Extended Abstract
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Paper/Poster Title	Modelling the impact of climate change on agriculture productivity in Russia

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Abstract	***200 words max***
Understanding the mechanisms of the impacts of global warming on agriculture productivity in main agricultural production regions of the world is important for identifying appropriate adaptation strategies and ensuring food security of the planet's growing population. In our study, we study the impact of climate change on agriculture productivity in Russia – a major wheat producing and exporting country. To derive marginal effects of climate change on agricultural land productivity in 65 Russian regions, we employ an approach that build upon both the standard Ricardian approach (Mendelson et al., 1994) as well as the identification strategy allowing to control for adaptation efforts and unobserved heterogeneity proposed by Gammans et al. (2020). Our preliminary results suggest that an uniform increase in temperature during the main growing period may negatively affect agricultural production in all important production regions of Russia, given the current state of technology and land use.	

Keywords	Russia, Ricardian approach, Climate change impact, Agriculture
JEL Code	Q1 Agriculture; Q540 Climate; Natural Disasters and Their Management; Global Warming; Q55 Environmental Economics: Technological Innovation see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

Adapting agricultural production to climate change and extreme weather events is crucial for ensuring food security of the planet's growing population. In this context, studying the implications of a changing climate on agriculture, especially on agricultural production in important crop growing regions, presents an urgent research question. Statistical methods employed to study the impacts of climate change on agriculture include the Ricardian approach first developed by Mendelson et al. (1994) and panel models using interannual weather fluctuations to identify the effect of climate change (Deschênes and Greenstone, 2007; Schlenker and Roberts, 2009). Both the Ricardian approach and panel regressions are based on modelling reduced-form relationships between economic variables of interest and selected climate or weather indicators.

A major drawback of statistical approaches has been their relatively limited capacity to account for producers efforts targeted at adapting to changes in climate. Accordingly, recent research in this area has focused on addressing these limitations. Burke and Emerick (2016) adopted an econometric approach based on long-term differences in yield and weather variables, while Gammans et al. (2020) propose an identification strategy that enables utilizing random weather fluctuations to estimate the effects of climate change while accounting for adaptation efforts undertaken by economic agents. The advantage of this approach compared to the standard Ricardian approach is that it allows to control for unobserved heterogeneity of study objects and spatial correlation.

Methodology	***100 – 250 words***

To obtain robust estimates of the sensitivity of agricultural production in Russian regions to climate change, we propose to employ both (i) the Ricardian approach by Mendelson that models the effect of climate variables but may produce biased estimates in presence of unobserved heterogeneity of study objects; and (ii) the approach by Gammans et al. (2020) that allows to estimate marginal effects of long-term changes in climate in panel regressions by modelling economic variable responses to interannual weather variation by climatic intervals.

In the Ricardian model, we regress the logarithm of the gross regional product from agriculture per hectare of sown area (for the 1999-2014 period), y, on a vector of k climatologies ($k = 1, \dots, K$), calculated as corresponding weather variables´ averages over the previous thirty years, $\bar{\boldsymbol{x}}$, *viz*.:

$$\ln y_{it} = \alpha + \beta_k \bar{\boldsymbol{x}}_i + \gamma_l \boldsymbol{g}_{it} + \varepsilon_{it}, \qquad (1)$$

where i indicates study regions ($i = 1, \dots, N = 65$), t is time (year) index, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are the vectors of corresponding regression coefficients and ε is the error term. We further control for other exogenous variables (vector $\boldsymbol{g}$ of dimension L) such as an index of soil fertility and population density.

In a complementary analysis, we estimate the marginal responses to long-run impacts of climate change using the approach by Gammans et al. (2020). In this case, we formulate our panel model as follows:

$$\ln y_{it} = \alpha_i + f_i(t) + \boldsymbol{\beta}_{\mu(i)} \boldsymbol{x}_{it} + \varphi \boldsymbol{g}_{\mathrm{it}} + \varepsilon_{it} \qquad (2)$$

where y_{it} is the agriculture´s gross regional product (measured in constant prices of 2000) per hectare of sown area in region i and period t, α_i are regions´ fixed effects, $f_i(t)$ are region-specific time trends used to capture the effect of technical change, $\boldsymbol{x}_{it}$ is a vector of K relevant weather variables, $\boldsymbol{p}_{it}$ is a vector of L control variables and ε is the stochastic error term. μ_i indicates the climatic interval to which region i belongs to, $\mu = 1, \dots, M$, $\boldsymbol{\beta}_\mu$ is $K \times M$ matrix of climatic interval slopes for the weather variables used in the study.

We define climatic intervals using 30-years rolling averages of regions´ average daily temperature in the period from May 1 to July 31. To this end, we rank regions according to this climatology and, successively, split them in five large climatic intervals (i.e. set $M = 5$), each with approximately the same number of (region–year) observations.

In both models we use a spatially robust standard errors estimator (Conley, 1999; Hsiang, 2010) to control for serial and spatial correlation.

Our dataset represents 65 Russian administrative regions and covers the period from 1999 to 2014. Regional statistics used in the study stem from the Russian Statistical Agency (Rosstat, 2000–2015). Weather data are derived using the meteorological forcing data provided by the Terrestrial Hydrology Group at Princeton University (Sheffield et al., 2006) and crop masks for individual regions.

Results

100 – 250 words

Table 1 presents preliminary estimates of marginal impacts of a uniform increase in the May–July average daily temperature by 1°C for the five climatic intervals specified and used in model 2.

Table 1: Estimates of marginal impacts of the May–July average daily temperature increase by 1°C (by climatic intervals)

	Marginal impacts, %[1)]	Marginal impacts per ha, RUB 2000	Marginal impacts per ha, EUR 2000[2)]	Total gain / damage, EUR 2000
Climatic interval 1	0.474 (0.485) [-0.424, 1.372]	--	--	--
Climatic interval 2	-0.738** (0.330) [-1.385, -0.091]	-112.6	-4.3	-4,511,442
Climatic interval 3	-1.193** (0.258) [-1.698, -0.688]	-321.5	-12.4	-12,388,150
Climatic interval 4	0.572* (0.294) [-1.147, 0.004]	-139.0	-5.3	-5,477,869
Climatic interval 5	-0.630** (0.307) [-1.232, -0.028]	-206.37	-7.9	-7,211,616

Note: [1)] standard errors are reported in parentheses, while 5% and 95% confidence intervals can be found in brackets; ***, **, * refer to 0.01, 0.05 and 0.10 significance level, respectively; [2)] 1 EUR of 2000 = 26.04 RUB of 2000. Source: authors´ estimates;

These results suggest that global warming may negatively affect agricultural productivity in almost all important production regions of Russia, given the current state of technological upgrading and land use in Russian agriculture.

Discussion and Conclusion

100 – 250 words

Our preliminary study results suggest that climate change may have a negative impact on Russian agriculture productivity. Technological improvements and land use changes introduced since the late 1990s helped to boost agriculture productivity but more (adaptation) efforts are necessary to reduce climatic sensitivity of agricultural production in Russia. The current policies aimed at increasing country food self-sufficiency may, however, distort economic incentives and, thus, decelerate economic agents' efforts to adapt to changing climate.

Considering the country's role as important grain producer and exporter, high climatic sensitivity of Russian agriculture may negatively affect global food security. Therefore, more efforts are necessary to better understand (and model) the mechanisms of the climate change impact on Russian agriculture and to identify effective adaptation strategies.