An Econometric Analysis of the Effects of Global Warming to Production of Wheat and Barley in Adana and Konya

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1. Objectives

In this paper we like to present a result of our econometric analysis of the effects of heat damage, drought, and output prices to wheat and barley production, and the evaluation of the impacts of pseudo-warming to these crops in Adana and Konya for 2070 based on the estimated yield and area sown functions for wheat and barley in these areas and on the RCM climatic projection by Dr. Kimura. We shall use time series statistical data on planted area and yield of the crops, crops' and Inputs' prices, and monthly weather data, etc. in order to estimate yield and area sown functions for wheat and barley in Adana and Konya. In the near future, we shall estimate models for other important crops in Adana and Konya, considering the interdependences between these crops, and analyze the impacts of global warming to the farmers' behavior concerning cropping pattern, land use and water use.

2. An econometric study of the interactions among wheat and barley production, heat damage, drought, wheat price in Konya and Adana.

2.1 The methodology

Hiroshi Tsujii and Ufuk Gultekin have been conducting an econometric and agro-climatological study of interactions among wheat and barley production, output prices, weather variables, technology, policy, and climatic change in Konya and Adana last few years. Ufuk Gultekin has visited Ishikawa Prefectural University in order to help research work done by Tsujii for 6 months in 2005. This study follows the methodology used in the past studies of H. Tsujii on the similar topic. Tsujii has conducted several econometric studies on the relationship among agricultural production, weather variables, and other variables in Thailand and Japan during the past few decades. Tsujii has published some English papers as well as Japanese papers from these studies. The English papers by Tsujii are as follows:

Hiroshi Tsujii with M. M. Yoshino and others, "The Effects of Climatic Variations on Agriculture in Japan," in M. L. Parry, T. R. Carter and N. T. Konjin, eds., ***The Impact of Climatic Variations on Agriculture. Volume 1. Assessments in Cool Temperate and Cold Regions***, Part VI, Dordrecht, The Netherland: Kluwer Academic Publishers, for International Institute of Applied Systems Analysis(IIASA) at Vienna and United Nations Environment

Program, pp. 725-863, 1988.

Hiroshi Tsujii, "An Economic Analysis of Rice Insurance in Japan," in P. Hazel, C. Pomareda and A. Valdes, eds., ***Crop Insurance for Agricultural Development--Issues and Experience***, Johns Hopkins University Press, pp.143-155, 1986 .

Hiroshi Tsujii, "Effect of Climatic Fluctuation on Rice Production in Continental Thailand," in K. Takahashi and M. Yoshino eds., ***Climatic Change and Food Production***, University of Tokyo Press, pp. 167-79, 1977.

2.2 The Results of Our Econometric Study for Adana, and Konya

(1) The estimated wheat yield and area sown functions for Adana and Konya

The period of analysis is for 1951 to 1998, and the linear function is used for the analysis. The variable description for the wheat yield function for Adana is shown in Table 1 just below.

Table 1. Description of the Variables for the Wheat Yield Function for Adana

NPC	:	Nominal Price Change
DDMA(t)10	:	Drought Effect in May in year (t) (1 if rainfall <= 10%, 0, otherwise)
DHDAA(t)16.2	:	Heat damage in April in year (t) (1 if temperature >= 16.2 °C, 0, otherwise)
DHDMA(t)23.5	:	Heat damage in May in year (t) (1 if temperature >= 23.5 °C, 0, otherwise)

Table 2. The Estimated Wheat Yield Function for Adana

Variables	R^2= 0.261	AR^2= 0.186	DW= 0.758
	Coefficient	**t-value**	**Significant**
CONSTANT	2417.33	6.84	0.00
NPC	11.60	3.41	0.00
DDMA(t)10	-286.29	-0.61	0.54
DHDAA(t)16.2	-179.24	-0.52	0.61
DHDMA(t)23.5	-409.09	-0.55	0.59

Table 3. Description of the Variables for the Wheat Yield Function for Konya

NPC	:	Nominal Price Change
CROCT(t-1)MAY(t)	:	Cumulative monthly rainfall from October in year (t-1) to May in year (t)
DDAK(t)20	:	Drought Effect in April in year (t) (1 if rainfall <= 20%, 0, otherwise)
DHDAK(t)12.8	:	Heat damage in April in year (t) (1 if temperature >= 12.8 °C, 0, otherwise)
DHDMK(t)16.3	:	Heat damage in May in year (t) (1 if temperature >= 16.3 °C, 0, otherwise)
DHDJK(t)20.7	:	Heat damage in June in year (t) (1 if temperature >= 20.7 °C, 0, otherwise)

Table 4. The Estimated Wheat Yield Function for Konya

	R^2= 0.526	AR^2= 0.449	DW= 1.185
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	1085.76	4.24	0.00
NPC	5.63	3.53	0.00
CROCT(t-1)MAY(t)	1.98	2.46	0.02
DDAK(t)20	-263.68	-1.38	0.18
DHDAK(t)12.8	-164.48	-1.09	0.28
DHDMK(t)16.3	-210.83	-1.83	0.08
DHDJK(t)20.7	-279.61	-2.08	0.04

Table 5. Description of the Variables for Wheat Area Sown in Adana

NPC(t-1)/(t-2)	Nominal farm gate price Change from year (t-1) to year (t-2)
CRSEP(t-1)OCT(t-1)	Cumulative monthly rainfall from September in year (t-1) to October in year (t-1)

Table 6. The Estimated Wheat Area Sown Function for Adana

	R^2= 0.467	AR^2= 0.441	DW= 1.058
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	199932.10	10.19	0.00
NPC(t-1)/(t-2)	1531.91	5.24	0.00
CRSEP(t-1)OCT(t-1)	535.42	2.12	0.04

Table 7. Description of the Variables for Wheat Area Sown in Konya

RPWB(t-1)	Relative farm gate price between wheat and barley in year (t-1)
CRJUN(t-1)SEP(t-1)	Cumulative monthly rainfall from June in year (t-1) to September in year (t-1)

Table 8. The Estimated Wheat Area Sown Function for Konya

	R^2= 0.134	AR^2= 0.092	DW= 0.453
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	623466.10	4.28	0.00
RPWB(t-1)	277925.50	2.52	0.02
CRJUN(t-1)SEP(t-1)	507.84	1.12	0.27

The estimated parameters were generally significant and had theoretically expected signs in both Adana and Konya. But there were some estimation problems regarding low explanatory power of some estimated functions as shown by some low R^2 values, and serial correlation problem as shown by Durbin Watson statistics.

Heat damage and drought effect to yield of wheat were found for both Adana and Konya. The heat damage were found in April and May in both provinces, and in June only in Konya.

Comparing the estimated heat damage coefficients, wheat yield in Adana was affected more by heat damage than in Konya. We think warmer climate in Adana than Konya is the reason for this difference.

Heat damage to wheat yield in Adana was identified when monthly average temperature became higher than 16.2 degrees centigrade in April and 23.5 degrees centigrade in May. Heat damage in Konya was identified when monthly average temperature became higher than 12.8 degrees centigrade in April, 16.3 degrees centigrade in May, and 20.7 degrees centigrade in June. Drought effect to wheat yield was identified in different months and at different levels, in May and less than 10% of the sample average monthly rainfall in Adana, and in April and less than 20% of the sample average monthly rainfall in Konya. The positive effects of nominal wheat price change to its yield was very significant statistically, and the effect in Adana was about twice as large as the effect in Konya. The positive effect of past cumulative rainfall was fount to be very significant only in Adana, and the period was from October previous year to May in current year. This may be caused by the fact that annual rainfall in Adana is about three times more than it in Konya, and most rainfall occurs from October to May in Adana, while monthly rainfall is more evenly distribute in Konya than in Adana.

(2) The estimated yield and area sown functions for barley for Adana and Konya

The period of analysis is for 1971 to 1998, and linear function is used for the estimation. The variable descriptions and the estimated yield and area sown functions are shown in the following tables.

Table 9. Description of the Variables for the Barley Yield Function for Adana

NPC	:	Nominal Price Change
DDDA(t)23	:	Drought Effect in December in year (t) (1 if rainfall <= 23%, 0, otherwise)
DHDAA(t)18.9	:	Heat damage in April in year (t) (1 if temperature >= 18.9 °C, 0, otherwise)
DHDMA(t)23.4	:	Heat damage in May in year (t) (1 if temperature >= 23.4 °C, 0, otherwise)

Table 10. The Estimated Barley Yield Function for Adana

	R^2= 0.254	AR^2= 0.178	DW= 1.342
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	2128.75	31.18	0.00
NPC	1.95	1.84	0.07
DDDA(t)23	-423.78	-1.90	0.07
DHDAA(t)18.9	-135.45	-0.84	0.41
DHDMA(t)23.4	-375.13	-1.42	0.16

The R^2 value was very low, but the Durbin Watson test tells us that there was no autocorrelation. Most of the estimated parameters are significant and have theoretically expected signs. This result also showed that heat damage[1)] and drought[2)] affected Adana barley yield negatively. Although statistically not very significant, it was found that if average monthly temperature became higher than 18.9 degree centigrade in April and 23.4 degree centigrade in May, barley yield was found to decrease considerably. Drought effect to Adana barley yield was found that the yield declined significantly when December rainfall became less than 23% of the sample average. Adana farmers were also found to respond significantly to the increase in the barley nominal price change.

Table 11. Description of the Variables for Barley Yield Function for Konya

NPC	Nominal Price Change
CROCT(t-1)JUN(t)	Cumulative monthly rainfall from October in year (t-1) to June in year (t)
DDMK(t)17	Dummy for drought in May, year (t) (1 if rainfall <= 17%, 0, otherwise)
DHDAK(t)13.7	Dummy for heat damage in April, year (t) (1 if temperature >= 13.7 °C, 0, otherwise)
DHDMK(t)16.3	Dummy for heat damage in May, year (t) (1 if temperature >= 16.3 °C, 0, otherwise)

Table 12. The Estimated Barley Yield function for Konya

	R^2= 0.533	AR^2= 0.472	DW= 1.384
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	858.22	3.04	0.00
NPC	4.69	3.22	0.00
CROCT(t-1)JUN(t)	3.43	3.96	0.00
DDMK(t)17	-579.05	-1.34	0.19
DHDAK(t)13.7	-505.21	-1.71	0.09
DHDMK(t)16.3	-309.10	-2.34	0.02

The estimated result for Konya yield is much better than it for Adana as is shown by the levels of R^2. And the Durbin Watson test tells us that there was no autocorrelation. Most of the estimated parameters for Konya barley yield function are generally more significant than those for Adana barley yield. In both Adana and Konya barley yield functions, the heat damage dummies for April and May were identified to be significant. Although their threshold temperature levels were much lower in Konya than in Adana. This is probably related to the difference in altitude between these two provinces. Konya is located on Anatolian Plateau which is about 1050 meter above sea level, and Konya is located on the Mediterranean Coast. Drought damage to barley yield was identified to occur by the drought dummy in December in Adana and in May in Konya. These months were the highest rainfall month in Adana and Konya respectively. Farmers' barley yield response to nominal barley price change from previous year to current year was found to be very significant both in Adana and Konya. This was also the case for wheat yield response in both provinces as was shown just above. This consistent result shows that the farmers in Adana and Konya adjusted their input level not responding to the changes in real price or relative price between wheat and barley, but to nominal price change of these crops probably because of the severe spiral inflation especially during the 90's and early 2000's. We call this finding the inflation yield response hypothesis. Cumulative rainfall[3)] from October to June was found to be highly significant for Konya barley yield. This period is the high rainfall months in Konya, and thus the rainfall in this period has a strong positive effect to the barley yield in rain-short and dry Konya area.

Next we shall show variable descriptions and our estimation results for barley area sown functions for Adana and Konya in the following tables.

Table 13. Description of the Variables for Barley Area Sown in Adana

RPBARLEY(t-1)	Real Farm Gate Price for Barley deflated by Whole Sale Price Index, 1938=100
CRJAN(t-1)OCT(t-1)	Cumulative monthly rainfall from January in year (t-1) to October in year (t-1)

Table 14. The Estimated Barley Area Sown Function for Adana

	R^2= 0.208	AR^2= 0.170	DW= 0.347
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	-9912.30	-0.84	0.41
RPBARLEY(t-1)	0.13	3.18	0.00
CRJAN(t-1)OCT(t-1)	15.44	1.11	0.28

Table 15. Description of the Variables for Barley Area Sown in Konya

RPBW(t-1)	Relative farm gate price between barley and wheat in year (t-1)
CROCT(t-2)SEP(t-1)	Cumulative monthly rainfall from October in year (t-1) to September in year (t-1)

Table 16. The Estimated Function for Barley Area Sown in Konya

	R^2= 0.114	AR^2= 0.070	DW= 0.277
Variables	**Coefficient**	**t-value**	**Significant**
CONSTANT	208247.40	1.67	0.10
RPBW(t-1)	290201.00	2.20	0.03
CROCT(t-2)SEP(t-1)	105.62	0.51	0.61

The explanatory power of the estimated area sown functions was low as shown by low R2 values. But the expected signs of the estimated coefficients met with the theoretical expectations. The durations of monthly cumulative rainfall[4] identified to be positively correlated with area sown were from January to October in the previous year for Adana and form October in two years ago to September in the previous year for Konya. Although the significance levels of these correlations were low as shown by the low t-values, these results seemed to indicate that more cumulative rainfall for long monthly periods increased soil moisture level which made framers to be able to plant barley for wider area.

As usually assumed in the supply response study, it is assumed that the estimated coefficient to the real farm gate price of barley in previous year is positive and very significant for Adana barley area sown function and the estimated coefficient to the relative farm gate price between barley and wheat in previous year is also positive and very significant for Konya barley area sown function. This result is consistent with many past supply response studies in the world. We also assume that the farmers in the rain fed area in Konya are given dichotomous choice between barley or wheat when they sow seed.

2.3 Revisions of the Model Biases in the RCM Prediction and Future Prediction Integrating Our Econometric Study Result and the Revised RCM Prediction

(1) Revisions of the model biases in the RCM prediction

Dr. Kimura's revised pseudo-warming second run N2 RCM prediction for the period from 2070 to 2080 has model biases. These biases were revised by adding these biases to the RCM prediction of monthly rainfall and temperature for the ten year period form 2070. The revised weather data was used to predict area sown, yield, and production of wheat and barley in Adana and Konya for 2070 when global warming will occur.

(2) Predictions of wheat and barley production in Adana and Konya by integrating our estimation result and bias revised pseudo-warming RCM prediction

Predictions of wheat and barley production in Adana and Konya was done by integrating our estimation results and bias revised pseudo-warming RCM prediction. The results are shown in the following table.

Table 17. Future Estimation on Barley And Wheat *

BARLEY

ADANA YIELD	Coefficient		2070-2079	1959-2002	%	
CONSTANT	2128.75	1	2128.75			
NPC	1.95	32.8	63.96			
DDDecember(t)23	-423.78	1	-423.78			
DHDApril(t)18,9	-135.45	1	-135.45			
DHDMay(t)23,4	-375.13	0	0.00			
			1,633	**2,328**	**- 29.8**	decrease

ADANA AREA SOWN	Coefficient		2070-2079	1959-2002	%	
CONSTANT	-9912.3	1	-9912.30			
Real PriceBARLEY(t-1)	0.13	241048.00	31336.24			
CRJAN(t-1)OCT(t-1)	15.44	338.0787	5219.93			
			26,644	**14,779**	**80.3**	increase

KONYA YIELD	Coefficient		2070-2079	1959-2002	%	
CONSTANT	858.22	1	858.22			
NPC	4.69	32.8	153.83			
CROCT(t-1)JUN(t)	3.43	214.8864	737.06			
DDMay(t)17	-579.05	1	-579.05			
DHDApril(t)137	-505.21	0	0.00			
DHDMay(t)163	-309.10	0	0.00			
			1,170	**2,178**	**- 46.3**	decrease

KONYA AREA SOWN	Coefficient		2070-2079	1959-2002	%	
CONSTANT	208247.40	1	208247.40			
RelativePriceBW(t-1)	290201.00	0.79	229258.79			
CROCT(t-2)SEP(t-1)	105.62	297.4769	31419.51			
			468,926	**587,142**	**- 20.1**	decrease

* In the equation, average price (1935-2002) was used for all price estimation

WHEAT

ADANA YIELD	Coefficient		2070-2079	1959-2002	%	
CONSTANT	2417.33	1	2417.33			
NPC	11.6	31.2	361.92			
DDMay(t)10	-286.29	1	-286.29			
DHDApril(t)162	-179.24	1	-179.24			
DHDMay(t)235	-409.09	0	0			
			2,314	**3,274**	**- 29.3**	decrease

ADANA AREA SOWN	Coefficient		2070-2079	1959-2002	%	
CONSTANT	199932.10	1	199932.10			
NPC	1531.91	31.2	47795.59			
CRSEP(t-1)OCT(t-1)	535.42	43.7	23386.87			
			271,115	**357,941**	**- 24.3**	decrease

KONYA YIELD	Coefficient		2070-2079	1959-2002	%	
CONSTANT	1085.76	1	1085.76			
NPC	5.63	31.2	175.66			
CROCT(t-1)MAY(t)	1.98	215	424.98			
DDApril(t)20	-263.68	1	-263.68			
DHDApril(t)128	-164.48	0	0.00			
DHDMay(t)163	-210.83	0	0.00			
DHDJune(t)207	-279.61	1	-279.61			
			1,143	**1,903**	**- 39.9**	decrease

KONYA AREA SOWN	Coefficient		2070-2079	1959-2002	%	
CONSTANT	623466.10	1	623466.10			
RelativePriceWB(t-1)	277925.50	1.3	361303.15			
CRJUN(t-1)SEP(t-1)	507.84	56.56	28722.00			
			1,013,491	**934,822**	**8.4**	increase

It was found that wheat yield will decrease by 29.3% from the average yield of 1959-2002 to 2070 in Adana and by 39.9% in Konya. The predicted decrease in wheat area sown in Adana was 24.3%, but wheat area sown in Konya was predicted to increase by 8.4%. Consequently, the total wheat production in Adana was predicted to decrease drastically by 54% in 2070. But in Konya wheat production in 2070 was predicted to decrease less by 32% in 2070. Our prediction seems to show that the global warming decreased Adana wheat production more than Konya because of greater heat damage in Adana than Konya.

For barley, yield in Adana was predicted to decrease by 29.8%, and by 46.3% in Konya. Barley area sown was predicted to increase by 80.3% in Adana, and to decrease by 20.1% in Konya. This difference in predicted area sown is caused by slight increase in the predicted rainfall in Adana, and considerable decrease in the predicted Konya rainfall. Consequently, barley production in Adana was predicted to increase by 50% by 2070, but in Konya it was predicted to decrease by 66%.

3. Conclusion

We can conclude that heat damage and drought effects identified to wheat and barley production in Adana and Konya from our econometric study using past monthly weather data, output price data, and production data have very strong negative effects to future wheat and barley production in these provinces under global warming situation.

Regional differences in predicted monthly temperature and rainfall for year 2070 also affect very much the predicted differences in wheat and barley production between these provinces.

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Notes:

1) For Barley for example the heat damage bands tested for Adana Province were (March 12.7 °C to 15.7 °C), (April 15.5 °C to 19.0 °C), (May 20.5 °C to 23.6 °C). For Konya the heat damage bands were (March 5.1 °C to 8.5 °C), (April 10.5 °C to 13.8 °C), (May 14.5 °C to 17.8 °C), (June 19.5 °C to 22.2 °C).
2) For barley for example drought damage bands tested for Adana were (December 7% to 25%); (January 7% to 25%); (February 7% to 25%); (March 7% to 25%), (April 7% to 25%), (May 7% to 25%). For Konya, the drought damage bands tested were (Mach 7% to 25%), (April 7% to 25%), (May 7% to 25%), (June 7% to 25%).
3) For the test of the effect of monthly periods of cumulative rainfall to barley yield for example, the periods tested for Adana were sep(t-1)-feb(t), dec(t-1)-may(t),dec(t-1)-apr(t)

nov(t-1)-may(t), nov(t-1)-apr(t), feb(t)-apr(t), jan(t)-may(t), mar(t)-may(t). The periods tested for Konya were oct(t-1)-may(t), nov(t-1)-may(t), oct(t-1)-jun(t), nov(t-1)-jun(t), jan(t)-may(t), mar(t)-may(t), mar(t)-jun(t), apr(t)-jun(t), may(t)-jun(t)

4) For the test of the effect of monthly periods of cumulative rainfall to barley area sown for example, the periods tested for Adana were jun(t-1)-sep(t-1), sep(t-1)-nov(t-1), sep(t-1)-oct(t-1), aug(t-1)-oct(t-1), may(t-1)-nov(t-1), jun(t-1)-aug(t-1), aug(t-1)-oct(t-1), jan(t-1)-oct(t-1), mar(t-1)-oct(t-1), feb(t-1)-oct(t-1). For Konya these periods were jun(t-1)-sep(t-1) apr(t-1)-sep(t-1) oct(t-2)-sep(t-1) jan(t-1)-sep(t-1) mar(t-1)-sep(t-1) may(t-1)-sep(t-1)

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