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# Impact of growing season temperature on wheat productivity in China

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ABSTRACT

Climate change continues to have major impact on crop productivity all over the world. Many researchers have evaluated the possible impact of global warming on crop yields using mainly indirect crop simulation models. Here we use a 1979–2000 Chinese crop-specific panel dataset to investigate the climate impact on Chinese wheat yield growth. We find that a 1 °C increase in wheat growing season temperature reduces wheat yields by about 3–10%. This negative impact is less severe than those reported in other regions. Rising temperature over the past two decades accounts for a 4.5% decline in wheat yields in China while the majority of the wheat yield growth, 64%, comes from increased use of physical inputs. We emphasize the necessity of including such major influencing factors as physical inputs into the crop yield-climate function in order to have an accurate estimation of climate impact on crop yields.



## 1. Introduction

The adoption of modern varieties and the increased use of irrigation and fertilizers during Green Revolution dramatically increased crop yields all over the world (Evenson and Gollin, 2003b; Rosegrant and Cline, 2003). The Green Revolution enabled food production in developing countries to keep pace with population growth (Conway and Toenniessen, 1999). Crop yield growth has slowed since 1990s (Evenson and Gollin, 2003b; Rosegrant and Cline, 2003). But continued crop yield increases are required to feed the world in the 21st century (Rosegrant and Cline, 2003; Cassman, 1999) given the continuing decline of area suitable for grain production due to urbanization and industrialization. Assuring food security, in particular in developing countries, remains a challenge. This challenge is becoming greater by the adverse effect of predicted climate change in most food insecure developing countries (Rosenzweig and Parry, 1994). There is accumulating evidence that greenhouse gas concentrations are warming the world's climate (IPCC, 2007). While there is some consensus that this warming will likely be harmful to tropic and sub-tropic agriculture, active debates still continues on where such warming will be hurt or benefit agriculture in more temperate zone such as China, USA (Schlenker et al., 2005; NDRC, 2007).

Given the large body of research that has been done to quantify the contributions to crop productivity (Evenson and Gollin, 2003a,b), we know factors such as modern varieties, increasing input use, and better farm management contribute greatly to crop yield growth. However, our knowledge on the impact of climate on crop productivity remains quite uncertain. While many researchers have evaluated the possible impact of global warming on crop yields using mainly indirect crop simulation models (e.g., Rosenzweig and Parry, 1994; Brown and Rosenberg, 1997; Reilly et al., 2003), there are relatively few direct assessments on the impact of observed climate on past crop yield and growth except for a few studies (Nicholls, 1997; Carter and Zhang, 1998; Naylor et al., 2002; Lobell and Asner, 2003; Peng et al., 2004). In a recent study, Peng et al. (2004) reported that rice yields decline with higher night temperatures. Lobell and Asner (2003) showed that corn and soybean yields in the US could drop by as much as 17% for each degree increase in the growing season temperature though Gu (2003) questioned the validity of this study. Climate is the major uncontrollable factor that influences crop yield, but it is difficult to separate this influence from other factors such as the increased use of modern inputs and intensified crop management that were introduced during the Green Revolution. In fact, one major concern for the above-mentioned studies is the simplification of approximating such non-climate contributions as a linear trend (Gu, 2003; Godden et al., 1998).

In this paper, we use crop-specific panel data to investigate the climate contribution to Chinese wheat yield growth. We find that temperature as well as precipitation in wheat growing seasons has a significantly negative impact on wheat yield in China, but the magnitude of impact is less than those reported by previous studies in other regions. In the following section, we would

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describe the data and model we are using. Section 3 introduces the estimation methods and results. Finally we would conclude with a summary and some policy implications.

## 2. Data and method

We use time series and provincial data from 1979 to 2000 for 22 major wheat producing provinces in China and the corresponding climate data such as temperature, rainfall, and solar radiation during this period. Wheat input and output data are from State Statistics Yearbook (1979–2002) and China's Rural Statistical Yearbook (1979–2002) published by China's National Statistical Bureau, and China Agricultural Cost and Return Yearbook (1979–2002) published by China's Price Bureau. Table 1 shows some of the basic statistics of the dataset. Both wheat yield and physical inputs demonstrate huge variations among the 462 observations. For example, the mean yield is about 394.9 Jin/mu while the wheat could be as low as 114.9 Jin/mu (minimum), or as high as 789.7 Jin/mu (maximum).

Climate data are from Climate Research Unit at University of East Anglia. The dataset used is CRU TS 2.0. This data-set comprises 1200 monthly grids of observed climate, for the period 1901–2000, and covering the global land surface at 0.5° resolution. There are five climatic variables available: cloud cover, diurnal temperature range, precipitation, temperature, vapour pressure (Mitchell and Jones, 2005). Since wheat is not grown all year round in every land within China, we need to account for the seasonal and spatial variation of climate parameters. China grows both winter wheat and spring wheat. The majority of wheat production in China, about 80–90%, is winter wheat. Winter wheat is grown throughout most of eastern and southern China while spring wheat in northeast and western China. Both winter and spring wheat are grown in Northern China. The growing season for wheat varies from province to province. Table 2 shows the wheat growing seasons by provinces. The annual climate data are monthly averages during the wheat growing seasons, taking account of the changing growing seasons by province. Ideally, we would like to average the climate data weighted by the wheat area by pixel for each year from 1979 to 2000. However, time-series data on crop distribution is hard to find. Recently there is some attempt to fill this gap (You et al., 2007; Monfreda et al., 2008). In our own work, we estimated global distribution maps for 20 major crops on a 5 min × 5 min resolution (You et al., 2006, 2007). Here we use wheat area distribution map in China around 2000 as a weight to estimate the climate parameters in each provinces. This would avoid account for those pixels where wheat is not grown. The provincial climate parameters are averages of all the pixels within the provinces but weighted by wheat area of the pixels. Some basic statistics for temperature, precipitation and cloud cover are shown in Table 1.

**Table 1**
Descriptive statistics.

| Variables | Unit | Mean | Minimum | Maximum | Std. deviation |
|---|---|---|---|---|---|
| Wheat yield | Jin/mu | 394.90 | 114.91 | 789.73 | 136.65 |
| Fertilizer | Jin/mu | 21.08 | 0.32 | 77.50 | 17.82 |
| Seeds | Yuan/mu | 14.47 | 1.02 | 53.64 | 11.35 |
| Pesticide | Yuan/mu | 2.56 | 0.01 | 21.80 | 3.13 |
| Machinery | Yuan/mu | 11.84 | 0.00 | 96.81 | 15.61 |
| Other inputs | Yuan/mu | 14.09 | 1.68 | 29.27 | 48.94 |
| Share of wheat | | 0.23 | 0.05 | 0.47 | 1.21 |
| Temperature | °C | 12.09 | 4.80 | 22.40 | 1.34 |
| Precipitation | mm/month | 51.06 | 12.20 | 196.00 | 161.40 |
| Cloud cover | % | 56.70 | 32.30 | 80.08 | 1.23 |
| Observations | | 462 | | | |

*Note*: Jin and mu are China imperial units for weight and area respectively, 1 Jin = 500 g, 1 mu = 0.0667 ha. Yuan (Chinese currency unit) is 1980 constant Yuan.

The analytical challenge is to separate the non-climate effect on crop yields from the climate change effect. We hypothesize the crop yield as a function of crop inputs, technology, management, land quality, and climate factors. The initial explanatory variables for the yield equation include inputs such as land, labor, chemical fertilizer, seeds, pesticide, machinery, irrigation and other physical inputs; regional production specialization; climate variables such as temperature, precipitation and solar radiation; a set of regional dummy variables; and two institutional change dummy variables. In this study, the labor input is measured in terms of working days from the survey data. Previous study (Stavis, 1997) found the marginal return to labor input was negligible due to the huge labor surplus in agricultural in China. Our own estimation confirms this finding: labor and draft animals have a negative sign for wheat yield equation, indicating the impact of these two variables on yield were negligible. Therefore the inputs of labor and draft animal are not included in the model. The physical inputs are measured in expenses per unit-harvested area, and are selected based upon the sign and level of statistical significance. We included chemical fertilizer, seeds, pesticide, machinery individually and combined the rest of inputs into an aggregated category of "other inputs". The regional production specialization variable is represented by the share of wheat area in total crop area in that province. This variable is created to reflect the other factors such as soil quality and others (e.g. regional government supports to wheat production). It is expected that the regions with a higher share of the crop production have better suitable land and better environment for wheat production and therefore higher wheat yield. Admittedly, this variable may be a potentially endogenous variable, as the decision between how much area to grow in a grain crop and how much to grow in a cash crop depends on trade-offs that involve yields and relative productivity and profitability. The Hausman–Wu procedure (Wu, 1973; Hausman, 1978) was used to test the exogeneity of the share of area under wheat. Predicted wheat areas are not significant in the test equation, indicating that it is exogenous for the yield equation. A set of regional dummy variables are used to represent time-persistent, regional differences in social, economic, and natural endowments not accounted for by the other variables. During our study period (1979–2000) China undertook major policy reforms: the Household Responsibility System in the early 1980 s and the new development in agricultural policy in late 1990s. We used time-specific dummy variables to reflect these two major policy changes. Finally, a time trend is used to represent the factor due to technological change during this period.

Finally, a Cobb–Douglas form of wheat yield function is specified as follows:

$$\ln Yield_{it} = (\alpha_0 + \alpha_1 t) + \sum_{j=1}^{5}\beta_j \ln X_{jit} + \gamma \ln S_{it} + w \ln Climate_{it} + \sum_{r=2}^{7}\delta_r D_r + \sum_{l=1}^{2} r_l D_l + \varepsilon_{it} \quad (1)$$

where ln is natural log, $t$ = 1, 2, ..., 22 denotes observations from the years 1979 to 2000. $Yield_{it}$ refers to wheat yield for Chinese province $i$ at time $t$ (the time trend from 1979 to 2000); $X$ represents the conventional inputs per hectare of sown wheat area including seeds, fertilizer, pesticide, machinery, and other inputs such as irrigation, manure, and animal power. Fertilizer is represented by actual amount of Nitrogen fertilizer applied, and all other inputs are represented by real expenses per hectare of sown wheat area (see Table 1 for more); $S$ denotes the share of wheat area in total sown area, reflecting the regional specialization (including land quality) in wheat production; *Climate* is the climate variables including temperature, rainfall and solar radiation during

**Table 2**
Wheat growing seasons by provinces in China.

| | Area (1000 Ha) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beijing | 47.4 | | | | | | | | | | | | |
| Tianjin | 95.9 | | | | | | | | | | | | |
| Hebei | 2449.6 | | | | | | | | | | | | |
| Shanxi | 798.1 | | | | | | | | | | | | |
| Mongolia | 464.6 | | | | | | | | | | | | |
| Liaoning | 49.8 | | | | | | | | | | | | |
| Jilin | 23.0 | | | | | | | | | | | | |
| Heilongjiang | 260.8 | | | | | | | | | | | | |
| Shanghai | 31.4 | | | | | | | | | | | | |
| Jiangsu | 1715.9 | | | | | | | | | | | | |
| Zhejiang | 94.2 | | | | | | | | | | | | |
| Anhui | 2056.9 | | | | | | | | | | | | |
| Fujian | 23.5 | | | | | | | | | | | | |
| Jiangxi | 28.5 | | | | | | | | | | | | |
| Shandong | 3397.5 | | | | | | | | | | | | |
| Henan | 4855.7 | | | | | | | | | | | | |
| Hubei | 700.1 | | | | | | | | | | | | |
| Hunan | 99.8 | | | | | | | | | | | | |
| Guangdong | 10.7 | | | | | | | | | | | | |
| Guangxi | 12.8 | | | | | | | | | | | | |
| Hainan | | | | | | | | | | | | | |
| Chongqing | 388.2 | | | | | | | | | | | | |
| Sichuan | 1456.9 | | | | | | | | | | | | |
| Guizhou | 498.4 | | | | | | | | | | | | |
| Yunnan | 604.2 | | | | | | | | | | | | |
| Tibet | 44.8 | | | | | | | end | start | | | | |
| Shaanxi | 1356.7 | | | | | | | | | | | | |
| Gansu | 1080.0 | | | | | | | | | | | | |
| Qinghai | 142.5 | | | | | | | | | | | | |
| Ningxia | 370.8 | | | | | | | | | | | | |
| Xinjiang | 749.7 | | | | | | | | | | | | |

*Note*: (1) Area (column 2) is the wheat harvested area in 2000. (2) *Source*: Chinese Academy of Agricultural Sciences (CAAS) and personal communication.

wheat growing season. We approximate the solar radiation with cloud cover expressed in percentage. Therefore, the higher the cloud cover, the weaker the sun radiation. Since we are dealing with different wheat seasons and latitudes, the day length and solar declination are different from place to place and from winter season to spring season. We tried the well-known Angstrom equation (Angstrom, 1924) to capture the above variation but found that the results are similar (e.g. sun radiation is still not statistically significant). Therefore, we still use the simpler cloud cover in our model. We include a set of regional dummy variables, $D_r$, to represent time-persistent, regional difference in social, economic and natural endowments not accounted for by other variables. These seven regions in China are: Northeast (Heilongjiang, Liaoning, Jilin), North (Beijing, Tianjin, Hebei, Henan, Shandong, Shanxi, Shaanxi), Northwest (Nei Mongguo, Ningxia, Xinjiang, Tibet, Qinghai, Gansu), Central (Jianxi, Hunan, Hubei), Southeast (Shanghai, Jiangsu, Zhejiang, Anhui), Southwest (Sichuan, Guizhou, Yunnan), South (Gangxi, Fujian, Hainan, Guangdong). Time-specific dummy variables, $D_I$, capture the effects of two major policy reforms in agriculture from 1979 to 1985, and from 1995 to 2000. $\alpha$, $\beta$, $\gamma$, $w$, $\delta$, $r$ are parameters to be estimated and $\varepsilon$ is the error term.

## 3. Estimation and results

We first perform augmented Dickey–Fuller unit root test to test the stationarity of both dependent and independent variables. No problems are found. The model is estimated by SAS package. Since the OLS (ordinary linear square) estimation has autocorrelation problems, we also estimated Eq. (1) using an autoregressive error model with one-year lag (AR1). The constant variance error (no heteroscedasticity) assumptions are examined by plots between the predicted values and residuals using AR1 estimation. The plot (not reported here) shows that the assumptions for Eq. (1) is reasonably held. We also examine another plot between predicted value and time trend and found no autocorrelation problem.

**Table 3**
Estimated wheat yield function in China, 1979–2000. Dependent variable = Ln(wheat yield).

| Explanatory variables | OLS | AR1 |
|---|---|---|
| Constant | 8.341 (48.73)*** | 7.549 (37.41)*** |
| Ln fertilizer | 0.057 (3.31)*** | 0.040 (2.63)*** |
| Ln seeds | 0.192 (5.14)*** | 0.181 (2.25)** |
| Ln pesticide | 0.064 (5.22)*** | 0.038 (4.61)*** |
| Ln machinery | 0.026 (1.99)** | 0.019 (2.09)** |
| Ln other inputs | 0.103 (13.08)*** | 0.114 (3.57)*** |
| Ln share of wheat | 0.122 (4.28)*** | 0.121 (3.06)*** |
| Ln temperature | −0.502 (−10.33)*** | −0.403 (−6.33)*** |
| Ln precipitation | 0.031 (−2.04)* | 0.021 (−2.26)** |
| Ln cloud cover | 0.073 (0.27) | 0.067 (0.98) |
| Time | 0.024 (4.96)*** | 0.021 (4.15)*** |
| Regional dummy (Northeast) | −0.109 (−1.89)** | −0.139 (−1.61)** |
| Regional dummy (North) | −0.103 (−0.39) | −0.120 (−0.38) |
| Regional dummy (Northwest) | −0.348 (−11.88)*** | −0.319 (−7.53)*** |
| Regional dummy (Central) (Central) | −0.102 (−2.09)*** | −0.127 (−1.63)** |
| Regional dummy (Southeast) (Central) | 0.006 (0.16) | 0.070 (1.38) |
| Regional dummy (Southwest) (Central) | −0.310 (−6.18)*** | −0.358 (−5.31)*** |
| Institutional dummy (1979–1985) | 0.051 (1.40) | 0.048 (1.03) |
| Institutional dummy (1995–2000) | −0.091 (−2.54)*** | −0.095 (−2.11)* |
| Degree of freedom | 462 | 461 |
| Adjusted $R^2$ | 0.801 | 0.835 |

Numbers in parentheses are $t$-values.
* 0.10 level of statistical significance.
** 0.05 level of statistical significance.
*** 0.01 level of statistical significance.

Another potential problem may be omitted variable bias where some temperature-related variables (such as disease or pests) that affect wheat yield but have been left out of Eq. (1). We perform the Ramsey (1969) regression specification error test (RESET) for omitted variables. The test is passed ($P > 28\%$). The assumptions of normal distribution for errors, outliers, and linearity are also diagnosed and these assumptions are found to still hold. In addition, we estimate the equation with both fixed-effects and random-effects but found little difference.

The estimated results are reported in Table 3. The OLS estimates for all parameters for physical inputs are significant at the 10% level or below with the expected signs. The AR1 estimates differ slightly from OLS with some improvements, and all parameters are still significant at the 10% level or below. So we will only refer to the OLS results in the rest of the paper. As expected, the regional specialization is positively correlated with wheat productivity. The regional dummies in Northeast, Northwest, Central, Southwest China are statistically significant. While the institutional dummy between 1979 and 1985 has a positive sign, meaning the policy reform during this period does contribute to the wheat productivity growth, it is not significant. On the other hand, the change in agricultural policy after 1995 has a negative impact on wheat productivity that is measurable at the 10% level of statistical significance. We find no significant relationships between wheat yield and solar radiation. However, the temperature has a significantly negative effect while rainfall has a significantly positive effect on wheat yield. The significance for rainfall is at 10% level, reflecting the influence of rainfall on wheat productivity in such dry areas as Loess Plateau. Temperature has at or above 1% significance level. This may reflect the significant impact of the wide range of wheat growing season temperatures as well as of global warming on wheat yield in China. Because we use double-log functional form, the estimated coefficients are elasticities in the above equation. The coefficient for temperature, −0.50, means a 1% increase of growing season temperature could reduce wheat yield by 0.5% (Table 3).

Since our major focus is to measure the contribution of growing season temperature on wheat yield, it is convenient to treat other terms in Eq. (1) as "residual" effect. By subtracting the non-climate terms from the wheat yield, we single out the wheat yield change due to climate change. We define $Yield^{Climate}$ as

$$\ln Yield^{Climate} = \ln Yield_{it} - (\alpha_0 + \alpha_1 t) - \sum_{j=1}^{5} \beta_j \ln X_{jit} - \gamma \ln S_{it} - \sum_{r=2}^{7} \delta_r D_r - \sum_{l=1}^{2} r_l D_l \tag{2}$$

The following figure shows the relationship between this net wheat yield change and the relative change of wheat growing season temperature. The downward slope of the trend line clearly

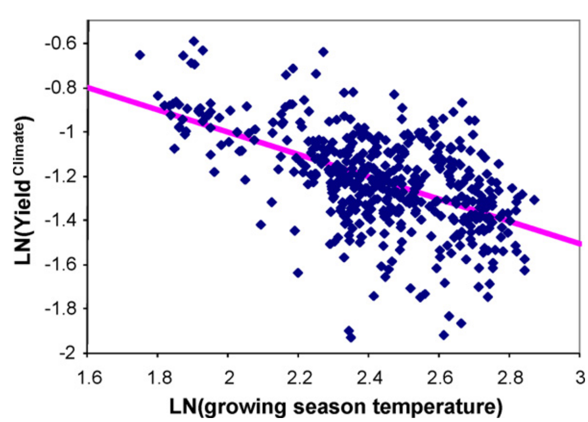


**Fig. 1.** Correlation between growing season temperature and wheat yield change due to climate change. The slope for the regression line is −0.268, $R^2$ = 0.80, $n$ = 462.

**Table 4**
Comparison: impact of 1 °C increase of growing season temperature.

| Study | Crop | Location | Impact |
|---|---|---|---|
| Nicholls (1997) | Wheat | Australia | +30 to +50% |
| Lobell and Asner (2003) | Corn, Soybean | USA | −17% |
| Peng et al. (2004) | Rice | Philippines | −10% |
| Our study | Wheat | China | −3% to −10% |

**Table 5**
Accounting for wheat yield growth.

| Explanatory variable | Estimated coefficients (1) | Average values | | 1979–2000 | |
|---|---|---|---|---|---|
| | | 1979–1981 | 1998–2000 | Change in explanatory variable (2) | Contribution to growth (3) = (1) × (2) |
| Inputs | | | | | 54.96 (64.35) |
| Chemical fertilizer | 0.06 | 8.84 | 40.20 | 355.00 | 20.08 (23.51) |
| Seeds | 0.19 | 15.90 | 26.14 | 64.39 | 12.34 (14.45) |
| Pesticide | 0.06 | 1.69 | 5.40 | 220.33 | 14.22 (16.65) |
| Machinery | 0.03 | 7.66 | 32.54 | 324.62 | 8.57 (10.03) |
| Other inputs | 0.10 | 12.30 | 12.00 | −2.43 | −0.25 (−0.29) |
| Specialization | 0.12 | 18.55 | 17.10 | −7.80 | −0.95 (−1.11) |
| Climate | | | | | −4.02 (−4.62) |
| Temperature | −0.50 | 12.36 | 13.29 | 7.57 | −3.80 (−4.45) |
| Precipitation | 0.03 | 64.53 | 61.42 | −4.82 | −0.15 (−0.17) |
| Residual[a] | | | | | 35.36 (41.39) |
| Total growth | | 268.87 | 498.51 | 85.41 | 85.41 (100.00) |

The estimated coefficients are taken from Table 3 and the change in explanatory variable refers to percentage growth of that variable from 1979–1981 to 1998–2000 (three-year averages are taken to avoid atypical year). The numbers in parentheses are the percentage shares of contribution to total wheat yield growth, with total yield growth set at 100.

[a] An accounting residual derived by netting out the effects of inputs, specialization and climate. Here it mainly reflects the impact of agricultural R&D and institutional change.

shows the negative impact of rising temperature on wheat yield in China (Fig. 1).

Across wheat growing provinces in China, the growing season temperatures vary from 5 to 18 °C. Therefore, 1 °C increase of temperature is equivalent to 5.6–20% of relative change. Considering the estimated temperature coefficient in the wheat yield function to be −0.50, this means 3–10% decline of wheat yield for each 1 °C increase of temperature. This estimated effect of temperature on wheat yield is smaller than the previous three studies: rice in Philippines (Peng et al., 2004), wheat in Australia (Nicholls, 1997), corn and soybean in USA (Lobell and Asner, 2003). Table 4 shows the comparison among these studies. The reason for this is two-fold: this might reflect the nonlinear effect of physical inputs and crop management on crop yields (Gu, 2003; Godden et al., 1998), or imply that the temperature effect on crop yields varies from one region to another, or from crop to crop. In particular, our result is of different sign from Nicholls (1997), a considerable difference. Both Godden et al. (1998) and Gifford et al. (1998) made a strong case that the result and method of Nicholls (1997) are questionable.

To assess the relative contribution of rising growing season temperature on the wheat yield, we take the first derivative of Eq. (1) with respect to $t$ (Lin, 1992; Huang and Rozelle, 1995; Fan and Pardey, 1997).

$$\frac{\partial \ln Yield_{it}}{\partial t} = \alpha_1 + \sum_j \beta_j \frac{\partial \ln X_{jit}}{\partial t} + \gamma \frac{\partial \ln S_{it}}{\partial t} + w \frac{\partial \ln Climate_{it}}{\partial t} + \sum_{r=2}^{7} \delta_r \frac{\partial D_r}{\partial t} + \sum_{r=1}^{2} r_l \frac{\partial D_l}{\partial t} + \frac{\partial \varepsilon_{it}}{\partial t} \quad (3)$$

Table 5 reports the growth accounting based on the estimate of the wheat yield function in column 2 of Table 3. To make the values easier to understand, we included the average value for each parameter at 1979–1981 and 1998–2000 (three-year average). The total wheat yield growth from 1979 to 2000 was 85.4% (from 268.9 Jin/mu in 1979 to 498.5 Jin/mu in 2000). From the accounting in Table 5, it appears that 64.4% of this yield growth comes from increased use of physical inputs. Rising temperature attributed to 4.5% of decline in wheat yield while rainfall has a negative contribution of about 0.2%, far smaller than that from rising temperature. The total negative contribution from climate, −4.7%, is relatively small compared to that of physical inputs, which underlines the necessity of including physical inputs in the regression analysis of crop yield-climate interactions (simple detrending of wheat yield and temperature while ignoring the physical inputs finds no significant relationship between wheat yield and temperature ($R^2 < 0.001$)).

## 4. Conclusion

Since the introduction of rural reforms in China in the late 1970s, agricultural production and productivity for wheat has increased significantly. While the majority of wheat productivity increase is due to increase use of physical inputs, agricultural R&D investment and the institutional change, the gradual increase in growing season temperature in the last few decades has had a measurable effect on wheat productivity. In this paper, we have evaluated the impacts of climate and non-climate factors on wheat yield growth in China, and find that a 1% increase in wheat growing season temperature reduces the yield by about 0.5%. The rising temperature from 1979 to 2000 cut wheat yield growth by 4.5% while declining precipitation results in −0.2% of wheat yield growth. There is a deficiency in the current literature about how to measure the influence of climate on productivity. Authors frequently fail to distinguish between climate factors and the influence of modern inputs and management practice on productivity. We emphasize the necessity of including such major influencing factors as physical inputs into crop yield-climate functions in order to have an accurate estimation of climate impact on crop yields. With so much uncertainty on the potential impacts of climate change, it is essential to first evaluate what past climate changes have had on agricultural productivity. Our study demonstrates a clear need to synthesize climate and crop-specific management and inputs data in order to investigate the impact of climate change.

In China, providing enough food to feed over 1.3 billion people is always a challenge. There is an increasing concern about the impacts of climate change on Chinese food security. Our study shows that climate change does have a measurable negative impact on wheat productivity. This negative impact would probably become worse with accelerating change of future climate. Our study demonstrates the need to consider climate change and its effects on crop productivity in order to meet the food security goals in China as well as in other developing countries. There is also a need to extend such studies to other regions, in particular to food insecure countries where climate change would have the most severe adverse impact on crop productivity.

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