Australian Government

Australian Centre for International Agricultural Research

Final report

project	**Assessing farmer responses to climate change — adjustment policy options**
project number	ADP/2011/039
date published	May 2017
prepared by	Christopher Findlay
co-authors/ contributors/ collaborators	Jikun Huang and Dang Kim Khoi
approved by	NA
final report number	FR2019-80
ISBN	978-1-925747-56-0
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The project leaders thank Dr Ejaz Qureshi, Research Program Manager for the Agriculture Development Policy Program at ACIAR for his support. We also welcomed the contribution to our work from our Review Team, Dr David Vanzetti, Professor Do Kim Chung, and Professor Zhong Funing, who reviewed the project in November 2016 prior to its completion.

2 Executive summary

Millions of farmers in East and Southeast Asia must decide how to respond to climate change. They risk poverty by not responding, but if they decide to act, their choices may be distorted by market failures and lack of information. Farmers in any country might adjust by a shift to new farming methods by growing new crops and even by relocation from an area or departure from an industry. There will be adjustment costs, which will vary between households and affect farmers' choices. There is a role for governments for two reasons. First, some farmers may not respond because of a lack of knowledge and/or the costs of adjustment. Second, in some developing countries, adjustment costs may be unnecessarily high because of market failures, which governments may be able to correct. This project examined these issues in the markets for rice in both China and Vietnam.

The objectives were primarily to identify those farmers at risk from climate change and then to suggest policy responses to assist farmer adaptation and adjustment.

Key to meeting these goals was to have access to information on how farmers were responding to climate change. Climate change involves a long-run series of changes and associated effects on temperature and rainfall. It is difficult to identify farmers' reactions to such long-run changes. Climate change is also associated with greater variations in climate conditions, such as the frequency of floods and droughts. A fundamental element of the methodology of this project was to examine farmers' responses to these events, and thereby infer their capacity to undertake longer run adjustments. This approach to the research led to the design of a novel sampling approach in order to select farmers who had recently experienced both normal years and years in which there were extreme weather events.

The work began therefore with the collection of data from households in an extensive set of surveys. These data were analysed and summarised using statistical techniques to identify which types of farmers were adopting which types of responses to extreme weather events. This work was followed by the application of economic modelling (methods) to identify farmers' responses to market signals that they would also be receiving as a result of climate change, and their likely consequences.

The project finds, firstly, that some farmers do respond to extreme weather events by adopting a variety of measures. These are mostly changes in farm management practice rather than engineering measures. When the latter are employed, they mainly involve the management of water. A number of household factors and institutional settings also interact with farmer decision, directing the choice of adaptation method.

Secondly, we find that adaptations by farmers, even in the short run, can make a significant difference to the outcomes in the context of climate change. A corollary is that ignoring farmers' responses, including those that are stimulated by signals from markets, will lead to overestimating the impact of climate change. We also find that in the longer term, farmer choices can offset from one-third to one-half of the impact of climate change.

Thirdly, however, we also find that the share of farmers who do respond is relatively low (one-third in one study in this project). The incentive of farmers to act also depends on the policy environment, the institutional environment and government investments. These planned and institutional measures are in the hands of various levels of government, so an important implication of this work is the degree of coordination required to put that package of measures in place.

3 Background

Millions of farmers in East and Southeast Asia must decide how to respond to climate change. They risk poverty by not responding but if they decide to act, their choices may be distorted by market failures and lack of information.

Many climate-related studies have identified the likelihood of significant effects on productivity, outputs and therefore prices of agricultural products as a result of climate change.

Farmers in any country might adjust by a shift to new farming methods, by growing new crops and even by relocation from an area or departure from an industry. There will be costs of adjustment, which will vary between households and affect farmers' choices.

In this situation, there is a role for governments for two reasons. First, some farmers may not respond, because of a lack of knowledge and/or the costs of adjustment. Second, in some developing countries, adjustment costs may be unnecessarily high because of market failures, which governments may be able to correct.

Climate change has attracted a substantial amount of funding for work on the science and the physical mechanisms involved. While it is important for that work to continue, less attention has been given to farmer choices in response to climate change and to related public policy responses. This study was designed to contribute to filling that gap in China and Vietnam. Its results were developed in an environment when a policy debate was well underway in both economies.

Over the past 50 years, the annual drought areas in China have increased from 3% to 9% and since the 1980s the frequency of flood events has been increasing, with major flood disasters occurring once in every two years by the 1990s. For China, Wang, Huang and Rozelle (2010) refer to scenarios in which rice yields in China fall between 9% and 13% by the 2020s (without a CO_2 fertilisation effect).

It is forecast that, by the end of the 21st century, the annual average temperature in Vietnam would increase by about 2 °C to 3 °C and the global sea level would rise by 0.75 m – 1 m, compared to the period 1980–1999. Rutten, Van Dijk, Van Rooij and Hilderink (2014) examine scenarios of the impact of climate change on land use in Vietnam. They find that 47% of paddy land area is at risk of flooding, and these areas are more concentrated in the Mekong River Delta. In the scenarios the World Bank (2010) applies, rice yields fall by 6.3% to 12% in the Mekong River Delta by 2050 (without a CO_2 fertilisation effect).

Rice was the major crop for analysis in the project, given its significance in food security and rural employment in both countries. Rice accounts for more than three-quarters of Vietnam's total annual harvested agricultural area and employs about two-thirds of the rural labour force, thus making a significant contribution to rural livelihoods. Climate change is expected to compound the existing challenges faced by rice farmers in Vietnam, such as land degradation, rapid industrialisation and declining agricultural productivity.

4 Objectives

The aim of this work was to design policy to mitigate the cost of adjustment by farmers to climate change and thereby to increase their livelihood. The project was focused on the rice sector. The objectives were primarily to identify those farmers at risk from climate change and then to suggest policy responses to assist farmer adaptation and adjustment.

The ultimate goal was to raise farmer welfare. The channel, however, was via the policy-making process, by engaging with those responsible for the policy response to climate change. The priority in this work was interventions designed to avoid extreme outcomes and to reduce the risk of higher levels of climate-induced poverty among groups and categories of farmers.

5 Methodology

The methodology involved the analysis of household survey data, the use of econometric analysis, the application of modelling methods, and policy analysis.

The first objective was to identify differences in farmer adjustment to past and anticipated climate change. Climate change has a number of consequences in the short and long run and the project considered both dimensions.

Long-run changes in temperature were examined and farmer perceptions of those changes compared to actual changes were assessed. A methodology based on the econometric analysis of panel data was also developed for examining the benefits of long-run adaptations to climate change.

Important in the short run is the change in weather variables, and another option is to examine farmer responses to extreme events. This was the focus of the survey work of the project; farm surveys were concentrated in areas where extreme events (droughts, floods, sea invasions) have occurred in the recent past. Surveys in China and Vietnam were undertaken over a number of years. Household-level data were collected in both normal and disaster years.

Statistical and econometric methods were then used to sort farmers into groups according to their choice of adjustment strategy, for example, combinations of crop choices, use of inputs like water and fertiliser or engineering responses. It was possible to identify the significant distinguishing characteristics of each group, such as their perception of climate change, and their demographic and socioeconomic characteristics. The results were used to explain which types of farmers adopt various types of responses, and to infer which types of farmers might be at risk.

The second objective was to model the effects of climate change, allowing for feedback to farmers from the markets for rice. Climate change affects agricultural output in the short run owing to changes in frequencies and seriousness of extreme weather events, and their impacts on agricultural production will affect market supply and therefore market prices. Individual farmers will respond directly to the immediate impacts of climate change, but their choices will also be influenced by market price changes. However, farmers' responses to market price changes differ, depending on the time available for adjustment. Within a short run and for a large shock, farmers' response to the price change is less than that under a smooth price change, given the resource constraints. That is, the response in a disaster year is different to and less than that in a normal year. Existing economic models were adjusted for this effect.

The third objective was to consider options for policy action by governments to assist farmer adaptation and adjustment to climate change. The various suggestions for policy responses were compiled and discussed in terms of their contribution to resolving the situation of farmers at risk.

Other aspects of methodology are discussed in Section 8.1 on the scientific contribution of the project. The results are reported in Section 10.2, which contains information on 32 papers associated with the project.

6 Achievements against activities and outputs/milestones

6.1 Objective 1: To identify those farmers at risk from climate change by using farm-level survey data

No.	Activity	Outputs/ milestones	What has been achieved?
1.1	Use the data collected in Stage I to sort farmers into groups by choice of adjustment strategy and use statistical methods to identify their significant distinguishing characteristics.	Paper on the choice of adaptation strategy by different types of farmers and a classification of farmers at risk from climate change	15 papers (see Section 10.1) have been completed and some submitted to journals.
1.1a	Undertake surveys of officials in local government areas.	A cleaned dataset (in Excel and Stata formats) compiled and made available from the village-level surveys	Survey completed in December 2014 and data cleaned in China and Vietnam.
1.1b	Classify farmers by their perceptions of climate change and summarise the relationship between these perceptions and characteristics.	Paper containing estimates of significant determinants of farmer perceptions of climate change, including tables of results summarising econometric estimations	For China, this topic has been divided into two parts, one on whether farmer perceptions about climate change are correct and the other on the relationship between perceptions and action. Two papers have been submitted to journals (papers 2.1 and 2.2 in Section 10.1). For Vietnam, one paper on this topic has been published and another is in progress (papers 2.3 and 2.4 in Section 10.1).
1.1c	Classify farmers by their choice of adaptation methods.	Paper containing tables of summary statistics and comments on classifications of farmer types	These tables are included in the papers produced in 1.1b.
1.1d	Explain the choice of adaptation methods by different types of farmers.	Paper containing econometric results on the significant determinants of farmers' choice of different adaptation methods	A number of papers have been produced. (Section 10.1, papers 1.3, 1.7, 1.9, 1.11, and 1.12.)
1.2	Conduct follow-up farm-level surveys in China and Vietnam to collect data from the same sample on the same parameters and variables for a longitudinal study.	A new cleaned dataset (in Excel and Stata formats) compiled from follow-up household-level surveys and made available	Surveys were completed in December 2014 and the data cleaning was completed by April 2015.
1.3	Reapply methodology in 1.1 to analyse the data collected in the follow-up surveys in Stage II.	Paper containing revised econometric results on the significant determinants of farmers' choice of different adaptation methods using the extended data set	A number of papers using the new dataset have been completed (e.g. papers 1.7 and 1.10 in Section 10.1.)

No.	Activity	Outputs/ milestones	What has been achieved?
1.2a	Conduct an additional farm-level survey in Vietnam (Ben Tre and Tra Vinh) following severe weather events in the first half of 2016.	A new cleaned dataset (in Excel and Stata formats) compiled from follow-up household-level surveys and made available	The new cleaned dataset from follow-up household-level surveys was made available from end September. This dataset has been used in several new working papers (e.g. papers 1.12 and 1.13 in Section 10.1.)

6.2 Objective 2: To develop the capacity to model the consequences through market processes for prices and outputs and farmers' responses to climate change

No.	Activity	Outputs/ milestones	What has been achieved?
2.1	Model the immediate effects of climate change.	Paper reporting price elasticities of supply, which allow for adaptation to climate change	For China, analyses based on the original design have been completed. See Section 10.1, papers 4.1, 4.2 and 4.3 for papers in progress. See more notes under 2.1a and 2.1b below. For Vietnam, panel household data in Ben Tre and Tra Vinh provinces during 2010–2016 is used to estimate the price elasticity of supply. A paper on this issue will be complete by the end of November. See Section 10.1 paper 4.4 and 4.5 for papers in progress.
2.1a	Estimate price elasticities with no adaptation.	A short paper on parameter values.	The results on estimated supply response parameters have been documented, with reports of estimated elasticities for China now available (included in working papers 4.1–4.3 of Section 10.1). For Vietnam, one paper is expected to be completed by the end of November. See Section 10.1, paper 4.3.

2.1b	Estimate price elasticities with adaptation .	A short paper on parameter values for the system equations	The analysis was completed by the China team in May based on the original research design. However, during the analysis, we found the differing price elasticities between the households with and without adaptations cannot be identified from such short time periods and a limited number of households. Therefore, the research focused on: 1. different price responses between normal and disaster years, based on household data 2. changing price responses due to variation in crop areas that had suffered from drought or flood, based on time-series data by province in China. These new analyses were completed in June and papers based on these analyses will be ready by end November 2016. See Section 10.1, 4.1 – 4.3 for papers on this topic. For Vietnam, see 2.1a above.
2.2	Model the long-run effects of climate change.	Paper containing estimates of the consequences of climate change in the long run, allowing for farmer responses and market adjustment, including through trade	Several papers have been prepared. See 2.2a, 2.2b, and 2.2c for details.
2.2a	Identify the long-run consequences of climate change, through literature review or expert consultation.	Paper on estimates of long-run impacts on yield	For China, several papers on long-run impacts on crop yields have been completed. See Section 10.1 papers 3.1–3.5. For Vietnam, a paper on this topic is in progress, and a draft will be available from end November 2016. See Section 10.1, paper 3.6.
2.2b	Model impacts of long-run climate change in Vietnam and China using the CAPSiM model.	Short paper on the results of CAPSiM modelling work	See papers 4.1–4.3 in Section 10.1 for China and papers 4.4–4.5 for Vietnam.

2.2c	Take into the account the transmission of climate change effects through international trade using GTAP and establish an equilibrium with CAPSiM results.	Paper providing an overview of the combination of modelling methods and the results	For China, see paper 4.3 in Section 10.1. For Vietnam, the research team used only the CAPSiM model as detailed in 2.2b. This is because of the relatively small size of the Vietnam economy and the lack of significant impacts to be captured by GTAP.

6.3 Objective 3: To identify and promote the adoption of the priority policy responses to assist farmer adaptation and adjustment to climate change

No.	Activity	Outputs/ milestones	What has been achieved?
3.1	Assess interventions that have been proposed or which might be designed to reduce those costs of adjustment, what incentives they create and how farmers might respond.	Two reports providing a ranking of policy options	A combined summary report has been prepared.
3.2	Distribute and hold discussions of results, leading to adoption of better policy measures and development of capacity for policy making.	Distribution and discussion of policy briefs	A number of policy briefs have been prepared and distributed in Vietnam and in China.
3.3	Conduct project review meetings: end-of-project review meetings (including project team presentations)	Preparation of review report	RC/board plus other stakeholders) met in Hanoi 31 Oct 2016 – 1 Nov (Monday and Tuesday) and in Beijing 3–4 Nov 2016 (Thursday and Friday).
3.4	Conduct final project workshop.	Communication of key results	The final workshop was held in Hanoi on 19 December, preceded by meetings of the research team.

7 Key results and discussion[1]

The focus in this project has been on the decision making by farmers, including questions of which farmers are likely to adapt and which are not likely to adapt, and then on the forms of adaptation that are selected.

7.1 Impact of climate change and farmer response

Research both preceding and undertaken in this project finds very significant effects of climate change through temperature rises, changes in rainfall and sea-level rises. The consequences include river flooding, storms, salinity intrusion and sea inundation.

A contribution of this project was to extend the understanding of the impact of climate change. Huang, Wang and Wang [3.1] used data from a survey of 1653 rice farmers to look at mean yields and risks to them. They found that floods and droughts significantly reduced yields and increased the downside risk of rice yields. Wang, Zhang and Huang [3.4], analysing 30 years of data, found that both the trend of climate change and change in its variability significantly influenced the yields and variability of yield of both indica and japonica rice types.

While farmers in both China and Vietnam are significantly affected by events associated with climate change, there is also evidence of their efforts to respond and to adapt. The research finds that the experience of a disaster does increase the application of measures for adaptation. However, the number of farmers who do adapt is found in some studies in this project to be relatively low, for example of the order of one-third (Huang, Wang and Wang [3.1]).

7.2 Categories of adaptations

The project examined the options for adaptation by farmers in some detail. It also reviewed which types of farmers would adopt which types of measure and, consequently, which farmers' livelihoods might be at risk from climate change–related events. Options are listed in Box 1. These include responses that are autonomous (and undertaken by farmers) and those which are planned (and undertaken by governments). The latter include investments in infrastructure or other forms of social support. Adaptations can also be divided into those associated with changes in management practice and those involving elements of engineering. The latter are more likely to be undertaken by communities or governments, and the former are in the hands of farmers.

The most popular non-engineering measures were changing inputs to production or adjusting the crop planting or harvesting times, according to Chen, Wang and Huang [1.1]. Other often-observed responses were to use the irrigation system more frequently, change crop varieties and buy crop insurance. Very few farmers (though more so in Vietnam relative to China), however, used engineering measures. Of the few who did, the most popular related to water management, such as investing in wells, building new dams, purchasing pumps, investing in surface pipes and sprinklers and maintaining channels.

When adaptation measures are applied, the effects are significant. Adaptors and non-adaptors are compared in one study in this project. Adaptors' output is estimated to be

[1] This section summarises results that are discussed in more detail in Findlay, Huang, Khoi and Plunkett, paper 5.1 in section 10.2. References to papers that are outputs of this project are made to the paper number in section 10.2 shown in square brackets.

16% higher than if they had not adapted. Non-adaptors, if they had adapted, would have increased their output by 2%. Applied to the whole the country, the impact on the value of rice production of these changes was more than US$8b.

Box 1 Categories of adaptations

Autonomous

- Changes in sowing dates
- Changes in the number of plantings
- Fixing and cleaning seedlings
- Planting new varieties (e.g. drought resistant)
- Changes of crops or other diversification
- Changes in water management practices
  - New tube wells, pumping out of irrigation systems, local storage pond building, changes to irrigation times
- Shift to off-farm work
- Relocation

Planned

- Public spending on research and development (e.g. new varieties)
- Irrigation investment
- Information, including early warning systems
  - Early warning, climate information, technology information, marketing
- Actions to support the creation of social capital
- Investment in sea walls

Institutional and policy

- Property rights for land
- Water pricing, including markets for water
- Actions to promote access to credit
- Support for (or removal of restrictions on) the movement of labour
- More open trade for agricultural products

Source: Project papers

A distinction is made in the project between short-run adaptations to climate change, such as those just discussed, and adaptations that are possible in the long run. According to a large sample study in rural China, long-run adaptations should mitigate one-third to one-half of the damages of warming on crop profits by the end of this century (Huang, Wang, Huang and Findlay [3.5]). This result is confirmed by empirical analyses using the same method in the US and Vietnam, where long-run adaptations mitigate one-third and one-half of the damages respectively. A corollary is that ignoring farmers' responses will lead to an overestimation of the impact of climate change.

7.3 Drivers of farmer choices

7.3.1 Market signals

An important factor in influencing farmer behaviour will be signals from markets, in the form of price changes. The effect of climate change is to reduce supply, so prices will rise, which will provide further incentives to farmers to respond.

A complication in identifying this effect is that the farmer response to price changes may also vary in the context of climate change. There have been a limited number of studies

looking at the influence of climate change on farmers' production response to market prices. Farmers' responses are not as strong in the short run: they are much weaker in periods of extreme weather, which limits the capacity to respond. This means that the impact of the weather event, even following the farmer response to the signals markets provide, will be greater: the impact will also be underestimated by models that do not allow for the reduction-in-supply response (Yang and Huang [4.1]; Huang and Yang [4.2]; and Thiep and Khoi [4.4]).

A further consideration with respect to the price signals is the extent of market integration. A weather event that shocks supply may have the initial effect of raising prices, but when local markets are integrated with the rest of the country or the rest of the world, the price impact will be reduced, because goods can be imported from other regions. The impact on consumers in that case is reduced, but a much greater impact is born by producers. Incentives to increase local production are also reduced. This effect is less significant when the weather events are more widespread.

The impacts of extreme weather events have been examined in this project, based on an integrated model called CAPSiM (a partial equilibrium model in agriculture for China) and a general equilibrium (GTAP, the global trade analysis project. The results show that without considering the lower supply elasticities of many commodities in the crop sector when encountering the extreme weather events, the impacts of climate variations on production, consumption and trade are underestimated. The extent of underestimation also varies with the degree of trade liberalisation. A more open economy in the agricultural sector can reduce the impacts of extreme weather events on crop production, consumption and price through import (Huang, Xie, Ali and Yang [4.3]).

7.3.2 Policy support

The research in this project finds that when 'policy support' is available the farmers are more likely to adopt both engineering and non-engineering of measures (Chen, Huang and Wang [1.1]). One estimate is that government support increases the probability of adaptation by 0.244 (Xu and Findlay [1.15]). Policy support includes early warning information, but also technical, financial and physical policy support (although very few (5%) farmers do receive this type of support in China). Farmers reporting higher levels of indicators of social capital were also more likely to adopt both types of responses. Likewise, in Vietnam, government support influences the willingness of farmers to adapt, and farmer and local government adaptations reinforce each other, particularly the more serious the event to which farmers are responding (Khoi, Thanh, Ninh and Warner [1.12]; Khoi, Lien, Warner, Thiep, Ninh and Dao [1.13]; Khoi and Ninh [1.11]).

Access to information is a critical element of policy support. Relevant are early warnings of drought and floods. The China-based research on access to information stresses the value of early warning systems. This is because, overall, when early warning information is provided:

- farmers are about 20% more likely to perceive increasing drought severity
- about 8% more farmers are expected to adopt, in particular, the use of surface pipes in response.

In one study in this project, set in China, over half of the farmers perceived the increase in severity of droughts in the previous ten years. Also, early warnings of drought had altered their perceptions and affected their adaptation choices. Those perceiving increased severity of drought were found to be more likely to adapt by adopting water-saving technologies (Hou, Huang and Wang [2.1]). Another study of farmer adaptive responses in the North China Plain – an ecologically vulnerable region frequently hit by drought – found that wheat farmers adapted better to coping with droughts when provided with early warning information and policy support (Wang, Yang, Huang and Chen [1.4]). The adaptations included adjusting seeding and harvesting dates and enhancing irrigation intensity.

In the case of Vietnam, in the Mekong River Delta, individual farmer perceptions of drought and salinity intrusion increases during the 2010–2016 period influenced their adaptation behaviours and the provision of early warnings of drought had altered those perceptions (Nguyen, Nguyen, Khoi and Lan [2.4]).

Although perceptions drive behaviour, they may not be correct. It was found in one study set in China that few farmers (only 18%) accurately perceived the actual increases in annual mean temperatures over the last ten years. However, social networks improved perceptions and those with larger land holdings had better perceptions (Hou, Huang and Wang [2.2]).

Likewise, in Vietnam, the provision of formal information with government supports has played an important role in improving farmers' perceptions of local climate variability (Khoi, Ninh and Lan [2.3]). However, researchers in Vietnam stress that any consideration of a policy to raise awareness of climate change should consider its ability to be applied widely.

The final point about information provision is that not only advance warning information but also post-event information matters, such as the availability of post-event services, assistance and support.

Other drivers of adaptation include the following.

7.3.3 Household characteristics

A common response in China is the diversification of crops planted. Use of crop diversification varied by the age and gender of the farmer. Younger farmers are more likely to plant more types of crops. Female farmers are more likely to employ diversity than males. Interestingly, farmers with less education are more likely to manage risk in this way. Farmers with larger farms are more likely to diversify (Huang, Jiang, Wang and Hou [1.3]). The researchers also note that the value of capacity building to support adjustment will vary between types of farmers; they suggest that older farmers and those with smaller farms may benefit from more attention.

Results do, however, vary on the scope of household characteristics that matter, depending on the form of adaptation studied. Other studies did not find statistically significant evidence that age, education or wealth affect adaptation in the form of changes in a variety of management practices (Thennakoon, Findlay, Huang and Wang [1.2]).

The drivers also depend on the nature of the adaptation. In a study of changes of irrigation practices in response to extreme drought events, a response was found to be more likely when the household head was male. The explanation was that changes in irrigation practices require more coordination among households, whose heads are mostly male. The effect of both age and, interestingly, education were negative in these results while the effect of landholding per head and a location in a plains area was positive (Wang, Huang, Wang and Findlay [1.7]).

Capital intensity and farm size also matter, according to the research results. Household-level capital intensity (production capital per hectare) has a significant positive effect on the adaptive capacity of farmers and, beyond a certain level, increases in farm size led to increases in adaptive capacity. Age had a significant negative effect in this case (Wang, Huang, Wang and Findlay [1.7]).

In the case of Vietnam, cultivated land size was a positive factor in adaptation, but this effect can be offset by fragmentation of land holdings (Lan, Huang, Ninh and Khoi [3.6]). Larger and more consolidated holdings would help farmers adapt. Other positive factors were the ease of access to main roads, higher quality cultivated soil, and a higher share of irrigated land. The authors referred to these features as matters of agricultural infrastructure. However, they found no effect of age and education levels. They speculated that farmers with higher education might be more likely to be involved in off-

farm work, which would reduce the incentive to implement adaptive measures on the farm.

Overall, these results reinforce the value of focusing on indicators of farmers at risk, such as:

- (smaller) farm size
- fragmented holdings
- (older) age
- location (other than a plains area)
- (lesser) wealth.

7.3.4 Land tenure

The nature of farmer rights to land and water has an important influence on farmer adaptation to climate change through their influence on farming practices. More sustainable and profitable practices depend on longer term investments to maintain and improve the quality of soil and the manner in which it is used. Such longer term investments are facilitated by land tenure arrangements that enable farmers to be assured of being able to reap their longer term benefits. Many of the successful adaptations to climate change–related events depend on there being such longer term investments. However, in this project, it was found that better defined property rights also had an impact on the use of management practices. In Guangdong province of China, rice farmers with contracted land were more likely to implement successful adaptation measures to extreme weather events than those who rented land from the collective or other farmers (Thennakoon, Findlay, Huang and Wang [1.2]).

Already noted is the value of land consolidation and larger holdings. These results indicate that scale management helps reduce production risks posed by extreme events. One study argues for intervention to promote land transfer markets (Huang, Wang and Wang [3.1]).

7.3.5 Water systems and infrastructure

As with property, well-defined rights for water use encourage longer term investment in its conservation and efficient use. Rights to the available supplies of water and the ability to trade those rights are important to encouraging the flow of water to its most profitable uses. This is especially so at times or in areas where water is scarce and there are many uses for the available supplies. The impact of climate change reinforces this argument. A decrease in the use of water for irrigation of crops such as rice and wheat is associated with decline in yields and production, and increased reliance on rainfed production. Adaptation measures to minimise these declines include institutional and policy innovations such as clarifying water rights and pricing mechanisms to encourage employment of water-saving techniques and technologies for both agricultural and urban uses (Yan, Wang and Huang [1.5]).

Where suitable water resources are available, farm-specific infrastructure such as irrigation systems can be developed or enhanced to further facilitate the expansion of intensive water-dependant farming (e.g. rice paddy) in drought-prone regions. Villages with irrigation infrastructure face lower downside risks in the context of climate change (Wang, Huang, Wang and Findlay [1.7], Wang, Yang, Huang and Adhikari [1.8]).

7.3.6 Social capital

Higher levels of social capital in a household are associated with better adaptation capacity against drought (Chen, Wang and Huang [1.1]). We expect this is associated with the value of networks in providing information among a like-minded group about the value of options for adaptation. The role of social capital in improving perceptions was also noted above.

7.3.7 Labour markets

Off-farm labour markets may also provide farmers with a means of adaptation to climate change. In response to the negative productivity shocks on agricultural output, farmers can mitigate the damage to their overall welfare by reallocating labour to off-farm work where the labour productivity is unlikely affected by the changed climate. However, the mitigating effect of labour reallocation depends on the property rights of farmland and the availability of off-farm work. Farmers with off-farm working opportunities who do not have property rights to farmland benefitted most from adaptation via labour reallocation in China (Huang, Wang, Huang and Findlay [1.7]).

7.4 Policy responses

As noted above, we find that farmers are more likely to make high-impact decisions when the measure is complemented by planned and institutional measures undertaken by governments. The most significant measure among the autonomous items is water management.

The willingness of farmers to adopt various measures and the impacts of these measures has been discussed. A framework for presenting these options and their impacts is shown in Table 1.

Table 1: Adaptation options

Easy to implement High impact	Difficult to implement High impact
Easy to implement Low impact	Difficult to implement Low impact

The ease of implementation indicated in Table 1 will generally depend on local conditions, for example, the ease of implementation of various water measures will depend on the extent and quality of the irrigation infrastructure that all farmers share. The ability to make investments will depend on access to credit. The security of property rights also affects the willingness to adopt management measures. Application of the items in the planned or institutional/policy areas is likely to ease (broadly defined to also include provision of

incentives for) the implementation of autonomous measures. In other words, farmer options that were previously difficult to apply are shifted to the left-hand column.

The planned and institutional measures also affect the impact of autonomous measures adopted. For example, good information systems will support more efficient choices by farmers. Likewise, water pricing provides incentives for farmers to make more efficient use of water, and also provides a benchmark for evaluating investments in local capture and storage of water. Removal of restrictions on labour mobility allows farmers to make efficient choices with respect to remaining on farm work or seeking work off the farm, or indeed relocating to urban areas permanently. Application of the items in the planned or institutional/policy areas are likely to add to the impact of the implementation of autonomous measures. In other words, farmer options that were previously low impact are shifted to the upper row.

The combined effect of the combination of planned and institutional measures on ease of implementation and impact is then to shift farmer options to the top left-hand box, which is the priority. Farmers will have an incentive to adopt autonomous measures, according to the drivers identified in the empirical work in this project. But the ease of doing so, including the incentive to do so, depend on the policy environment, the institutional environment and the investments by governments. These planned and institutional measures are in the hands of various levels of government, so an important implication of this work is the degree of coordination required to put that package of measures in place.

One issue in this coordination is that governments may have incentives to adopt particular types of measures. Visible initiatives such as large-scale engineering measures (e.g. sea walls) may be attractive, despite a lack of return to the investment compared to others that are less visible in those terms (e.g. water markets).

8 Impacts

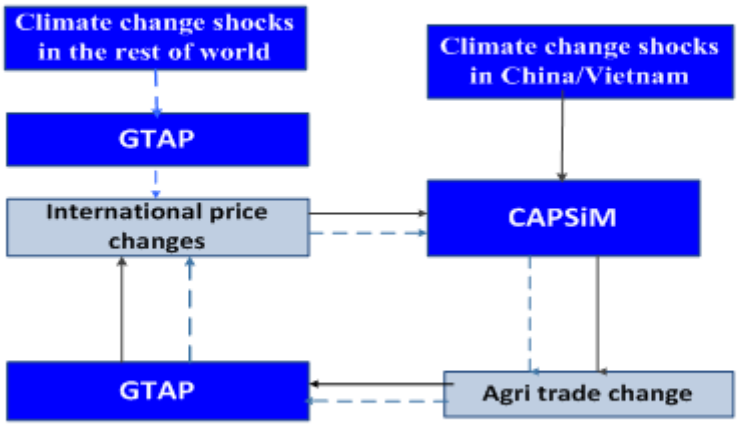
8.1 Scientific impacts – now and in five years

The first significant scientific impact of the project related to the sampling method. The methodology developed here (in terms of survey sampling and questionnaire design) will provide a guide for other studies. The research in this project was driven by the interest in farmer adaptation to climate change, which, as noted, involves long-run changes in temperature and rainfall. These changes are difficult to assess and those assessments may also be made in error. More immediate, however, are changes in variability of the weather, which are also associated with climate change. The research therefore focused on farmer decision making in the context of weather-related shocks, in particular, floods of various types, and droughts. This interest also drove the design of the sampling methodologies, which is explained in more detail in the papers referred to below. A typical example is the following:

- The first step was to select counties that had been affected by the most severe category of weather event during a three-year period.
- Of these, the next to be selected were those that also experienced years categorised as experiencing moderate flooding or less. The years of moderate or lesser flood events were defined as ‘normal years’ and the years during which farmers experienced the most severe event were defined as ‘disaster years’. Thus, a disaster year was defined by the presence of more disaster events (in frequency and magnitude) compared to a normal year.
- From the counties selected in this way, four counties were randomly selected as the study area.
- Townships were selected randomly in those counties from three main groups on the basis of their agricultural production infrastructure, which was categorised as above average, average, and below average. One township was selected from each category.
- The selection of villages followed the same method, and 10 households in each village thus selected were then selected randomly.
- The sample comprises three townships per county, three villages per township, and 10 households per village. Two plots for each household were surveyed.

A further significant scientific contribution was the modelling methodology. A key component of this methodology was establishing the equilibrium between the domestic and global levels of modelling. This linkage process was developed by the CCAP team of researchers using their domestic policy simulation model (CAPSiM) and the GTAP models. This linkage has not previously been developed successfully and it will become the benchmark for work of this type. The modelling work is summarised in Figure 1.

Figure 1. Linkage strategy for the two models



The linkages between CAPSiM and GTAP were carried out the following way. First, we simulated the impacts of climate change on China's agricultural production, consumption, price and trade, based on CAPSiM. Second, we transferred the results of China's climate change impact on agricultural trade from CAPSiM to GTAP. Based on GTAP, the changes in China's agricultural trade resulted in changes to international prices of agricultural commodity. Third, we transferred the changes in international agricultural prices from GTAP to CAPSiM to further simulate their impacts on China's agricultural trade, production, consumption and prices. This procedure can be continued until both models are in equilibrium. In both the national partial equilibrium model (e.g. CAPSiM) and a global model (e.g. GTAP), the scale of domestic commodity production and price are at national level. Figure 1 also shows how the impacts of climate change on agriculture in the rest of world can be transmitted to China.

Papers from the project provide methodologies that support similar studies in the rest of the world. They have already been widely cited and their results are providing guidance for other work.

- A paper published in 2014 in *Global Environmental Change* (Chen, Wang and Huang [1.1]) has already been cited 26 times. For example, Alam et al. (2016) (in *Ecological Economics*) cited this paper in relation to the following statements: '…there is a growing interest in the role of social capital (i.e., social connection) in enhancing vulnerable households' resilience", "(i)nstitutional variables (as determinants of adaptation choices include) comprising access to climate information, extension services, credit facilities, markets, irrigation, and off-farm employment opportunities" and (in their methodology) "the adaptation strategies were reorganized by grouping closely related choices into the same category based on the best practices in the field and expert opinions for the model estimation".
- The paper published in *American Journal of Agricultural Economics* (Huang, Wang and Wang [3.1]), although only published two years ago, has already been cited 15 times.

8.2 Capacity impacts – now and in five years

The most significant capacity impacts relate to the contribution of the research team in Vietnam. Colleagues in Vietnam, who came from different levels of research experience, have made substantial progress in their appreciation of the methodology for using farm-level data for policy analysis in this area, in their ability to apply that methodology, which involves large-scale household surveys, in their ability to apply statistical methods to those data and in their ability to translate the results to policy measures. The Vietnam team members also showed great adaptability in responding to an opportunity to add to the sample of surveyed households in the final months of the project by running additional surveys in a disaster-affected area. The experience of this project is expected to provide significant future benefits in terms of capacity in the partner agency. Overall, there were two working trips to CCAP for four researchers from Vietnam to develop their skills in the use of the CAPSiM model and to review the methodology in some specific papers. Dr Kaixing Huang from the University of Adelaide also visited CCAP to support the development of methodology in some papers.

There were also significant capacity impacts in China. In particular, a number of people were trained in the course of the project:

- More than 100 enumerators, on the sampling methods, questionnaire designs, and field surveys in China; most are PhD and Master students, research assistants and postdoctoral fellows
- More than 20 research assistants and graduate students, on the skills for data cleaning and statistical analysis; 15 of them were trained on the project design and research methodologies; 10 of them were trained on paper writing
- 4 PhD and 3 MS graduate students from CCAP in the research field of climate change.

These newly graduated young scholars are expected to play important roles in areas of the economics of climate change in their universities or research institutes in the near future.

8.3 Community impacts – now and in five years

8.3.1 Economic impacts

The focus of the project is on the short and long-run economic impacts in a baseline scenario of no intervention, compared to the effects of various forms of policy response to resolve market failures that might arise in the climate-induced adjustment process. Our results provide guidance on how policy measures can support the autonomous decision making of farmers. They also identify sets of farmers more likely to be at risk of climate change, due to a failure to adapt.

The significance of economic impacts of the work in this project can be inferred from other studies. In 2010 IFPRI released a report on *Food security, farming and climate change to 2050*, which concluded that properly targeted agricultural productivity investments can mitigate the effects of climate change and add to food security.

Work in the current project also finds that farmers do adapt to climate change and that a failure to take that adaptation into account leads to an overestimation of its impact. The potential for significant amelioration of the effects of climate change are reported here. Up to one-half of those effects are described in some studies of long-run adaptation. The consequences of adaptation in the short term were estimated to be more than US$8b.

The economic consequences of the combination of farmer adaptation and the farmer response to climate change depends on other factors. These are identified in the

modelling work undertaken here. For example, the research (Huang and Yang [4.1]) shows ‘a significant negative relationship between price elasticities and extreme weather events for wheat, maize, cotton, and edible oil crops but not for rice’. That is, except for rice, price elasticities are lower in the period with extreme weather events than in the period with normal years. The weak relationship between price elasticity and extreme weather events may be explained by the nature of rice production. Rice is fully irrigated with good infrastructure in China. The impact of extreme weather events (e.g. drought and flood) on rice yield is much less than that in other crops, which results in less price change in rice than in other crops when the extreme weather events occur. The above results imply that the impacts of climate variation on market price responses are crop-specific, which has important implications for agricultural commodity market analysis and food supply/demand projections.

Furthermore, other work (Huang, Xie, Ali and Yang [4.3]) applies the empirically estimated price elasticities of major crops in both the normal and extreme weather event years (and) simulates the impacts of extreme weather events based on a partial equilibrium model in agriculture for China) and a general equilibrium model. The results show that without considering the lower supply elasticities of many commodities in the crop sector when encountering the extreme weather events, the impacts of climate variations on production, consumption and trade are underestimated. The extent of underestimation also varies with the degree of trade liberalisation. A more open economy in the agricultural sector can reduce the impacts of extreme weather events through imports.

8.3.2 Social impacts

A target of the project is to identify the sorts of households that might be ‘at risk’ as a result of the challenges of climate change. An assessment of those more likely to shift back into poverty was undertaken and policy packages were designed to respond to that situation. Differential impacts of both climate change and the policy responses on men and women in rural areas were also discussed.

In Vietnam, in project meetings, farmers had the chance to report their problems to district and commune leaders. At provincial level, following the recommendations from the research results, the Department of Agriculture and Rural Departments of Tra Vinh and Ben Tre Provinces adjusted its annual production planning towards diversification, where farmers are encouraged to diversify their agricultural activities, thus reducing their production risks and improving their livelihoods.

Other social impacts include the pressure for institutional rebuilding in rural areas. One efficient form of adjustment may be to operate at a larger scale, but in communities with small holdings this requires significant changes in the management of land and the institutions that determine the land management system.

Other forms of adjustment include relocation or the shift to greater extent of off-farm work. The scope to make these changes depends on having other policies in place, including those affecting the ease of transition of farm labour to urban areas.

8.3.3 Environmental impacts

Most of the recommendations of both research teams aimed to reduce the negative impacts of extreme weather events in the short term, and climate change in the long term. Farmers’ own responses have a series of environmental impacts, including better water use and more efficient fertiliser use. These responses include the consequences of options such as new cropping and grazing regimes and improved manure management.

A further contribution of the project was to water management. CAP researchers point out from their experience in China that climate change is likely to increase the pressure to

design better institutions and infrastructure in water-scarce regions and to treat water as a scarce resource. This was among the policy options considered here.

8.4 Communication and dissemination activities

In a policy project, it is important to consider how policy research affects national policy and the views of policy makers. Research of this type takes time to complete its impact. The results of this two-year project, which was completed at the end of 2016, continue to be digested by policy makers. Changes in policy makers' views and policy impacts are best evaluated several years after the completion of any policy-related project.

In the case of China, the policy recommendations through CCAP's policy briefs and workshops have reached the top national leaders and many officials at the ministries. Many government officials have recognised the results from this project. The country team leader (Jikun Huang) and CCAP staff member (Jinxia Wang) have been invited to participate in several rounds of discussions and preparation of reports on climate change, its impacts and national adaptation strategies, organised by the National Climate Change Expert Commission. They were also invited to be on the panels for and became authors of the Third National Climate Change Evaluation Report in China, and reviewers of the fifth Report of Intergovernmental Panel on Climate Change, organised by the Chinese IPCC Commission.

The policy impact in China occurs at two levels: national and ministerial. This is done by sending policy briefs to national policy makers though the State Council. The policy recommendations were also passed to ministries using CCAP's current networking or though the team members in high-level government advisory boards. Organisation of project workshops to which advisory board members were invited was also a very effective method of generating impact.

Two policy briefs were prepared and circulated:

- Pay more attention to the poor: risk of climate change to farmers' livelihoods and adaptation capacity to climate change (submitted to State Council Office)
- Policy suggestions for improving adaptation capacity of agriculture and securing food security

Information consultations were held with government officials from several ministries:

- Ministry of Science and Technology
- Ministry of Finance
- Ministry of Agriculture

Regular meetings with the China Advisory Board were also organised.

Finally, media reports were prepared, for example:

- 8 December 2015. Impacts of climate change on China's agriculture are not so large (Jikun Huang), *Science and Technology Daily*
- 12 February 2016. Impacts of climate change on the output of China's agriculture are limited (Jinxia Wang), *Dialogue between China and the World*

Communication and dissemination activities of the Vietnam team were carried out via a number of channels.

Advisory Board meetings (7) were held to circulate preliminary research results. The workshops involved participants from a wide range of departments, including the Ministry of Agricultural and Rural Development, the Ministry of Natural Resources and Environment, the Vietnam Academy for Water Resources, the University of National Economics and the Water Resources University, as well as international organisations and development agencies that are currently involved in climate change projects.

Working sessions with provincial organisations and agencies in the survey provinces were carried out to circulate and to verify research results. During the meetings, the research team was also provided with important updates at provincial level in terms of early warning schemes, agriculture development plans in response to climate change and policies supporting farmers production.

Research results were presented in workshops (6 national and international workshops) and mass media (1 article in a newspaper; 2 interviews on the national TV channel). The research team also sent research results to An Giang University and Quy Nhon University, two partners that had supported the survey implementation.

The Vietnam team also submitted 2 policy briefs (1 for Mekong River Delta and 1 for South Central Coast) to respective ministries, including: 3 departments of MARD, 1 department of MONRE, 3 provinces (Ben Tre, Tra Vinh and Binh Dinh), the South-West Steering Committee and The Communist Party Central Economic Committee.

The final workshop for the project was held in Hanoi on 18 December 2016, followed by a public seminar on Monday 19 December 2016. A number of policy agencies participated. To illustrate the feedback Mr Trần Xuân Định – Deputy Director of Crops Department – MARD noted that his department had been provided important policy briefs and research results from the project team. As a member of the Advisory Board as well as manager of the beneficiary department, he appreciated the efforts and contribution of the project team. Key findings and recommendations from the research provided MARD with a sound basis, he said, for proceeding important policy adjustments (propositions for adjustment of Decree 42/2012/NĐ-CP on management and use of land for rice production: designing long-term, medium-term and short-term plans for climate change adaptation).

8.4.1 Research conferences

The project team met in Milan, Italy in August 2015 during the International Conference of Agricultural Economists (ICAE 2015) where they led an organized symposium on ‘Impacts of and Adaptation to Climate Change on Agriculture in China and Vietnam’, held 12 August The members of the team presented findings of research papers on (1) Impacts of climate change on crop yields in China; (2) Assessing the impacts of community’s and household’s assets on the adaptation behaviour of Vietnamese rice farmers against weather extreme events; (3) Adaptation capacity of irrigation infrastructure against extreme weather events and their cost evaluation in China; (3) Adaptation to climate change in Guangdong Province in China: Do land rights matter?; (4) Early warning information, farmers’ perceptions of and adaptations to drought in China, and (5) Impacts of climate change on China’s food security (see Appendix C for details).

Members of the Chinese team and the University of Adelaide team met in Canberra in February 2016 and presented their research findings at the AARES annual conference 2016 as a part of a special session, Farmers’ Adaptation to Climate Change (see Appendix C for details). The team members presented papers on (1) Impacts of climate change on major crop yield in China; (2) Climate change and China’s Agriculture: Impact and adaptation; (3) Adaptation to climate change in Guangdong Province in China: Do property rights matter?, and (4) The economic impacts of climate change on U.S. agriculture: the role of adaptation. The Vietnam team presented a paper to the AARES annual conference in 2017, on Impacts of farmers’ adaptation to drought and salinity intrusion on rice yield: an endogenous switching regression application.

9 Conclusions and recommendations

9.1 Conclusions

Climate change influences farming not only through changes to temperature and precipitation but also, importantly, through increases in the frequency of adverse events such as droughts, floods and severe storms. A contribution of this project was to provide new evidence of the effects of climate change on crop yields, where significant impacts were observed.

Farmer responses to these adverse events were the focus of this project, and from those responses the drivers of the farmer adaptation to climate change were identified. The project found there was a significant response by farmers to extreme weather events. A further contribution of the project was to present a system of classification of those responses. These include traditional adaptations to farm management practice, such as changing the use of farm inputs and altering seeding and harvesting times. Other options are more oriented to changes in engineering methods.

The contribution of farmer adaptation when it occurs is significant. A major result of this project is that farmer actions can offset from one-third to one-half of the effects of climate change in the long run. Significant output responses to the short-run adaptations were also found. These adaptations cannot be ignored. If they are ignored, then the impact of climate change on agriculture will be overstated.

However, not all farmers do adapt in the short term. Facilitating and improving the efficiency of farmer adaptations should therefore be an essential part of any policy response to climate change. The research identified the positive interaction between supportive policy and farmer willingness to adapt. The following actions will contribute to that purpose:

- The provision of early warning information on floods and droughts has a positive effect on farmer strategy.
- Reinforcing farmers' property rights to land and water rights encourages longer term investments and facilitates adaptation: it also supports the consolidation of land and its management at a larger scale, which also supports adaptation.
- Investment in infrastructure supports farmer adaptation – both physical infrastructure (e.g. roads and waterways) and social infrastructure (e.g. schools, training and systems for the extension of knowledge about weather; and farming techniques and technologies).

The capacity of farmers to adapt varies considerably. There are farmers at risk. Those who are older, less wealthy, with smaller and less consolidated farms, and living in mountainous areas are more likely to be at risk of climate change. That is, they are less likely to adapt and more likely to have their incomes reduced. A focus on these farmers is important. Early warning and other information systems and greater access to social capital are part of the set of responses.

The project highlighted the role of market signals in driving farmer responses. Climate change that reduces supply will lead to higher prices, to which farmers will respond. However, their responsiveness is affected by the circumstances. It will be lower in the context of climate change, it was found here, than in normal circumstances. An important contribution of the project was to take account of that lesser degree of responsiveness in work modelling the interactions of markets and farmer choices.

Coordination among levels of government will be important. The increased frequency of extreme events such as droughts, floods and severe storms will increase the incidence of episodic poverty among farmers and farm-dependent communities. These will require policies that facilitate increasing the resilience of farming systems and the adaptive

capacities of farmers and farm-dependent communities. A key result here was the willingness of farmers to adjust their management practice, but their relative lack of interest in engineering measures. These tend to require a greater degree of coordination with governments. Thus, the policy response to climate change will need to provide for the continual review of existing measures by local, regional and national governments, to assess their adequacy and appropriateness in facilitating structural changes and alleviating poverty. It will also need to consider new adaptation measures, including welfare measures, and the coordination of such measures among the different levels of government.

9.2 Recommendations

Research in this project concentrated on farm households involved in rice production. Future work might also involve the consideration of other crops, allowing comparative work across types of crops.

Future work could also involve the analysis of specific experiments in which policy is varied and impacts are identified, such as the provision of information systems as discussed here. The value of the experiments would be to identify the impacts of information delivered in different formats and in the context of complementary investments in physical and social infrastructure. Institutional settings, such as the regimes for property and water rights, will also be important items to control in these experiments.

There is value in continuing to build the empirical foundations of policy advice to support farmer adaptation to climate change. In this project, data collected in two economies were analysed and compared. Additional insights can be gained by broadening the set of countries included in the study. This project has established the survey design, the survey instruments, the econometric methods and the modelling technologies. The marginal cost of including additional countries in the study is therefore relatively small, but the insights from examining farmer behaviour in a wider set of circumstances are expected to be significant.

10 References

10.1 References cited in the report

Alam, G.M. Monirul, Khorshed Alam and Shahbazx Mushtaq 2016. Influence of institutional access and social capital on adaptation decision: empirical evidence from hazard-prone rural households in Bangladesh. *Ecological Economics*. 30, 243-251.

Rutten, M, M Van Dijk, W Van Rooij, and H. Hilderink. 2014. Land use dynamics, climate change, and food security in Vietnam: A global-to-local modeling approach. *World Development*, 59, 29–46.

Wang, J, J Huang and S Rozelle. 2010. *Climate change and China's agricultural sector: An overview of impacts, adaptation and mitigation.* ICTSD–IPC Platform on Climate Change, Agriculture and Trade. Issue Brief No.5, International Centre for Trade and Sustainable Development (ICTSD) Geneva, Switzerland and International Food & Agricultural Trade Policy Council, Washington DC, USA.

World Bank. 2010. *Vietnam: Economics of adaptation to climate change*. Washington,DC: World Bank.

10.2 List of publications produced by project

1. Adaptation strategies

1.1.

Title: Policy support, social capital, and farmers' adaptation to drought in China
Authors: Chen, Huang, Jinxia Wang, Jikun Huang
Publication status: Published in *Global Environmental Change*, 2014

Abstract: Increasingly severe drought has not only threatened food security but also resulted in massive socioeconomic losses. In the face of increasingly serious drought conditions, the question of how to mitigate its impacts through appropriate measures has received great attention. The overall goal of this study is to examine the influence of policies and social capital on farmers' decisions to adopt adaptation measures against drought. The study is based on a large-scale household and village survey conducted in six provinces nationwide. The survey results show that 86% of rural households have taken adaptive measures to protect crop production against drought, most of which are non-engineering measures. In the case of non-engineering measures, changing agricultural production inputs and adjusting seeding or harvesting dates are two popular options. A multivariate regression analysis reveals that government policy support against drought such as releasing early warning information and post-disaster services, technical assistance, and financial and physical supports, has significantly improved farmers' ability to adapt to drought. However, since only 5% of villages benefited from such supports, the government in China still has significant room to implement these assistances. Moreover, having a higher level of social capital in a farm household significantly increases their adaptation capacity against drought. Therefore, the government should pay particular attention to the farming communities, and farmers within a community who have a low level of social capital. Finally, farmers' ability to adapt to drought is also associated with the characteristics of their households and local communities. The results of this study

also have implications for national adaptation plans for agriculture under climate change in other developing countries.

1.2.

Title: Adaptation to climate change in Guangdong Province in China: Do property rights matter?
Authors: Thennakoon, Jayanthi, Christopher Findlay, Jikun Huang and Jinxia Wang
Publication status: Resubmission to *World Development*, 2017

Abstract: Improving land rights in China is often considered an important factor that facilitates farmers' investments in agriculture. However, whether securing land rights is important for farmers' adaptation to changing climate has not been addressed in the literature, particularly with respect to management decisions. This paper examines the relationship between land tenure types and farmer adaptation through management decisions in response to extreme weather events in Guangdong Province in China. Based on a household survey of rice farmers, our results show that farmers with contracted land are more likely to implement adaptation measures than those who have rented their land from the collective and from other farmers. The estimation results also suggest that farmers' adaptive behaviour in response to extreme weather events is significantly different from their day-to-day adaptation to ongoing changes in climate. Compared to a normal year with minor weather events, farmers are more likely to introduce adaptation measures in a disaster year. Farmers' adaptive capacity is also positively influenced by the public provision of information, social capital and plot quality. Results of this study highlight the importance of properly defined land rights for the likelihood of adaptation, and thereby increasing agricultural productivity and ensuring food security in the context of a changing climate.

1.3.

Title: Crop diversification in coping with extreme weather events in China
Authors: Huang, Jikun, Jing Jiang, Jinxia Wang and Lingling Hou
Publication status: Published in *Journal of Integrative Agriculture,* 2014

Abstract: Apart from the long-term effects of climate change, the frequency and severity of extreme weather events have been increasing. Given the risks posed by climate change, particularly the changes in extreme weather events, the question of how to adapt to these changes and mitigate their negative impacts has received great attention from policy makers. The overall goals of this study are to examine whether farmers adapt to extreme weather events through crop diversification and which factors influence farmers' decisions on crop diversification against extreme weather events in China. To limit the scope of this study, we focus on drought and flood events only. Based on a unique large-scale household survey in nine provinces, this study finds that farmers respond to extreme weather events by increasing crop diversification. Their decision to diversify crops is significantly influenced by their experiences of extreme weather events in the previous year. Such results are understandable because farmers' behaviors are normally based on their expectations. Moreover, household characteristics also affect farmers' decisions on crop diversification strategy, and their effects differ by farmers' age and gender. This paper concludes with several policy implications.

1.4.

Title: Information provision, policy support, and farmers' adaptive responses against drought: An empirical study in the North China Plain
Authors: Wang, Jinxia, Yu Yang, Jikun Huang and Kevin Chen
Publication status: Published in *Ecological Modelling*, 2015

Abstract: As an important agricultural production region in China, the North China Plain (NCP) is an ecologically vulnerable region that frequently is hit by drought. Faced with drought and other extreme climate events, policy makers have given top priority to the formulation and implementation of adaptation policies. This paper assessed the effectiveness of adaptation policies, including the provision of early warning information and policy supports, on farmers' adaptive decisions regarding the planting of the wheat crop in the NCP. Based on a unique dataset from a large-scale village and farm survey in five provinces in the NCP, an econometric model of farmers' adaptation practices is estimated. Results show that when faced with a more severe drought, farmers change their management practices to mitigate its effects by adjusting seeding or harvesting dates and enhancing irrigation intensity. The provisions of early warning and prevention information and policy supports against drought facilitate farmers to make farm management adaptations. However, the effectiveness of early warning and prevention information or policy supports differs by their provision channels or types. The findings of this study have policy implications in coping with the rising frequency and seriousness of extreme weather events in China as a whole and in ecologically more vulnerable NCP in particular.

1.5.

Title: Urbanization, agricultural water use, and regional and national crop production in China
Authors: Yan, TingtingJinxia Wang and Jikun Huang
Publication status: Published in *Ecological Modelling*, 2015

Abstract: The overall goal of this paper is to analyze the impacts of the urbanization on regional and national agricultural production through its impact on water use in agriculture in China. Given the historical trend of water use in agriculture and its correlation with urbanization, the change in agricultural water use due to urbanization is estimated. Then the impacts of this change on regional crop production are simulated based on the China Water Simulation Model (CWSM). Within CWSM, a positive mathematical programming (PMP) optimizes water allocation among crops and between irrigated and rainfed areas within a crop in each of ten river basins in China. The results show that water use in China has an obvious increasing trend, particularly in the industrial and domestic sectors, while the share of water use in agricultural sector has been dropping. A 1-percentage-point increase in urbanization can result in a 0.47 percentage-point decline in share of water use. Based on the model simulation, this will lead to the further decrease of irrigated areas and the increase of rain fed areas at both the national and river basin levels, particularly for water intensive crops (such as rice and wheat). Accordingly, average yields and total production will also decrease. A river basin with large production of either rice or wheat (or both) decreases more in irrigated area as urban area expands. Adaptation measures are recommended for both authorities and farmers to ensure food security, such as providing incentive for farmers to adopt water saving technology, implementing appropriate institutional and policy innovations (e.g. water use association, water pricing and water use rights).

1.6.

Title: Household and community assets and farmers' adaptation to extreme weather event: The case of drought in China
Authors: Wang, Yangjie, Jikun Huang and Jinxia Wang
Publication status: Published in *Journal of Integrative Agriculture,* 2014

Abstract: Under climate change, rising frequency and serious extreme weather events have challenged agricultural production. Designing appropriate adaptation measures to the extreme weather events requires rigorous and empirical analysis. The overall goals of this study are to understand physical adaptation measures taken by farmers and the impacts of household and community assets on farmers' adaptation when they face drought. The analyses are based on a unique data set collected from a household survey in three provinces in China. The survey results show that though not common on annual basis, some farmers did use physical adaptation measures to fight drought. Regression analysis reveals that both household and community assets significantly affect farmers' adaptation behaviors. Improving households' social capital and wealth, communities' network and access to government's anti-drought service can facilitate farmers' adaptation to drought. Results indicate that community's irrigation infrastructure and physical adaptation taken by farmers can substitute each other. Further analysis shows that the households taking adaptation measures have higher crop yields than those without taking these measures. The paper concludes with several policy implications.

1.7.

Title: Farmers' adaptive response on adjusting irrigation and its effect on reducing drought risk for rice production in China
Authors: Wang, Yangjie, Jikun Huang, Jinxia Wang and Christopher Findlay.
Publication status: Resubmission to *Australian Journal of Agricultural and Resource Economics*, 2017

Abstract: This paper investigates the role of farmers' adaptive response adjusting irrigation in the management of drought risk, with an application to Chinese rice farms. The analysis relies on a moment-based specification of the stochastic production function capturing mean, variance, and skewness effects. Based on field survey data, we jointly estimate farmers' adaptive irrigation decisions and their effects on rice yield and production risk. Our econometric analyses show that irrigation infrastructure in villages contribute to enhancing farmers' irrigation capacity in adapting to drought. Irrigation leads to a significant increase in yield and a significant reduction in the exposure to risk as well as downside risk in rice production. Hence, we stress the role of irrigation adjustment as a means of managing drought risk. In terms of policies, our findings suggest that the government should mainstream the investment in irrigation infrastructure into a climate change adaptation plan, and thereby improve rice farmers' adaptive capacity by adjusting irrigation and reducing their exposure to drought risk.

1.8.

Title: Adaptive irrigation measures to deal with extreme weather events in the North China Plain
Authors: Wang, Jinxia, Yu Yang, Jikun Huang and Bhim Adhikari
Publication status: Submitted to *Journal of Agricultural and Resource Economics*, 2017

Abstract: The overall goal of this study is to examine how farmers have made adaptive irrigation responses against drought and the determinants and effectiveness of these responses in the NCP. The data comes from a large field survey in five provinces. The results show that when faced with a more severe drought, farmers change their management practices to mitigate its effects mainly by taking some irrigation measures, such as enhancing irrigation intensity by increasing frequency and increasing efficiency by adopting surface pipes. The local irrigation infrastructure (such as tubewell density and whether there is access to surface water), provision of physical, financial and technical policy support and early warning information services against drought facilitate farmers to take adaptive responses. In addition, existing villages, households and plot characteristics also significantly influence farmers' decisions on adopting adaptive measures. Further analysis shows that adaptation through farmers' responses significantly increases crop yield and reduces the risk associated with extreme weather eve ts. The paper concludes with some policy implications.

1.9.

Title: Labor reallocation of farmers as an adaptation to global warming, and its welfare implications
Authors: Huang, Kaixing, Jikun Huang, Wang, Jinxia, and Christopher Findlay
Publication status: To be submitted to a journal, 2017

Abstract: Utility-maximizing farmers are likely to reallocate their working time in response to the decline of agricultural productivity caused by climate change. This paper develops a representative agent model to examine the consequences of this adaptation behavior. In the model, the target of each family is to maximize the family utility that is derived from both consumption and leisure. The model shows that, by reallocating time between agricultural production, non-agricultural production, and leisure, farmers can mitigate the overall damage of climate change on family welfare. The model suggests the efficiency of adaptation depends on the availability of off-farm working opportunities and farmland property rights. Farmers with off-farm working opportunities will benefit more from adaptation than farmers who do not have such opportunities. If property rights of the farmland do not belong to the family, the adaptation may even offset all of the damage of climate change. However, interestingly, the adaptation will always reduce agricultural output because labor is shifted to other sectors.

1.10.

Title: Assessing the impacts of household and community assets on the adaptation behavior of Vietnamese rice farmers to climate change
Author: Khôi, Đặng Kim
Publication status: Published in *Journal of Economics and Development,* 2016

Abstract: Vietnamese farmers have conducted various adaptation measures in the complicated context of climate change. However, these adaptation measures are implemented spontaneously and ineffectively. In fact, there are very few comprehensive studies focusing on this important aspect, assessing impact factors in farmers' capacity to adapt to climate change. This study is to fill these knowledge gaps through assessing the impacts of farmers' capital (including social, human and asset) and local characteristics (socioeconomic aspects and infrastructure) on their capacity to adapt to climate change. Based on a large-scale survey of 623 rice farmers affected by climate change in the Mekong River Delta and South Central Coast, statistical and econometric analyses are carried out to quantify impact factors on farmers' capacity to adapt to climate change. Research results indicate that farmers' better economic conditions, better infrastructure and government support facilitate adaptation to climate change.

1.11.

Title: Enhancing farmers' capacity to adapt to climate change: Empirical study of the role of information provision and policy supports

Authors: Khoi, Đặng Kimi and Nguyen Tam Ninh

Publication status: Published in the proceedings of the international workshop in Ha Noi on 'Vietnam's Economy in the Medium Term: Prospects and Some Impacts of the Environment' organised by the National Centre of Information and Forecasting, Ministry of Planning and Investment, 18 November 2016

Abstract: In the context that Vietnam is one of top five countries vulnerable to climate change, both government and farmers are actively adapting. The relationship between these two adaptation types has not been studied in detail. To fill this gap, the current study, based on a sample of 2157 plots of 695 households drawn from 66 villages in 3 provinces, aims to quantify the role of government intervention in increasing farmers' likelihood of adopting adaptive measures against climate change. The channels of government support include: (i) provision of early warning information; (ii) financial support; (iii) technical support; and (iv) in-kind support. Econometric analysis using Logit estimation provides sound evidence about the positive effects of government support for adaptation. Support in any form significantly improves farmers' adaptive capacity. However, some channels of support have stronger effects than others.

1.12.

Title: Policy support, household assets, community assets, and farmer adaptation to drought and salinity intrusion in Mekong River Delta during 2010–2016
Authors: Khoi, Dang Kim, Bui Thanh, Nguyen Thi Tam Ninh & Bob Warner
Publication status: Submitted to *Asia and the Pacific Policy Studies*, Australian National University, 2016

Abstract: Although Mekong River Delta has been suffering serious droughts and salinity intrusion in recent years, there is no study in Vietnam identifying determinants of farmer's adaptation over a long period of time. This study, based on a panel sample of 340 households during 2010–2016 in Ben Tra and Tra Vinh provinces, aims to quantify the role of farmer and community assets, and the effect of government intervention on farmers' adoption of engineering measures. For the first time, both pooled OLS and panel data estimations are used to analyse the impacts of various factors on farmers' adaptation

in three levels of disaster seriousness: no disaster (Winter–Spring 2015), small disaster (Winter–Spring 2011), and big disaster (Winter–Spring 2016). Econometric results show that farmers tend to adapt more in big disaster year compared to normal and small-disaster years. Moreover, households assets and governmental supports significantly affect the adaptation behaviors of farmers.

1.13.

Title: Agriculture under climate change in the Mekong Delta: From incremental adaptation to transformational options
Author: Khoi, Dang Kim, Le Thi Ha Lien, Bob Warner, Do Huy Thiep, Nguyen Tam Ninh, Nguyen Dinh Dao
Publication status: Completed and to be submitted to a journal

Abstract: The Mekong Delta of Vietnam is the most vulnerable to climate change of the world's rice bowls. Uncoordinated upstream development of water and land resources is altering the hydrological regime of the Mekong River. The combination of these two threats is causing serious drought and salinity intrusion that undermines food security and livelihoods. Drawing on a survey of 390 rice households in Ben Tre and Tra Vinh provinces from 2011, 2015 and 2016, this paper shows that local governments and farmers reinforce their adaptation actions in response to the most serious disasters. However, the overall level of adaptation is typically incremental and inconsistent with the magnitude of growing challenges. Current government policies and farmer practices are reactive and failing to keep pace with fundamental shifts in climate and water systems. A new, proactive approach is needed to emphasize systemic and transformational changes that increase the resilience of the delta's agricultural systems to current and future risks.

1.14.

Title: Impacts of farmers' adaptation to drought and salinity intrusion on rice yield in the Mekong River Delta: An endogenous switching regression application
Author: Nguyen Thi Tam Ninh, Chu Hoang Long, Dang Kim Khoi
Publication status: Completed and to be submitted to a journal

Abstract: Climate change, characterized by a changing rainfall pattern, increasing temperature and rising sea level, is leading to severe droughts, floods and salt water intrusion. Scarcity of fresh water for agricultural production is becoming one of the major challenges to crop productivity and therefore to national and global food security. Farmers' adaptation, varying from a wide range of measures to respond to or to mitigate negative impacts of the climate extremes, has been shown to be beneficial in lessening production yield loss. Based on five years of survey data of 4102 rice plots in two coastal provinces in Mekong River Delta, this study examines the effect of farmers' adoption of adaptive measures on rice yield, taking into account the impact of disaster, measured by its level of severity. Given that the endogeneity of adaptive behaviors may generate biased evaluation of such impacts, this study applies endogenous switching regression to separate treatment effects of adopters and non-adopters. The study finds that those who did adapt are better off from applying adaptation measures, whereas those who did not adapt may be worse off if they could have adapted. This finding may imply that farmers' decisions are optimal given their resource constraints. Without breaking innovation or strong changes in farmers' capacity, adaptation to climate change would not be always effective.

1.15.

Title: Farmers' constraints, governmental support and climate change adaptation: Evidence from Guangdong Province, China
Authors: Xu Ying and Christopher Findlay
Publication status: Working paper

While climate change is widely recognised, the role of governmental support in adaptation is much less understood. We aim to narrow this gap through innovative modelling of the adaptation decision as a three-stage process: (1) whether the farmer needs adaptation, (2) whether there are constraints that prevent adaptation, and (3) whether such constraints are removed through governmental support. We develop a triple-hurdle model to exactly depict such decision-making process. It is found that governmental support is positively associated with an increase in the probability of adaptation of 0.244. This positive change is much larger than the estimates in recent literature, suggesting governmental support works much more effectively among the farmers with constraints. Therefore, there is a need to correctly identify each subgroup in need to optimise expected policy results.

2. Perceptions

2.1

Title: Early warning information, farmers' perceptions of and adaptations to drought in China
Authors: Hou,Lingling, Jikun Huang and Jinxia Wang
Publication status: Published in *Climatic Change*, 2017

Abstract: Farmers' perceptions of the local climate reflect their own judgments of climate change and may affect their adaptation behaviors. However, the current literature lacks adequate coverage of the relationship between farmers' perceptions and adaptation practices. Therefore, this study uses original household survey data from nine provinces of China to examine major factors influencing farmers' perceptions of drought and whether these perceptions affect adaptation practices. The results show that over half of the sample farmers perceived that the severity of drought had increased in the past ten years. Moreover, econometric analysis indicates that providing early warnings of drought to farmers can alter their perceptions, which affect their adaptation choices. Farmers perceiving increasing severity of drought are more likely to attempt to adapt by adopting water-saving technologies. The paper concludes by offering policy implications of the results.

2.2

Title: Farmers' perceptions of climate change in China: The influence of social networks and farm assets
Authors: Hou, Lingling, Jikun Huang and Jinxia Wang
Publication status: Published in *Climate Research,* 2015

Abstract: Farmers' perceptions of the local climate reflect their awareness of climate change and may affect their adaptation behaviours. However, current literature suffers a knowledge gap on farmers' perceptions of climate change. This study examines farmers'

perceptions of annual mean temperature, the consistency of these perceptions with meteorological record data, and what influences this relationship. The study found that >70% of farmers in China perceived an increasing trend of annual mean temperature over the past 10 years, while only 8% of farmers perceived a decreasing trend. Moreover, only 18% of farmers perceived a temperature change that was consistent with the meteorological record data. Econometric analysis shows that social networks can improve a farmer's ability to correctly perceive temperature changes. Additionally, those with a larger farm size are more likely to be able to consistently perceive temperature. This study concludes with several policy and research implications.

2.3

Title: Determinants of farmers' perception on climate change
Authors: Khôi, Đặng Kim, Nguyễn Thị Tâm Ninh, Vũ Thị Lan
Publication status: Published in *Economy and Forecast,* Ministry of Planning and Investment, 2016

Abstract: The study examines the factors influencing the farmer's awareness of climate change. Overall, the result shows that formal information sources, with government support, play an important role in improving the farmers' perception of local climate variability. Technical support of climate change adaptation reveals the highest effect on perception, while the effectiveness of training is lowest. Whereas all villagers can access information about climate change, technical training can be provided for only one member of each family. Therefore, the respondents in this survey might or might not have attended the training. The proposal is that after attending the training the participants will share the information they obtained with the others, but the information from training cannot pass through one hundred per cent. One policy implication is that before implementing any policy to improve farmers' awareness of climate change, policy makers should consider whether that policy can be widely applied.

2.4

Title: Early warning information, farmers' perceptions of and adaptations to drought and salinity intrusion in Mekong River Delta of Vietnam
Authors: Nguyen Thanh Hue, Thanh Nguyen, Dang Kim Khoi, Vu Thi Lan
Publication status: In progress

Abstract: Farmers' perceptions of the local climate reflect their own judgments of climate change and may affect their adaptation behaviors. However, the current literature lacks adequate coverage of the mechanisms linkingnformation provision, farmers' perceptions and adaptation practices. Therefore, this study uses original rice household survey data from Ben Tra and Tra Vinh provinces of Vietnam to examine major factors influencing farmers' perceptions of drought and whether these perceptions affect adaptation practices. The results show the number of farmers who perceived that the severity of drought and salinity intrusion had increased during 2010–2016. Moreover, econometric analysis indicates that providing early warnings of drought to farmers can change their perceptions, which affects their adaptation choices. Farmers perceiving increasing severity of drought are more likely to attempt to adapt by adopting adaptation measures.

3. Effects of climate change

3.1

Title: Farmers' adaptation to extreme weather events through farm management and its impacts on the mean and risk of rice yield in China
Authors: Huang, Jikun, Yanggjie Wang and Jinxia Wang
Publication status: Published in *American Journal of Agricultural Economics*, 2015

Abstract: We explore how rice farmers adjust their farm management practices in response to extreme weather events and determine whether their adjustments affect the mean, risk, and downside risk of rice yield. Based on a survey of 1,653 rice farmers in China, our econometric analyses show that the severity of drought and flood in the study areas significantly increases the risk and downside risk of rice yield. The applied farm management measures respond to severe drought and flood and can be considered as adaptation to climate change, an issue often ignored in previous studies. We model adaptation and its impact on rice yield for adapters and non-adapters. Utilizing a moment-based approach, we show that adaptation through farm management measures significantly increases rice yield and reduces the risk and downside risk of rice yield. Several policies, including scaling up the cost-effective farm management adaptation and providing public services related to natural disasters, are recommended to improve adaptive capacity of farmers, particularly the poor, in response to extreme events.

3.2

Title: Impacts of climate change on net crop revenue in North and South China
Authors: Wang. Jinxia , Jikun Huang, Lijuan Zhang and Yumin Li
Publication status: Published in *China Agricultural Economic Review*, 2014

Abstract: The purpose of this paper is to explore the impacts of climate change on crop net revenue by region. Particularly, the authors focus on the impact differences between north and south regions. The authors applied the Ricardian approach which assumes that each farmer wishes to maximize revenue subject to the exogenous conditions of their farm. The climate data are based on actual measurements in 753 national meteorological stations and the socio-economic data covers 8,405 farms across 28 provinces in China. On average, the rise of annual temperature will hurt farms both in the north or south. The impacts of climate change on both precipitation and temperatures have different seasonal impacts on producers in the north and the south of China. As a consequence, the impact on net farm revenues varies with farms in the north and the south being adversely affected (to different degrees) by a rise in the temperature, but both benefiting from an anticipated increase in rainfall. The results also reveal that irrigation is one key adaption measure to dealing with climate change. Whether in the north or south of China, increasing temperature is beneficial to irrigated farms, while for rainfed farms, higher temperature will result in a reduction in net revenues. The results also reveal that farms in the north are more vulnerable to temperature and precipitation variation than that in the south. Irrigated farms in the south are more vulnerable to precipitation variation than that in the north; but rainfed farms in the north are more vulnerable to precipitation variation than that in the south. Applying empirical analysis to identify the differences of climate change impacts between north and south regions will help policy makers to design reasonable adaptation policies for various regions.

3.3

Title: Impacts of climate change on water and agricultural production in ten large river basins in China
Authors: Wang, Jinxia Jikun Huang and Tingting Yan
Publication status: Published in *Journal of Integrative Agriculture*, 2013

Abstract: The overall goal of this paper is to examine impacts of climate change on water supply and demand balance and their consequences on agricultural production in ten river basins in China. To realize this goal, China Water Simulation Model (CWSM) is used to analyze three alternative climate scenarios (A1B, A2 and B2). The results show that the impacts of climate change on water supply and demand balance differ largely among alternative scenarios. While significant impacts of climate change on water balance will occur under the A1B scenario, the impacts of climate change under the A2 and B2 scenarios will be marginal. Under the A1B scenario, the water shortage in the river basins located in the northern China will become more serious, particularly in Liaohe and Haihe river basins, but the other river basins in the southern China will improve their water balance situations. Despite larger impacts of climate change on water balance in the northern China, its impacts on total crops' production will be moderate if farmers would be able to reallocate water among crops and adjust irrigated and rainfed land. The paper concludes with some policy implications.

3.4

Title: Impacts of climate change on the mean and variance of indica and japonica rice yield in China
Authors: Wang, Jinxia, Lijuan Zhang and Jikun Huang
Publication status: To be submitted to a journal, 2017

Abstract: The overall goal of this study is to examine the impacts of climate change and its variation on both the mean and the variance of rice yields in China. This study uses an econometric model to estimate Just-Pope stochastic production functions and identify the potential impacts of temperature and precipitation on the mean and variance of rice yield by rice type (Indica rice and Japonic rice). Based on the estimated production functions, the contribution rate of climatic factors to rice yield is then assessed by conducting the growth accounting of yield over the past 30 years. In the future, after keeping constant other factors, the relationship between the change in the temperature and precipitation and the mean of rice yield is analyzed. The estimation results show that not only the mean of rice yield, but the yield variance also will be influenced by climate change. Moreover, not only the mean trend change of climate change, but also the climate variance will significantly influence rice yield. In the future, the impacts of climate change on rice yield depends on local regions' present climate condition. The results have implications for improving adaptation capacity of rice production.

3.5

Title: The potential benefits of agricultural adaptation to warming in China in the long run
Authors: Huang, Kaixing, Jinxia Wang, Jikun Huang, and Christopher Findlay
Publication status: Revise and submit to *Environment and Development Economics*, 2017

Abstract: Understanding the extent to which agriculture can adapt to climate change and the determinants of farmers' adaptive capacity are of paramount importance from a policy

perspective. Based on a panel of household survey data from a large sample in rural China, the present article adopts a panel approach to estimate the potential benefits of long-run adaptation and to identify the determinants of farmers' adaptive capacity. The empirical results suggest that, for various model settings and climate change scenarios, long-run adaptations should mitigate one-third to one-half of the damages of warming on crop profits by the end of this century. These findings support the basic argument of the hedonic approach that omitting long-run adaptations will dramatically overestimate the potential damage of climate change. The paper also finds that household-level capital intensity and farmland size have significant effects on farmers' adaptive capacities.

3.6

Title: The potential benefit of agricultural adaptation to climate change in Vietnam in the long term
Authors: Vu Thi Lan, Kaixing Huang, Nguyen Thi Tam Ninh and Dang Kim Khoi
Publication status: Completed

Abstract: Given that farmer's adaptation can mitigate the potential impacts of climate change on agriculture, the omission of such adaptive practices in econometric models may overestimate the damages of climate change in the long term. Thus, understanding the value of long-run adaptation measures and factors influencing overall farmers' adaptation capacity are the keys in designing effective adaptation policies. By employing large-scale household survey data in the Mekong River Delta and South Central Coast of Vietnam from 2010 to 2015, a panel approach has been taken to examine the overall benefit of agricultural adaptation and the determinants of farmers' capacity to adapt to climate change. The results show that the long-run adaptation is able to offset approximately 35 per cent of the damage of climate change. In addition, the availability of infrastructure helps farmers diversify their adaptive measures and large land size increases the value of adaptations. This supports the case for agricultural land consolidation policies.

3.7

Title: Supply reliability of groundwater irrigation, climate change and tubewell density in rural China
Authors: Li Yanrong, Jinxia Wang, Jikun Huang, Bhim Adhikari and Liangzhi You
Publication status: Submitted to *China Agricultural Economic Review* in 2017

Abstract: The paper aims to examine the status of the supply reliability of groundwater irrigation, and discusses how it is affected by climate change and tubewell density in rural China. Based on a large-scale, 9-province village survey and secondary climate data, results showed that on average, supply reliability was 89 per cent in the past three years. Econometric results presented a non-linear relationship, which revealed that the annual temperature significantly influenced the supply reliability of groundwater irrigation. When the temperature is higher than the turning point, the relationship between temperature and supply reliability of groundwater irrigation changes from being positive to being negative. Except for Jilin Province, the annual temperature in eight provinces was higher than the turning point. In the future, after keeping other factors constant, if the temperature increases by 20 ^{o}C, supply reliability will be reduced by 20%. However, if precipitation increases by 50%, supply reliability can be increased by 10%, whereas if precipitation reduces by 50%, supply reliability will be reduced by 10%. Increasing the density of tubewell is greatly beneficial to supply reliability. However, although increasing the density of tubewells may ensure that enough groundwater is available for irrigation, such a

conclusion is one-sided, and sustainability concerns should be raised in assessing this method of creating supply reliability.

4. Modelling

4.1

Title: Farmers' production responses to market prices with consideration of the effects of extreme weather events in Guangdong Province: Micro-level analysis based on household survey data
Authors: Yang Guolei and Jikun Huang
Publication status: Writing in progress and to be submitted to a journal in China in 2017

Abstract: This analysis is based on household data collected in Guangdong provinces over the period 2010–2014. We find that the relationship between price responses and climate variations is weak in rice production but significantly negative in vegetable production. The reason for the weak relationship for rice is lack of transmission of potential climate-induced rice price change into actual rice prices received by farmers during 2010–2014, when the government implemented the minimum price procurement policy for rice. The strong negative relationship between price responses and climate variations in the vegetable sector confirms as expected that supply elasticity of vegetables with respect to price falls in the period with extreme weather events, which has implications for the commodity projection when market equilibrium models are used in the analysis.

4.2

Title: Farmers' production responses to market prices with consideration of the effects of extreme weather events in China: Macro-level analysis based on cross-section and time-series data in 1998–2013
Authors: Huang Jikun and Guolei Yang
Publication status: Writing in progress and to be submitted to a journal in China in 2017

Abstract: This analysis is based on provincial-level data over a period of 16 years. The results show a significant negative relationship between price elasticities and extreme weather events for wheat, maize, cotton, and edible oil crops but not for rice. That is, except for rice, price elasticities are lower in the period with extreme weather events than in the period with normal years. The weak relationship between price elasticity and extreme weather events may be explained by the nature of rice production. Rice is fully irrigated with much better infrastructure in China. The impact of extreme weather events (e.g. drought and flood) on rice yield is much less than on other crops, which results in less price change in rice than in other crops when extreme weather events occur. The above results imply that the impacts of climate variation on market price responses are crop-specific, which has important implications for agricultural commodity market analysis and food supply/demand projections.

4.3

Title: Impacts of extreme weather events on agricultural commodity markets with consideration of the different supply responses between the normal and extreme weather event years in China
Authors: Huang, Jikun, Wei Xie, Tariq Ali and Guolei Yang
Publication status: Writing in progress and to be submitted to a journal in 2017

Abstract: Applying the empirically estimated price elasticities of major crops in both the normal and extreme weather event years, this study simulates the impacts of extreme weather events based on an integrated model of CAPSiM (a partial equilibrium model in agriculture for China) and a general equilibrium (GTAP, a global trade analysis program). The results show that without considering the lower supply elasticities of many commodities in the crop sector when encountering extreme weather events, the impacts of climate variations on production, consumption and trade are underestimated. The extent of underestimation also varies with the degree of trade liberalization. A more open economy in the agricultural sector can reduce the impacts of extreme weather events on crop production, consumption and price through imports.

4.4

Title: Estimating supply elasticity to price under normal year and disaster year
Author: Do Huy Thiep, Dang Kim Khoi
Publication status: Completed and a working paper available

Abstract: This paper use a 6-year panel data of 340 rice farmers in Ben Tre and Tra Vinh – who was affected by salinity intrusion in 2011 and 2016 – to estimate the elasticity of supply to price and its difference during normal years and disaster years. Panel regression models were used to control the impact of other factors, including household characteristics and farm characteristics. The regression results show that the price elasticity of area and yield are lower than the estimated number in previous studies, and this elasticity is also much smaller during disaster years compared to a normal year.

4.5

Title: Impacts of drought and salinity intrusion in the Mekong River Delta on the Vietnamese rice sector – results from a multi-sectoral equilibrium model
Author: Nguyen Ngoc Que, Do Huy Thiep, Dang Kim Khoi
Publication status: Completed and to be submitted to a journal

Abstract: The agricultural sector in the Mekong River Delta is facing serious constraints from climate change and upstream development activities. Climate change – represented by extreme weather events – not only affects the productivity and production of farmers but also affects farmers' production behavior. The research team developed a multi-sectoral equilibrium model for the Vietnamese agricultural sector, which can be used to predict the development of the Vietnamese rice sector and the impacts of drought and salinity intrusion on this sector in the 2016–2035 period. The results show that climate change is associated with a reduction of 11.31% of Vietnamese rice production at the end of the prediction period, equal to 6.46 million tons of rice. It also shows a significant impact of climate change on Vietnamese rice exports: the annual growth rate of rice export

quantity falls from 2.05%/year to 0.9%/year and the total losses caused by climate change during this period are estimated to be US$8.2b of export value.

5. Overview

5.1

Title: Rural adaptation to climate change
Author: Findlay, Christopher, Jikun Huang, Khoi Dang Kim and Herb Plunkett
Publication status: In draft

Abstract: A research project was recently undertaken with support from the Australian Centre for International Agricultural Research. Here, we review the results of that work along with those of related and relevant literature. We outline the context in which adaptation decisions are made, in particular, the changes in the structure of the agricultural sector. The work in this project was concentrated in China and Vietnam and those economies are the focus of this section of the paper. We then review the recorded impacts and adaptations to climate change to date before turning to the research results in this project.