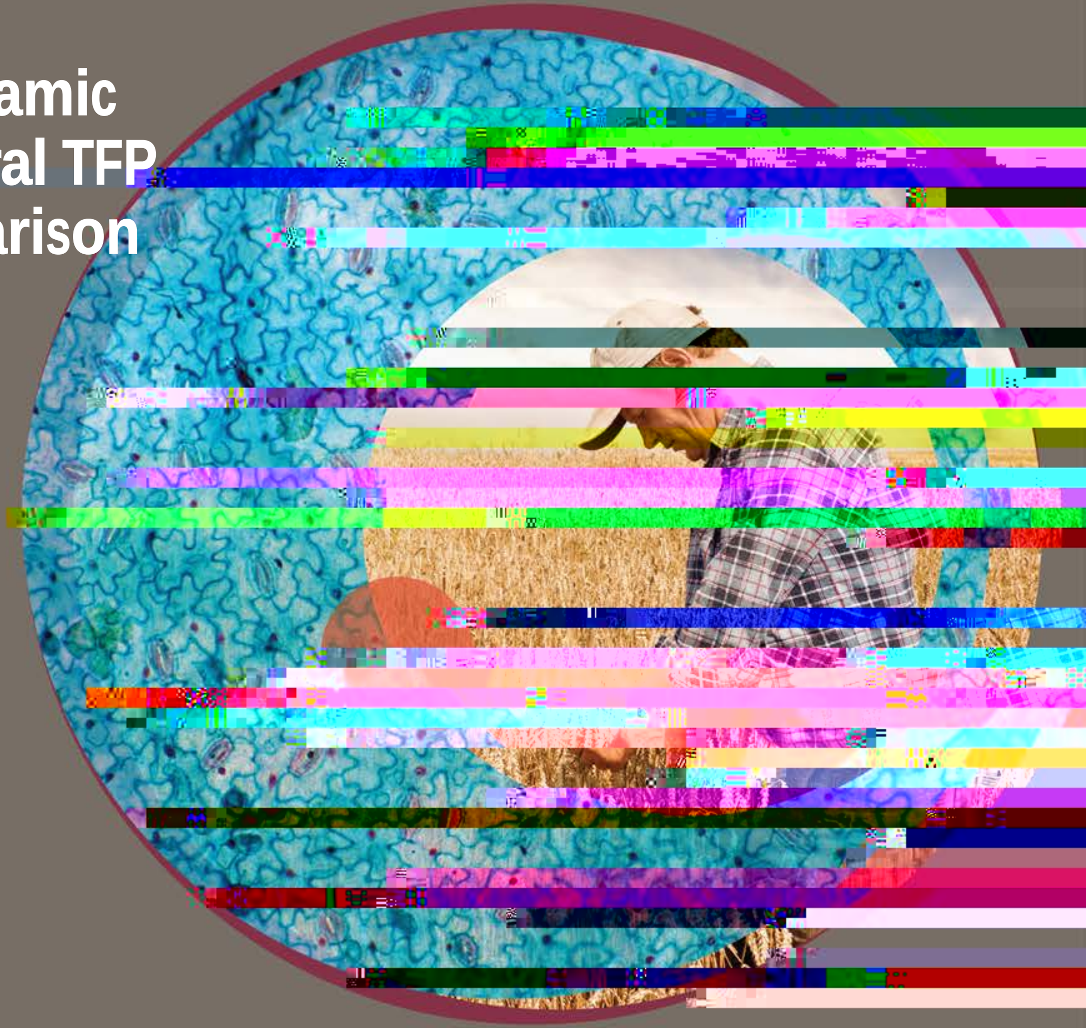
Australian Government

Department of Agriculture and Water Resources

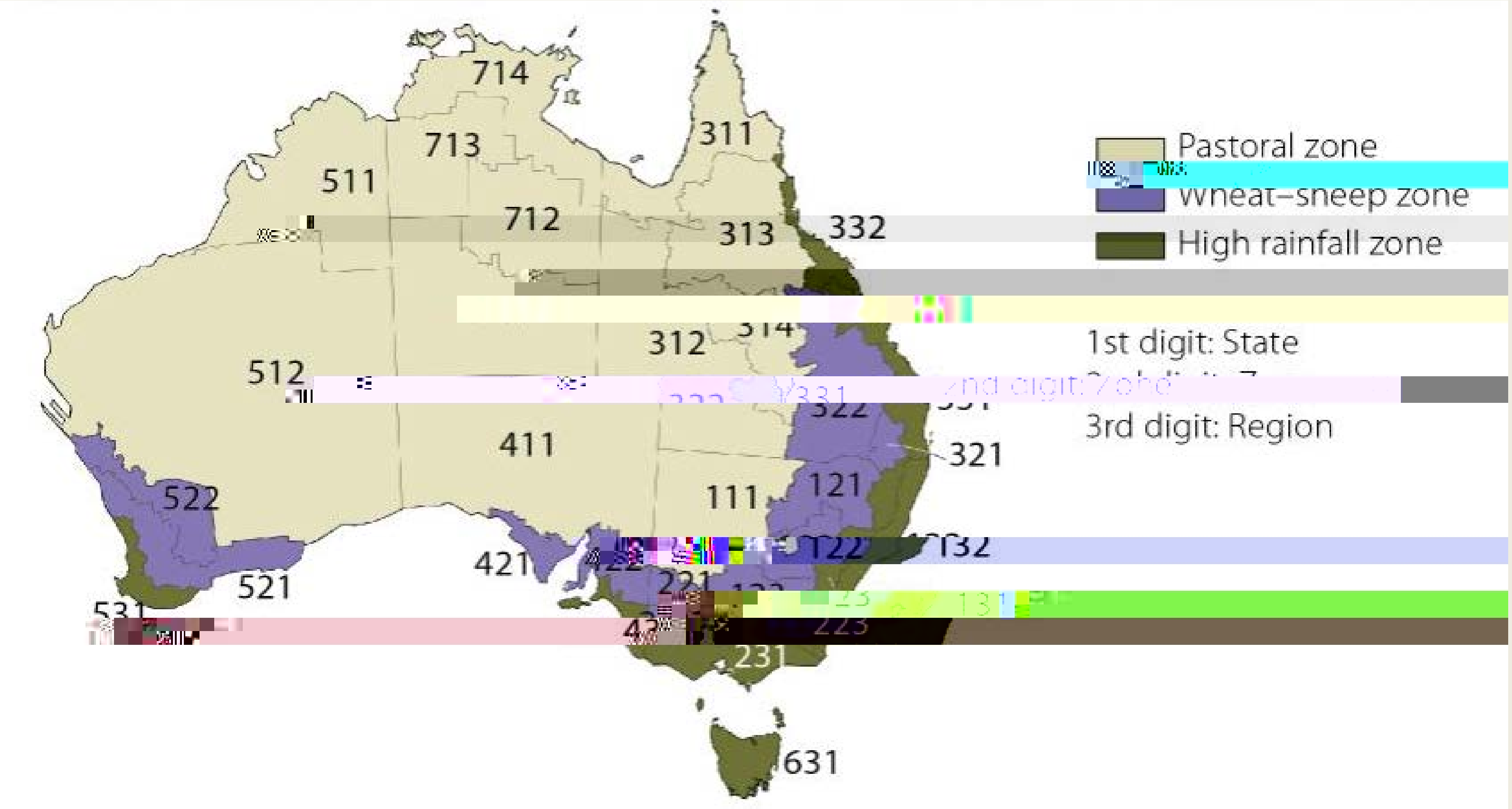
Climate Change and Dynamic Adjustment of Agricultural TFP : A Cross-regional Comparison of Broadacre Farms in Australia



University of NSW, Coogee Bay

- Our research contributes to the literature in three areas
    - To unravel the dynamic response of agricultural productivity to climatic shocks, and show the spatial pattern of these responses;
    - To investigate the channels through which region-level agricultural productivity adapts to climate change;
    - To provide a way to construct an agricultural production

- Broadacre agriculture is an important primary industry in Australia
    - The broadacre industry accounts for 1.9 per cent of GDP and 2.3 per cent of employment in 2015-16;
    - The industry covers all non-irrigated crop and livestock farms, accounting for around 70 percent of agricultural production;
    - Broadacre farms widely distribute throughout the country, and adopt different production systems in different locations;
- Given the nature of broadacre agriculture, climate conditions heavily influence the productivity of the industry;
    - For simplicity, two aspects are address: water and temperature.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Pastoral zone
Wheat–sheep zone
High rainfall zone
1st digit: State
2nd digit: Zone
3rd digit: Region

- Rainfall (or soil moisture)
  - Australia is a relatively dry continent and for broadacre agriculture, rainfall is the main source of soil moisture
    - Rainfall determines the growth of crops (i.e. wheat and barley etc.);
    - Rainfall also affects pastoral grassland and livestock production
- Air temperature
  - Temperature affects the growth of plant in different development stages, together with other climate factors such as water, CO2;
  - Temperature assists crop growth and livestock raising through a non-linear way, with extremely high temperature doing harm to farm production;

- Over time, broadacre farms have demonstrated a remarkable adaptive capacity to cope with climate change.
  - A strong productivity growth of 2 % a year over the long run;

- In practice, farmers can adapt to climate change through many alternative channels, e.g.
  - Change the production technology by optimising the use of capital and labor;
  - Adjust the output mixture to diversify the risk from climate change;

- Many adaptation activities require a significant amount of time and incur additional costs.

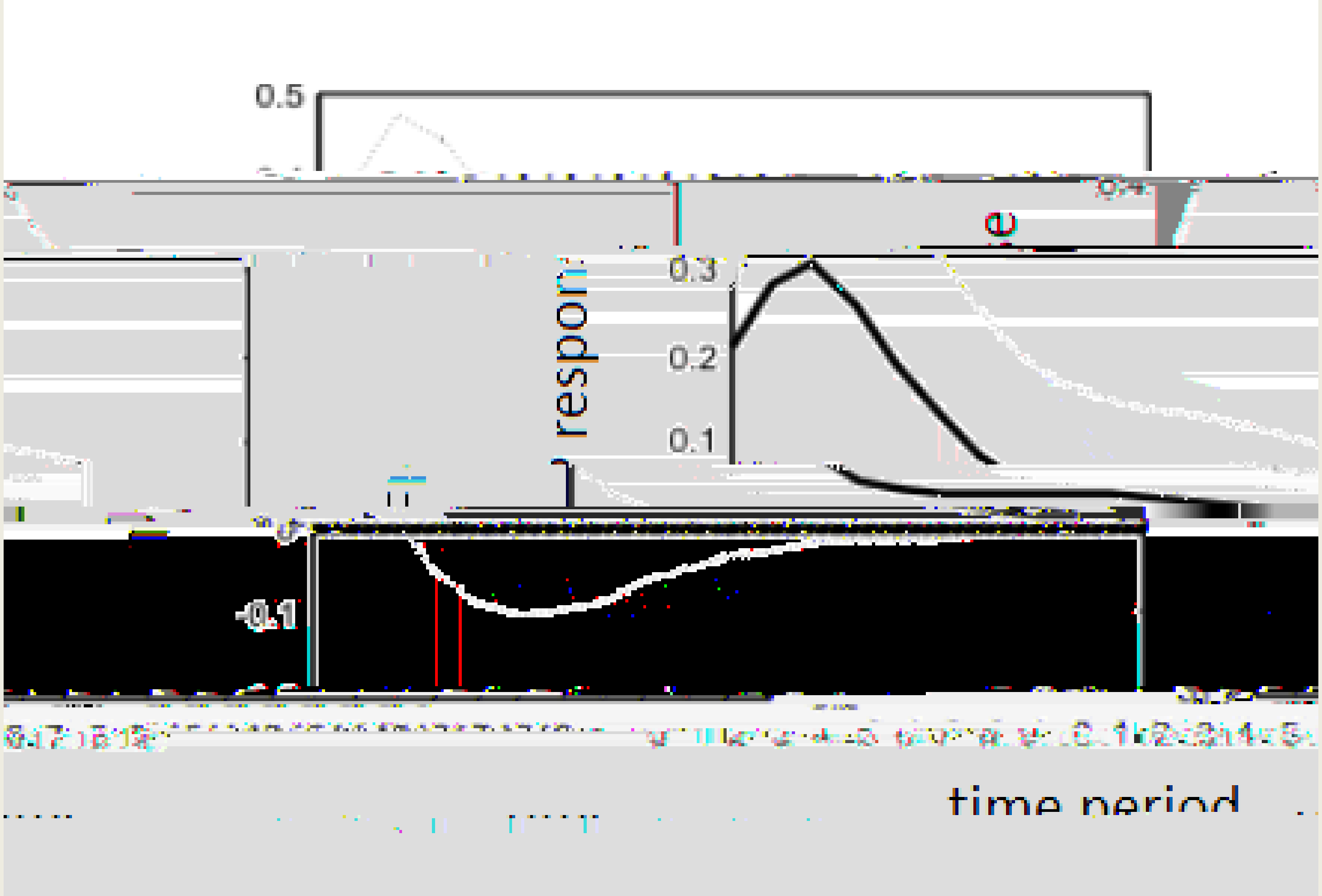
- If two conditions hold
  - Regional agricultural TFP and its determinants are integrated of order one I(1);
  - The error term is integrated of order zero I(0) for all regions;

$$\Delta lnTFP_{rt} = \emptyset_i[lnTFP_{rt-1} - \theta'_i f_{rt-1}(W_{rt}, T_{rt}, Z_{rt}, F_r, F_t)] +$$

$$\lambda_i \Delta f_{rt}(W_{rt}, T_{rt}, Z_{rt}, F_r, F_t) + \varepsilon_{rt} \qquad (2)$$

- $\emptyset_i$ is the error-correcting speed of adjustment term

λ_i are the long-term and the short-term effects of • θ'_i an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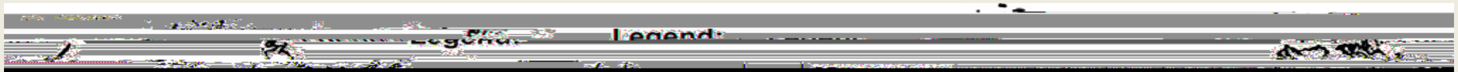
time period

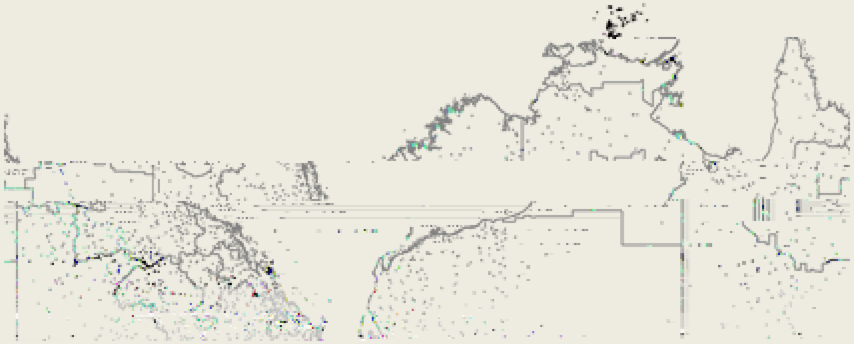
- The data used in this paper come mainly from four sources
    - Australian Agricultural and Grazing Industry Survey (AAGIS): regional TFP measures;
    - The Queensland University and the government of Queensland: soil moisture and air temperature;
    -

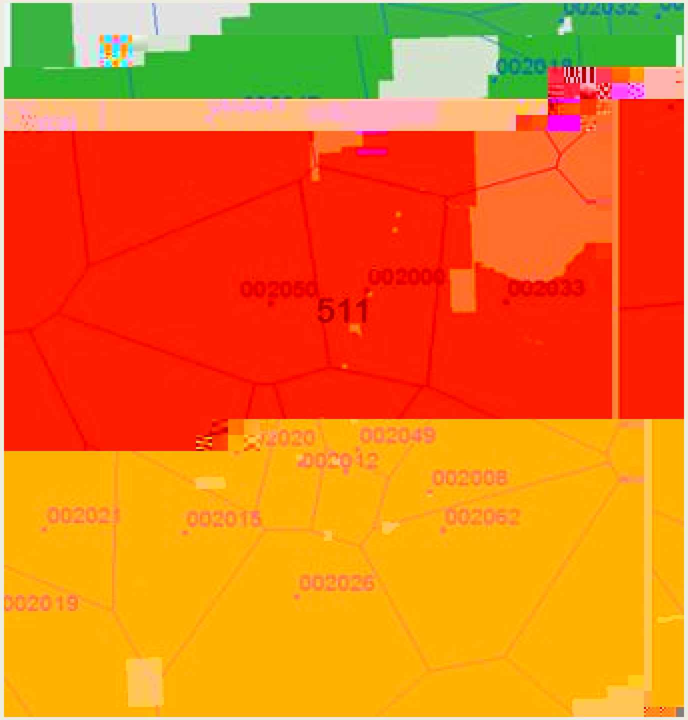
- Region

- Water availability measure
    - The index is measured by using three agro-climatic indicators called “wheat water-stress index”, “sorghum water index” and “pasture growth index”.
    - Wheat and sorghum water-stress indexes are derived from a water-balance model (Potgieter et al. 2005, 2006).
    - The pasture growth index is also calculated based on a water balance model (Carter et al 2000, Rickert et al 2000).
- We aggregate the indexes up to the regional level using land areas for cropping and grazing as weights.
    - The three indexes, in their original form, are annual time series defined at sub-regional (shire) level.
- Total rainfall has also been used as a robustness check


Legend:

- Two indicators are used to measure temperature / radiation:
    - degree-days accumulated over the growing seasons;
    - average daily temperature;
- A base of 8^{o}C and a ceiling of 32^{o} C are used as the temperature threshold (Schlenker et al., 2006 and Deschenes and Greenstone, 2007)
    - 1st April to 31st October for the winter season;
    - 1st November to 31st March for the summer season;
- The daily average temperature and rainfall are
    - obtained at the 8, 023 weather stations of the Australian Bureau of Mereology (BoM);
    - Matched with each farm in our survey;





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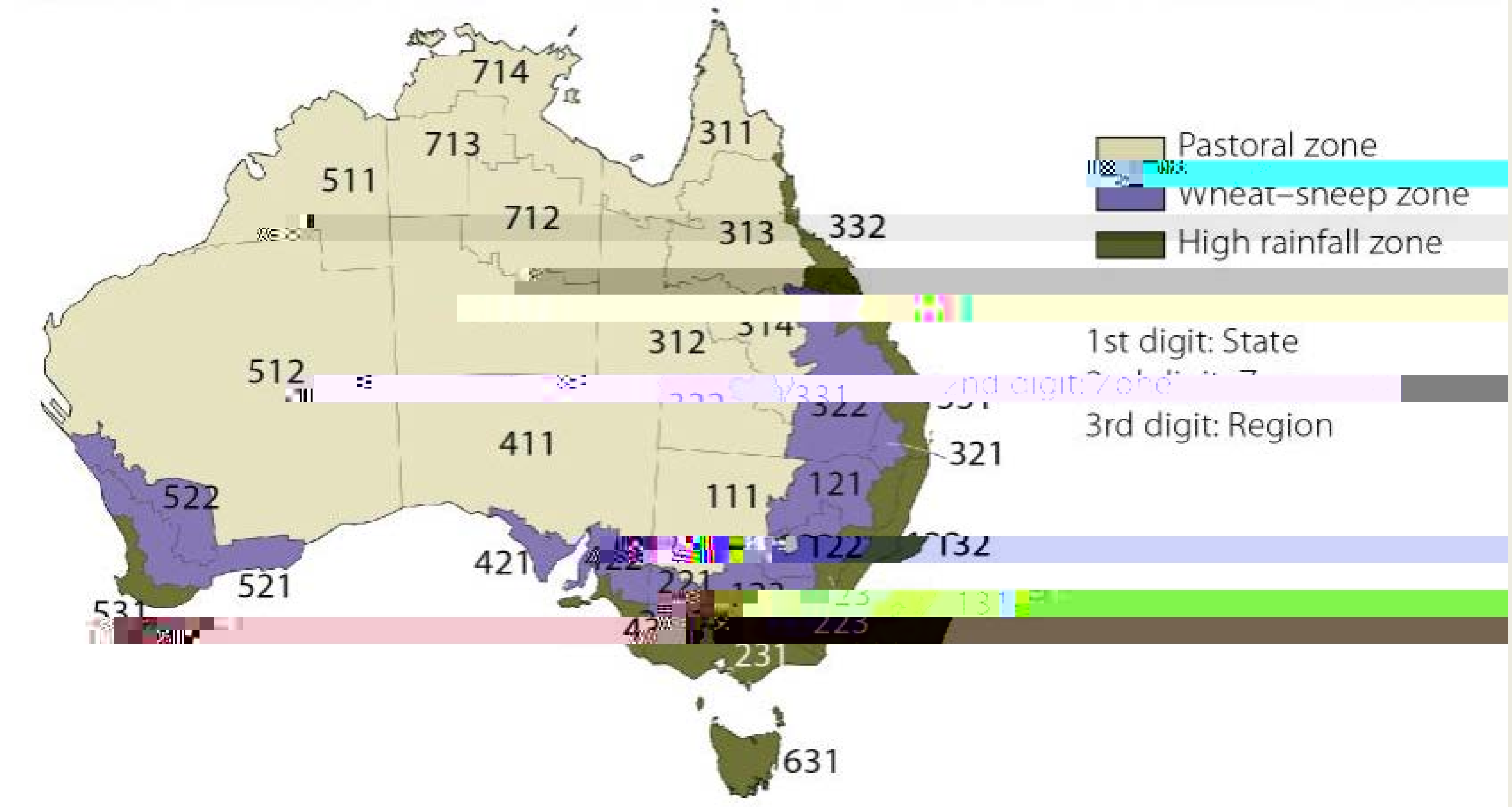
- A descriptive statistics shows the relationship between region-level agricultural TFP and climate conditions.
    - There are monotonic relationship between water-stress index and regional TFP;
    - The relationship between degree-day measures and regional TFP is non-linear;

- Panel-data co-integration test has been conducted
    - I(1) stationary tests have been conducted for all variables used in the model
    - A co-integration relationship has been identified between region-level TFP and climate variables

- There is a significant long-term relationship between climate condition and region-level agricultural productivity.
    - Water availability positively contributes to regional TFP growth in the long run;
    - Degree-days will positively contribute to regional TFP initially but its marginal contribution tends to decline when the degree-day measure reach a threshold;
- In the short run, water availability also generate the short

	Baseline Model (Model I)		Full Model (Model II)	
Dependent variable: regional-level agricultural TFP (log)				
Water-stress index (log)				
Growing season degree-days				
Growing season degree-days (log) square				
SEFA index (log)				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- Region-level TFP is re-measured by using an alternative index formulas
  - The Fisher index adjusted by the EKS formula is used instead;

- Climate variables are re-defined by directly using
  - the total rainfall over the growing season
  - the daily average temperature over the growing season

- Stability of the PECM model has been double-checked.

- We investigate the dynamic impact of climate change on agricultural TFP in Australia through
  - Using a vector error correction model to the panel data;
  - Allowing for regional heterogeneity and other control variables;
- Climate change generates a complex impact on agricultural productivity across regions
  - In the long run, water availability and temperature
  - In the short run, water availability matters more
- Farmers are able to adopt to climate change through
  - Optimising the capital-labor ratio;
  - Adjusting the output mix

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