specific projections in order to attain the projected inputs and outputs.

Within this context, the target for usage of hydraulic resources will be satisfied with the improvement of hydroelectric power plant technologies. Wind power plants having a power level of 1MW or higher have become commercially competitive. Wind turbine/solar cell hybrid power plants for use in mobile applications in rural areas and the generation of electric energy from solar power in local and mobile applications with the enhancement of photovoltaic cells which have high efficiency of transformation are both commercially competitive and within technological reach.

Table 2. Window analysis results for Turkey

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Turkey	2,34	2,80	2,33								1,92	0,81	2,62
		1,78	1,60	1,49									
			1,66	1,51	1,18								
				1,31	1,01	1,31							
					1,00	1,29	1,73						
						1,10	1,63	2,95					
							1,04	2,37	3,62				
								2,15	3,11	3,65			

Table 3. Window analysis results for selected countries.

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Australia	6,08	6,32	6,57								4,95	0,84	2,54
		6,20	6,44	6,40									
			4,03	4,13	4,26								
				4,38	4,52	4,55							
					4,56	4,59	4,67						
						4,72	4,70	4,70					
							4,43	4,44	4,54				
								4,48	4,59	4,48			
Austria	1,00	1,03	6,16								2,97	2,03	9,57
		1,00	6,15	10,57									
			2,50	3,08	2,94								
				2,83	2,72	2,80							
					2,18	2,31	2,19						
						2,34	2,26	2,35					
							2,12	2,38	2,48				
								2,53	2,64	2,62			
Belgium	18,44	28,19	28,16								5,49	7,71	26,18
		3,67	3,53	3,34									
			2,39	2,20	3,76								
				3,84	3,34	2,55							
					3,36	2,55	2,01						
						2,58	2,05	2,07					
							2,03	2,17	2,31				
								2,46	2,33	2,33			
Canada	1,65	1,72	1,66								1,68	0,02	0,09
		1,72	1,66	1,69									
			1,66	1,69	1,70								
				1,69	1,70	1,66							
					1,70	1,67	1,68						
						1,67	1,68	1,68					
							1,68	1,68	1,65				
								1,67	1,64	1,63			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Czech Rep.	1,88	1,93	2,80								2,66	0,39	1,38
		1,92	2,59	3,22									
			2,21	2,50	2,37								
				2,56	2,59	2,57							
					2,58	2,57	2,66						
						2,81	2,91	2,93					
							2,89	2,94	3,13				
								3,16	3,26	2,79			
Denmark	1,00	1,00	1,00								1,04	0,07	0,29
		1,00	1,00	1,00									
			1,00	1,04	1,00								
				1,22	1,03	1,00							
					1,03	1,00	1,29						
						1,00	1,08	1,02					
							1,12	1,06	1,00				
								1,00	1,00	1,00			
Finland	1,53	1,72	1,74								1,21	0,32	1,02
		1,67	1,71	2,02									
			1,00	1,11	1,04								
				1,08	1,03	1,00							
					1,03	1,00	1,06						
						1,00	1,08	1,13					
							1,02	1,06	1,00				
								1,07	1,00	1,00			
France	6,23	5,89	6,78								6,17	0,52	1,86
		5,82	6,73	6,91									
			6,10	6,23	6,27								
				6,39	6,43	6,86							
					6,37	6,81	6,41						
						6,68	6,27	5,87					
							6,08	5,71	5,41				
								5,56	5,25	5,05			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Germany	9,13	8,83	7,31								18,82	36,34	117,19
		8,63	7,14	6,86									
			5,70	5,33	4,65								
				5,81	5,04	4,56							
					5,04	4,56	4,10						
						4,56	4,10	3,36					
							3,86	3,16	119,52				
								3,16	120,35	97,00			
Greece	5,27	7,33	6,16								2,13	1,63	4,23
		1,66	1,64	1,53									
			1,63	1,53	1,59								
				1,47	1,57	1,48							
					1,57	1,48	1,29						
						1,50	1,29	1,78					
							1,04	1,80	1,56				
								1,88	1,76	1,33			
Hungary	1,05	3,07	3,10								1,56	0,99	2,10
		3,06	3,10	4,49									
			1,32	1,53	1,00								
				1,46	1,03	1,00							
					1,00	1,00	1,06						
						1,00	1,06	1,12					
							1,00	1,00	1,00				
								1,00	1,06	1,00			
Iceland	1,00	1,00	1,00								1,00	0,00	0,00
		1,00	1,00	1,00									
			1,00	1,00	1,00								
				1,00	1,00	1,00							
					1,00	1,00	1,00						
						1,00	1,00	1,00					
							1,00	1,00	1,00				
								1,00	1,00	1,00			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Ireland	7,93	9,41	7,09								1,92	2,43	8,41
		1,31	1,12	1,20									
			1,00	1,01	1,00								
				1,00	1,00	1,00							
					1,00	1,00	1,00						
						1,00	1,00	1,00					
							1,00	1,00	1,00				
								1,02	1,04	1,00			
Italy	66,17	106,00	141,65								42,68	30,73	123,32
		55,18	68,45	87,18									
			29,75	36,24	36,24								
				34,51	34,36	34,55							
					27,34	27,04	27,94						
						25,06	25,83	27,02					
							20,31	21,09	23,37				
								18,33	21,22	29,40			
Japan	64,82	86,23	113,15								82,56	21,00	54,76
		84,26	111,15	157,25									
			58,39	63,59	74,62								
				61,24	70,23	83,17							
					65,22	76,08	76,98						
						71,93	72,57	83,04					
							74,17	86,64	82,07				
								86,45	82,27	95,99			
Korea	23,82	18,11	25,14								15,56	4,67	17,43
		18,05	25,09	20,75									
			10,48	8,05	11,52								
				7,71	11,12	13,48							
					11,62	13,91	13,86						
						14,87	14,94	15,00					
							15,08	15,30	16,39				
								16,40	17,28	15,35			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Luxemburg	1,00	1,00	6,07								1,56	1,49	5,07
		1,00	5,52	4,50									
			1,00	1,00	1,00								
				1,00	1,00	1,00							
					1,00	1,00	1,00						
						1,00	1,05	1,00					
							1,23	1,06	1,00				
								1,08	1,00	1,00			
Mexico	25,16	27,37	29,25								23,52	4,14	16,14
		25,61	28,07	24,88									
			25,06	21,81	23,81								
				21,73	23,72	25,34							
					23,71	25,34	27,85						
						25,34	26,76	27,62					
							19,53	22,20	16,78				
								17,99	13,11	16,43			
Netherlands	11,91	11,34	8,99								4,04	3,39	10,09
		10,59	8,34	5,80									
			2,11	2,19	2,11								
				2,41	2,35	1,77							
					2,41	1,82	1,91						
						1,92	1,99	2,57					
							2,09	2,63	2,37				
								2,65	2,39	2,28			
N. Zealand	1,40	1,59	1,40								1,49	0,08	0,23
		1,59	1,40	1,49									
			1,40	1,49	1,36								
				1,49	1,36	1,55							
					1,36	1,55	1,55						
						1,55	1,55	1,52					
							1,55	1,52	1,56				
								1,52	1,56	1,40			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Norway	1,00	1,00	1,00								1,00	0,00	0,01
		1,00	1,00	1,00									
			1,00	1,00	1,00								
				1,00	1,00	1,00							
					1,00	1,00	1,00						
						1,00	1,00	1,01					
							1,00	1,01	1,01				
								1,00	1,00	1,00			
Poland	8,94	14,18	21,26								5,53	4,08	18,60
		5,10	5,04	5,41									
			4,56	4,76	4,16								
				5,34	4,72	3,88							
					4,99	4,11	3,73						
						4,52	4,09	3,65					
							3,98	3,61	3,01				
								3,87	3,25	2,66			
Portugal	9,45	11,22	25,65								4,04	5,18	23,95
		2,30	4,96	4,34									
			2,18	2,02	2,19								
				1,94	2,07	2,46							
					1,70	1,92	1,92						
						1,89	1,94	2,20					
							1,88	2,14	2,32				
								2,15	2,30	3,86			
Slovakia	1,00	1,00	1,00								1,01	0,03	0,09
		1,00	1,00	1,08									
			1,00	1,00	1,00								
				1,00	1,00	1,00							
					1,00	1,00	1,00						
						1,00	1,00	1,00					
							1,00	1,00	1,00				
								1,07	1,09	1,00			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
Spain	3,91	3,40	4,00								2,96	0,50	2,06
		3,29	3,91	3,18									
			3,12	2,70	2,73								
				2,81	2,91	3,06							
					2,91	3,06	2,91						
						3,06	2,91	2,71					
							2,72	2,53	2,32				
								2,53	2,32	1,94			
Sweden	1,46	1,66	1,67								1,43	0,16	0,60
		1,69	1,64	1,66									
			1,46	1,4	1,47								
				1,44	1,5	1,5							
					1,48	1,47	1,36						
						1,39	1,29	1,31					
							1,28	1,3	1,29				
								1,23	1,21	1,09			
Switzerland	1,00	1,00	1,02								1,01	0,02	0,07
		1,00	1,00	1,00									
			1,00	1,00	1,00								
				1,00	1,00	1,00							
					1,00	1,00	1,07						
						1,00	1,07	1,03					
							1,00	1,00	1,00				
								1,00	1,00	1,00			
Turkey	2,34	2,80	2,33								1,92	0,81	2,62
		1,78	1,60	1,49									
			1,66	1,51	1,18								
				1,31	1,01	1,31							
					1,00	1,29	1,73						
						1,10	1,63	2,95					
							1,04	2,37	3,62				
								2,15	3,11	3,65			

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean	Std. D.	Range
U. K.	16,03	16,98	14,84								8,45	4,35	12,23
		16,79	14,66	15,31									
			6,63	5,98	5,87								
				6,11	6,06	5,87							
					6,20	5,93	6,32						
						6,09	6,35	6,43					
							6,04	6,16	5,67				
								6,14	5,68	4,75			
U.S.A.	1269,82	1759,52	2063,42								707,24	692,94	1846,72
		1748,08	2053,85	2132,77									
			483,88	493,02	589,97								
				439,55	518,69	514,35							
					266,49	266,64	257,46						
						248,97	242,43	256,08					
							219,70	232,22	243,43				
								222,66	234,16	216,70			
Mean	52,38	69,31	62,09	42,52	21,82	18,20	14,46	14,64	18,24	17,39	31,92	177,38	2062,42

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