

## COMPARISON OF RENEWABLE AND CONVENTIONAL ENERGY COSTS BY WAVELET TECHNIQUES

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**Abstract-** This paper aims to compare the cost of renewable energy to conventional energy sources in production. It is argued that advantage in cost of production would support competitiveness of Turkish manufacturing industry in international trade. In this paper an export model has been developed to forecast competitive advantage of Turkish manufacturing industry on international trade by using renewable energy in production. Data on the cost of energy on Turkish manufacturing industry and export performance in past 10 years were processed. This study utilizes 1D wavelet packets and continuous wavelets on historical cost and export values in Turkey. Wavelet and regression analysis have been applied to define variation in temporal and spatial patterns. Wavelet techniques detect sudden changing, increasing and decreasing trends of data and define the role of factors small and large scale effects. Actual share of energy usage in production cost and usage of renewable energy instead of conventional energy values were compared to other countries data analyses.

**Keywords:** Cost of renewable energy, wavelet analysis, cost advantage, competitiveness, international trade

### 1. INTRODUCTION

Turkey export has been following high and rapid growth since 1980. This growth is considered as highly successful development in comparison to the period prior to 1980. However, the driving forces behind this successful export are still a matter of debate. Some of the economists attributed this success to liberal policies on international trade while others aggressive foreign exchange policies. In this article, competitive advantage of export commodities in the foreign markets is considered as one of the important reason of the growth. It is argued the lower cost of production had contributed competitive advantage for a long time. In this analysis, contribution of lower energy cost to supply of products exported has been analyzed.

### 2. BASIC FACTORS UNDERLYING EXPORT & COMPETITIVENESS

Income level of target export market is important determinant of the export level. In early years of 1980s, demand originated in Middle East countries are considered as

important factor for rapid growth of export. These export markets were the upper middle and upper income level countries (Arslan, I and Winjbergen, 1991). The Customs Union between Turkey and the European Union (EU) has been considered as an important source of export growth since all tariffs and quotas were removed in trade between the EU and Turkey. On the other hand, exporting country should have capacity for competing in these markets. A large number of definitions for competitiveness have been proposed in the economic and business literature. Firstly, Adam Smith explained international trade due to the differences among the nations and specialization on production of good countries has absolute advantage. Later, Ricardo extended the analysis of international trade theories by adding wages and productivity concepts to the absolute cost advantage in determination of competitiveness. Ricardo argued trade would be beneficial even if the first country held an absolute cost advantage over the other country in both commodities at his two nations-two commodities example (Ricardo,1814(1932;111)).In simple one factor

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Ricardian model, labor is the only important resource for production. Labor productivity only varies across countries depending on differences in technology. But labor productivity in each country is constant across time as well the supply of labor is constant. Only two goods are important for production and consumption. Labors receive competitive wage due to their productivity (Krugman and Obstfeld, 2006:26). The benefits of higher productivity in one country can be transmitted from one country to another through trade. Therefore, movements of goods provide a substitute for movements of factors between countries. And each can employ its own resources where they are relatively most efficient or relatively least inefficient.

Although, comparative advantage is the cornerstone of the original theory of international trade, it was not able to explain what goods would be exported and imported. Later, by introduction of the terms of trade comparative advantage provides the answer to problems of country's both growth and efficiency in resource allocation (Wexler, 1972:54). If one country has an absolute advantage in the production of both goods (as assumed by Ricardo) then real wages of workers (i.e., the purchasing power of wages) in that country will be higher in both industries compared to wages in the other country. Workers in the technologically advanced country would get a higher standard of living than in the technologically inferior country since in the country that is more productive, workers get higher wages.

A substantial explanation of the causes underlying trade and competitiveness has grown by Heckscher-Ohlin (H-O) Model. Based on two essential assumptions that countries are differently endowed with productive resources and in perfectly competitive markets, H-O model argues that trading countries would benefit by exporting those goods that are relatively intensive in the country's abundant factor and import those goods that are relative intensive in the use of the country's scarce factor. When society decides to produce more of capital intensive good, they have to produce less of labour intensive good. H-O model says differences in labour skills, physical capital and land between countries cause productive differences leading to gains from trade (Krugman and Obstfeld, 2006:51).

The Stolper Samuelson Model criticizes the H-O model and states a rise in the price of a good will increase the real price of the factor used intensively in the sector and decreases the real price of the other factor. The crucial effects on income of an opening of trade depend on the flexibility of the affected factors.

The Rybczynski theorem explains the relationship between changes in national factor endowments and changes in the outputs of the final goods in 1950s (Winters, 1991:39). According to theorem, an increase in country's endowments of a factor will cause an increase in output which uses that factor intensively and a decrease in the output of the other good. Therefore, countries produce and export more of labour intensive goods.

Although, the traditional general equilibrium approach to international trade is considered as powerful intellectual analytical structure explaining and providing many useful insights about a trading world economy, Helpman and Krugman (1985) explain four major subjects in which traditional trade theory seems to be inadequate in explaining the empirical observations: failure to explain the volume of trade, the composition of trade, the volume and role of intra-industry trade and direct foreign investment and the welfare effects of trade liberalization (Helpman and Krugman, 1985:2).

Balassa (1995) focused on the essential characteristics of producers in competition for market share and profits and the ability to export. Durand and Giorno (1987) argued the ability to compete depends on price ratios and cost competitiveness. Turner and Gollup (1997) and Siggel (2007) introduced more complex and multi-dimensional indicators about competitiveness. Kotan and Sayan (2001) showed a relatively higher price charged by an exporter will reduce its market share relative to other in the case of the technology intensive products in Turkey. High prices are considered due to high cost.

Traditionally, cost of production is considered as main factor determining competition. Labor wage, cost of raw materials and energy used in production would be considered as main factors of production. Besides labour cost and cost of raw material, energy is an important factor contributing to production. Here, mainly cost of energy has been analyzed to compare cost effectiveness of renewable

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energy. Electricity, fuel oil, coal has been used to generate electricity in Turkey.

In practice, nearly half of the world's trade consists of trade between industrial countries that are relatively similar in their factor endowments. Further both the share of trade among industrial countries and the share of this trade in these countries incomes rose for the last decades, even as these countries were becoming more similar by most measures. In some cases, the government policies would restructure some of the adverse effects of these market imperfections (Stiglitz, 1989:197). If commodity price are chosen properly to reduce the risks that producers may face, this price may lead to higher level of production and investment. One of the factor determining the price is cost, in Turkey, large part of cost seems to be in energy cost. The Energy markets are in general imperfectly competitive markets. In this case, the government would support the producers to reduce energy prices by different kind of incentives given to energy producers. Government may also eliminate some taxes that worsen the risks facing energy producing firms. At that time this would be considered as positive role of government for the economy through taxes and subsidies (Stiglitz, 1989:197). Subsidies given to the producers who use renewable energy resources would may provide sustainable production and export opportunities to the countries.

According to argument of Baldwin, new trade theory is that a country may increase its welfare through strategic trade-policy behaviour when its firms are competing in imperfectly competitive international markets (Baldwin, 1992:806). Additionally, this net gain earned by the firm in imperfectly competitive domestic market may behave strategically, the net gain from the international trading will be more than the net gain under the perfectly competitive markets. The most controversial suggestion by the new trade theory was that government intervention can raise national welfare by shifting monopoly rents from foreign to domestic firms (Brander, 1981).

Trade policy can serve for a given country as a tool or obtaining as large a share of these international profits as possible. Brander states implementing strategic policies might" allow the country to capture rents that would

otherwise go elsewhere" (Brander, 1988). The government should play more active role in international trade by following two basic policies : Shifting rents supporting and more external economies. Energy is one of the important example of externam economies. Either its production or consumption has direct and indirect influences on economy, ecology and society. Traditionally, sustainability has been framed in the three pillar model: Economy, ecology and Society are all considered to be interconnected and relevant for sustainability (BMU, 1998). The relationship between RE and sustainability can be viewed as a hierarchy goals and considerations. The energy sector has generally been perceived as key to economic development with an economic growth and expansion of energy consumption. Indicators such as GDP or per capita GDP have been used as proxies for economic development for several decades such as in integrated models. The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in June 1992 stated target of worldwide sustainable development. The goal of sustainable development cannot be realized without major changes in the World's energy system. Accordingly, Agenda 21, called for "new policies or programs, as appropriate, to increase the contribution of environmentally safe and sound environmentally safe and sound and cost effective energy systems, particularly new and renewable ones, through less polluting and more efficient energy production, transmission, distribution and use" (Johansson, T. Kelly H. Amulya K.N.Reddy, R.Williams, 1993)

If the world economy expands to meet the objectives of countries all over the World, energy demand is likely to increase even if energy use should be more efficient. Given adequate support, renewable energy technologies can meet much of the growing demand at prices lower than those usually forecast for conventional energy. By the middle of the 21<sup>st</sup> century, renewable sources of energy could account for three fifths of the world's electricity market and two fifths of the market for fuels used directly. Moreover, making a transition to renewable intensive energy economy would be reduced to 75 percent of their 1985 levels provided that

environmental and other benefits not measured in standard economic accounts.

Renewable energy systems have benefited from developments in electronics, biotechnology, material sciences and in other energy areas. Renewables can play major roles in the global energy economy in the decades ahead. In the global energy demand scenario adopted for this study, global electricity

production would more than double by 2025 and more than triple by 2050. By 2050, renewable energy sources can play a central role in the world energy markets. They can do this even if world energy prices increase very slowly and without subsidies or credits to reflect external benefits not tracked in standard economic accounting.

### 3. CONVENTIONAL ENERGY RESOURCES AND THEIR COST IN PRODUCT

Unfortunately, energy resources are not sufficient in Turkey. National energy resources would only meet 35% of the energy demand in Turkey. It is also forecasted this ratio would decrease to 25% while energy demand for manufacturing industry is forecasted as the amount more than 4 times required in 2000s. Turkey need to find out energy resources at cheaper prices and renewable to maintain sustainable growth, development and export (Under Secretariat of Treasury, R.T. 2010: 1)

Turkey has hard coal, lignite, asphalt, petroleum, natural gas, hydroelectric energy, and geothermal energy sources. Turkey does not have own large fossil fuel reserves (Akan, Dogan, Isik, 2011:). Baris (2011) analyzed the current and future role of coal in energy strategy of Turkey and the compatibility of energy policies of Turkey to the EU policies. Coal and hydropower are considered as the most important indigenous energy sources in Turkey since their supplies are stable. Turkish government set targets to fully utilize coal reserves of the country in next decades. Electricity production of Turkey was 46.998 in 2010. It was largely based on thermic sources (59 %); hydro sources (33 %) and wind (3.8%). Baris(2011) forecasted the capacity for electricity would increase 2014 to 55.691. The share of hydro and wind sources would increase to 36%.

The cost of renewable energy declined over the past thirty years due to efficiency obtained in thermal energy; reduction in manufacturing cost; developed architectural designs (Sovacool, 2007: 111) New wind technologies are operating at lower wind speeds and employing stronger materials and dollar technologies have greatly improved efficiency, lowered cost and enhanced performance (Sovacool, 2007: 111). The competitiveness of renewable energy technologies has been further heightened by improvements in energy storage (Sovacool, 2007: 111)

There are several alternative technological ways to generate electricity and reduce green house gas emissions cost effectively. Sometimes plant design would offer more efficient power generation conversion of fossil fuels, greater use of renewable energy or nuclear power and the capture and disposal of CO<sub>2</sub>. The choice in terms of cost saving and carbon emission reduction benefit. The global electricity sector has the potential to lower its carbon emission reductions by between 1.5-4.7% by 2010 and 8.7-18.7% by 2020 (Sims, Hans and Gregory, 2003:1324). Gokcecinar and Uyumaz (2008), compared endogenous and exogenous cost of coal, natural gas and wind, coal has 4.8 endogenous cost but its exogenous cost is 5.0; natural gas has 4.0 endogenous cost but is exogenous cost is 2.5 and wind has the lowest exogenous cost 0.1

**Figure 1:** Comparison of Alternative Energy Cost / 2008

Energy Source	Typical Installation	Cost Per Kilowatt Peak and Per Kilowatt hour
Fuel Cells	1-200 kilowatts	1500-3000 kwp 5-10 cents per kwh (Lower number associated with larger Wind Farms)
Biomass Generator	1-1 Megawat-Multi mW	\$1500-\$1800 per kWp 5-10 kWh

Source: Gokcecinar and Uyumaz, 2008

The figure below shows the cost per kilowatt hour. Renewable energy cost is more than fuel cells source.

**Figure 2: Comparison of Alternative Energy Cost 2012**

Energy Source	Typical Characteristics	Typical Energy Cost ( US cents kilowatt hour)
Large Hydro	10 MW-18.000 MW	3-5
Small Hydro	1-10 MW	5-12
On Shore Wind	1.5-3.5 Rotor Diameter: 60-100 m	5-9
Off Shore Wind	1.5-3.5 MW; Rotor diameter: 70-125 m	10-20
Biomass Power	1-20 MW	5-12
Geothermal Power	1-100 MW	4-7
Solar PV	Crystalline 12-19 %;thin film 4-13 %	
Solar PV (Concentrating)	25%	
Rooftop Solar PV	2-5 kW peak	17-34
Utility- Scale Solar PV	200 kW to 100 MW	15-30
Concentrating Solar Thermal Power	50-500 MW to 10-20 MW (tower)	14-18

Source: Sabuncu and Colakoglu, 2012

Fossil fuels continue to dominate as the main sources of energy produced and consumed worldwide despite the growth of the share of renewables in both production and consumption. However, the use of fossil fuels has stalled when it comes to electricity production through its use has continued to dominate the transport sector. Oil is the main fossil fuel used and has remained so since the end of the Second World War. It has a near monopoly as the main source fuel for the transport sector. However, the use of petroleum fuels to produce electricity has drastically declined with the exception of natural gas. This is due to the oil shock of 1973-1974 that decreased economic growth in every oil importing nation and lead to a drastic hike in electricity tariffs.

As nations like Japan and Germany plan to shut down their nuclear power plants. Many developing nations like Nigeria, Jordan and Ghana are making plans to build nuclear power plants thus in future most nuclear power plants may be located in developing countries in future. However, in all nations renewables are taking a larger and larger share of energy produced and consumed. However, in all nations, renewables are taking a larger and larger share of energy produced and

consumed. Already in Paraguay, 100% of all the electricity generated is from hydropower. Spain, in its efforts to reduce reliance on fossils in energy production has some of the largest solar and wind power projects in the world. Germany exports wind power energy to the EU. Morocco, Egypt and Kenya have large wind power plants which are helping them keep up with the growing energy consumption as the USA, Indonesia, Iceland and Kenya are making strides in developing geothermal energy.

The 9.8 magnitude earthquake in Japan just made nuclear energy producers to rethink their energy resources in all countries all over the World. The most significant reaction was from Germany and Italy. German government declared that the life span of the Country's 17 nuclear power plants, which originally had to be closed for 12 years on average. However, the Fukushima crisis introduced a change in plans. Initially, the German government closed the nuclear reactors built before 1980. 23% of German electricity comes from nuclear power. However, even German government takes the risk to import electricity and changed their production for renewable energy.

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World energy consumption has been on the rise worldwide as developing nations begin to industrialize and as consumers in developed national buy more energy consuming appliances to make life more comfortable. If the current trends continue, we may face an energy shortage in future. In Turkey, the renewable energy sector and government policies have interacted and changed at drastic speed over the last few years. Supporting renewable energy has been a great experiment for policymakers all around the world. Policy reversals in the US, Germany, Italy and Spain

have already started to reduce investment in despite the global financial crisis, the renewable energy sector has achieved important advances in technology and power project development over the past few years. In 2010, 195 GW of new power generation capacity was established globally and approximately half of this capacity is based on renewables. Renewables constitute nearly 25% of global installed capacity, whereas in power generation the share of renewables is around 20% (Sabuncu and Colakoglu, 2012)

**Figure 3:** Renewable Energy Share of Global Final Energy Consumption, 2009

Type of Energy Resource	%
Nuclear	2.8 %
Renewables	16.2%
Fossil Fuels	81%

**Source:** Renewables 2011 Global Status Report,( Sabuncu and Colakoglu, 2012)

As it is shown at figure 3 and 4, the use of renewable energy resources growing so rapidly. However, at 2009 statistics, fossil

energy resources were still the largest energy resources consumed.

**Figure 4:** Growth Rates of Renewable Energy Capacity and Production, 2005-2010

Type of Energy Resource	Annual Average Growth Rate
Biodiesel Production	38 %
Ethanol Production	23 %
Solar hot water –heating	16 %
Hydropower	3%
Geothermal Power	4%
Concentrating Solar Thermal Power	25%
Wind Power	27%
Solar PV	60%
Solar PV	49%

**Source:** Enerji Piyasaları Düzenleme Kurulu, Energy Markets Regulating Board  
[http://www.epdk.gov.tr/documents/elektrik/rapor\\_yayin/Elektrik\\_Piyasasi\\_Gelisim\\_Raporu\\_2011.pdf](http://www.epdk.gov.tr/documents/elektrik/rapor_yayin/Elektrik_Piyasasi_Gelisim_Raporu_2011.pdf)

Turkey energy demand will increase more than past demand in the future depending on

its target expected change in demand in economy and technology.

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**Figure 6:** Electricity Demand Forecast During the Period Between

2011	227.000
2012	241.300
2013	257.060
2014	273.900
2015	291.790
2016	310.730
2017	330.800
2018	352.010
2019	374.430
2020	398.160

**Source:** Electricity Market Development Report, 2011

[http://www.epdk.gov.tr/documents/elektrik/rapor\\_yayin/Elektrik\\_Piyasasi\\_Gelisim\\_Raporu\\_2011.pdf](http://www.epdk.gov.tr/documents/elektrik/rapor_yayin/Elektrik_Piyasasi_Gelisim_Raporu_2011.pdf)

**4. APPLICATION OF WAVELET TECHNIQUES**

Second part of this study is based on wavelet techniques and their applications on energy prices and economic parameters (export and crude oil prices). In this section, the basic definitions has been given about the wavelet transform. Wavelets are families of small waves generated from a single function  $f(t)$  which is called the mother wavelet. A sufficient condition for  $f(t)$  to qualify as a mother wavelet is given as below (Meyer, 2000; Siddiqi et al., 2002; Kenisarina et al. 2006; Aslan and Caglar, 2011, Aslan and Gencoğlu, 200; Tolun et al., 1995; Turksoy 1995):

$$\int_{-\infty}^{\infty} |f(t)|^2 dt < \infty \tag{2(a)}$$

The Fourier transform  $F$  of  $f(t)$  is defined as

$$F(w) = \int_{-\infty}^{\infty} f(t)e^{iwt} dt \tag{2(b)}$$

A function  $\psi(t)$  satisfying the following condition is called a continuous wavelet:

$$\int_{-\infty}^{\infty} |\psi(t)|^2 dt = 1 \tag{3(a)}$$

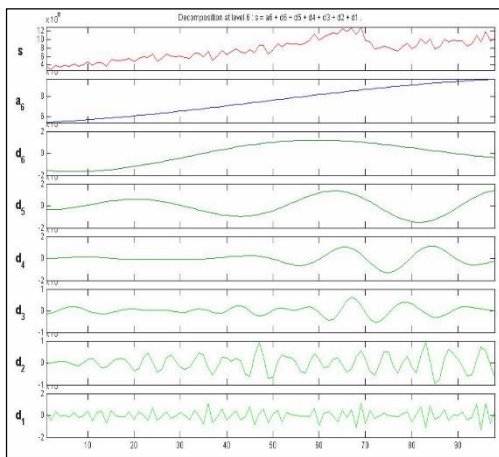
and

$$\int_{-\infty}^{\infty} |\psi(t)| dt = 0 \tag{3(b)}$$

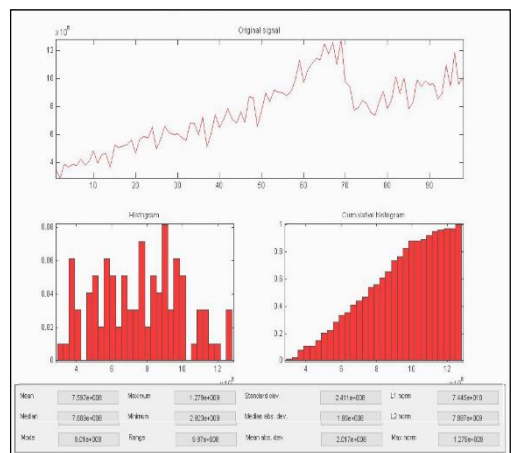
It may be observed that the scalogram can be represented either as three-dimensional plot or as a two-dimensional grey scale image. As mentioned above,  $a, b$  parameters represent the scaling factor and the location in time, (Siddiqi et al., 2005). Different variability of time scales from inter-monthly fluctuations (2,0 – 3,1 months) to decadal – centennial changes (10,6-110,7 years) have been considered to analyze data. In the following sections,  $f(t)$  will be considered as monthly and annual average values of export and crude oil prices in Turkey.

**4.1 Wavelet Analyses of Export**

Figures 1 (a-d) show wavelet analyses of export. Fig. 1a shows an increasing trend all period. Some decreasing trend has been observed in 2008. Amplitudes of small ( $d1$ , high frequencies) and large scale ( $d6$ , low frequencies) influences on monthly export in Turkey increase in the second part of the period.



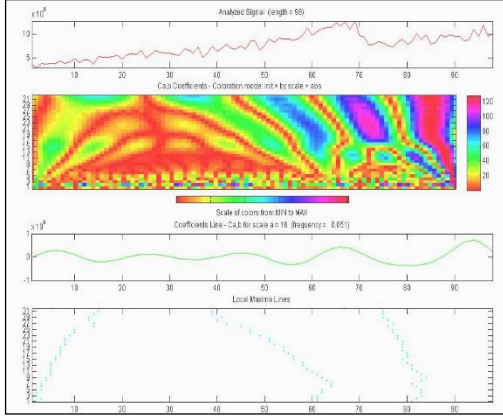
**Figure 1a:** Monthly Export, January 2003 – February 2011, 1D Wavelet, DMeyer, Level 6



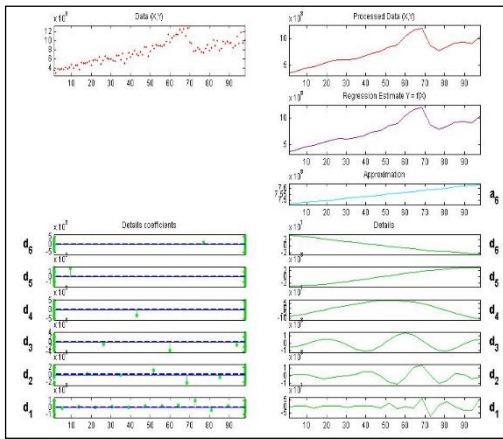
**Figure 1b:** Statistical Descriptive of Monthly Export, January 2003 – February 2011



Frequency distribution of export values does not show a very well bell shape distribution. There is a negative skewness, (Fig. 1.b).



**Figure 1c:** Analyses of continuous wavelet 1-D, Morlet, Level 1, Monthly Export, and January 2003 – February 2011



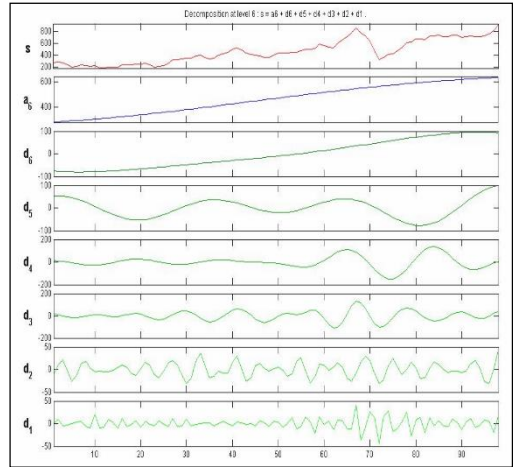
**Figure 1d:** Analyses of Regression estimation for export, Fixed design 1-D, DMeyer, Level 6.

Figure 1c shows the role of different scale effects on monthly export values. In 2008 there are large scale factors on this variation with the periodicity of 20 to 30 months (inter-annual variations). Regression estimation explains the linearly increasing trend of export data (Fig. 1d).

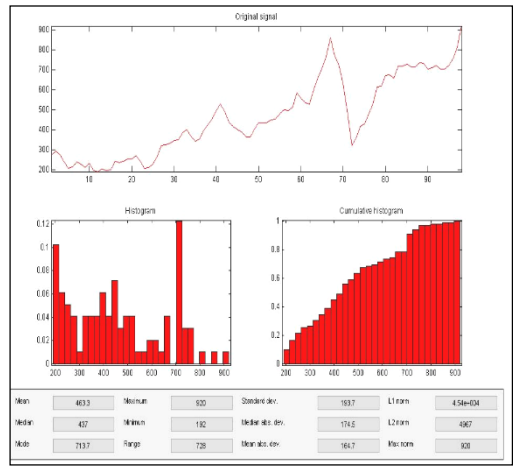
**4.2 Wavelet Analyses of Crude Oil Prices**

Figures 2 (a-d) show wavelet analyses of monthly crude oil prices. Fig. 2.a shows an

increasing trend in most part of the period. Some decreasing trend (similar trend in Fig. 1) has been observed in 2008.

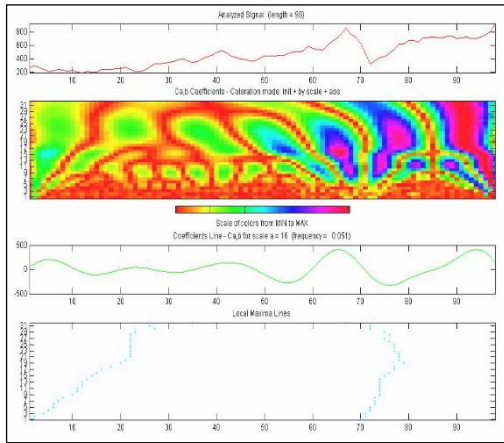


**Figure 2a:** Monthly variation of crude oil prices, January 2003 – February 2011, 1D Wavelet, DMeyer, Level 6

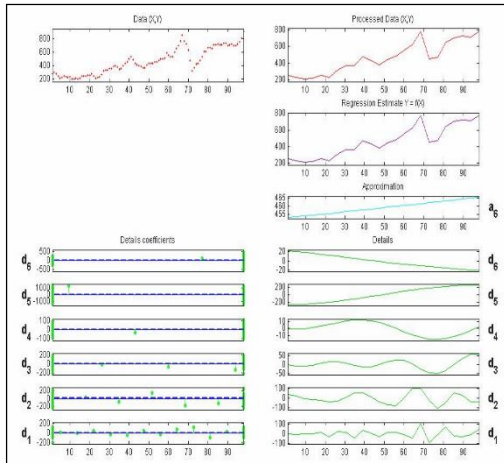


**Figure 2b:** Statistical descriptive of monthly crude oil prices, January 2003 – February 2011

Amplitudes of small (d1, high frequencies, medium scale (level d4) and large scale (d6) influences on monthly crude oil prices in Turkey increase in the second part of the period. Frequency distribution of crude oil does not show a very well bell shape distribution. There is a three modal distribution, (Fig. 2b).



**Figure 2c:** Analyses of continuous wavelet 1-D, Morlet, Level 1, monthly crude oil prices, January 2003 –February 2011



**Figure 2d:** Analyses of regression estimation for crude oil prices, fixed design 1-D, DMeyer, Level 6.

Figure 2c shows the role of different scale influences on monthly variation of crude oil prices. In 2008 there is a large scale influence on this variation with the periodicity of 7 to 30 months. Roles of large scale effects on export follow observation of similar effects on crude oil prices in figure 2c. These variations are associated with semi-annual cycle and inter annual variations. Regression estimation explains the increasing trend of crude oil prices except the period between November 2008 and February 2009, (Fig. 2d).

## 5. CONCLUSION

Despite serious development in renewable energy technologies, renewable energy sources are still at competitive disadvantage. However, not only for increasing the level of export but also international agreements are binding for Turkey, Turkey has to use renewable energy source more. Due to obligations arises with Kyoto Protocol, Turkey should limit CO<sub>2</sub> emission together with other greenhouse gases. Coal is a very important domestic energy source for Turkey but new policies have to be developed and adopted immediately, and more realistic targets for the country should be set accordingly.

The first part of this study covers multiple regression analyses of export, energy price and label cost. There is sufficient evidence ( $\alpha=0,05$ ) to support a linear correlation amongst these variables. In the model set in this article sets clearly, the negative relationship between the energy cost and level of export. If Turkey succeeds to decrease cost of energy, the level of export will increase. The competitive cost advantage is one of the important factors, however, the international agreements and sustainable development policies also require clean and sustainable energy policies.

Crude oil prices and other economical parameters analyzed above by using wavelet techniques seem will be persist in longer term. As a result of these analyses installation of renewable energy systems (like solar and wind) will support national energy consuming as environmentally friendly energy sources. The total number of wind power plants under operation in Turkey is 41 (TWEA, 2011). In general at Aegean Sea Region at different 41 wind parks, there are 700 wind energy converting systems (WEcS) and they transfer 1414, 50MW wind energy to interconnected system. Furthermore, 19 different Wind Parks with 750MW generating capacity is under construction in Turkey.

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