# How Responsive is the Crop Yield to producer prices? A panel data approach for the case of Turkey

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Jel classification: C230, Q100, Q180


## Abstract

The food crisis in 2008 clearly shows the importance of productivity in agriculture. This topic has recently become even more important since the countries are obliged to decrease their agricultural protection due to WTO rules which have an important effect on crop prices. As the global land area for agricultural production remains fixed, it is important to investigate how responsive productivity is to price changes. In this study, price responsiveness of yield is investigated by using balanced panel data from 15 provinces in Turkey. The results from a fixed effects model that controls for unobserved heterogeneity indicate that the relative prices of wheat to barley and wheat to fertilizer are important factors to determine productivity. The coefficients for the price of other crops as well as price of inputs, and average April and May rainfall are also found to be significant determinants of productivity.


**Key words:** Price responsiveness, Yield, Fixed Effect Panel Least Squares, Wheat


## Résumé

*La crise alimentaire de l'année 2008 montre clairement l'importance de la productivité agricole. Ce sujet a récemment acquis encore plus d'importance puisque tous les pays ont été obligés à réduire la protection de leurs secteurs agricoles à cause des normes imposée par l'OMC qui ont eu des effets importants sur les prix des produits agricoles. Comme à l'échelle mondiale, la surface agricole totale reste toujours la même, il est important de comprendre comment la productivité répond aux changements de prix. Cette étude examine la sensibilité du rendement au prix sur la base de données de panel équilibré provenant de 15 différentes provinces de la Turquie. Les résultats dérivant du model à effet fixe qui contrôle l'hétérogénéité non observée indiquent que les prix relatifs du blé par rapport à l'orge et du blé par rapport aux fertilisants sont des facteurs importants déterminant la productivité. De surcroît, même les prix d'autres produits, les prix des intrants et la pluviométrie moyenne des mois d'Avril et Mai sont des déterminants significatifs de la productivité.*


**Mots-clés:** *Sensibilité des prix, Rendement, Méthode des moindres carrés appliquée aux données de panel du modèle à effet fixe, Blé.*

## 1. Introduction

The idea that agricultural compatibility is complementary to macroeconomic compatibility and sustains upward shifts in the agricultural production (Oya Oya, 2007) was the basis of the agricultural policies of most of the developing countries in the 1980s and the 1990s. Yet, the expectations did not come true and a common crisis broke out in 2008. The prices of rice, corn and wheat increased of about 180 % between 2006-2008 (Der Spiegel, 2008). Corn prices increased by 31 %, wheat price by 130 %, rice price by 74 % and soya bean price by 87 % in the period between March 2007 and March 2008. The increase in prices forced the food deficit countries depending on international markets to satisfy their food needs. It also put these countries into big financial and demand problems and thustherefore some of these countries faced food uprisings. This deficiency was explained in many cases with drought in several parts of the world and with the change in the global food demand structure (United Nations, 2008). On the other hand, the current fluctuations in food/agricultural production can not be explained by the effects of drought or shifts in the food consumption habits. As the number of undernourished people in the world increased to 852 million in 2005 according to the FAO, one can say that the liberalization process of agricultural markets after the Uruguay Round and the export- based food security packets provided by the World Bank and IMF to developing countries after the 1980s' (Windfur and Jansen, 2005) – which allowed the specialization in production (Woods, 2002) – were not successful.

Basic agriculture is integrated in itself and it is widely said that farmers have enough power to determine the physical process of production. This means that the decisions on what to produce, how to produce and which inputs to use are in the hands of the farmers and the farmers take the prices as decision-making factor. Yet, there are some limiting factors in this analysis. Firstly, as agriculture becomes more industrialized, the dependence of agricultural production on high energy inputs increases, so the prices of these inputs have considerable effects on production. Secondly, as markets for agricultural products are highly concentrated, and as the efficiency of food supply chains increases due to the demand for processed goods, the value is created not just in the production phase but also between the production and the final phase where goods are placed on the supermarket shelves. This transformation of value creation supports new ways of production and pricing practices such as the contract farming where farmers have less sovereignty on production. Thirdly, since the global land area for agricultural production remains fixed, the production shifts more to industrial crops and the lands devoted to that kind of production increases, there is

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pressure on food production caused by the demand from industrial needs. These limits, together with the liberalization of markets, where the government regulations and support on agricultural markets disappear mostly in the developing countries and make farmers lose their sovereignty on production.

Next, how the increasing food demand due to the increasing population can be satisfied is an important question that needs to be answered. Here, the role of prices appears to be important but it has an indirect effect on the process. Farmers concentrate more on the gross revenue they obtain from a unit of land. They take into account the revenue per hectare, rather than the real price per kilogram, and their gross revenue is the revenue they get from a hectare, minus the variable costs of production. The costs include the cost of inputs used in production. The revenue should be enough to compensate their cost of living until the next crop season. This is why the ratio of the crop price relative to inputs is important. If an increase in the crop prices does not compensate the increase in the prices of inputs, it would not mean much to the farmers, since the gross revenue decreases. Farmers' decision to produce or not is mostly affected by the gross revenue. Since prices fluctuate, in order to sustain stability of their revenues, farmers work in secondary jobs, decide not to produce, or just intend to leave the sector. As a consequence, further fluctuations on the agricultural production are experienced. The prices also affect the investment and consumption nexus in agriculture. The factor endowment of the farmer determines his capacity of production. In case of scarce or inadequate physical resources, the improvement of production techniques and processes increases the production capacity. Thus, the gross revenue should be high enough to support the living of farmers and also encourage farmers to invest and continue producing. However, the importance of relative prices received by farmers is significant for production, but as the global land area for agricultural production remains fixed and as the production shifts more to industrial crops, in order to increase production, increasing yield seems the only possible way. This can be done mostly by increasing the welfare of farmers as long as prices received by farmers are important.

Hence, an increase in the yield depends on the increase in the farmers' welfare and indirectly on prices received by farmers. This study intends to analyze this relationship. For that purpose, the responsiveness of productivity to price changes by examining the factors affecting wheat yield are investigated. A panel data set of 15 provinces from the Central Anatolia Region of Turkey is used as a proxy for the production practises. The phases of the study will be conducted in four stages. Section II discusses the factors determining the yield. Section III presents an empirical model in which each of the 15 provinces has the same number of time series observations, reflecting a balanced panel. A fixed effects regression is used to estimate the yield function in order to present the province effects. This approach allows taking the intercept to be a group specific constant term in the regression model. Section IV presents the empirical results. Finally results are discussed in section V.

## 2. Methodological Framework

Yield as a measure of agricultural productivity refers to the output that can be produced with a given level of inputs in a given area. Yield is an important variable in determining the agricultural policy. High variability in yield increases the risk and makes the decision making process more important for producers. Any consideration regarding future prices requires detailed information about the yield as a shift in the production where area expansion is difficult to achieve. It is therefore important to investigate the elasticities of the variables determining the yield in order to project the future.

Yield can be decomposed into trend and random elements. The rate of increase of the trend element is assumed to reflect changes in mean yield, resulting from the development of new technologies. The random element reflects the variation in the mean yield and is attributed to non-economic factors, such as weather. Some studies suggest that the cereal yield growth can be expected to plateau in developing countries in the medium term. This is because, both fertilizer and pesticide use reached their optimum levels and existing high yielding varieties exhibited diminishing return in yield. The OECD (1989) indicated that these assessments tend to ignore the large increases in yields achieved within existing technologies at a time of record harvesting. However, there is still a potential for yield increase by using improved technologies and input intensification. Yield could possibly be increased by advancing the genetic resource base in developing new varieties which are resistant to cold and drought.

The profitability of a crop can undoubtedly be an important factor in encouraging its production and area expansion. Normally, farmers base their production decisions on the expectation of future relative returns available from various activities that comprise their production choices. Therefore, they try to maximize the return in a given area. Since the supply of some of the factors is fixed in the short-term, producers would then increase the use of inputs to boost the yield (Bayaner and Hallam, 1996). Input and output price policies have significant effects on returns and risk. Thus, policy-based economic incentives are most likely to contribute to yield increase. Rational producers are expected to increase the use of inputs in response to crop price increases, suggesting that producers base their decisions on the expected crop prices.

Previous studies found different results on the impact of price on the average yield. Houck and Gallagher (1976), for instance, showed that some of the factors, such as prices, affecting the acreage decisions would also affect the average yield. They chose aggregate corn yield to test the response of yields to prices. They used time series data of US yields and estimated the corn yield elasticity with respect to corn prices in the range of 0.24-0.76. Choi and Helmberger (1993) investigated the sensitivity of corn, wheat and soy bean yields to price changes using a time series and found that the yields positively respond to increases in expected output prices.

Fertilizers exert a positive effect on the crop yield (Choi and Helberger, 1993). DAP (Di ammonium phosphate) is the most intensively used fertilizer. Since the data on the quantity of fertilizer used in wheat production is not available on a province level, the price of DAP paid by producers at planting, exclusive of subsidies, is included in the model.

It is expected that farmers shift the use of inputs to higher revenue crops and concentrate on the production of that crop provided that the anticipated gross revenue is higher. Therefore, the price of barley is included in the analysis to account for a substitute crop. Sugar beet is also an important crop for that region and is grown in a three-year-rotation with cereals. Sugar beet prices were added to the model. However, the estimated coefficient was not significant. Therefore, it was excluded from the model. The reason might be that sugar beet is produced on the same land every three years. Even if the price or gross revenue obtained from sugar beet is high, this crop is not produced on the same land every year because of technical barriers.

One of the most important factors causing the yield variability is the climate. Kun *et al*. (2005) indicated that the most limiting factor in crop production is soil moisture. The effect of climate brings about changes in the yield trend as well as in the yield variability (Cahves, 2001; Wiebe *et al.,* 2000). Bayaner *et al*. (1995) also demonstrated the differences in wheat yield under dry *versus* irrigated conditions. Avci and Uzunlu (1995) reported several studies on the impact of rain on wheat yield. These studies investigated the impact of seasonal rainfall on the wheat yield. They indicated that among other factors, rainfall in the spring season, mainly the April-May rainfall, increased the wheat yield. Rainfall in April and May is important as tillering, shooting and heading occur in this period in Central Anatolia in Turkey where data are collected. Therefore the rainfall is an important factor affecting crop yield in dry regions, which determines the level of moisture in the soil. In the literature, dummy variables are used to account for the variability in rainfall. However, variability in rainfall in Central Anatolia is low, therefore, average rainfall of April and May in millimetres is calculated for each province and included in the model to account for the rainfall in the analysis.

A variety of other variables can have an impact on wheat yield. Among these variables there are fuel prices, irrigation water prices, prices of seed and other substitutes such as sugar beet. The cost of fuel accounts for about 8 % of the wheat production costs. Therefore, price changes in fuel will not significantly affect the decision making. As public irrigation is not widespread, the irrigation water prices are not included in the model. Because the farmers mostly use their own production as seeds for future crops, the seed prices are not included.

The level of mechanization, the number and quality of tractors and harvesters and the change in the use of improved seeds are important indicators of technology. The standard method for taking technological change into account is to insert a trend into the equation as an independent variable (Metz and Pardey, 1983). Yet, as the time period covered in the analysis is short, it is assumed that the trend variable does not contribute much, since no structural change was observed in the investigated period. Also the number of tractors and harvesters does not vary much in the chosen period in Turkey and, since wheat seed is changed every three to four years and most of the farmers use their own seeds from their own production, technological development is assumed to be constant and it is not therefore included in the model.

Data on wheat yield are used in the analysis. There are several important factors in choosing wheat in Turkey for this study. Wheat is sown in all regions of the country and accounts for 50 % of the total cultivated area. Therefore, wheat production can be used to reflect the level of technology in the agricultural sector. As the majority of the agricultural population is involved in wheat production, it may also reflect the behaviour of producers. It is estimated that more than two million farmers produce wheat every year, accounting for approximately 60 % of the agricultural population (SIS, 2005).

Turkey has eight agricultural regions, the classification of which is based on soil specification, climate, and topography (Turkish Fertilizer Guidelines, 1995). All the regions display different characteristics. Yields vary across and within regions due to differences in technology, resource quality and input use that arise from differences in market incentives and property rights (Wiebe, 2003). In order to eliminate these differences, provinces in the same agro-ecological zone are chosen for this study. The analysis covers 15 provinces in Central Anatolia where labour quality, institutional setting and infrastructures are assumed to be constant within the region.

## 3. Empirical Model

Agricultural prices, along with non-price factors, including exogenous shocks, determine agricultural output or supply in the forms of yield or land. In order to investigate the determinants of wheat yield, a Nerlovian yield response model is used. A typical Nerlovian model can be written as follows (Askari and Cumrnings, 1976):

$$A_t^d = a + b_1 P_t^e + b_2 Z_t + u_t$$

$$P_t^e = P_{t-1}^e + B(P_{t-1} - P_{t-1}^e) \tag{1}$$

$$A_t = A_{t-1} + y(A_t^d - A_{t-1})$$

Where;

$A_t$ = actual area under cultivation at time t,

$A_t^d$ = area desired to be under cultivation at time t,

$P_t$ = actual real producer price at time t,

$P_t^e$ = expected producer price at time t,

$Z_t$ = other exogenous factors affecting supply at time t,

$B,y$ = expectation and adjustment coefficients.

Following Askari and Cummings (1976), as producers take into account the quantity rather than the area of field crops, the adjustment is realized in one year in field crops, and therefore, $y$ = 1.With a suitable definition of price, the above equation gives us the following:

$$Q_t = a_0 + a_1 (P_{ct}/P_{dt}) + a_2 Z_t + u_t \quad (2)$$

Here, $Q_t$ is the agricultural output or yield per hectare, $P_{ct}$ is the price of the crop at time $t$, $P_{dt}$ is the deflator at time $t$. By imposing a restriction on the coefficients of nominal output price and the deflator price, equation (2) can be estimated in an unrestricted form with nominal output price and potential deflators;

$$Q_t = a_0 + a_1 P_{ct} + a_{12} P_{it} + a_{13} P_{st} + a_{14} P_{dt} + a_2 Z_t + u_t \quad (3)$$

Here, $P_{it}$ is the input price, $P_{st}$ is the price of substitute crops, $P_{dt}$ is the price of consumer goods (CPI). A model is developed to estimate wheat yield in Central Anatolia based on the assumptions given in Section II and above, with the suitable definition of prices. The model uses both cross-sectional and time series data to examine the yield determinants across 15 provinces from 1991 to 2000. The model is depicted by the equation;

$$y_{it} = \sum_{i=1}^{15}\sum_{t=1}^{10} \alpha_i + \beta X_{it} + \varepsilon_{it} \quad (4)$$

where:

$y_{it}$ is the wheat yield for the province i in year t; $\alpha_i$ is the dummy variable for the intercept of the ith province $\beta$'s are the parameters for the explanatory variables; $X_{it}$ is a matrix of independent variables for the ith province in year t.

This equation is written in an implicit form as;

$$Y_{it} = a_1 + a_2 (Pw_{t-1}/Pb_{t-1}) + a_3 (Pw_{t-1}/Pdap_t) + a_4 \; Rain_{it} + u_t \quad (5)$$

The independent variables in the model are the ratio of wheat price to barley price $(Pw_{t-1}/Pb_{t-1})$, wheat price to fertilizer price $(Pw_{t-1}/Pdap_t)$ and rainfall $(Rain_{it})$. All the variables are in natural logarithms.

Equation (5) is a panel regression model with «$i$» denoting provinces (a cross-section dimension) and «$t$» denoting time (a time series dimension). The use of panel data provides some benefits for estimation. It especially reduces the problems of data multi-co linearity (Baltagi, 2001). The disturbances model is given by $u_{it} = u_i + v_{it}$ where «$u_i$» denotes unobservable individual specific effect and «$v_{it}$» denotes the remaining disturbance.

The fixed effect model assumes that «$u_i$» are fixed, time-invariant parameters which are independent of the «$v_{it}$» for all $i$ and $t$. A set of province dummy variables were included in the equation so that the model is a fixed-effect specification. The fixed-effect specification is preferred to alternative random effect models when the number of cross-section observations relative to time periods is higher and the cross-sectional units are not randomly drawn from a larger sample (Wooldridge, 1999). The intercept in the regression model is allowed to differ among provinces in recognition of the fact that cross-sectional units may have some special characteristics of their own (Gujarati, 2003). Hence, one-way fixed effect model is appropriate.

Data on productivity and prices are derived from the Turkish State Institute of Statistics. Data on rainfall are obtained from the State Meteorology Institute (SMI, 2005).The price of fertilizers was obtained from the Ministry of Agriculture and Rural Affairs. Data cover the 1991-2000 period. Because of the Direct Income Support (DIS) system launched as a pilot project in 2000 and later applied countrywide, the year 2000 was taken as a possible break point for yield changes. To take into account the DIS impact on yield, the analysis was limited to this period. In addition, no radical change has been observed in policies regarding cereals in the period covered, and therefore no policy-related shift in the yield in this period is anticipated.

## 4. Empirical Results

The fixed effects panel least squares method is used in estimating the model. Fifteen cross-sections regarding the provinces are included and there are 135 panel observations, 9 for each province. All variables are in natural logarithm. Estimated results are as follows:

$$Y_{it} = 3.86 + \underset{(4.00)}{0.89} (Pw_{t-1}/Pb_{t-1}) + \underset{(2.71)}{0.10} (Pw_{t-1}/Pdap_t) + \underset{(6.98)}{0.18} \; Rain_{it} + u_t$$

(23.88) (4.00) (2.71) (6.98)

(5.1)

$$R^2 = 0.64, \; \bar{R}^2 = 0.59, \; SEE = 0.13, \; SSR = 2.16, \; DW = 1.69, \; F = 12.33$$

The values in parenthesis are $t$-statistics

* the values are significant at a 1% significance level

All the estimated coefficients are of the correct sign. The coefficient of the relative price of wheat to barley is 0.89 and it is significant at 1%. The coefficient of relative price of wheat to di-ammonium phosphate price is 0.10 and significant at 1%. The coefficient of rainfall is 0.18 and significant at 1%. The F-statistic is 12.33 and shows that the overall analysis is significant and satisfactory. The Levin, Lin &Chu t-test indicates that the series are stationary at level (Table 1).

There is a potential source of endogeneity in this type of regressions. The dependent variables may influence some of the explanatory variables. There may be a causal relationship between wheat yield and wheat prices. In order to solve the endogeneity problem, instrumental variable estimation is used. A good instrument would be a variable which is highly correlated with wheat price but not with the error term in the regressions. One year lagged values of the explanatory variables including wheat prices are used as an instrument to control the endogeneity issue (Table 2).

Instrumental variable estimation suggests that the issue of endogeneity of wheat prices and yield is not acute as the results of regression incorporating instrumental variables do not significantly differ from those of the regular regression.

The results evaluate the significance of fixed effects and suggest that the corresponding effects are statistically significant. All the 15 provinces have intercepts significantly different from zero. The coefficients and t-values are similar and significant at $P < 0.001$ (Table 3).

## 5. Conclusions

Food needs increase due to the population growth. The industrial demand for agricultural products increases at the same time. All these needs require an increase in the agricultural production. Yet, there is no further possibility to increase the cultivated areas for agricultural production. Therefore, increase in yield per unit area is a plausible choice to meet the increasing demand for agricultural production. For that purpose, in this study, the yield is analyzed by a fixed effects regression model.

The results indicate that the price responsiveness of wheat yield is significant. The coefficient of the relative price of wheat to barley is estimated at 0.89. As the price of wheat increases more than the price of barley, farmers adjust production practices accordingly and wheat yield increase since farmers can allocate more of the resources to wheat production. Conversely, as the price of barley increases, farmers allocate resources to barley production. The coefficient of relative price of wheat to the price of di-ammonium phosphate is 0.10. This indicates that the importance of fertilizer in the region is well understood by farmers. Once the production decision is made by the farmers, they use the fertilizer without taking into account its price. However, as the price of wheat relative to fertilizer prices increases, farmers use relatively more fertilizer. Rainfall in April and May is important as tillering, shooting and heading that occur in this period in Central Anatolia in Turkey where the data is derived. Therefore, the rainfall is an important factor that affects the crop yield in dry regions. The coefficient of rainfall is found 0.18. The coefficient of weather proxy, average rainfall of April and May, is positive as expected, and the results are plausible. Soil moisture is supported by underground water, if needed.

This study indicates that the yield is responsive to the prices received and paid by farmers**.** Since there is an imperfect competition in the agricultural input market, in order to increase the yield, prices paid and received by farmers need to be taken into account. Findings result in an important policy inference. Policy considerations on the structure of agriculture should concern the effects of price on crop yields. Policy objectives to increase the yield or self-sufficiency could also be partly achieved by the increases in the relative price of crops and inputs which have strong implications on both food security and food sovereignty.

Table 1 – *Panel Unit Root Test (Levin, Lin & Chu t Method).*

| *Variables* | *Test Statistic* | *Variables* | *Test Statistic* |
|---|---|---|---|
| $Y_{it}$ | -3.38* | $Pw_{t-1} / Pdap_t$ | -14.70* |
| $Pw_{t-1} / Pb_{t-1}$ | -6.55* | $Rain_{it}$ | - 6.57* |

*Significant at 1 % significance level
** Probabilities are computed assuming asymptotic normality.

Table 2 – *Two-Stage Least Squares Estimation.*

$$Y_{it} = a_1 + a_2\ (Pw_{t-1} / Pb_{t-1}) + a_3\ (Pw_{t-1} / Pdap_t) + a_4\ Rain_{it}$$

| Instrument list | C,$Y_{it}$, lag_($Pw_{t-1}/Pb_{t-1}$), $Pw_{t-1}/P_{DAP}$, $Rain_{it}$ | C,$Y_{it}$, $Pw_{t-1}/Pb_{t-1}$, lag_($Pw_{t-1}/P_{DAP}$), $Rain_{it}$ | C,lag_$Y_{it}$, $Pw_{t-1}/Pb_{t-1}$, $Pw_{t-1}/P_{DAP}$, $Rain_{it}$ |
|---|---|---|---|
| $a_1$ | 4.089 (23.78)* | 4.331 (22.78)* | 4.176 (28.40)* |
| $a_2$ | 2.094 (6.84)* | 1.452 (5.76)* | 1.002 (5.50)* |
| $a_3$ | 0.192 (4.88)* | 0.387 (5.52)* | 0.132 (4.10)* |
| $a_4$ | 0.100 (3.50)* | 0.086 (2.71)* | 0.129 (5.36)* |

The values in parenthesis are *t*-statistics
*significant at a 1 % significance level

Table 3 – *Cross-Section Fixed Effects.*

| *Province* | *Coefficient* | *Province* | *Coefficient* |
|---|---|---|---|
| Ankara | 3.0860 (11.41)* | Nevsehir | 2.9722 (10.90)* |
| Bolu | 3.3032 (12.17)* | Kayseri | 2.7586 (10.12)* |
| Cankiri | 2.7692 (10.16)* | Malatya | 3.0803 (11.41)* |
| Corum | 3.1499 (11.66)* | Aksaray | 3.1738 (11.89)* |
| Kırıkkale | 3.0708 (11.42)* | Nigde | 3.2032 (11.86)* |
| Yozgat | 3.0142 (10.99)* | Konya | 3.1569 (11.81)* |
| Kirsehir | 3.1302 (11.53)* | Karaman | 3.1163 (11.51)* |
| Sivas | 3.1726 (11.65)* | | |

The values in parenthesis are t-statistics
* significant at % 1 significance level

As markets are more liberalized in developing countries, the agricultural production is under the competition pressure of the highly industrialized production capacity of the developed world. In addition, since there is a pressure oriented by the W-TO agreement, IMF and WB impositions, the tariffs and export subsidies will be reduced. Decrease in the market price support and input subsidies will decrease the prices and therefore the yield. On the other hand, decreases in the tariffs and export subsidies may lead to an increase in prices which favour the yield. Therefore, the effect of the liberalization on the yield will depend on the effect of the liberalization on the prices. However, a change in the prices should be expected, and policies need to be designed accordingly. Otherwise, since the rural income is very low, the level of agricultural technology is not high still, and regional differences are evident, a major breakdown in the agricultural structure is expected. As the producers base their production decisions on the expectation of the future relative returns available from the various activities, a decrease in price would negatively affect the level of agricultural production due to a decrease in the agricultural income. Here, the regulating role of governments in crop prices through price-based support and/or other protection measures is significant.

However, the findings of the study could be strengthened by supporting evidences in other regions covering most of the country and over a wider range of crops to justify the conclusions. This would possibly be a further research in this field.

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