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Climate change, adaptation and China's grain production

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This paper measures the economic impacts of climate change on China's grain production by using provincial time series data over a 32-year period. The panel data model and time series region model with/without adaptation are applied at the same time to assess the effectiveness of a common production function. To capture the effects of weather variables we employ a random coefficients model where the production elasticities are the logarithmic function on temperature and rainfall. A Cobb–Douglas production function with additional interaction between inputs and climate variables is applied. We find that the economic impacts of climate change are mixed, that is, some regions are winners and others are losers, and the effect is crop-specific, not general. With adaptation, the economic impacts of warming on grain production are always positive; less precipitation will benefit rice production, but will harm wheat and maize production. Most of the central, western and northern China, which have already been adapted, are less sensitive to climate variables, but some eastern provinces, such as Shandong and Hebei, are very vulnerable. However, this study finds that the adaptation by irrigation is not sensitive to climate change. In summary, the analysis indicates that policymakers should recognize that the climate change would change the productivity of factors, so a regional and crop-specific total-factor-adaptation model is recommended.

1. Introduction

Adaptation to global climate change refers to "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change." (IPCC, 2001, p. 879; cf Burton & Lim, 2005). The importance of climate change to China's agricultural and rural economies cannot be understated. With some 750 million individuals and 250 million households directly or indirectly engaged in primary agricultural production in China the issue of global climate change and how climate change affects agricultural productivity is of major political and economic importance (IPCC, 2007; Lobell, Cahill, & Field, 2007; Peng et al., 2004; Sheehy, Mitchell, & Ferrer, 2006; Xiong et al., 2008). As the fourth largest country in the world, China has a complex and diverse terrain and a large cross-latitude which touches the tropical belt in the south and cold temperate zone in the north. Over the past decades, China has already experienced a strong warming trend and some devastating climate extremes. Hence, the assessment of China's agriculture vulnerability to climate change has become increasingly important for such a populous country. We suspect that like the rest of the world, China would be sensitive to the impacts of climate change, but whether this sensitivity will have positive or negative effects on agriculture and agricultural productivity remains an open question. Even at the most basic level, understanding how farmers might adapt to climate change is a significant step towards understanding the uncertainties regarding technology adoption, market competition, trade

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negotiations and regulation, economic and relative efficiency and comparative advantage, aggregate demand, and consumer demand, population growth and income inequality, environmental externalities, and the minutiae of seemingly unrelated activities that individually might have no apparent consequence but can collectively have substantial effects (Burton & Lim, 2005; Mount, 1994). The broader question, as put by Reilly (1999) is how will society be affected by global climate change through its effect on agriculture? This requires answering the question of 'what effects would climate change have in agricultural production?'

This paper measures the economic impacts of climate change on China's grain gross revenue by using provincial panel data over a 32-year period. To capture the effects of weather variables we employ a random coefficients model where the production elasticities are the logarithmic function on temperature and rainfall. A Cobb–Douglas production function with additional interaction between inputs and climate variables is assumed. Our results bring good and bad news. The heat elasticities for Early Indica rice, Indica rice, Late Indica rice, Japonica rice, wheat and maize are 0.801, 0.265, −1.060, 0.068, 0.142, and 0.018 respectively. Only Late Indica rice has a negative and nearly perfectly elastic response. These results suggest that if temperatures rise by 1% Early Indica rice will benefit most with an increase in value of 0.801% but Late Indica rice will fall in gross value by 1.060%. The rainfall elasticities for Early Indica rice (−0.023), Indica rice (−0.032), Late Indica rice (−0.024) and Japonica rice (−0.033) will have a generally inelastic response to decreased rainfall, but wheat (0.022) and maize (0.004) may see reductions in production but by a small amount. A 1% decrease in rainfall will result in a 0.022% reduction in gross value of wheat and only 0.004% reduction in maize.

This paper reports results of a new study that measures the sensitivity and adaptation of China's grain production to climate change. Compared to previous studies, this paper focuses on the climatic impact on the elasticity of the factors of production, rather than on the factors themselves. Matching the input and output data to climate data (temperature and precipitation) is a more effective method to analyze the economic effect of climate change and we do this in a unique way: Rather than treating weather variables as ordinary inputs to the production inputs with their own production elasticities, we argue that the real effects are through their impact on the physical/economic production elasticities themselves. In other words, rather than determining (for example) the input elasticity and precipitation elasticity separately, our approach asks how the input elasticity changes endogenously and simultaneously with precipitation. Thus, in terms of adaptation strategies we show how the input elasticity, and hence its marginal productivity, increases or decreases with changes in precipitation while simultaneously creating a measure of precipitation elasticity that is conditional on input use or expenditures. The analysis employs provincial data from 1979 to 2010 (which includes all of the data available to us), including six crop varieties (Early Indica rice, Indica rice, Late Indica rice, Japonica rice, wheat, maize). The data contains the information on each crop's provincial average economic cost data, such as labor, fixed assets, fertilizer, pesticide, machine, irrigation and operating cost. We use a hedonic approach which is a blend of Ricardian analysis which focuses on land as the unit of output and the whole farm production function approach which uses crop revenue as the unit of measure.

The paper proceeds as follows: In the next section we develop our theoretical model which shows how weather variables and input variables interact. Our focus is on the structure and form of the production and weather elasticities. The following section reviews various approaches used to capture adaptation to climate change including growth and climate models, dynamic statistical approaches, and our preferred hedonic method which blends the Ricardian and whole farm production function approaches. This is followed by the specification of our econometric models, discussion of results and conclusions.

2. Theory and methods

2.1. Theory

There are two main approaches to estimating adaptation strategies to climate change. The first approach is to use historical weather and output relationships and the second is to use climate forecasts and crop simulation models. We combine these approaches by first estimating the historical relationships over the past 32 years to capture yearly variables and trends, and then we use long-run predictions from climate models to evaluate what the likely impact will be under global climate change.

To place our results in perspective, agronomic studies have shown that grains have the greatest potential to be adversely affected by climate change due to the low responsiveness of C_4 crops[2] to increased CO_2 concentrations (Ainsworth, Leakey, Ort, & Long, 2008; Long, Ainsworth, Leakey, Nosberger, & Ort, 2006), and their relatively high sensitivity to extreme heat (Schlenker & Lobell, 2010; Schlenker & Roberts, 2006). Several studies investigating the impact on China's grain yield (e.g., rice, maize, and wheat) in response to climate change have been conducted (Tao, Hayashi, Zhang, Sakamoto, & Yokozawa, 2008; Xiong, Lin, Ju, & Xu, 2007; Zhang, Zhu, & Wassmann, 2010) but with conflicting results that are highly dependent on climate scenarios, socio-economic development and the effects of CO_2 fertilization on crop yields (Xiong et al., 2009). Xiong et al. (2009) project climate-induced yield reductions of 4–14% for rice, 2–20% for wheat, and 0–23% for maize by the year 2050 with some scenarios without adaptation showing a decrease in cereal production up to 40%. Tao et al. (2008) project that a one-degree rise in temperature may decrease rice yield; You, Rosegrant, Wood, and Sun (2009) found a 4.5% reduction in wheat yields attributable to rising temperature recorded from 1979 to 2000. Maize yields may also have been sensitive to recent warming, with data from eight Chinese provinces showing a negative response to the rising temperature during the period 1979–2002 (Tao et al., 2008).

[2] A C_4 plant in which the CO_2 is first fixed into a compound containing four carbon atoms before entering the Calvin cycle of photosynthesis. A C_4 plant is better adapted than a C_3 plant in an environment with high daytime temperatures, intense sunlight, drought, or nitrogen or CO_2 limitation.