HOW CHINA'S FARMERS ADAPT TO CLIMATE CHANGE?

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ABSTRACT

This paper examines how farmers have adapted to the current range of climates across China. A cross sectional method is used to analyze irrigation choice and crop choice across 8,405 farmers in 28 provinces in China. We find that both irrigation and crop choice decisions are climate sensitive. Chinese farmers are more likely to irrigate when facing lower temperatures and less precipitation. Farmers in warmer places are more likely to choose oil crops, maize, and especially cotton and wheat, and are less likely to choose vegetables, potatoes, sugar and especially rice and soybeans. In wetter locations, farmers are more likely to choose soybeans, oil crops, sugar, vegetables, cotton and especially rice, and they are less likely to choose potato, wheat and especially maize. The analysis of how Chinese farmers have adapted to current climate, provides insight into how they will likely adapt when climate changes. The analysis does not take into account other background changes that may well occur, including changes in prices, technology, and water availability. Policy makers should anticipate that adaptation is important, that the magnitude of changes depends on the climate scenario, and that the desired changes depend on the location of each farm.

Key words: Climate Change, Adaptation, Irrigation Choice, Crop Choice, China

I. INTRODUCTION

Although there is an extensive literature on the effects of climate on agriculture (Reilly et al 1996; McCarthy et al 2001), there are very few studies that have measured adaptation. Studies that compare the impacts of climate change that include adaptation, such as Ricardian studies (Mendelsohn, Nordhaus, and Shaw 1994, Mendelsohn and Dinar 1999; Mendelsohn et al. 2001; Mendelsohn and Dinar 2003; Seo et al. 2005; Kurukulasuriya et al. 2006; Fleischer et al 2007; Seo and Mendelsohn 2007, Wang et al. 2008), tend to find much lower damages than studies that do not include adaptation, such as agronomic analyses (Rosenzweig and Parry 2004; Reilly et al. 1996; McCarthy et al 2001; Parry et al. 2004). It is clear from this empirical evidence that it is very important to include adaptation in any impact analysis of long term climate change. Of course, adaptation is likely to be less important with respect to year to year weather fluctuations as farmers may have fewer options to adapt to sudden or abrupt changes.

Adaptations are actions that people and firms take in response to climate change to reduce damages or increase benefits (IPCC 2007). What specifically do farmers do to adapt to climate? How have they adjusted to the climates that they live in today? A new series of studies have begun to examine this question. By comparing what farmers do in one climate zone versus another, the studies quantify how farmers have made long term adjustments to climate. For example, studies have examined how climate affects the choice of irrigation in Africa (Kurukulasuriya and Mendelsohn 2006a) and South America (Mendelsohn and Seo 2007). Studies have explored how climate affects livestock choice in Africa (Seo and Mendelsohn 2006) and South America (Seo and Mendelsohn 2007a). Previous studies have explored how climate alters crop choice in Africa (Kurukulasuriya and Mendelsohn 2006) and South America (Seo and Mendelsohn 2007b). All of the above mentioned adaptation studies find that farmers adjust irrigation practices, crop varieties, and livestock species to both temperature and precipitation levels.

In the present analysis, we use the same cross sectional methods used in the above studies of Africa and South America to study farm adaptation in China. We expect that farmers in China have also adapted to the range of climates that they face in China. In

order to realize this purpose, the paper is organized as follows. In the second section, we discuss the available data and the construction of the variables in the data set. In the third section, we present the econometric models and the estimation results for current farmers. The paper concludes with a summary of the key results and a discussion of policy relevance.

II. DATA

The climate data (monthly temperature and precipitation) were obtained from the National Meteorological Information Center in China. The data are based on actual measurements in 753 national meteorological stations that are located throughout China. The temperature and precipitation data were collected from 1951 to 2001. We rely on the mean values of these variables (climate normal) over this time period for each month. We average the monthly climate data into four seasons in the following way: winter is the average of December to February, spring is the average of March to May, summer is the average of June to August, and fall is the average of September to November.

Socio-economic data is obtained from the Household Income and Expenditure Survey (HIES) administered by China National Bureau of Statistics in 2001. There is more than 50,000 observations in the HIES. We have selected a sub-sample from only those counties for which we have climate data (from meteorological stations located in these counties). Our final sample has 8405 households in 915 villages in 124 counties in 28 provinces.

The HIES includes a number of household and village characteristics. Irrigation data was collected at the village level. Information about crop choice was collected at the farm level. Nine major crops were identified: cotton, maize, oil crops, potato, rice, soybean, sugar, wheat and vegetables. Additional household variables include the education level of members of the farm household, each family's land area, the number of family laborers that belong to the household. Additional village variables include indicators about the topographical environment of each village (e.g., if it is located on a plain or in a mountainous region), the share of cultivated area that is irrigated in the village, membership in associations, extension service, and access to markets (e.g., the

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presence of paved roads between the village and key services; the distance to each township's government).

To account for soils, we downloaded a soil map from FAO's website. There are three major soil types—clay, sand and loam soils. The final set of soil variables for our analysis was created by generating a variable measuring the share of cultivated area with each type of soil.

III. MULTIVARIATE ANALYSIS AND RESULTS

Irrigation choice

In order to study irrigation choice, we rely on a dichotomous logit. We test how climate influences the probability of choosing whether to irrigate or not, while controlling for a number of other independent variables such as soils, household characteristics and farm characteristics.

We estimate two logit regressions of irrigation using a quadratic model of climate (Table 1). Because the household characteristics could be considered endogenous, they are included in one model and excluded from the second model. The regression results confirm that climate has a significant impact on a farmer's irrigation adoption decision. Both temperature and precipitation variables are significant. The quadratic climate terms are significant suggesting the climate relationship is nonlinear as expected. The seasonal coefficients are not alike suggesting that the consequences of warming and precipitation are not the same in each season. Several of the control variables are significant. Irrigation is more likely with clay and silt soils, when the farm is on a flat plain, and near a road. Farms further away from township governments are less likely to irrigate possibly because the farm is more remote and possibly because the farm is less likely to receive extension services. Household characteristics such as participating in production associations and the level of education of the labor increase the likelihood of irrigation. More land per household member reduces the likelihood of irrigation, probably because irrigated land is more labor intensive relative to rainfed land.

In order to interpret the coefficients of the logit model, we calculate marginal impacts for each climate variable (Table 2). The results suggest that seasons have strong

but offsetting effects. Warmer summer and fall temperatures increase the likelihood of irrigation selection but warmer spring and winter temperatures reduce it. Wetter springs, summer and falls reduce the likelihood of irrigation selection but wetter winters increase it. In general, warmer annual temperatures reduce irrigation selection likelihood. It implies that farmers in warmer locations are much less likely to choose irrigation and farmers in cooler places are more likely to irrigate. In addition, farmers in locations with more rainfall are also less likely to irrigate because farmers get sufficient moisture without the expense of irrigation. However, the marginal effects depend on the distribution of seasonal rainfall and temperature so that it can vary from place to place.

The analysis does not include water availability. This remains an important caveat to the results. If there is not enough water, farmers may want to shift to irrigation but they may not be able to. Higher temperatures could lead to a reduction in irrigation if higher evaporation reduces available water. Changes in precipitation could also change flows. As China uses all of its available water in some regions, changes in flows are likely to have very important consequences for irrigation.

Crop choice

In order to study crop choice, we rely on a multinomial logit regression. The multinomial logit examines the probability that a farmer chooses one of the 9 major crops grown in China. We do not examine minor crops. We assume that the choice among the 9 crops is independent of these other choices. The multinomial tests the influence of climate on the probability of choosing each crop controlling for a number of other independent variables such as soils, household characteristics, and farm characteristics. We model irrigation choice and crop choice separately.

The analysis of crop choice indicates that farmers plant different crops depending on the climate they face (Table 3). Both temperature and precipitation play a role in crop choice. The quadratic climate coefficients are significant, implying that the response function is nonlinear. The climate coefficients are quite different across seasons suggesting that seasonal effects are, once again, important.

Many of the control variables are significant (Table 3). Soils, as expected, influence crop choice. Cotton and sugar are more likely to be planted on clay soils whereas rice,

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wheat, vegetables, soybeans and oil crops are less likely. Farmers with silt soils are more likely to choose potatoes but less likely to choose rice, sugar, and several other crops. Cotton and sugar are much more likely to be grown on plains but potato and oil crops are not. Being close to a road increases the likelihood that a farmer will select wheat, rice, vegetables and oil crops and reduces the chance the farmer will select cotton. This may reflect the relative cost of transporting each of these products. The farther the farmer is from the township government, the more likely the farmer will grow wheat and the less likely he will grow oil crops. Proximity to township government makes public extension more accessible. Access to extension may help farmers grow wheat whereas oil crops are relatively simple to grow and so do not require extension services. If a farmer is in a village with major irrigated areas, the farmer is more likely to grow wheat, rice, and sugar but less likely to grow potatoes. Rice and sugar tend to be irrigated whereas potatoes are never irrigated. Farmers who join production associations are more likely to grow cotton, because of the additional ginning and marketing needed for the final product, that are taken care by the association. Farms with less educated workers are more likely to grow soybeans and oil crops, which are the least sophisticated crops to grow. The more cultivated land per household member, the more likely the farmer will grow cotton, oil crops, sugar, and wheat—crops that take advantage of economies of scale—but the less likely they will grow rice and vegetables—crops that can be grown on small fields.

In Table 4, we calculate the marginal effects of temperature and precipitation on crop choice. Across China, farmers are more likely to select cotton, wheat, oil crops and maize as temperatures warm and they are less likely to select rice, vegetables, soybeans, potatoes and sugar. With more precipitation, farmers are more likely to pick rice, cotton, vegetables, soybean, oil crops and sugar and less likely to pick maize, wheat and potato. However, the seasonal effects are quite different from the annual effects. For example, warmer summers favor cotton, wheat, and oil crops whereas warmer falls favor rice, vegetables and potato. Wetter springs are very bad for vegetables, oil crops and maize but good for wheat, potato, cotton, and rice. Wetter winters are good for most of the crops (cotton, oil crops, vegetables, soybeans, maize, sugar and rice) but bad for wheat and potato. The actual impact in each location is therefore going to depend on the seasonal distribution of temperature and precipitation, and not just the annual average.

IV. CONCLUSION AND POLICY IMPLICATIONS

The results of the adaptation analysis strongly suggest that Chinese farmers do adapt to climate by shifting to irrigation (where possible) and by switching crops. With warmer temperatures, they are more likely to increase irrigation and grow oil crops, wheat, and especially cotton. As precipitation increases, they may also increase irrigation and choose to grow more soybean, oil crops, and especially rice, cotton, and vegetables. However, all of these results are dependent on no changes in water flow. Since all of these decisions are likely to be affected by water flow and climate change is likely to change water flows, the results must be interpreted cautiously. It is clearly very important to follow this study with an additional analysis where water flow can be taken into account.

One point that is clear from the results concerning adaptation is that Chinese farmers already have adapted to climate. Climate affects irrigation choice and crop choice. Therefore, it is very likely that Chinese farmers will adapt to climate change. Examining a set of future climate scenarios, the model predicts there will be substantial changes in both the irrigation mix and the crop mix across China with climate change. The magnitude of the change will depend on the climate scenario. Future studies of the impacts of climate change on Chinese agriculture must take these adaptations into account. Failing to account for adaptation will overestimate the damages from climate change.

The analysis in this paper examined irrigation and crop choice. Farmers can take other measures as well in response to climate change. They can adjust varieties, not just species. They can alter when they plant and harvest. They can choose different tillage practices. They can adopt different irrigation technologies. They can adjust other inputs such as labor, capital, and fertilizer. All of these measures need to be examined.

Farmers can select from an arsenal of adoption alternatives. This implies that adoption options have to be available. This is a policy matter. Government and private sector may be in a position to prepare sets of adaptation options to be available for use by individual farmers, and to provide needed knowhow via efficient public extension services or private agents. The government could also help establish the background or

prerequisites for private adaptation. That includes establishing accessible credit lines, and enforcing private property ownership.

Additional public adaptations are also needed at the government level. One of the most important adaptations that China can make concerns water management. By reallocating water to its best use, the government can make important adaptations. This includes sending signals of the economic value of water by establishing water markets or efficient quotas and/or regulatory policies. Water management may also involve engineering efforts to store water or transfer water from water abundant to water short regions. Another important adaptation concerns developing new crop varieties. If the government can develop new crops suited for a warmer world, it would provide farmers with new opportunities that could be very valuable in the future.

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Table 1: Regression of Irrigation Choice

Variables	If irrigate (1=Yes; 0=No)	
	Without household variables	With household variables
	Quadratic	Quadratic
Spring temp	-1.2439	-1.3439
	(8.83)***	(9.30)***
Spring temp sq	0.0293	0.0314
	(6.75)***	(7.11)***
Summer temp	0.6607	0.6795
	(3.28)***	(3.31)***
Summer temp sq	-0.0008	-0.0009
	-0.17	-0.19
Fall temp	0.2180	0.3189
	(1.68)*	(2.42)**
Fall temp sq	-0.0277	-0.0316
	(5.18)***	(5.81)***
Winter temp	0.6087	0.6319
	(8.75)***	(8.92)***
Winter temp sq	0.0086	0.0102
	(4.50)***	(5.19)***
Spring prec	-0.7896	-0.7931
	(8.02)***	(8.02)***
Spring prec sq	0.0343	0.0345
	(8.80)***	(8.82)***
Summer prec	-0.1559	-0.1826
	(4.92)***	(5.59)***
Summer prec sq	0.0003	0.0008
	(0.29)	(0.82)
Fall prec	-0.1123	-0.1199
	(1.25)	(1.33)
Fall prec sq	0.0071	0.0074
	(1.63)	(1.71)*
Winter prec	1.2560	1.2345
	(7.47)***	(7.31)***
Winter prec sq	-0.1455	-0.1432
	(7.02)***	(6.88)***
Share of land areas with clay soil	1.1462	1.1690
	(7.47)***	(7.54)***
Share of land areas with silt soil	0.1272	0.1395
	(1.01)	(1.11)
Plain (1=Yes; 0=No)	0.5169	0.4861
	(6.49)***	(6.09)***
Road (1=Yes; 0=No)	0.8485	0.8304
	(5.49)***	(5.34)***
Distance to township government	-0.0548	-0.0492
	(8.63)***	(7.65)***
If participate production association (1=Yes; 0=No)		0.8579
		(3.88)***
Share of labor without receiving education		-0.0030
		(1.93)*
Cultivated land area per household		-0.1438
		(4.27)***
Constant	1.6391	1.928
	(0.97)	(1.11)
Pseudo R^2	0.19	0.2
Observations	8405	8405

Values in parenthesis are t-statistics. One asterisk implies significant at 5% level and two asterisks implies significant at 1% level.

Table 2　Marginal effect of climate change on irrigation choice

Without household variables	Temperature ˚C	Precipitation cm/mo
Spring	-0.2110	-0.3647
Summer	0.0751	-0.0245
Fall	0.0414	-0.0151
Winter	-0.0001	0.1218
Annual	**-0.0204**	**-0.1217**
With household variables		
Spring	-0.2310	-0.3654
Summer	0.0758	-0.0295
Fall	0.0540	-0.0161
Winter	-0.0130	0.1197
Annual	**-0.0276**	**-0.1354**

Note：Marginal effects calculated using regressions coefficients from Table 1 evaluated at each climate point in sample.

Table 3 Multinomial logit regression of crop choice

	Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil Crops	Sugar
Spring temp	0.119	0.27	-0.025	-1.21	0.229	-1.191	-0.176	-0.181
	(-0.82)	(1.84)*	(-0.25)	(8.84)***	(2.03)**	(2.20)**	(-1.38)	(-0.46)
Spring temp sq	-0.013	-0.0048	-0.0034	0.0313	-0.0177	0.0158	-0.0094	0.0015
	(2.86)***	(-1.07)	(-1.11)	(7.05)***	(5.12)***	(-0.77)	(2.39)**	(-0.13)
Summer temp	-1.027	-0.681	-0.125	2.446	0.237	-2.541	0.436	1.457
	(6.22)***	(2.82)***	(-0.88)	(10.03)***	(-1.53)	(2.45)**	(2.56)**	(2.24)**
Summer temp sq	0.031	0.0078	0.0042	-0.0427	-0.0034	0.0903	0.0002	-0.0225
	(8.06)***	(-1.57)	(-1.32)	(8.37)***	(-0.98)	(4.17)***	(-0.07)	(-1.56)
Fall temp	-0.118	1.05	0.177	-0.458	-0.445	-0.589	-0.9	-1.411
	(-0.90)	(7.11)***	(1.88)*	(3.70)***	(4.03)***	(-0.85)	(7.09)***	(3.22)***
Fall temp sq	-0.014	-0.024	-0.0113	-0.0016	0.0094	0.0025	0.0118	0.0044
	(2.81)**	(5.07)***	(3.13)***	(-0.34)	(2.31)**	(-0.09)	(2.67)**	(-0.31)
Winter temp	0.347	-0.294	0.111	0.365	0.242	-0.307	0.542	0.813
	(6.83)***	(4.46)***	(2.50)**	(5.94)***	(4.54)***	(-1.42)	(9.92)***	(4.94)***
Winter temp sq	0.0004	0.0094	0.007	-0.0023	0.0073	-0.0972	-0.0001	0.0136
	(-0.20)	(4.94)***	(5.27)***	(-1.17)	(4.79)***	(5.79)***	(-0.06)	(2.26)**
Spring prec	0.831	0.11	-0.08	0.27	0.162	0.447	-0.189	0.64
	(8.43)***	(1.75)*	(-1.40)	(3.64)***	(2.52)**	(1.84)*	(2.84)***	(3.40)***
Spring prec sq	-0.048	-0.0013	0.0038	-0.0127	-0.0017	-0.0002	0.0056	-0.0314
	(10.63)***	(-0.58)	(1.81)*	(4.78)***	(-0.72)	(-0.02)	(2.31)**	(4.92)***
Summer prec	-0.213	-0.038	-0.108	0.021	-0.075	-0.253	-0.0052	-0.009
	(7.69)***	(-1.32)	(5.19)***	(-0.70)	(2.85)***	(2.81)***	(-0.20)	(-0.12)
Summer prec sq	0.00676	0.0003	0.0023	-0.0002	0.0002	-0.0028	-0.0008	0.001
	(7.17)***	(-0.36)	(3.59)***	(-0.18)	(-0.28)	(-0.66)	(-1.01)	(-0.53)
Fall prec	-0.522	0.416	0.129	0.218	0.247	-0.799	-0.223	-1.026
	(6.59)***	(5.57)***	(2.21)**	(2.97)***	(3.59)***	(3.61)***	(3.23)***	(3.93)***
Fall prec sq	0.0257	-0.0203	-0.0098	-0.0271	-0.016	0.0479	0.0083	0.0184

	(6.47)***	(5.76)***	(3.47)***	(7.62)***	(4.88)***	(3.92)***	(2.53)***	(-1.41)
Winter prec	-0.173	0.892	0.892	0.194	0.201	2.771	1.293	1.198
	(-1.10)	(7.13)***	(8.12)***	(-1.33)	(-1.56)	(4.91)***	(9.92)***	(2.58)***
Winter prec sq	0.0694	-0.0603	-0.057	0.0582	-0.0051	-0.3558	-0.0946	0.0177
	(3.55)***	(4.20)***	(4.40)***	(3.45)***	(-0.35)	(5.52)***	(6.22)***	(-0.35)
Share of land areas with clay soil	-0.69	-0.913	-0.528	-0.382	-0.2	0.873	-0.39	0.801
	(5.09)***	(8.03)***	(5.14)***	(2.82)***	(1.66)*	(2.77)***	(3.36)***	(2.26)**
Share of land areas with silt soil	-0.243	-0.67	-0.026	0.055	0.706	-0.207	-0.194	-0.894
	(2.77)**	(5.82)***	(-0.32)	(-0.50)	(6.63)***	(-1.20)	(1.97)*	(2.28)**
Plain (1=Yes; 0=No)	-0.0412	-0.0968	-0.0028	-0.0761	-0.3192	1.6194	-0.3589	0.6544
	(-0.59)	(-1.53)	(-0.05)	(-1.13)	(4.95)***	(9.59)***	(5.56)***	(4.20)***
Road (1=Yes; 0=No)	0.362	0.449	0.376	0.002	0.427	-0.222	0.2709	0.0917
	(3.03)***	(4.11)***	(3.81)***	(-0.01)	(3.79)***	(-1.07)	(2.42)**	(-0.29)
Distance to township government	0.0115	-0.0098	-0.0091	-0.0021	0.0004	-0.0166	-0.0115	-0.0182
	(2.15)**	(1.86)*	(2.07)**	(-0.39)	(-0.09)	(-1.39)	(2.18)**	(-1.29)
Share of irrigated areas in village	0.00501	0.005	0.0007	-0.0014	-0.004	-0.0004	0.0014	0.006
	(6.40)***	(6.32)***	(-1.05)	(-1.64)	(4.77)***	(-0.32)	(1.82)*	(2.48)**
If participating in a production association	0.076	0.074	-0.116	-0.291	0.278	1.052	0.162	-0.433
	(-0.55)	(-0.57)	(-0.95)	(1.72)*	(1.96)*	(5.17)***	(-1.22)	(-1.12)
Share of labors without receiving education	0.0005	0.0016	0.001	0.0037	0.0022	0.0026	0.0034	-0.0033
	(-0.38)	(-1.28)	(-0.94)	(2.60)**	(1.80)*	(-1.13)	(2.79)**	(-0.85)
Cultivated land area per household	0.232	-0.164	-0.0967	0.009	0.06	0.422	0.305	0.26
	(7.22)***	(3.84)***	(3.53)***	(-0.31)	(1.98)*	(5.37)***	(10.05)***	(4.17)***
Constant	11.64	-4.21	0.92	-19.87	-1.68	27.2	2.74	-6.7
	(7.91)***	(1.93)*	-0.74	(9.67)***	(-1.29)	(2.88)**	(1.92)*	(-1.17)

Note: Absolute value of z statistics in parentheses. Maize is the omitted choice. There are 8405 observations. The LR chi2 of the regression is13347 and the Pseudo R squared is 0.1034.

Table 4 Marginal effect of climate change on crop choice

	Change of probability of choosing crops								
	Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil Crops	Sugar	Maize
Temperature (°C)									
Spring	-0.0073	0.0417	0.0067	-0.0161	-0.0116	-0.0113	-0.0299	0.0002	0.0276
Summer	0.0172	-0.0527	-0.0339	0.0127	-0.0134	0.0860	0.0225	0.0009	0.0009
Fall	-0.0293	0.0657	0.0040	-0.0254	0.0005	-0.0063	-0.0338	-0.0066	-0.0066
Winter	0.0157	-0.0453	-0.0143	0.0177	0.0073	-0.0056	0.0445	0.0091	0.0091
Annual	0.0090	-0.0092	-0.0054	-0.0113	-0.0052	0.0168	0.0048	-0.0014	0.0019
Precipitation (cm/mo)									
Spring	0.0274	0.0057	-0.0170	0.0003	0.0083	0.0075	-0.0167	0.0000	-0.0155
Summer	0.5562	-0.0665	-0.1269	-0.0500	-0.1160	-0.0190	-0.0639	-0.0053	-0.0053
Fall	-0.0176	0.0160	0.0064	-0.0081	0.0055	-0.0068	0.0042	-0.0053	-0.0053
Winter	-0.0378	0.0012	0.0238	0.0156	-0.0260	0.0382	0.0361	0.0141	0.0141
Annual	-0.0327	0.0326	0.0237	0.0100	-0.0128	0.0266	0.0110	0.0021	-0.0602

Note: Marginal effects calculated using coefficients from Table 3, evaluated at each climate point in sample.