Journal of Environmental Economics and Management 76 (2016) 105–124

Contents lists available at ScienceDirect

Journal of
Environmental Economics and Management

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

Impacts of climate change on agriculture: Evidence from China

Shuai Chen [a,1], Xiaoguang Chen [b,*,1], Jintao Xu [c,1]

[a] Guanghua School of Management and IEPR, Peking University, Beijing 100871, China
[b] Research Institute of Economics and Management, Southwestern University of Finance and Economics, No. 55 Guanghuacun Street, Chengdu 610074, China
[c] National School of Development, Peking University, Beijing 100871, China

ARTICLE INFO

Article history:
Received 29 May 2014
Available online 30 January 2015

JEL classification:
Q54
Q10

Keywords:
Climate change
Agriculture
Temperature
Crop yields
Corn and soybeans
China

ABSTRACT

To move China's climate policy forward, improved analyses of climate impacts on economic sectors using rigorous methodology and high quality data are called for. We develop an empirical framework, using fine-scale meteorological data, to estimate the link between corn and soybean yields and weather in China. We find that (i) there are nonlinear and inverted U-shaped relationships between crop yields and weather variables; (ii) global warming has caused an economic loss of about $820 million to China's corn and soybean sectors in the past decade; and (iii) corn and soybean yields are projected to decline by 3–12% and 7–19%, respectively, by 2100.

Introduction

Development of effective strategies whereby agriculture can adapt to climate change over the coming decades requires farmers, agribusiness, crop scientists, and policy makers to understand potential climate risks posed by climate change (Howden et al., 2007). Existing studies have assessed the impacts of climate change on farmland value (Deschênes and Greenstone, 2007; Mendelsohn et al., 1994; Schlenker et al., 2006), and agricultural productivity (Lobell and Asner, 2003; McCarl et al., 2008; Olesen and Bindi, 2002; Ortiz-Bobea, 2013; Schlenker and Roberts, 2009) in the developed world. However, studies addressing similar issues in China, the world's largest developing economy, using a rigorous approach and high quality data, remain limited.

Over the past century, China has experienced some noticeable climate change. Annual average temperature has increased by about 0.5–0.8 °C during the past 100 years (Ding et al., 2007). The last century has also witnessed an increasingly uneven distribution of precipitation between the south with abundant water and the drier north, as well as some extreme climate events (Piao et al., 2010), such as the great flood in 1998 and the 2010–2011 drought. Although agriculture only accounts for a small share of GDP in China, it is an important industry, as it supports over 20% of the world's population with only 8% of global sown area. China has the world's largest agricultural economy, and is a major producer of cereal grains, meat, and vegetables (FAO Faostat-Agriculture, 2012). China is also a major importer of feed grains in the world market; it imported about 60% of the

* Corresponding author. Fax: +86 28 8735 6958.
E-mail addresses: shuaichenyz@gmail.com (S. Chen), cxg@swufe.edu.cn (X. Chen), xujt@pku.edu.cn (J. Xu).
[1] Seniority of authorship is shared equally.

http://dx.doi.org/10.1016/j.jeem.2015.01.005
0095-0696/

soybeans sold in the international market in 2010 (FAO Faostat-Agriculture, 2012). Therefore, how climate change affects China's agriculture can have important implications for the welfare of China's population of 1.3 billion and can generate profound impacts on world food/feed markets.

This issue is also highly relevant to the formation of China's national climate strategy. Agriculture is the most vulnerable economic sector under climate change, especially in developing countries like China. Different interpretations of climate change impacts on agriculture could lead to differences in a developing nation's strategy to address climate change. If the nation's agriculture is believed to suffer from severe climate change, it will be more likely to adopt an aggressive policy toward climate change mitigation. If, instead, the belief is that climate change is not going to have negative effects, or even will be beneficial to the nation's agriculture, the nation's response to climate change will not be strong. In this case, a conservative strategy would be developed and used by the nation in international climate negotiation. In fact, China's national climate strategy has been under the influence of agronomic studies (for example Xiong et al., 2007),[2] which found no adverse climate impacts on China's agriculture. As a result, China has been focusing on the costs of climate change mitigation instead of the benefits from mitigation, and has embraced a rather conservative national strategy to address climate change.[3] To affect the course of this strategic development, more analyses with high quality data and rigorous approaches are called for.

Currently, only two economic studies have investigated the impacts of climate change on China's agriculture with a particular focus on farmland value (Liu et al., 2004; Wang et al., 2009). However, due to the difference in the data used, they yielded mixed results. While Liu et al. (2004) found that warming had a positive impact on China's agriculture, Wang et al. (2009) showed that the climate effect on Chinese agriculture was negative. Both studies used cross-sectional data and thus relied on variations in weather across regions to identify the coefficients of weather variables. Therefore, they cannot capture the effects of year-to-year change in weather on agriculture. Crop simulation models have also been applied to assess the consequence of climate change on crop production in China (Lin et al., 2005; Xiong et al., 2007). However, these models apply agronomically optimal levels of inputs and ignore input prices, and thus tend to underestimate the true weather effects on crop yields (Schlenker et al., 2006).

Using a unique county-level panel on crop yields and newly available daily weather outcomes, we provide an empirical estimation on the relationship between weather variables and crop yields in China. The dataset contains county-specific crop yields in China during the period 2000–2009. The weather data consist of daily minimum, maximum, and average temperatures, precipitation, and solar radiation for most Chinese counties over the same period. The daily weather data facilitate accurate estimation of cumulative heat, precipitation, and radiation received by crops over their growing seasons. Here, we focus on corn and soybeans, because (1) China produces about 20% of the world's corn, second behind the U.S. (FAO Faostat-Agriculture, 2012); (2) soybean is the nation's predominant crop for edible oil production; (3) the two crops are widely produced across China and are important feed grains for livestock production; and (4) China heavily depends on imports to meet domestic demand for the two crops.

When estimating the relationship between corn and soybean yields and weather, we include temperature, precipitation, and radiation as weather variables. Using county-level crop yields and daily weather data in the U.S., Schlenker and Roberts (2009) found nonlinear temperature effects on corn, soybean, and cotton yields. In their regression analysis, they included temperature, precipication, and regional time trends as explanatory variables to explain the variations in crop yields. Agronomic literature has long suggested that temperature, precipitation, and radiation are three imporant factors for plant growth (Muchow et al., 1990; Szeicz, 1974). Radiation has also been emphasized as an important input for rice and wheat growth (see Auffhammer et al., 2006; Chameides et al., 1999; Welch et al., 2010). Therefore, omitting radiation as a weather variable in Schlenker and Roberts (2009) may lead to biased parameter estimates of the temperature and precipitation variables. This issue could be particularly serious if radiation was highly correlated with temperature or precipitation over crop growing seasons in their sample.

We construct two land-use-change (LUC) variables to reflect the change in soil quality under corn and soybeans stemming from the changes in regional land use patterns at the extensive and intensive margins, respectively. Most existing studies examining the impacts of climate change on crop yields assumed that soil quality remained constant over their study periods and used fixed-effect models to control for this unobservable heterogeneity across regions (see Schlenker and Roberts, 2009; Welch et al., 2010). Due to rising food prices in the past decade, corn and soybean production areas in China expanded by 8 and 1 million hectares (see Fig. 1), respectively, over the same period (NBS China, 2000–2009). Of the additional land under the two crops, some came from the reductions in land previously under other crops, such as rice, wheat, potato, cotton, sugarcane, and sugar beet, while the rest was converted from marginal lands. Because of the differences in soil quality of different land covers, regional land use changes may have affected county-average crop yields.

We also control for other factors that could affect county-average crop yields, such as input use and farmers' contemporaneous climate adaptation behaviors. Standard producer theory tells us that a rational farmer makes production decisions based on, among other factors, input and output prices, to maximize the net returns from crop production. The farmer may also make adaptations to climate change by adjusting cropping systems and altering irrigation water use in warmer growing seasons (Howden et al., 2007).

[2] The paper is the work of a team of agricultural scientists who were believed to be the most influential in China's climate strategy formation related to agriculture.

[3] For instance, China has stuck to performance-based environmental/climate policies for decades, such as energy-intensity and carbon-intensity targets rather than an overall greenhouse gas (GHG) emissions reduction target. Holland (2012)) showed that an intensity standard could be an inefficient instrument for reducing aggregate GHG emissions relative to an emissions target due to the provision of an implicit output subsidy.