Journal of Environmental Economics and Management 83 (2017) 8–31

Contents lists available at ScienceDirect

Journal of Environmental Economics and Management

journal homepage: www.elsevier.com/locate/jeem

Economic impacts of climate change on agriculture: The importance of additional climatic variables other than temperature and precipitation

Peng Zhang [a], Junjie Zhang [b,*], Minpeng Chen [c]

[a] School of Accounting and Finance; M507c Li Ka Shing Tower; The Hong Kong Polytechnic University; Hung Hom, Kowloon, Hong Kong

[b] Environmental Research Center, Duke Kunshan University; Nicholas School of the Environment, Duke University. No.8 Duke Avenue, Kunshan, Jiangsu 215316, China

[c] Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Science, Haidian District, Beijing 100081, China

ARTICLE INFO

Article history:
Received 7 May 2015
Available online 8 December 2016

JEL classification:
Q54
Q56
C23

Keywords:
Climate change
Agriculture
Humidity
Wind speed
China

ABSTRACT

Climate change shifts the distributions of a set of climatic variables, including temperature, precipitation, humidity, wind speed, sunshine duration, and evaporation. This paper explores the importance of those additional climatic variables other than temperature and precipitation. Using the county-level agricultural data from 1980 to 2010 in China, we find that those additional climatic variables, especially humidity and wind speed, are critical for crop growth. Therefore, omitting those variables is likely to bias the predicted impacts of climate change on crop yields. In particular, omitting humidity tends to overpredict the cost of climate change on crop yields, while ignoring wind speed is likely to underpredict the effect. Our preferred specification indicates that climate change is likely to decrease the yields of rice, wheat, and corn in China by 36.25%, 18.26%, and 45.10%, respectively, by the end of this century.

Introduction

Over the past decade, a growing body of economics research has projected the impacts of climate change on important facets of well-being, such as agriculture, industry, human health, energy demand, and economic growth (Dell et al., 2014). Given the natural relationship between climatic factors and plant growth, the agricultural sector is thoroughly researched (Mendelsohn et al., 1994; Schlenker et al., 2005, 2006; Deschênes and Greenstone, 2007; Schlenker and Roberts, 2009; Welch et al., 2010; Deschênes and Greenstone, 2012; Fisher et al., 2012; Roberts et al., 2012; Lobell et al., 2013; Chen et al., 2015; Burke and Emerick, 2016). However, the majority of these studies focus on temperature and precipitation, largely ignoring other climatic variables such as humidity, wind speed, sunshine duration, and evaporation (hereinafter referred to as additional climatic variables).[1] Though some studies have included one additional climatic variable, to our best

* Corresponding author.
E-mail addresses: peng.af.zhang@polyu.edu.hk (P. Zhang), junjie.zhang@duke.edu (J. Zhang), chenmp@ami.ac.cn (M. Chen).

[1] Relative humidity is a common measurement for humidity. It is defined as the ratio of the amount of water vapor in air to the maximum water vapor that air can hold at the given temperature. Humidity can also be approximately measured by vapor pressure deficit (VPD). We also explore the effect of VPD. In the rest of the paper, we use "humidity" interchangeably with "relative humidity."

http://dx.doi.org/10.1016/j.jeem.2016.12.001
0095-0696/

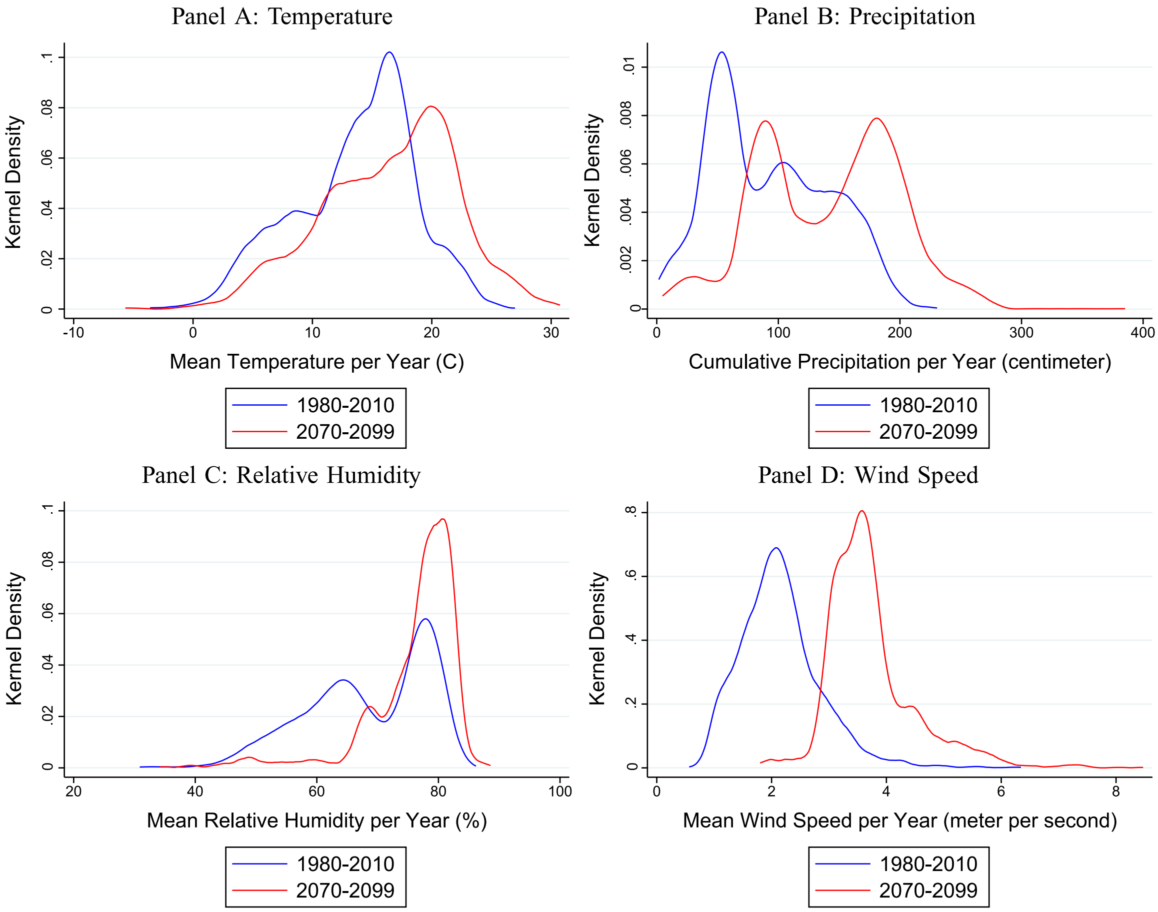

Fig. 1. The Kernel Density for Temperature, Precipitation, Relative Humidity and Wind Speed (1980–2010, 2070–2099). *Notes*: The observations are calculated at the county-year level. Temperature, relative humidity, and wind speed are annual averages calculated using daily values. Precipitation is calculated as the annual cumulative value. The blue line denotes historical distribution (1980–2010), while the red line represents forecast distribution (2070–2099). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

knowledge, none have systematically studied this issue.[2] Therefore, this paper identifies the key climatic variables besides temperature and precipitation that should be included in the models that use reduced-form econometrics to evaluate the impacts of climate change.

Omitting additional climatic variables can bias the predicted cost of climate change for a number of reasons. First, climate change shifts the distributions of a set of climatic variables (Hartmann et al., 2013), which is illustrated in Fig. 1 according to the widely used Hadley Model. Second, additional climatic variables could be essential for crop growth (Hoffman and Jobes, 1978; Nobel, 1981; Gallagher and Biscoe, 1978; Batchelor and Roberts, 1983). Furthermore, omitting additional climatic variables may also bias the estimated coefficients of temperature and precipitation, because climatic variables are highly inter-correlated (see Table 1) (Lawrence, 2005; Wooten, 2011; Rebetez and Beniston, 1998; Nkemdirim, 1991). As a consequence, including temperature and precipitation only is insufficient. The net effect of all climatic variables is essentially an empirical question.

In this paper, we explore the importance of those additional climatic variables—humidity, wind speed, sunshine duration, and evaporation—in the climate–agriculture relationship. Using the county-level agricultural data from 1980 to 2010 in China, we estimate and compare two models. The first model, referred to henceforth as the restricted model, includes only temperature and precipitation. The second model, referred to henceforth as the full model, includes additional climatic variables besides temperature and precipitation.

To begin with, we estimate the impacts of weather fluctuations on the yields of the three most important crops in China: rice, wheat, and corn. Our identification comes from the presumably random year-to-year fluctuations in local weather (Deschênes and Greenstone, 2007). To measure the nonlinear effects of temperature and also account for within-day variation in temperature, following Schlenker and Roberts (2009), we calculate the exposure within small temperature

[2] For example, Welch et al. (2010) and Chen et al. (2015) include solar radiation in addition to temperature and precipitation. Roberts et al. (2012) and Lobell et al. (2013) include vapor pressure deficit, which is used to approximately measure humidity, in addition to temperature and precipitation.