An attempt to assess the impact of climate change on the agricultural sector in FYR Macedonia using an aridity index approach

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Poster paper prepared for presentation at the EAAE 2014 Congress
'Agri-Food and Rural Innovations for Healthier Societies'

August 26 to 29, 2014
Ljubljana, Slovenia

Abstract: Considering the scale of global warming, we make an attempt to assess the impact of climate change on Macedonian agriculture. Farmers' adaptation is taken into account by using an alternative specification of the Ricardian model based on the use of aridity indices to capture the non-linear response of farmland values to temperature and precipitation. Econometric results indicate that winter and spring aridity indices influence unit gross returns of crop farms. A decomposition analysis of aridity indices between temperatures and precipitations results in the derivation or marginal responses of unit gross returns of crop farms to seasonal temperatures and precipitations.

Key words: Ricardian model, climate change, Macedonian agriculture, aridity index

Introduction

Agriculture is an especially vulnerable sector, strongly sensitive and dependent on climate. Macedonia is classified in the Continental south agro-climatic zone in Europe, where it is expected that climate change brings potential changes in the precipitation pattern consisting of increased rainfall in winter and decreased water availability in summer (Iglesias *et al.*, 2007). Although Macedonia is a small landlocked country "comparable to a single grid-cell of current global climate models that are used to simulate the future climate change in a large scale", there is great variance in elevation and the heterogeneity of climate conditions is very high (Bergant, 2006: 3). Climate change will grow more severe in the country over the course of the next 40 years and could lead to losses for farmers of 50 percent or more for most crops under the medium impact scenario unless adaptation measures are put in place (Sutton *et al.*, 2013).

Few studies conducted recently focused on the impacts of climate change and identified areas where adaptation may be necessary (Callaway *et al.*, 2011, Sutton *et al.*, 2013). They conclude that climate change will have an impact on the reduction of yields in most crops and additionally assess that water resource management implications of the forecast change in climate could be severe, with increased water shortages especially during the summer season. Adaptation is pointed out as the key remedy for addressing climate change effects; "without adaptation, the climate change damages may become approximately the same or bigger than current net income, hence jeopardizing the economic sustainability of farming in some areas" (Callaway *et al.*, 2011: 17), but it is not taken into account directly in these models. Therefore, in this paper we make an attempt to assess the impact of climate change on Macedonian agriculture, taking into account farmers' adaptation by using the Ricardian model approach.

Method and data

Mendelsohn, Nordhaus and Shaw (1994) developed the "Ricardian approach" based on David Ricardo's theory that rent of land is equal to the economic advantage obtained by its most productive use. This technique examines the impact of climate on farm revenue, hence accounting for the direct impact of climate on yields of different crops, substitution of inputs, farm diverse activities and other potential adaptations to different climatic conditions (Mendelsohn *et al.*, 1994). The method itself consists of regression analysis of statistical relationships between economic indicators and climate variables; the end-result measures the degree of influence of each factor (climatic and other control variables) on land values.

The effects of climate through temperature and precipitation on agricultural rents tend to be highly non-linear and vary considerably by season (Mendelsohn *et al.*, 1994; Kurukulasuriya *et al.*, 2006). Interactions or more complicated nonlinearities between

temperatures and rainfall could occur; this problem has been recently evidenced by Fezzi and Bateman (2012) in the case of the United Kingdom. Climatologists and geographers for this reason suggest the use of so-called aridity indices. So far and to our knowledge, the idea of specifying a Ricardian model using aridity indices has not been explored in the relevant literature and it is one objective of this work to attempt to estimate a Ricardian model where instead of using the common second order polynomial forms linking directly the dependent variable to temperatures and precipitations, we introduce de Martonne aridity indicator (*DMI*):

$$DMI_i = \frac{P_i \cdot 12}{T_i + 10} \tag{1}$$

where P_i = monthly rainfall for month i in millimeters (mm), T_i = average monthly temperature (^oC) for month or season *i*. We regress the gross return per ha over the de Martonne index and other control variables:

$$GR_k = \alpha + \sum_i l_i\left(DMI_{ik}\right) + \sum_j m_j G_{jk} + \varepsilon_k \tag{2}$$

where GR_k is the (unit) gross return (on a per hectare basis) of the unit of observation *k,* l_i is a quadratic function of the aridity index for season *i, G* is a vector of all other control *j* variables (farm elevation, irrigation, agro-climatic regions, etc…), and ε is the error term.

$$l_i\left(DMI_i\right) = \beta_{1i}\ DMI_i + 0.5\beta_{2i}\left(DMI_i\right)^2 \tag{3}$$

Replacing l_i and *DMIs* in the Ricardian model specification (2), leads to the following nonlinear relationship between temperatures and rainfall (where β_1 and β_2 are parameters):

$$GR_k = \alpha + \sum_i \beta_{1i} \frac{P_{ik} \cdot 12}{T_{ik} + 10} + 0.5\sum_i \beta_{2i}\left(\frac{P_{ik} \cdot 12}{T_{ik} + 10}\right)^2 + \sum_j m_j G_{jk} + \varepsilon_k \tag{4}$$

From expression (4), we can derive the marginal effects on land rents *k* (unit gross returns) as follows:

$$\frac{\partial GR_k}{\partial P_{ik}} = \frac{\beta_{1i}}{T_{ik} + 10} + \frac{\beta_{2i} P_{ik} \cdot 12}{\left(T_{ik} + 10\right)^2} \qquad \frac{\partial GR_k}{\partial T_{ik}} = -\frac{\beta_{1i}\ P_{ik} \cdot 12}{\left(T_{ik} + 10\right)^2} - \frac{\beta_{2i}\left(P_{ik} \cdot 12\right)^2}{\left(T_{ik} + 10\right)^3} \tag{5}$$

The impact of the rainfall on the dependent variable is linear for a given level of temperature (expression 5). The sign and magnitude of this impact will depend upon the signs and magnitude of the parameters β_{1i} and β_{2i}, but also upon the values of the temperature T_{ik}. The effect of the temperature variable is highly nonlinear for a given level of rainfall.

The data used in this study were derived from several sources. The annual Farm Monitoring Survey (FMS) of the Macedonian National Extension Agency was used for the farm level variables: location, age of the farmer, utilized agricultural area, irrigated crop area, farm income, specific costs and gross margin. The empirical application of the Ricardian model is based on 129 farms with crop production in year 2005. The variables with meteorological data are obtained from eight main meteorological stations existing in the country.

Results and discussion

The empirical implementation of the modified Ricardian model used in this work led us to estimate several empirical specifications but in the end only one with satisfactory econometric results is selected reported in Table 1. We used climatic variables (aridity indices), along with irrigation[1] and regional dummy variables. Regarding the climatic variables, we include only the winter and spring aridity indices, since they are most importantly effecting the

[1] Irrigation is captured by a dummy variable indicating whether a crop farmer has irrigated land on his farm.

vegetation period. The model is corrected by ordinary least squares with a use of a robust heterocedastic-consistent estimator (Eicker-White) for the estimated standard errors of the coefficients. The adjusted R^2 explaining the total variation in the (unit) gross farm return is 0.3953. Irrigation, a responding strategy to the inadequate rainfall during the vegetation period, as predicted, has a positive effect on the gross margin. Elevation and other control variables did not have significant effects on the gross margin and thus have been dropped.

The climatic variables (measured by de Martonne indices) for the winter and spring season are statistically significant (with p-values <0.01), indicating that climate change has an impact on Macedonian farms. All estimated coefficients associated with the quadratic climatic variable terms are statistically different from zero, which confirms the non-linear relationship between climatic variables, in our case represented through the compound aridity index and the unit gross return. The squared term of the spring aridity index is positive meaning that its relationship with the farm gross return is U-shaped. On the other hand, the winter aridity index squared term is negative; hence the relationship with unit gross return has a U-inverted or hill shape. The combined Kumanovo/Stip region variable is the only one among all the region dummy variables which is statistically significant.

Table 1: Econometric results

Explanatory variables	Coefficients	Standard error	t-statistic	p-value
Intercept	24601.0	47914.3	0.513437	0.608
Irrigation	24476.6***	8008.07	3.05649	0.002
Winter de Martonne index (DMIW)	7352.08***	2334.14	3.14980	0.002
DMIW×DMIW	-69.9924***	19.9048	-3.51636	0.000
Spring de Martonne index (DMISP)	-10256.3***	3703.89	-2.76908	0.006
DMISP×DMISP	210.052**	85.1530	2.46676	0.014
Region Kumanovo/Stip	-38260.9***	8014.57	-4.7739	0.000
Adjusted R^2	0.395323			

Further interpretation of the impact of climatic variables is conducted through the calculated elasticities obtained at the sample means on unit gross return (see Table 2). The elasticity of the DMI variable implies that a 1% increase in the index would lead to a 0.49% decrease in the unit gross margin. The spring DMI inversely indicates that a 1% index increase will improve the gross return by 0.16%.

Looking at the impact of average winter temperature through elasticities, it can be seen that a 1% increase in the average winter temperature results in a to 0.08% increase in unit gross returns. The higher winter temperature should benefit the crops and would have positive impact on farm income. On the other hand, the rainfall in winter has a decreasing effect on unit gross margin (every 1% increase in rainfall will decrease the gross return by 0.49%). Precipitation is normally considered as beneficial, although it can have negative impact if not distributed appropriately during the vegetation season.

In the spring period, an increase in the temperature leads to a decrease of unit farm return, or for every 1% of increase in temperature, the farmer would lose on average 0.06% of his unit farm return. On the other hand, spring precipitations have a positive effect, so gross return is more responsive to the higher availability of rainfall, meaning that a 1% of increase in rainfall boosts on average the unit farm gross margin by 0.10% during the spring season. Water nevertheless has to be conserved over winter in order to maintain proper supply during the spring and summer period.

Table 2: Climate variable elasticities (computed at sample means)

	Elasticity values	Standard errors
Winter period		
De Martonne aridity index	-0.491549	0.355399
Temperatures	0.076224	0.055111
Precipitations	-0.485804	0.351245
Spring period		
De Martonne aridity index	0.157476	0.435456
Temperatures	-0.069059	0.190964
Precipitations	0.096097	0.265728

We also attempted to estimate the effect of climate change on the farm gross return at regional level, based on the projected variation in temperature and precipitation for year 2025 (low, medium and high impact scenarios, as in Bergand, 2006). Taking into account the elasticities of the regional aridity indices for the winter and spring period, the tested change in gross return for the region of Skopje turned out to have be negative *i.e.* to decrease by -1.30% for the low impact scenario, -2.69% for the medium impact scenario and -4.53% for the high impact scenario. The climate change in the low impact scenario had positive effect in the region of Stip (1.47%), and negative effect in the medium and high impact scenarios (-0.18% and -0.98%, respectively). The effect for Strumica region was positive in the low and medium impact scenarios (0.37% and 0.02%, respectively), though negative for the most pessimistic scenario (-0.17%).

Conclusion

The Ricardian approach is a widely applied and popular model when assessing the impact of climate change on agriculture. Taking into consideration the specifics of the Macedonian conditions and the availability and reliability of data, this approach has been modified for the purpose of this study. The modified specification combines temperature and precipitation into a single index (de Martonne aridity index), and uses is as such in the model regressions.

Recent studies have raised the issue on climate change, reporting the predictions on the nature and scale of the impact in the country (Sutton *et al.*, 2013, Bergant, 2006, Callaway *et al.*, 2011). There is an improved awareness of this issue, but still it is not highly positioned in the policy framework. These studies have stressed the need for adaptation and proposed concrete courses of action in order to mitigate the effect. Our work attempts to capture the adaptations with the current farming systems and managerial practices, as a response to the changing climate. In this respect, we add to the effort of increased understanding of the impact and sensitivity of climate change on Macedonian agriculture, as the study disclosed that climate change has influence on the farm returns. Major advantage to the applied approach is that it already accounts for the structural changes and farm responses (Van Passel, 2012), and thus enables a comparative analysis. The coefficients derived from the regressions were used to project future impact through different climate scenarios.

The empirical results presented herein are exploratory and further in-depth investigation must be conducted. These findings reflect the state of affairs of this research which is ongoing. It is our intention to refine the empirical analysis by examining more closely the characteristics of the non-linear response of unit farm returns of crop farms to precipitations and temperature.

References

Bergant, K. (2006). Climate Change Scenarios for Macedonia – Summary. University of Nova Gorica, Slovenia.

Callaway, J. M., Markovska, N., Cukaliev, O., Causevski, A., Gjoshevski, D., Taseska, V., Nikolova, S. (2011) Assessing the Economic Impact of Climate Change : National Case studies. Skopje: UNDP.

Iglesias, A., Avis, K., Benzie, M., Fisher, P., Harley, M., Hodgson, N., Horrocks, L., Moneo, M., Webb, J. (2007). Adaptation to Climate Change in the Agricultural Sector. Report to European Commission Directorate - General for Agriculture and Rural Development. AGRI-2006-G4-05 AEA Energy & Environment, Didcot.

Fezzi, C. and Bateman, I. (2012). Non-linear effects and aggregation bias in Ricardian models of climate change. CSERGE working paper 2012-02. School of Environmental Sciences, University of East Anglia, Norwich, UK.

Mendelsohn, R., Nordhaus, W., Shaw, D. (1994). The impact of Global Warming on Agriculture: A Ricardian Analysis. *The American Economic Review* 84 (4): 753– 771.

Sutton, W. R., Srivastava, J. P., Neumann, J. E., Strzepek, K., Boehlert, B. (2013). *Reducing the Vulnerability of FYR Macedonia's Agricultural Systems to Climate Change: Impact Assessment and Adaptation Options*. World Bank Study. Washington, DC: World Bank.

Van Passel, S., Massetti, E., Mendelsohn, R. (2012). A Ricardian analysis of the impact of Climate Change on European Agriculture. Nota di Lavoro No. 83.2012. Milano: Fondazione Eni Enrico Mattei.