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Managing climate risks through transformational adaptation: Economic and policy implications for key production regions in Australia

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ABSTRACT

Transformational adaptations are expected to become more frequent and widespread in Australia, and globally, with a changing climate. However, any transformation adaptation will have complex and interconnected effects on rural communities, particularly income, employment and service provision, which will impact on regional sustainability. This paper investigates regional transformative adaptation options to manage climate risks for the rice and cotton industries of northern Queensland, Australia. More specifically, it seeks to identify when to move from incremental adaptation to transformative adaptation and, more importantly, to assess the potential regional economic consequences of such a transformative adaptation. The results indicate transformative adaptation could have large negative effects on regional economies. Relocation of rice or cotton in sugarcane production system will not compensate some negative regional impacts. More importantly, the increase in wheat production in Riverina will not compensate for the reduction in the higher value rice commodity. However, the cotton production system in Queensland is capable of transformational adaptation and incremental adaptation with little impact on regional communities. In contrast, the southern rice production region of the Riverina shows limited capacity for incremental adaptation, given the already high adoption of improved irrigation technologies and practices, and the limited scope to improve these further. The market incentives for the transformation adaptation of cotton and/or rice production in north Queensland are limited without government support. Alternatively, there may be interest from international investors, which would shift the focus from market opportunities to international food security.

1. Introduction

Climate change poses major challenges to all key sectors of the economy, but particularly those sectors such as agriculture and food that are dependent on natural resources (Vermeulen et al., 2013; Antle and Capalbo, 2010; Brown and Funk, 2008; Schmidhuber and Tubiello, 2007). Climate change impacts on almost every aspect of agricultural production, including crop yield and quality, threatening regional stability and the economic viability of rural communities (Marshall et al., 2014; Vermeulen et al., 2012a, 2012b; Nelson et al., 2010; Santhanam-Martin et al., 2015). While adaptation is more the norm than the exception for rural communities, the key challenge in the coming decades will be the rate and nature of climate change compared with the adaptation capacity of farmers (Rosenzweig and Tubiello, 2007; Dow et al., 2013; Dovers and Hezri, 2010; Kenny, 2011). If future changes are incrementally small,

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farmers may adapt to the changing climate by adjusting structurally and by applying agronomic techniques (Rosenzweig and Tubiello, 2007; Mushtaq et al., 2013; Chatzopoulos and Lippert, 2015). However, it is unlikely that incremental change alone will be sufficient to enable some agricultural production systems and regions to function within the limits of adaptive capacity (Park et al., 2012; Vermeulen et al., 2013; Howden et al., 2007).

Natural and social systems often have significant but finite capacities to adapt. Exceeding adaptation limits will result in mounting losses or require transformational change (Dow et al., 2013; Park et al., 2012; McDonald-Madden et al., 2011; Adger et al., 2013). A farmer seeking to cultivate a specific crop under increasingly stressed water resources will invest in the available adaptation options to enhance the efficiency of water use and will magnify the adaptive effort as access to water resources becomes more constrained. At some point, adaptation efforts under the existing regime will become disproportionate to the benefits and a new adaptation action such as a new irrigation system or changing a crop will be needed to maintain a farming livelihood. This new adaptation would allow alternative farming practices or other valued objectives to continue. But at some point there may not be new adaptation options available to respond to incremental risks or the level of adaptive effort required to maintain valued objectives may become unfeasible. At this point the farmer may, for example, choose to abandon farming altogether or relocate to a more favourable location (Dow et al., 2013; Vermeulen et al., 2013).

Two key regional adaptation responses are emerging: incremental adaptation and transformation adaptation (Palutikof et al., 2013; Park et al., 2012; Dow et al., 2013; Vermeulen et al., 2012a,b), although systemic adaptation, an adaptation option suggested for moderately extensive climate change, with the characteristics of potential irreversibility, capital required and lifetime, is also suggested in the literature (see Vermeulen et al., 2013; Rickards and Howden, 2012; Leclère et al., 2014; Crimp et al., 2014). The difference between the systemic and transformational adaptations may not always be obvious. However, the costs incurred by incremental, systemic and transformational change, and scale and intensity of climate change offer some clarity (Kates et al., 2012; Rickards and Howden, 2012). Moser and Ekstrom (2010) suggest that transformational change occurs at the long-term end of the adaptation spectrum whilst systemic and incremental changes occur in the medium and short term. Nonetheless, the capacity to undertake a specific adaptation response will largely depend on the magnitude of climate change and the biophysical settings, socioeconomic, local knowledge and environmental awareness and infrastructure development and possessing flexibility, demographic characteristics, and legal, political and institutional systems (Marshall et al., 2014; Marshall et al., 2012; Dovers and Hezri, 2010; Palutikof et al., 2013).

A pure incremental adaptation, defined as *adaptation actions, which aim to maintain the essence and integrity of the system*, is largely an extension of actions and behaviours that have shown potential to reduce the losses or enhance the benefits of natural variations in climate and extreme events (Kates et al., 2012). For example, deficit irrigation practices have been shown to be an effective adaptive response to manage increased climate variability (Williams et al., 2018; Mushtaq and Moghaddasi, 2011). However, incremental adaptation has its limits (Park et al., 2012; Dow et al., 2013) and continuous reliance on incremental adaptation can lead to costly maladaptation and system collapse (Palutikof et al., 2013; Nelson et al., 2010). Transformation adaptation, however, defined as *adaptation that changes the fundamental attributes or irreversible regime change of a system*, aims to increase the capacity of the biophysical, social or economic systems to achieve the desired values (Marshall et al., 2012; Park et al., 2012; Kates et al., 2012; Peeling, 2011). For example, increased aridification has led to transitioning from farming to herding, where increased climatic marginality compromised rain-fed agriculture but allowed extensive grazing (Brooks, 2010; Clarke et al., 2016). Transformation in the broad political, economic and social systems can lead to policy change for more resilient and sustainable climate responses, particularly for those regions that have reached the incremental adaptation limit (Peeling, 2011).

As a result of an increasing limitation of incremental adaptation and the need for regional sustainability, some transformative adaptation options are currently being explored (Marshall et al. 2012; Catrien et al. 2017; Dovers and Hezri, 2010; Thorburn et al., 2011). One such transformational adaptation response is the relocation of industries to more suitable climatic zones (Park et al., 2012; McDonald-Madden et al., 2011; Marshall et al. 2012). However, the key challenge for regional relocation, particularly for key agricultural industries, is to identify when and where to move from incremental adaptation to transformative adaptation (e.g., relocation) and, more importantly, to assess the potential regional economic consequences of such transformative adaptation.

Using Australia as an example, this paper investigates regional adaptation options – incremental and transformative adaptation – for the rice and cotton industries (see Fig. 1 for the location of these industries) for managing climate risks. In particular, the paper examines the economic and policy implications of incremental and transformational changes in production locations by considering the net effects of shifting regional production from a climatically vulnerable zone such as the southern Murray–Darling Basin (see two bottom locations in the Fig. 1) to a potentially more suitable climatic zone such as northern Queensland (top right in Fig. 1) using a dynamic regional Computable General Equilibrium (CGE) model.

2. Key drivers of transformation adaptation in Australia

Climate change has the potential to change the rainfall distribution and conditions for crop production in Australia significantly (Kevin et al., 2017; Ingram et al., 2008; Carberry et al., 2011; Smith et al., 2013; Risbey, 2011; Steffen et al., 2011). Regional differences in rainfall distribution and crop productivity are likely to emerge (Sprigg et al., 2014; Iglesias et al., 2012; Olesen and Bindi, 2002). It is expected that the southern part of Australia will generally become drier, while there is a likelihood of increased rainfall and frequency and intensity of extreme events in parts of the north (IPCC, 2007; Potgieter et al., 2013; CSIRO and Australian Bureau of Meteorology, 2014).

The possibility of greater water security in northern Australia has generated renewed interest in irrigation projects with proposals to reconfigure the geography of intensive agriculture (Camkin et al., 2007; Shanahan, 2007; Northern Australia Land and Water