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The impact of weather variations on maize yields and household income: Income diversification as adaptation in rural China

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ABSTRACT

Climate change is threatening global food production and could potentially exacerbate food insecurity in many parts of the world. China is the second largest maize producer. Variations in maize yields in China are likely to have major implications for food security in the world. Based on longitudinal data of 4861 households collected annually between 2004 and 2010, we assess the impact of weather variations on maize yields in the two main producing regions in China, the Northern spring maize zone and the Yellow-Huai Valley summer maize zone. We also explore the role of adaptation, by estimating the response of Chinese farmers in both regions, in particular in terms of income diversification. With the use of household and time fixed effects, our estimates relate within-household variations in household outcomes (maize yields, net income, land and input use) to within-location variations in weather conditions. Temperature, drought, wet conditions, and precipitations have detrimental effects on maize yields in the two maize zones. The impact is stronger in the Northern spring maize zone where one standard deviation in temperature and drought conditions decreases maize yields by 1.4% and 2.5%, respectively. Nonetheless, such impact does not seem to translate into a significant fall in total net income. Adaptation seems to be key in explaining such a contrast in the Northern spring maize zone where the largest impact is estimated. On the contrary, we find a lower impact in the other region, the Yellow-Huai Valley summer maize zone but such impact is likely to intensify. The lack of adaptation observed in that region results into detrimental impacts on net farm and total income. Enhancing adaptative behaviors among Chinese farmers even further is likely to be key to future food security in China and in the rest of the world.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2014) indicates with high confidence that climate variability together with extreme climatic events (heat waves, droughts, floods, and wildfires) threaten natural and human systems across the world. Distributional effects are expected but overall, climate changes are likely to reduce food production and potentially exacerbate food insecurity in many parts of the world (Burke et al., 2015). The extent to which economic agents adapt their production processes to changes in the environment is key to assess food security prospects (Lobell et al., 2014).

In this paper, we assess the impact of weather variations on maize yields in the two main producing regions in China. China is the second largest maize producer of the world. Variations in maize yields and production caused by weather events will strongly affect the world maize supply and demand. It has even been argued that shocks on Chinese maize supply could bear significant geopolitical consequences in other parts of world (Sternberg and Thomas, 2014). Moreover, with the dietary changes and higher meat consumption in China, the domestic demand for maize is strongly increasing. Maize is indeed widely used not only for human consumption but also for animal feeding and chemical industry in China. Therefore, understanding both the impacts of weather variations on maize yields and the ability of Chinese farmers to adapt is key to unleashing the potential of Chinese maize production under limited land resources, improving food security in China, and foreseeing potential economic and geopolitical consequences for the rest of the world.

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Our contribution is twofold. First, we contribute to the literature seeking to identify the impact of climatic variations on agriculture (Auffhammer and Schlenker, 2014; Dell et al., 2014; Hsiang, 2016). At the global level, extreme daytime temperatures have been documented to have a large negative effect on crop yields (IPCC, 2014). The relationship is unchanged since 1960 in both rich and poor countries (Burke et al., 2015). Global warming since 1981 has resulted in roughly 40 Mt or 5$ billion annual combined losses of three crops, wheat, maize and barley (Lobell and Field, 2007). In North America, although higher precipitation partly contributes to crop yield increases (Pearson et al., 2008; Nadler and Bullock, 2011), other climatic events, such as extreme heats and droughts have caused a marked increase in crop losses since 1999 (Hatfield et al., 2011). Temperature has also been found to be detrimental to agriculture in the United States (Schlenker et al., 2006; Fisher et al., 2012). So far, little evidence has been provided for developing countries, especially for Asian countries (IPCC, 2014). Africa has received much of the academic interest, with an overall negative effect on yields of major cereal crops (Schlenker and Lobell, 2010; Lobell et al., 2011; Roudier et al., 2011; Blanc, 2012).

As reviewed by Dell et al. (2014), the detrimental impact of weather variations, in particular temperature on rice yields, has also been documented for India (Guiteras, 2007), Indonesia, Thailand, as well as the Philippines (Welch et al., 2010). Maize has been found to be one of the most sensitive crops to weather variations, in particular temperature (Schlenker and Lobell, 2010). In China, weather variations also constitute a crucial determinant of maize yields and production, but there is little quantitative evidence on the impact of weather variations on maize yields in the main maize producing regions (Tao and Zhang, 2010; Zhang and Huang, 2012; Yao et al., 2014; Zhang et al., 2015).

In this paper, we assess the impacts of weather variations on maize yields from 2004 to 2010, using data from 4861 households across seven Chinese provinces. These provinces are grouped into the two main producing regions in China, the Northern spring maize zone and the Yellow-Huai Valley summer maize zone. These provinces account for about two thirds of Chinese maize production. One of the strengths of our analysis is the use of a panel dataset of households. That allows us to track maize yields for the same households over time while controlling for unobserved determinants of crop yields at the farm level. While other approaches, such as the enumerative one, have the advantage to be based on natural science experiments (Tol, 2009), one of the strengths of panel regression analyses in this setting is to track maize yields for the same households overtime while controlling for unobserved determinants of crop yields at the farm level. Such approaches has been popularized in modern economic analysis since Deschenes and Greenstone (2007) and has been widely used to assess the impact of weather variations on socio-economic outcomes (Dell et al., 2014; Hsiang, 2016), and agricultural outcomes in particular (Auffhammer and Schlenker, 2014). We also use advanced weather indexes (such as the "standardized precipitation evaporation index", "moderate degree days" and "extreme heat days") to capture extreme weather deviations. Compared to previous studies on China (Tao et al., 2008; Tao and Zhang, 2010; Li et al., 2011; Zhang and Huang, 2012; Ming et al., 2015; Zhang et al., 2015), we provide a more credible identification by exploiting within-village variations in weather together with observed and unobserved household characteristics to account for potential heterogeneity within villages. Our results indicate that in the Northern spring maize zone, an increase by one standard deviation in temperature translates into a fall of about 1.4% in maize yields. According to the IPCC (2014), average temperature is expected to increase by 2–4 °C in the second half of the 21st century and beyond (IPCC, 2014). Without adaptation, that would correspond to a decrease between 1.8% and 3.6% in maize yields in China. The impact of a similar change in the occurrence of SPEI based drought is almost twice as large, with a partial effect of −2.5%. Similar results are found for the Yellow-Huai Valley summer maize zone with much smaller partial effects of −1.09% and −0.8% for temperature and SPEI based drought indexes, respectively.

The second contribution of the paper is to shed light on the issue of adaptation, recognized as the most pressing research question in the most recent and comprehensive overview on the social and economic impact of climate (Carleton and Hsiang, 2016). The importance of adaptation has also been recently recognized as the missing link to bridge short-run impacts to long-run interpolation, while maintaining careful identification (Burke and Emerick, 2016; Dell et al., 2014). Adaptation has indeed been found to constitute a key strategy to cope with the negative effects of climate change (Costinot et al., 2016; Olmstead and Rhode, 2011). On average, adaptation seems to improve yields by the equivalent of 15–18% of current yields, but the effectiveness of adaptation has varied significantly across different regions of the world (IPCC, 2014). Adaptation has also been found to be more limited for maize production, compared to wheat and rice (Lobell et al., 2014). In this study, information about the sources of income and input use at the household level is exploited to explore the adoption of adaptation strategies at the micro-level, often overlooked or attenuated at more aggregated levels (Di Falco et al., 2011). In particular, we investigate how estimated impacts on maize yields may translate into net income changes at the household level. One approach is to directly observe behavioral responses of farmers in terms of planting and management practices. For example, Di Falco et al. (2011) directly analyze how adaptation strategies at the farm level in the form of changing crop varieties, adoption of soil and water conservation strategies and tree planting affect food productivity in the Nile Bassin of Ethiopia. In this area, adaptation seems to have been quite effective in increasing food productivity. Our paper is closer to a second approach that seeks to indirectly infer adaptation based on different estimation methods or alternative dependent variables. Burke and Emerick (2016) have seminally shown how contrasting results from fixed effects model with those from long difference model can shed light on possible adaptation or intensification. Applying a similar approach, we do find mixed evidence with respect to adaptation. In the Northern Spring maize zone, where the short-run impact of weather variations has been the strongest, we do find some evidence for (limited) adaptation, in particular to temperature variations. About 14% of short-term yield losses from temperature have been alleviated in the long run. On the contrary, intensification effects of temperature amounting to about 13% have been observed in the Yellow-Huai Valley summer maize zone.

Our paper is also related to a literature that seek to infer adaptation by contrasting the impact on yields to the one on household income. To the best of our knowledge, the literature using micro-level data is fairly limited in that respect. Most studies have investigated the impact on net farm income at an aggregated level (Deschenes and Greenstone, 2007; Fisher et al., 2012; Prajapati et al., 2010). At a household or farm level, there is only limited evidence. Kurukulasuriya et al. (2006) adopt the Ricardian method to estimate the impacts of climatic variations on total net farm incomes (defined as the sum of incomes from dryland crops, irrigated crops, and livestock) in Africa. They find that net income originating from dryland crops fall on average by $27 per hectare following 1 °C increase in temperature. By contrast, revenue from irrigated crops increases on average by $30 per hectare. Temperature is found to have a muted effect on irrigated crops, partially because irrigation buffers rainfall shortages and irrigated crops are planted in relatively cool locations in Africa. In the case of