The growing impact of climate change on European crops

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MOTIVATION

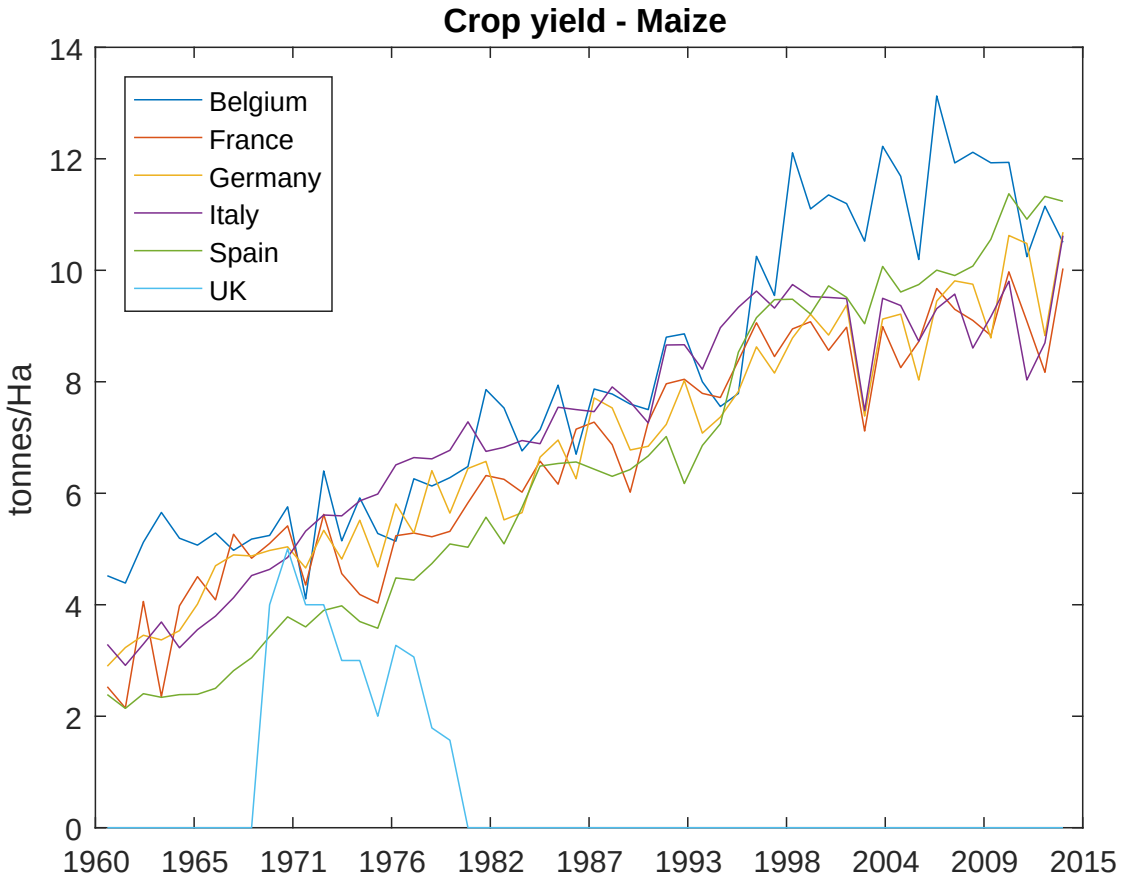
- Climate change: physical phenomenon evolving over time.
- Evidence on dynamic consequences for agriculture is rather poor.
- Why is it important to explicitly characterize the time dimension of the effects of climate change?
  - Forecasts
  - Future adaptation.
  - Food security.
- Now we have enough long time series to perform such analysis.
- We examine 6 countries (Spain, Italy, France, Germany, UK, Belgium) and 3 crops (maize, sugar beet, wheat), over the period 1961-2014

WHY FOCUS ON EUROPE?

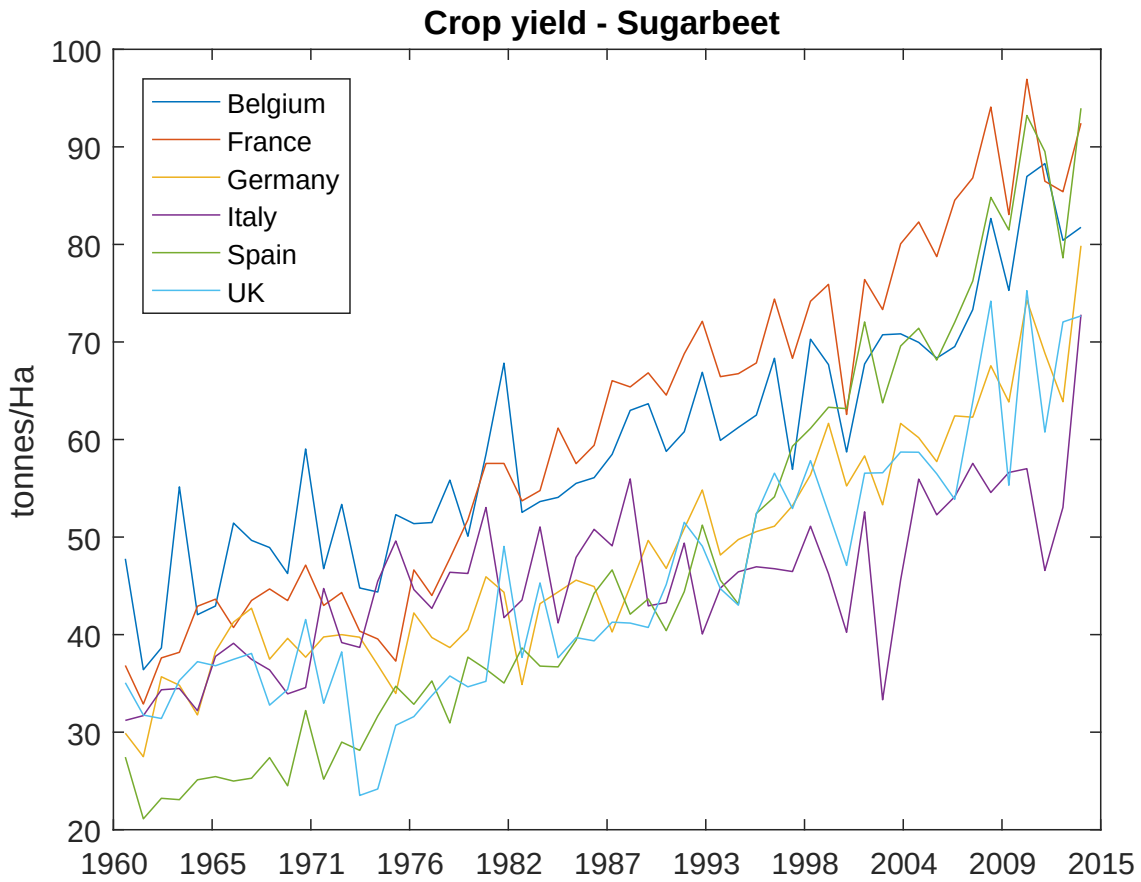
barley *rank*	*country*	*prod*	*w share*	*eu share*	*yield rank*	**maize** *rank*	*country*	*prod*	*w share*	*eu share*	*yield rank*
2	France	11,728,556	8.12%	12.52%	9	10	France	18,343,420	1.77%	14.23%	20
3	Germany	11,562,800	8.00%	12.35%	6	17	Italy	9,239,545	0.89%	7.17%	16
7	Spain	6,983,109	4.83%	7.46%	58	25	Germany	5,142,100	0.50%	3.99%	15
8	UK	6,911,000	4.78%	7.38%	10	28	Spain	4,776,190	0.46%	3.71%	9
32	Italy	846,142	0.59%	0.90%	36	70	Belgium	662,700	0.06%	0.51%	17
43	Belgium	434,700	0.30%	0.46%	1						

sugarbeet *rank*	*country*	*prod*	*w share*	*eu share*	*yield rank*	**wheat** *rank*	*country*	*prod*	*w share*	*eu share*	*yield rank*
1	France	37,844,567	14.03%	19.74%	3	6	France	38,950,202	5.34%	15.62%	8
3	Germany	29,748,100	11.03%	15.52%	5	8	Germany	27,784,700	3.81%	11.14%	4
9	UK	9,430,000	3.50%	4.92%	11	13	UK	16,606,000	2.28%	6.66%	6
14	Belgium	4,790,700	1.78%	2.50%	7	20	Italy	7,141,926	0.98%	2.86%	42
17	Italy	3,784,435	1.40%	1.97%	10	22	Spain	6,471,400	0.89%	2.60%	60
19	Spain	3,723,309	1.38%	1.94%	1	40	Belgium	1,994,600	0.27%	0.80%	2

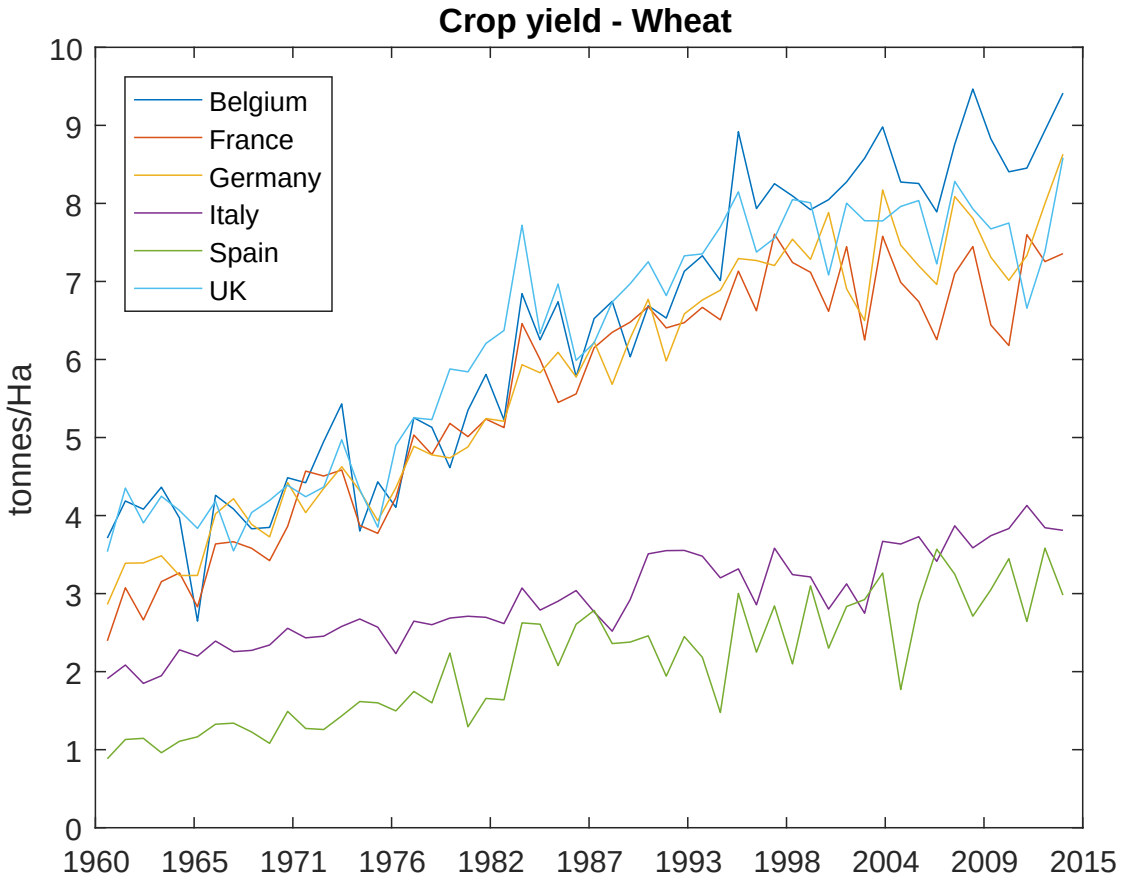
MAIZE YIELD IN EUROPE



SUGAR BEET YIELD IN EUROPE



WHEAT YIELD IN EUROPE



RESEARCH QUESTION

- Is the impact of climate change different across regions?
  - We perform a model selection procedure for each crop-country case.
- Has the impact been constant or varying over time?
  - We allow the coefficients on weather variables to vary over time.
- Can we improve calculation of total loss due to climate change?
  - We estimate the date since when there is an acceleration of trend in temperature.
  - We propose a new measure of output loss, which includes changes in crop's sensitivity to temperature.
- Is the recent slowdown in long-run yield growth related to temperature?
  - We find evidence confirming this hypothesis.

DATA

- Yearly data over 1961-2014, for 6 countries (Spain, Italy, France, Germany, UK, Belgium) and 3 crops (maize, sugar beet, wheat)
- Variables
  - Crop yield in logs (source: FAO).
  - Temperature and precipitation as area-weighted average over the growing season.
- Construction of weather variables from 3 elements:
  - Crop-specific area.
    - Source: Monfreda et al. (2008), average over 1997-2003.
  - Growing months.
    - Source: Sacks et al. (2010).
  - Temperature series as monthly average on 30min grid.
    - CRU (UEA).
- Which season.
  - Maize: main season.
  - Sugar beet: single season.
  - Wheat: winter.

ECONOMETRIC APPROACH

- Time series model: linear Gaussian state space models.
- Estimation technique: diffuse Kalman filter.
  - Stock and Watson (1998) estimator for the state error variance.
- Why this choice?
  - Most general time-series approach.
  - Allows a careful study of the long-run trend.
  - Allows assess whether the impact of regressors is constant or time-varying.
- For each crop-country case we perform standard model selection by considering the information provided by
  - Goodness of fit via alternative information criteria.
  - Diagnostic checks on residuals.
  - Plausibility of coefficients estimates.

ESTIMATION OUTCOME - WHEAT

	Belgium		**France**		**Germany**		**Italy**		**Spain**		**UK**	
	Value	*p-value*	*Value*	*p-value*	*Value*	*p-value*	*Value*	*p-value*	*Value*	*p-value*	*Value*	*p-value*
Constant	(2.21,3.04)	0.00	(2.49,3.55)	0.00	(1.97,3.01)	0.00	(1.5,2.14)	0.00	(0.48,1.62)	0.01	(2.04,2.54)	0.00
Slope	0.017	0.00	0.022	0.00	0.022	0.00	1.31E-02	0.00	2.36E-02	0.00	1.05E-02	0.05
T	(-0.04,0.03)	0.00	(-0.1,-0.07)	0.00	(-0.05,-0.03)	0.00	(-0.06,-0.05)	0.00	(-0.06,-0.04)	0.15	(-0.05,-0.02)	0.17
T^2					-0.01	0.07	-0.02	0.01				
P	-2.9E-03	0.00	-1.43E-03	0.12	-1.87E-03	0.04			0.01	0.00	-1.97E-03	0.01
P^2	-5.1E-05	0.01			-1.10E-04	0.02			-3.20R-04	0.00	-5.00E-05	0.10
JB	0.25		0.25		0.81		0.88		0.63		0.86	
LB	0.09		0.09		0.13		0.79		0.14		0.95	
Het	0.38		0.38		0.43		0.15		0.12		0.43	
Stoch.	T coeff		T coeff		T coeff		T coeff		T coeff		T coeff	

MARGINAL EFFECT OF TEMPERATURE

Maize

Marg Eff	Belgium	France	Germany	Italy	Spain
Min	0.043	-0.039	0.020	-0.043	-0.012
Average	0.052	-0.027	0.028	-0.024	0.001
Max	0.063	-0.023	0.036	0.010	0.011

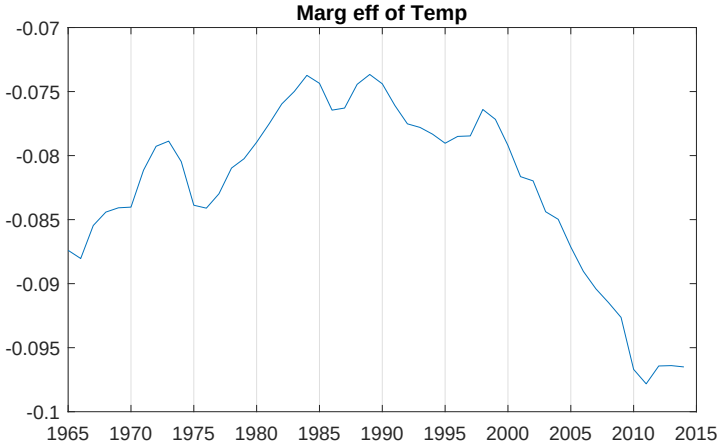
Sugar beet

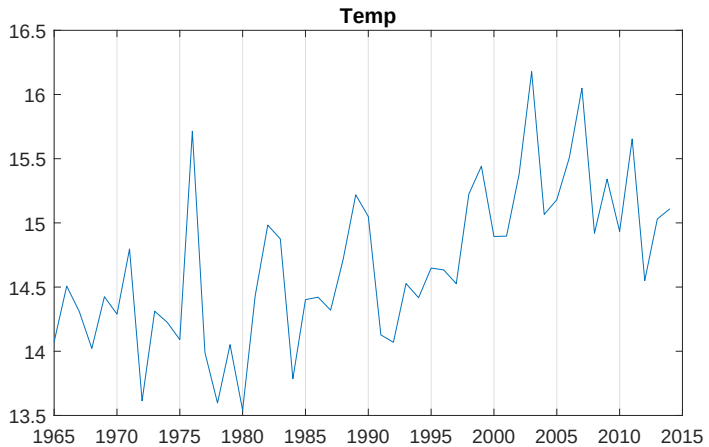
Marg Eff	Belgium	France	Germany	Italy	Spain	UK
Min	0.012	0.036	0.038	-0.054	0.023	0.057
Average	0.033	0.036	0.038	-0.028	0.025	0.057
Max	0.058	0.036	0.038	0.007	0.030	0.057

Wheat

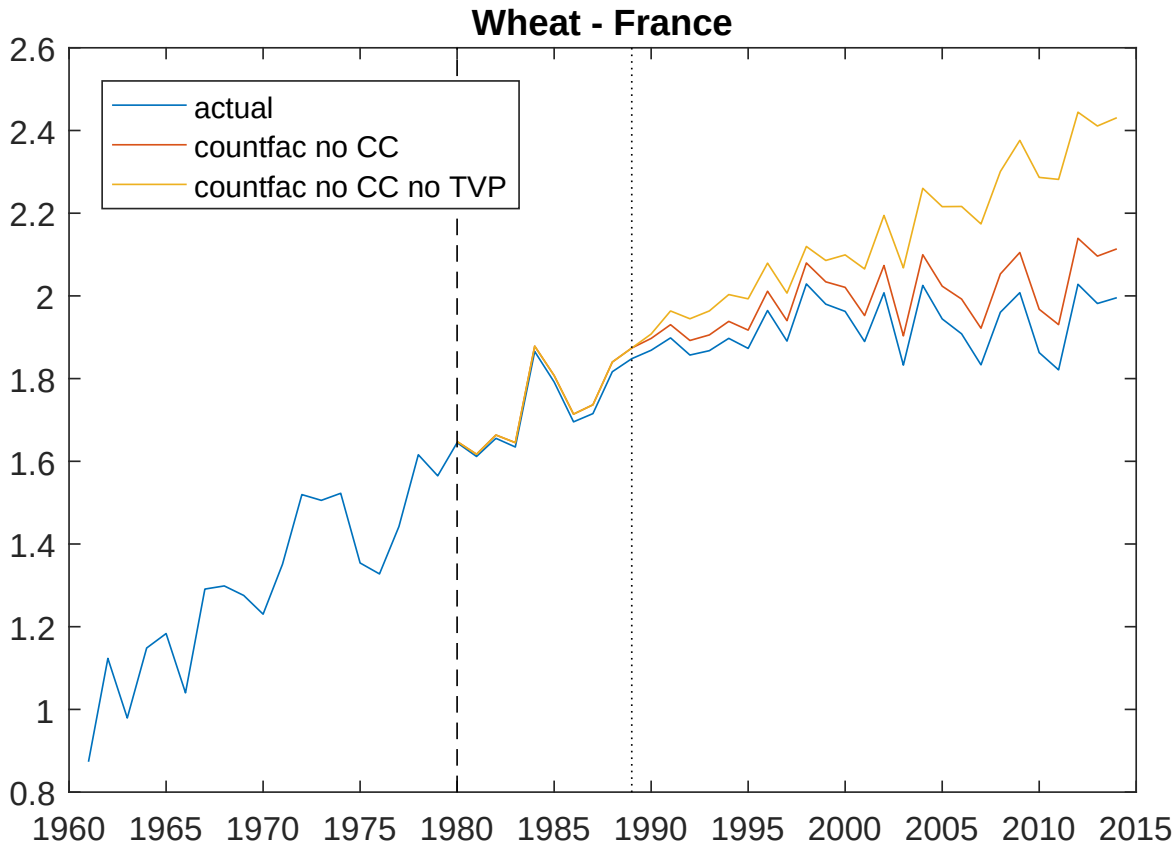
Marg Eff	Belgium	France	Germany	Italy	Spain	UK
Min	-0.043	-0.098	-0.051	-0.058	-0.065	-0.048
Average	-0.035	-0.078	-0.036	-0.052	-0.053	-0.025
Max	-0.031	-0.074	-0.033	-0.049	-0.040	-0.016

TIME-VARYING IMPACT OF TEMPERATURE: WHEAT-FRANCE





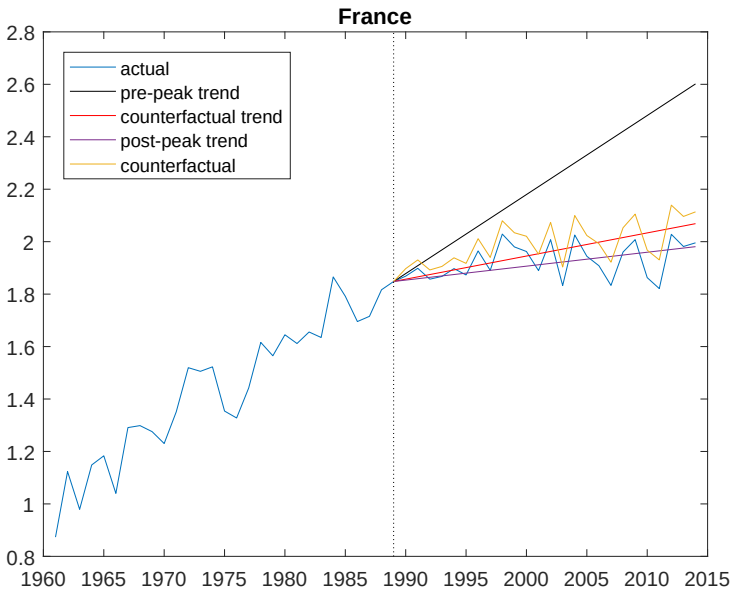
CALCULATING THE OUTPUT LOSS



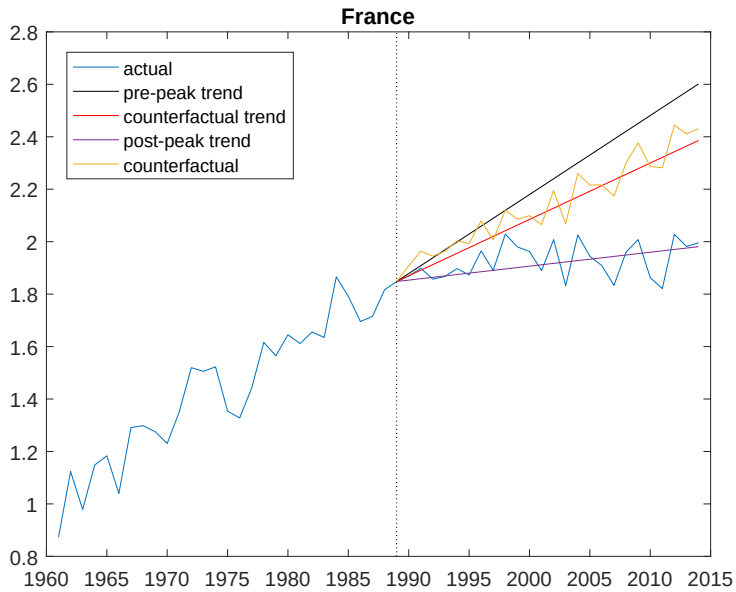
OUTPUT LOSS DUE TO CLIMATE CHANGE

	Maize				**Sugar beet**		**Wheat**			
	Temperature effect		Total effect		Temperature effect		Temperature effect		Total effect	
Country	*1000 tonnes*	*%*	*1000 tonnes*	*%*	*1000 tonnes*	*%*	*1000 tonnes*	*%*	*1000 tonnes*	*%*
Belgium	651	5.9	-307	-2.56	3,616	1.39	-1,972	-3.59	-4,071	-7.14
France	-15,963	-2.95	-52,965	-9.17	31,157	2.94	-70,560	-5.72	-250,037	-17.68
Germany	4,122	4.27	-7,706	-7.11	32,872	3.59	-25,174	-3.68	-102,780	-13.49
Italy	-9,571	-3.08	n/a	n/a	-10,348	-2.55	-17,236	-5.08	-29,731	-8.45
Spain	-11	-0.01	-19,159	-12.52	6,790	2.46	-14,654	-6.31	-46,388	-17.57
UK					9,083	3.21	-9,478	-1.93	-25,715	-5.07
Overall	-20,039	-1.99	-88,969	-8.27			-137,551	-4.73	-457,193	-14.17

THE SLOWDOWN IN LONG-RUN TREND



(A) Temp effect



(B) Total effect

CONTRIBUTIONS

- This is the first thorough analysis of the time-series dimension of the impact of climate change on agriculture.
- There are important heterogeneities across countries with respect to: timing of the change in temperature's trend, sensitivity of crop yield to temperature.
- The impact of temperature on crop yield is time-varying; it has improved from 1960s to 1990s, and then it has become increasingly adverse, with the gains from the improvements of previous decades being more than offset by the recent acceleration in temperature.
- We proposed a new approach to calculate the output loss due to climate change.
- The recent slowdown in the long-run growth in European crop yield is mostly due to climate change.
- The historical impact of climate change has become more severe over time, not only because of increasing temperature levels but also, and more importantly, due to an increasingly higher sensitivity of crop yield to changes in temperature.