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Wheat Yield Dynamics: A Structural Econometric Analysis

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Abstract: In this study we initially have tried to explore the wheat situation in Turkey, which has a small-open economy and in the member countries of European Union (EU). We have observed that increasing the wheat yield is fundamental to obtain comparative advantage among countries by depressing domestic prices. Also the changing structure of supporting schemes in Turkey makes it necessary to increase its wheat yield level. For this purpose, we have used available data to determine the dynamics of wheat yield by Ordinary Least Square Regression methods. In order to find out whether there is a linear relationship among these series we have checked each series whether they are integrated at the same order or not. Consequently, we have pointed out that fertilizer usage and precipitation level are substantial inputs for producing high wheat yield. Furthermore, in respect for our model, fertilizer usage affects wheat yield more than precipitation level.

Key words: Wheat yield, ordinary least square, unit root, cointegration

INTRODUCTION

It is estimated by US Census Bureau that world population will increase 20 and 44% from 2007 to 2025 and 2007 to 2050, respectively. By 2025 more than 83% of world's population will live in developing countries and 57% of the population in developing countries will live in cities (McCalla, 1994). By 2020 two-thirds of the world's wheat consumption will occur in developing countries. Because of this, the world should increase wheat yield growth at 25% per year over the next 30 years as the size of cropped area is expected to remain minimal or even negative (Hobbs *et al*., 1998). According to Dyson (1999), world cereal demand will be 3.046 million tons and linearly projected yield will be 4.076 kg ha^{-1} and production will be 2.977 million tons in 2025. Cassman ***et al.*** (2003) also tells concerns by thinking environmental issues that the world cereal demand is projected to increase by about 13% annually until 2025. He mentions that livestock production will increase and the demand for grain will be higher than the population increase. The need for irrigation will increase and the world will need more water.

In response to global warming signals, the world should utilize water efficiently. Member countries of European Union have taken some measures such as user pays and polluter pays to control water prices in agriculture for sustainable environment and optimal allocation of water resources (Sahin, 2007). Bluemling *et al*. (2007) also tells about the importance of agricultural water productivity concept.

Innovation which is related to technical efficiency ensures decreasing of yield varieties among countries. Technical innovation is a key point at this stage. Relative yield residuals are tended to decrease with modernization of the wheat producing systems Calderini and Slafer (1998). It is essential to determine the sources of wheat yield increase, target potential level of wheat production and stipulate comparative advantage within this context (Khan *et al*., 2000).

Countries owning comparative advantage in producing high yield wheat have a high probability of decreasing food prices and unit costs of production (Usherwood, 2000; Sahin and Akdi, 2007). Also there is a positive relationship between food prices and general price level (Yucel and Ciplak, 2004). Consequently, producing high yield wheat increases the burden of the consumers and producers. We think that improvement of wheat yield is critical for accomplishing the common mission of meeting the food needs of the world population and alleviating poverty in developing countries. Also wheat yield is a good indicator to explore wheat prices and rural wealth distribution in political economic history affecting much larger agricultural groups (Schofield, 2007; Overton, 1996). Increasing wheat yield to improve wheat production is a key point here (Brunt, 2002). Thereby, assuming a fixed area, obtaining comparative advantage is positive correlated by accrual of production.

There are several studies in the recent literature trying to explore and understand the wheat yield differentials among countries and its dynamics. These

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recent studies has substantial contribution to show us the importance of water management, effects of climate change on high yield and proper fertilizer usage in agriculture (Basso *et al*., 2007; Sun *et al*., 2007; Mari *et al*., 2007). Input-output causality and exploring its dynamics in wheat yield also varies among countries and regions.

This study tries to explore links among the main determinants of wheat yield dynamics by econometric methods in Turkey. Initially we described the EU and Turkey's wheat situation. The second section of the article presents the material and method. The third part provides the results obtained by the model.

Improvements in input and technology usage and land consolidation has increased the level of wheat production and yield in Turkey. Table 1 gives production area, production and yield as wheat indicators of World, EU-25 countries and Turkey. Area seeded to wheat for harvest was 9.2 million hectares (M ha) in 2005 (wheat production occupies 67% of Turkey's cereal lands) (Table 1). With a 21.5 millions ton (MT) wheat production in 2005 for Turkey is one of the world's biggest wheat producers in (Table 1). From 1986 through 2005 wheat production grew by 13%, wheat yield rose by 14% and wheat production area dropped by 1% (TURKSTAT).

Cereals are important crops in Turkish agricultural industry. There are nearly 1.535 factories oriented to process cereals, 71% of them produce flour, 3% of them produce pasta, biscuit and semolina (Turkish Grain Board TGB, 2005). Domestic use of wheat was 17 MT in 2005. Wheat consumption in food industry amounted to 14 MT (flour, flour products and boiled and pounded wheat), as seed to 1.8 and in feed to 1 MT in 2005 (TGB).

An increasingly modern milling industry, combined with an ineffective domestic wheat sector, has made Turkey both a significant importer and exporter of wheat and flour, respectively. Turkey's growth into the world's second largest flour exporter helped turn its wheat and flour balance of trade positive and the nation became an important supplier for a number of years. Turkey takes the first place in world wheat flour export competition to Near East Asia. Turkey's wheat export and import averaging nearly 96 million kg (16 million dollar) and 1.041 million kg (169 million dollar) annually from 2002 to 2005 (Undersecreteriat of the Prime Ministry for Foreign Trade (UPMFT). Turkey exported 84% of its wheat products as flour, 8% as pasta, 5% as biscuit and 3% as boiled and pounded wheat in 2005 (calculated by TGB resources as wheat equivalent).

The initial purchase price of wheat had been determined by Council of Ministers from 1980 to 2001. After 2001 economic crisis, TGB has been authorized for about determining the initial wheat purchase prices (Berument *et al*., 2007). TGB initial purchase prices are generally above the world prices (258 dollar per ton in 2005 prices) (TGB). As the linkages are developed, Turkey plans to further decrease its purchase price of wheat in order to harmonize its structure and position to CAP legislations and conditions. CAP legislations set TGB down for an intervention agency. Thence, it has been planned and implemented to transform TGB to an intervention agency according to sustainability and qualification standards.

Effects of improved seed quality, modern input usage have been ensured wheat yield to be increased over the last few decades in the world. Average world wheat production was nearly 619 MT and EU-25 has produced 20% of this amount in 2005. The main EU wheat producer countries were France and Germany in 2005 (Table 1).

EU increased wheat yield by promoting technical progress and ensuring the rational development of wheat production and optimum utilization of the factors of production by applying Common Agricultural Policy (CAP). Moreover, according to agrometeorological product yield data calculated by FAO, EU can increase its level of yield potentially (FAO, 2003). Average wheat yield for EU-25 was 540 kg day^{-1} in 2005. Holland, Belgium, Ireland, England, Germany and France were leading wheat producing countries in EU-25 (Table 1).

Table 1: Economics of Wheat Indicators (2005)

Countries	Production area (1000 ha)	Production (1000 t)	Yield (100 kg ha^{-1})	Countries	Production area (1000 ha)	Production (1000 t)	Yield (100 kg ha^{-1})
Turkey	9250	21500	23.24	Lithuania	370	1379	37.33
World	215600	619251	29.10	Lux.	12	72	60.15
EU25	22870	124091	54.26	Hungary	1131	5080	44.93
Belgium	214	1799	84.16	Holland	136	1175	86.56
Chez R.	820	4145	50.52	Austria	289	1453	50.29
Denmark	676	4887	72.34	Poland	2218	8771	39.55
Germany	3174	23693	74.65	Portugal	123	81	6.64
Estonia	85	263	30.84	Slovenia	30	141	47.01
Greece	846	1761	20.83	Slovakia	376	1608	42.79
Spain	2250	3815	16.96	Finland	215	801	37.25
France	5272	36841	69.87	Sweden	354	2247	63.45
Ireland	95	798	84.27	England	1869	14877	79.60
Italia	2123	7717	36.35	Latvia	188	677	36.08

Source: Eurostat (08/12/2006) and TURKSTAT

High wheat yield advantage had been ensured EU countries to perform approximately 7% of world wheat import and 13% of export in 2005 (IGC, 2006). Average EU-25 wheat producer price is below the world average. (World wheat prices (FOB) was USA HRW 167 USD per ton in 2005. In the same year EU-25 average wheat price was 101 Euro per ton (Eurostat).)

In 2005, 618 MT wheat produced and 621 MT used for food and feed in the world in 2005. EU-25 produced 122 MT of this amount and used 119 MT as food and feed (Sahin, 2006). The European Union is the world's largest consumer of feed wheat, accounting for over half of the world's consumption.

Wheat for pasta and bread are within the context of intervention in EU-25. Intervention minimum purchase for wheat for bread and pasta are 80 and 10 tons. Intervention price for cereals is 101 Euro per ton. Payments are given after one month later for the cereals. Intervention agencies had purchased wheat by giving high prices before CAP reforms (for example intervention and compensation prices were 144 and 30 Euro per ton in 1993, respectively). But the process of reform initiated in 1992 with the McSharry Reforms focused on harmonizing regulations according to World Trade Organization (WTO) Agriculture Treaty. The Reform brought changes in policy, which affected intervention prices. Producers have started to receive 101,31 (intervention price) + 63 (compensation payment) = 164 Euro per ton (TGB, 2005). Up to 2007, producers got direct income payments to compensate their loss from the decrease in intervention prices (After 2007, Single Farm Payment Scheme have started to be executed in EU).

1992 McSharry Reforms had some important effects on EU wheat related economic structure. From 1992 to 2005, feed utilization of cereals had been increased. The increasing demand for wheat caused EU wheat production and consumption to jump. Also for to prepare EU to WTO Agriculture Treaty negotiations, from 1992 to 2005 the amounts of export paybacks by subventions have been reduced (TGB).

MATERIALS AND METHODS

In this study, we used fertilizer consumption (GM 1980 = 1), precipitation (YM, 1980 = 1), number of tractors (TR, 1980 = 1)) to analyze the determinants of wheat yield (Y, 1980 = 1). Yearly data (1980-2005) for GM and YM obtained from Ministry of Agriculture and Rural Affairs and Directorate General of Meteorology Affairs; TR and Y gathered from Turkish Statistical Institute (TURKSTAT). Y (kg ha^{-1}) defined as wheat production (*Triticum aestivum* + *Triticum durum* + *Triticum compactum*) divided by production area.

Literature defines wheat yield by several methods. Miller and Bean (1999) defines wheat yield as a function of three components, these are heads per square foot, seeds per head and seed size and tries to estimate potential wheat yield by the formula: (No. of heads per square foot × (No. of seed per head per No. of seeds per 1b.) × 726). To follow up the determinants of wheat yield and develop new methods to measure the variables, FAO (strengthening the crop yield and production forecasting capability project) developed agrometeorological simulation method by using climate factors. Turkish Central Research Institute for Field Crops (TCRIFC) used this method to measure agrometeorological product yield forecasts (TCRIFC, 2006).

In the globalized world, high yield wheat production is one of the important elements of comparative advantage and high farmer profits per acre. Plant population (heads per acre), seed number per head, seed formation (test weight), site selection, tillage and seedbed preparation, liming and adjusting soil fertility, variety selection and seeding, nutrition management, weed, insect and disease management, field scouting are important to manage for getting high yield wheat (Usherwood, 2000).

It is also possible to measure the yield using multi-temporal NDVI satellite imagery. This method will not be mentioned in the article but Labus *et al.* (2002) tries to estimate wheat yield using NDVI parameter regionally.

The average agricultural holding sizes are small when compared with EU. This situation is one of the big barriers to increase the wheat yield. Because of insufficient data, this variable could not be included to the model. Expletory variables like human capital or biotechnology could be injected to the model. Using high tech seeds widely increases the yield of wheat (Furtan *et al.*, 1999). TCRIFC cultures new wheat which's yields are more between 15 to 30%. This shows that improvements in the wheat varieties are essential to get better yield. Because of lack of data from 1980 to 2005, we could not add species verifications to the model. But, according to data gathered from Turkish Directorate General of Agriculture Production and Development (TDGAPD), from 1990 to 2005 distribution of certificated seeds had been increased more than 75% Using certificated seeds in wheat production is very essential to get high yields in the year.

Fertilizer usage amount is another variable affecting the wheat yield level. Nitrogen, phosphorus (P_2O_5), potassium (K_2O), magnesium, sulfur are important nutrient requirements for high yield wheat production. Thanks to the developments in technology, obtaining proper fertilizers for wheat production are available. We defined proper fertilizer for high yield wheat while calculating GM. We defined GM as a fertilizer usage per unit area for wheat production (Equivalent) (kg ha^{-1}):

$$GM = \frac{\text{Fertilizer usage equivalent (Ton) [(Nitrogen (\%21)+ Phosphorus (\%17 P2O5) + Potassium (\%50 K2O)]}}{\text{Fertized Area (103 ha)}}$$

Parker and Nelson (1966) tells about the limiting of yields by plant nutrients. According to them most of the soils of the less-developed countries are low in one or more of the major plant nutrients and there is an increasing evidence that many of them are deficient in some of the secondary a minor nutrient elements. Thus, trying to explore the contribution and effectiveness of fertilizer usage is essential.

Sustainable increases in wheat system yield depend on adequate levels of water as well as adequate levels of nutrients. Water scarcity or water logging can affect wheat yield negatively, so water management is crucial to get high wheat yield. The potential wheat-producing variability of a given area is dependent primarily to the existing climatic and soil conditions. Thompson (1975) tells about the importance of weather variability and production relationship. In recent years external effects like greenhouse gases increased global temperatures (Houghton *et al.*, 1996). Developing countries have grown increasingly concerned about the economic impact of climate change on agriculture (Mendelsohn and Dinar, 1999). Climate change directly affects the precipitation and indirectly the wheat yield.

There are methods like building thermostatically-controlled chambers or by studying yield and contemporary weather data for a number of places within given area in science for establishing weather-crop relationships (Frisby, 1951). In this study we try to explore precipitation and yield relationship by an econometric method using data obtained from Directorate General of Meteorology Affairs. We use yearly average precipitation data (mm) (1980-2005). We calculated the average of the rainfall of the cities Adana, Ankara, Diyarbakir, Edirne, Erzurum, Izmir, Konya, Manisa, Sanliurfa and Tekirdag's averages. Each city represents the seven regions of seasonal rainfall properties. Nearly in every region of Turkey wheat is produced so we assume the average of them represents the yearly rainfall in Turkey for wheat production.

Precipitation is essential for wheat water use. Hubbard and Hanks (1983) defines $\Delta S = p+I-r_0-ET$ to determine crop water use where soil moisture determines how much water is available at any time for evapotranspiration (ET) where, p is defined as precipitation, I irrigation and r_0 is surface runoff. Also ET is the sum of transpiration and the evaporation from the soil surface. In this study we define precipitation as a proxy for wheat water use because wheat does need external artificial irrigation much in Turkey. Precipitation in the proper season is generally sufficient for the wheat water use. Also, because of lack of historical data we can not define the exact wheat water use.

Chen *et al.* (2004) tries to analyze the impacts of climate on yield variability of major US agricultural crops by incorporating recent time series and panel data in Just-Pope stochastic production function estimation exercise finds that more rainfall decreases the variability of wheat yields, but the temperature effect is mixed.

In our model we used yearly number of tractors (TR) (1980-2005) gathered from TURKSTAT for technology coefficient.

In literature there are several studies trying to explore the components of yield with different methods. Hardwick (1976) uses yield component analysis to improve productivity. Thurling (1974) and Dewey and Lu (1959) also analysis the interpretation of quantitative relationships among yield components by correlation and regression analysis. Boken (2000) uses trend and moving average time series techniques relying on past yield data for yield forecasting.

RESULTS

In this study we constructed a set of Ordinary Least Square (OLS) regression models to estimate the parameters and conduct yield analysis. Several methods were conducted to find the best-fitted parameters. Table 2 summaries the main properties of the models.

In order to do regression analysis about the parameters, the residuals are assumed to be independent and identically distributed. Moreover, to do some statistical inference about the parameters, the residuals

Table 2: Model Selection (p values are given in the parenthesis)

Model I	Model II	Model III
$Y_t = \beta_0+\beta_1 YM_t+\beta_2 GM_t+\beta_3 TR_t+e_t$	$Y_t = \beta_0+\beta_1 YM_t+\beta_2 GM_t+e_t$	$Y_t = \beta_1 YM_t+\beta_2 GM_t+e_t$
Parameter estimate	Parameter estimate	Parameter estimate
Intercept: 1372.02 (0.0003)	Intercept: 1660.57 (0.0003)	YM: 1.220478 (0.0069)
YM: 0.018525 (0.9609)	YM: -0.073851 (0.8643)	GM: 2.838327 (0.000)
GM: 0.465612 (0.3365)	GM: 0.812779 (0.1755)	
TR: 0.000545 (0.0011)		
R^2: 0.4404	R^2: 0.0835	R^2: 0.9897
Jarque-Bera: 0.727815	Jarque-Bera: 0.7718	Jarque-Bera: 0.1984

should be distributed as normal. In order to check whether residuals are normally distributed or not we used Jarque-Bera statistic and normal probability plot (Fig. 1). If there is a linear pattern is observed in the normal probability plot, this implies that the residuals are normally distributed. When we exclude the intercept term in the model, we observe high R^2. Linear pattern can be seen in Model II and III (Fig. 2).

The graph of the normal distribution is the familiar bell-shaped curve. We express the density function as

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(x-\mu)^2 / 2\sigma^2} \quad \text{where}, -\infty < x < \infty$$

Testing the normality of residual series we attempted to investigate Jarque-Bera test statistic. Jarque-Bera test statistic which is calculated by the formula

$$\frac{N-k}{6}\left[S^2 + \frac{(K-3)^2}{4}\right]$$

where, S is the skewness, K is the kurtosis and k represents the number of estimated coefficients used to

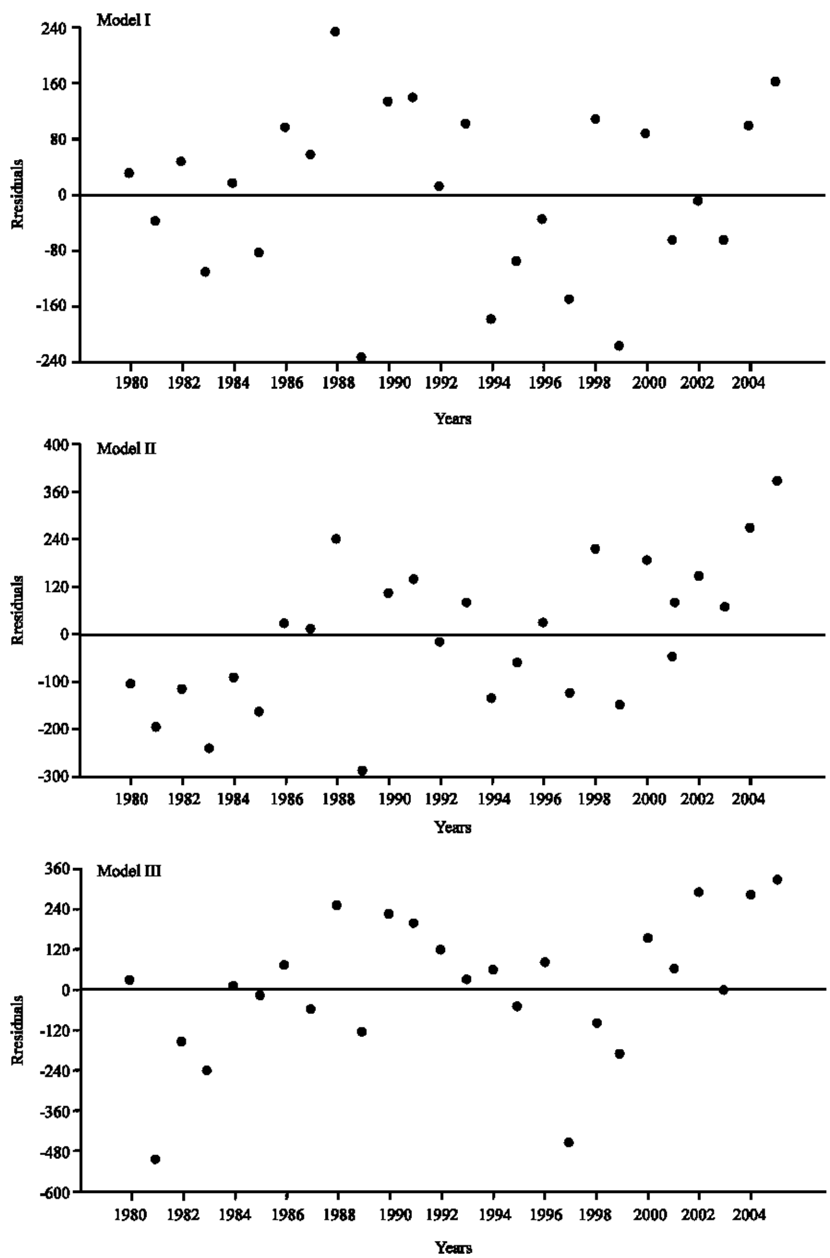

Fig. 1: Residual plots of the models

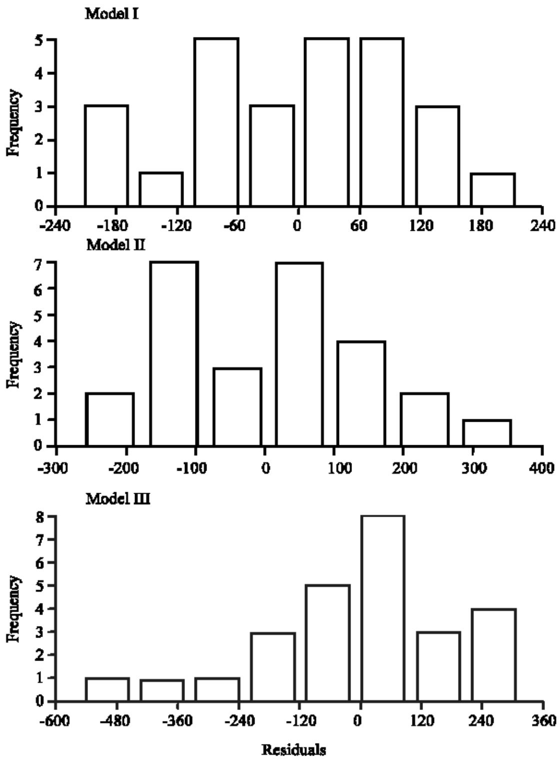

Fig. 2: Frequency plots of the models

Table 3: Augmented dickey-fuller test

	ADF*	(%1) **	(5%) **	(10%) **	Result
Y	-3.74	-3.72	-2.98	-2.63	I(0)
YM	-4.03	-3.72	-2.98	-2.63	I(0)
GM	-4.78	-3.72	-2.98	-2.63	I(0)
TR	-0.61	-3.72	-2.98	-2.63	I(1)

*: ADF test statistic, **: Critical values

create the series. S, K are 0 and 3 respectively for normally distributed series (Bera, 1987).

The p-value is low in Model III compared with the others for the calculated Chi square distribution.

In order to search a linear relationship among Y, M, GM and TR, each has to be integrated at the same order (Engle and Granger, 1987). We have computed Augmented-Dickey-Fuller test statistics for the series an observe that Y, YM and GM are I(0) and we fail to reject the null of unit root for TR (Dickey and Fuller, 1979). That is, TR series is integrated at order 1. Therefore, we exclude TR series from the model. The test results are given in Table 3.

The estimated equation is $Y = 1.22*YM+2.84*GM$ for Model III. Positive and significant coefficients show us that precipitation and fertilizer usage are important inputs for to produce high yield wheat. Model III results of the model point out us that fertilizer usage affect wheat yield more than precipitation level.

DISCUSSION

In the new globalized world whom rules are determined by World Trade Organization WTO negotiations, state subventions have been started to be removed. The countries should abolish price, quantity supports and decrease customs duties in a few decades. Abolishing the support scheme models which distort trade and create deadweight losses substitute with de-coupled supporting schemes like single farm payment scheme or direct income payment scheme. These supporting schemes are becoming commonplace in worldwide. Consequently, production quantity achieved from unit area stand in the forefront. In the strict sense, the countries farmers which can produce high yield wheat can earn high profit from their holdings and become much more competitive as compared to others. Developing new methods to increase the level of wheat yield especially in poor and undeveloped countries is one of the key concepts to struggle with poverty.

Wheat production has been increased in Turkey historically in good sense. When we compare with EU success after CAP, it seems that several structural problems keep going. These problems rebound to the foreign trade figures and Turkey can not export sufficient level of wheat to EU countries compared with the potential level. Efforts must also be made to generalize the use of the certificated seeds by farmers. Industry, business associations and the government should increase awareness of optimal and efficient usage of proper fertilizers in cropping. Also encouraging farmers to undertake educational programmes for improved environmental awareness and responsibility are other issues. Proper fertilizer application promotes a healthier plant and quicker plant establishment for the farmers. It is essential to ensure proper fertilizer efficiency. Thanks to the developed technology, most cost-effective methods are available to provide the necessarily fertilizers and maintain a proper sustainable environment. Creating awareness among farmers in using optimum fertilizer usage and in water management are key points. Inefficient water usage damages the soil and crop. Besides, in Central Anatolia, irrigation investments should receive priority (PSD, 2006).

High intervention prices decrease the producer's competitiveness in world market. Because of this, it is crucial to converge the wheat prices to EU's. The loss of the producer should be compensated by de-coupled supports. The benefits of agricultural research often accrue to consumers rather than to the adopters of the new technology through reduction in commodity prices as a result of increased supply so social returns may be greater than private returns to research. Therefore, a sustained public role in funding agricultural research will be essential, particularly for crops and regions in less favorable environments, which are unlikely to be served by the private sector.

Turkish wheat producers have new alternatives to gain more from agricultural production. It is crucial to increase the level of organic farming as an opportunity in wheat production. Technology intensive seed usage is another alternative for the farmers to compete with the leading world countries.

Utilizing agricultural inputs inefficiently is one the big problems of Turkey's agriculture yield concept (SPO, 2006). Climate change, global warming, depletion in water resources and drought in some regions affect yield level negatively. Wheat producers should prepare themselves well to increase their wheat yield level.

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