ASSESSING THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE IN GERMANY - A RICARDIAN ANALYSIS

JOACHIM AURBACHER, CHRISTIAN LIPPERT, and **TATJANA KRIMLY**
Institute of Farm Management (410A), Universität Hohenheim, Germany,
joachim.aurbacher@uni-hohenheim.de

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Abstract

To assess the impact of climate change on agriculture in German districts, a Ricardian analysis accounting for spatial autocorrelation is used. The analysis relies on land rental prices from agricultural statistics and climate data from the network of German weather observation stations. The results of the cross-sectional analysis show a significant correlation between land rents and increasing mean temperatures, as well as (except for East Germany) a significant increase of land rents along with declining spring precipitation. Next, climate data from the regional climate model REMO are used to calculate local land rent changes under different IPCC scenarios for a time horizon between 2011 and 2040. The overall result is an increase in land rents which relates to 5-6 % of net German agricultural income. In West Germany the increase in land rents rises from the north to south, because of the higher temperature increases in the South of Germany. East Germany shows a greater increase in land rents than West Germany, due to the presently more unfavourable climatic water balance which profits from the increase in spring precipitation. However, agricultural income in Germany might decrease in the long run, when the changes in the climatic conditions will be more severe than those simulated in this study. We plan to extend and improve the research in this field. Different approaches to consider soil qualities at district level shall be compared. In order to understand farmers' adaptation to different climatic conditions multinomial logit models will be used to investigate how German land use structures depend on the climate. Furthermore, a typology of related transaction costs shall be devised. This will allow the identification of those regions where the adaptation needs and the corresponding costs are likely to be relatively high.

1 Introduction

In the upcoming years for Germany an increase in temperatures and a modified distribution of precipitation is being expected. Likely a higher precipitation in winter will be attended by drier summers and an overall warming.

Figure 1 shows the shifts of the mean annual temperatures and the spring precipitation in the German districts for the IPCC scenario A1B on base of the REMO-Modell (MPI on behalf of the Umweltbundesamt, 2006). This scenario assumes a world with high economic growth and a population growth until mid-century as well as a balanced use of fossil and non-fossil energy sources. In addition, a larger variability of the weather events can be expected: storms and extreme summer droughts are likely to occur more frequently (cf. Zebisch et al., 2005, p. 38f).

In order to assess the effects of such a climate change on German agriculture we performed a Ricardian analysis relying on the land rental price data represented in Figure 2 which had been communicated by Statistisches Landesamt Baden-Württemberg (2007).
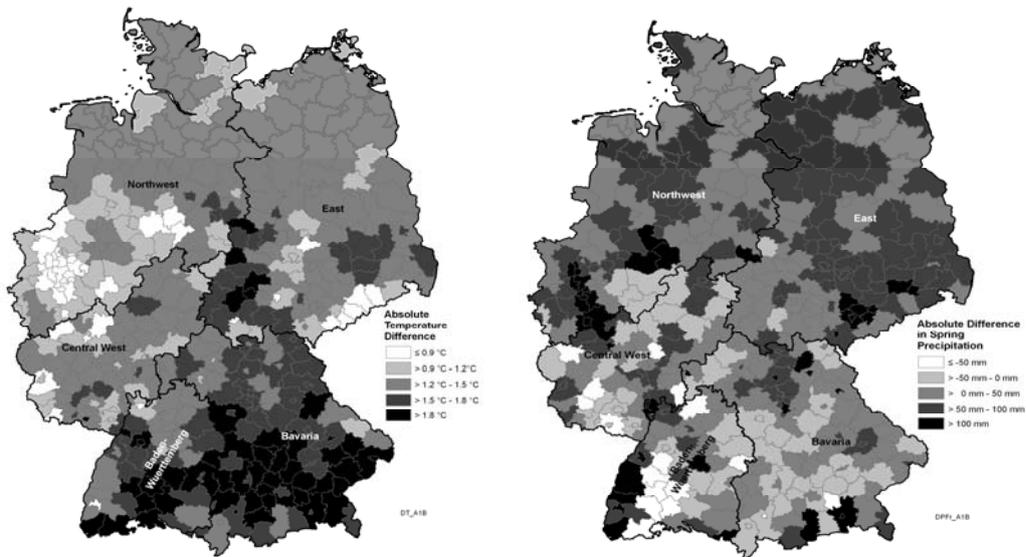
Figure 1: Expected changes in (a) annual mean temperature and (b) spring precipitation
(March - June) for IPCC scenario A1B according to REMO; Changes 2011-2041
against 1961-1990
*Source: Calculations on the basis of DWD (2007) und MPI on behalf of the
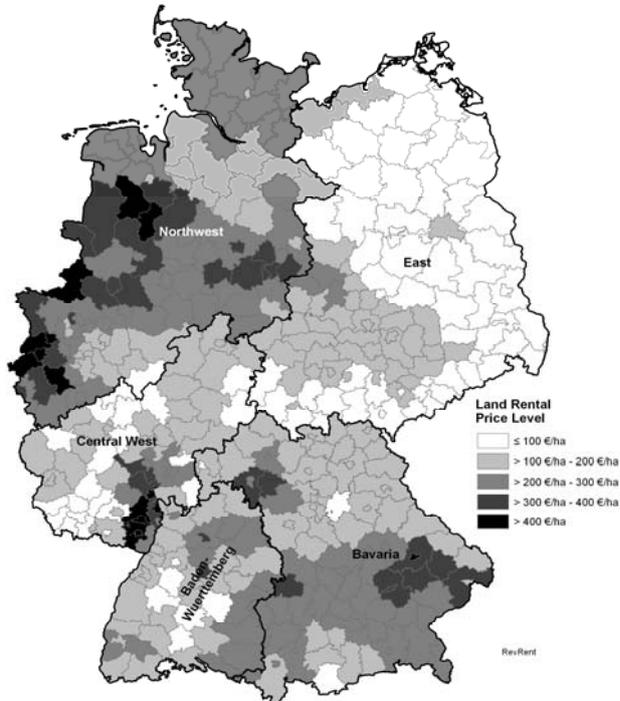Umweltbundesamt (2006); depiction from Lippert et al. (2009)*

Figure 2: Land rental prices per ha UAA in the German districts in 1999
*Source: Statistisches Landesamt Baden-Württemberg (2007); depiction from
Lippert et al. (2009)*

2   Method

Equations 1 and 2 outline the cross-sectional statistical approach applied (Anselin 1988: 34ff.; LeSage 1999: 52f.) which accounts for spatial error dependence (due to spatially correlated omitted explaining variables), since we could not obtain data for all possibly relevant variables:

$$r = X\beta + u \tag{1}$$

$$u = \lambda W u + \varepsilon \tag{2}$$

with
$$\varepsilon \sim N(0, \sigma^2 I),$$

where

r = n x 1 vector of reported average farmland rental prices for the different districts (Landkreise) i ($i = 1, \ldots, n$);

X = n x $(1+k)$ matrix containing a set of observations for k explanatory climate and non-climate variables;

W = standardised first order contiguity matrix;

I = n x n identity matrix;

u = n x 1 vector of the spatially correlated residuals;

ε = n x 1 vector of normally distributed errors (mean = 0, variance = σ^2).

The vector of regression coefficients β and the parameter λ were estimated. Further details of our Ricardian analysis along with an overview on recent studies in this field are given in Lippert et al. (2009) (for the basic principles of the method cf. the seminal paper by Mendelsohn et al., 1994).

3   Results of the Ricardian Analysis

Explaining land rental prices represented in Figure 2 by spatially interpolated climate data from the weather observation stations of the German Weather Service (DWD, 2007) we obtained the results outlined in Table 1 (cf. Lippert et al., 2009):

Table 1: Ricardian regression models for German land rental prices [a)]

Variable	Average	Regression coefficients (t-statistics)[d)]	
		Model I	Model II
Constant (Euro/ha UAA)	182.90	120.065 *(2.14)*	74.588 *(0.32)*
Share of grassland in % UAA [b)]	31.43	-1.735 *(-10.24)*	-
East Germany (yes = 1; no = 0)	0.26	-192.154 *(-3.35)*	-218.780 *(-3.39)*
Precipitation in March - June in mm [c)]	270.17	-	-0.397 *(-4.14)*
East Germany *and* precipitation in March - June in mm [c)]	55.81	0.465 *(1.95)*	0.531 *(2.01)*
Mean annual temperature in °C [c)]	8.40	16.532 *(2.71)*	27.736 *(4.08)*
λ (coefficient reflecting spatial error autocorrelation)		0.834 *(31.64)*	0.838 *(31.95)*
adjusted R^2		80.87 %	77.23 %

[a)] Mean annual land rental price on district level in 1999, according to Statistisches Landesamt Baden-Württemberg (2007). - [b)] Data from agricultural census 1999 according to Statistische Ämter des Bundes und der Länder (2001). - [c)] Own calculations based on DWD (2007). - [d)] n = 439; in brackets: asymptotic t-statistics; except the constant in model II all coefficients are significant at a 5% level.
Source: Lippert et al., 2009

The results show a significant correlation between land rents and increasing mean temperatures, as well as (except for East Germany) a significant increase of land rents along with declining spring precipitation. For East Germany the relation between spring precipitation (March to June) and land rents is however significantly positive. Further, East Germany (i.e. the new federal states) has a significantly lower level of land rental prices.

The differences between the models arise from the explicit inclusion of grassland in model I: its share significantly correlates both with spring precipitation (correlation coefficient = 0.61 ***) and with annual average temperature (correlation coefficient = -0.34 ***). Further, grassland shares correlate negatively with land rents. This means that at least as long as it is allowed for farmers to convert grassland to arable land both a reduction in spring precipitation as well as a temperature increase will lead to a reduction of grassland which results in the stronger marginal effects of temperature and precipitation on land rents in model II .

Which of the two models is appropriate depends on the future legal possibilities of farmers to convert grassland in reaction to climate change. At present such a conversion is limited because of the cross compliance regulations of the Common Agricultural Policy (CAP). However, in a decade or two this restriction could be lifted due to increasing food prices. On the other hand, in the interpretation of the results one has to consider that natural site conditions, especially slope may hamper in some cases a change to arable land use.

4   Predictions

Next, we used average predicted future climate data in order to calculate local land rent changes under different IPCC scenarios for a time horizon between 2011 and 2040. The

corresponding IPCC (2007) scenario data was taken from the regional climate model REMO (Jacob, 2001; UBA, 2006). REMO is based on a former weather prediction model of the German Weather Service (Europamodell) which was improved by implementing physical parameterisations of the global climate model ECHAM3/T42 and ECHAM4/T106 (cf. Jacob and Podzun, 1997; Jacob, 2001).

When the average climate data from 2011 to 2040 according to REMO are inserted into the above estimation equations, for different IPCC scenarios the estimated land rents as given in Table 2 are obtained. With an average net income of German agriculture in the years 1998 to 2000 of 10,566 million Euros (BMVEL, 2004, p. 127) the accumulated increase of land rents of 600 million Euros accounts for 5 to 6 % of net German agricultural income. The weighted average increase is between 31 and 36 Euros per hectare UAA, which corresponds to an increase by 17 % to 20 % of the average land rent in the reference situation. Figure 3 shows the relatively high variability of the estimated land rent increases for the IPCC scenario A1B.

Table 2: Estimated future climate and resulting land rents

Scenario [a] Period	Reference 1961-'90	A1B 2011-'40	A2 2011-'40	B1 2011-'40
Spring precipitation (March - June) in mm [b]	270.17	314.18	325.54	302.02
East Germany and spring precipitation in mm [b]	55.81	70.83	71.36	67.41
Average annual temperature in °C [b]	8.40	9.86	9.97	9.82
Model I: Change in land rents (Mio. €) [c] weighted average change (€/ha UAA) [d]		**568.59** 33.14	**599.17** 34.92	**527.21** 30.73
Model II: Change in land rents (Mio. €) [c] weighted average change (€/ha UAA) [d]		**611.90** 35.66	**597.81** 34.84	**623.14** 36.32

[a] IPCC scenarios. - [b] Calculations based on DWD (2007) and MPI on behalf of the Umweltbundesamt (2006) (REMO-Model). - [c] Total change for Germany = $\sum_i$ UAA$_i$ times (difference between estimated land rental prices after climate change and estimated prices for 1999)$_i$ for the 439 German districts (i = 1, …, 439); for model I and II cf. Table 1. - [d] Weighted by the utilisable agricultural area (UAA$_i$) of the districts.
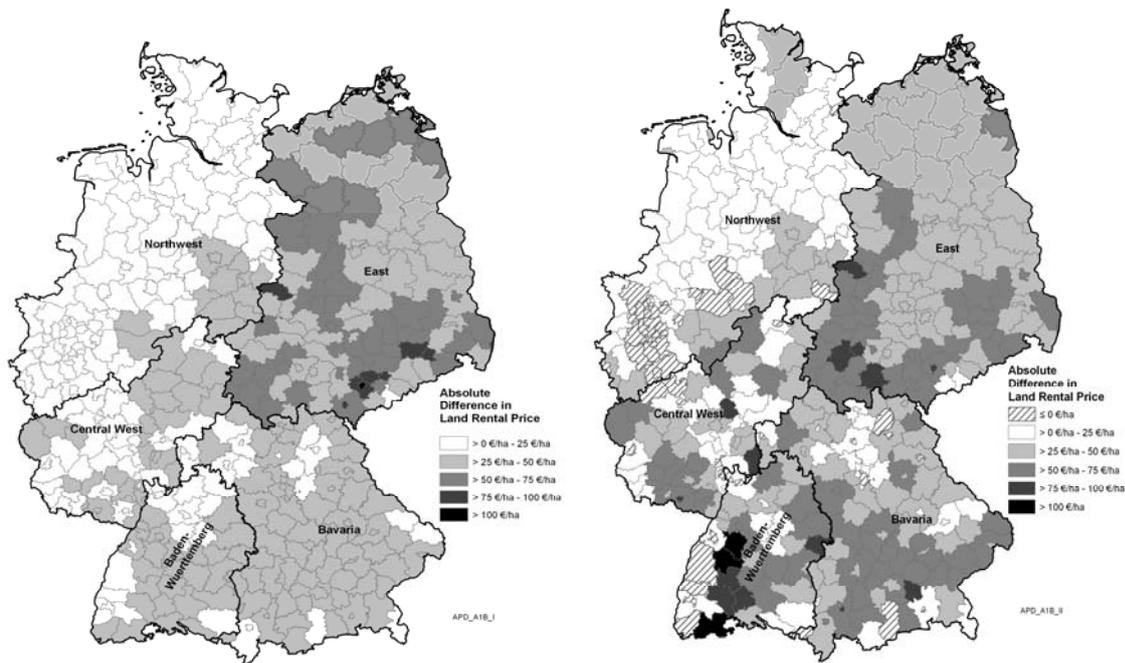*Source: Lippert et al., 2009*

Figure 3: Change of the land rental prices for scenario A1B according to model I (left) and model II (right)
Depiction from Lippert et al. (2009)

According to Figure 3 in West Germany the positive land rent changes are predicted to rise from the north to the south. This is a result of higher temperature increases in Southern Germany. The estimated greater increase in East German land rents is due to the presently more unfavourable climatic water balance in this part of the country which is supposed to profit from the predicted local increases in spring precipitation.

5   Discussion and scope for future research

The above estimations of future land rent changes were done for moderate temperature and precipitation changes. Anyway, estimations should only be based on predicted climate variables that do not exceed the observed range of these variables in the cross-sectional analysis. In case of strong climatic change leading to local climates that have not been observed in any German district so far the regression equations found should not be used. Albeit, it cannot be excluded that in the long run, when the changes in the climatic conditions will be more severe than those simulated in this study, the net impact on German agricultural income will be negative.

Moreover, it should be noted that the predicted beneficial effects of climate change on German agriculture may be partly offset by higher yield variability due to more frequent extreme precipitations and droughts which, in the end, would result in increasing insurance cost. Also, new pests and animal diseases which are unknown so far in Central Europe may appear as a consequence of climate change.

On the other hand, in our analysis we implicitly assumed a constant price level for agricultural produce. However, because of the negative consequences of climate change in other parts of the world, world prices will tend to increase (cf. von Braun, 2007, p. 3f). This would lead to a

further advantage for a German agriculture with a higher yield potential when compared to the present situation.

In case of omitted explaining variables that correlate with climate variables used in the regression equations marginal climate effects may be overestimated. This problem is conceivable for the estimated effect of average slope of local farmland: supposing that farmland at higher altitudes is simultaneously characterized by lower mean temperatures *and* strongly sloped agricultural area (which usually is less profitable) only part of the lower farmland profitability at higher altitudes would result from reduced temperatures.

Due to the comparative-static character of the Ricardian approach a further aspect we did not account for when estimating land rent changes are climate related adaptation costs in the strict sense.

In the future we plan to extend and improve our research especially regarding the two latter aspects:

(a) When an omitted variable correlates with one of the land value explaining climate variables used in the Ricardian analysis the results will be biased. For instance, if temperature was correlated with soil quality this would lead to a substantial overestimation of the effect of the former variable on the land rent. Consequently, we will try to assess the effects of different ways to account for soil quality by comparing the results of several feasible approaches to control for German districts' average soil attributes. Extrapolating broad soil types from the FAO soil classification (as done by Seo and Mendelsohn, 2008a, p. 111; 2008b) will be compared to the use of the more detailed German soil map (cf. BGR, 2009) and to the use of the sophisticated German soil index. For selected regions of Southern Germany we will also try to do corresponding analyses at lower spatial scales than district level. Such comparisons will give interesting insights into the reliability of common Ricardian analyses at higher spatial scales. Here, an important aim will be to find out whether a coarse consideration, e. g. by using dummies for main soil types, has a strong impact on the outcome.

(b) So far, common Ricardian analysis is just a "black box" approach which does not reveal *how* climate change affects farmers' adaptation decisions and the resulting pattern of cultivated crops and farming activities. Thus, it seems to be promising to apply and to further develop the multinominal logit approach recently suggested by Seo and Mendelsohn (2008a, b) at a lower spatial scale. For such an approach observed crop shares but also reported main farm types may be used to describe existing farming patterns. The objective is to explain the climate dependency of German land use patterns and systems in order to get a better idea on how farmers' adaptation measures may look like in future. Next, based on theoretical considerations on climate change adaptation options and related adjustment cost (cf. Smit and Skinner, 2002; Kelly et al., 2005) we want to develop an appropriate typology of all relevant transition cost to be borne by the farming sector. Using this typology, regional adjustment difficulties related to the predicted changes may be identified accounting for socioeconomic as well as ecological constraints in the different German districts. Thus, we want to elaborate a systematic way to detect which climate change induced agricultural adaptation needs and related costs different regions will

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