Australian Government
Department of Agriculture
ABARES

Climate adjusted total factor productivity for Australian broad-acre farms: 1989 to 2018

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Research by the
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Some background

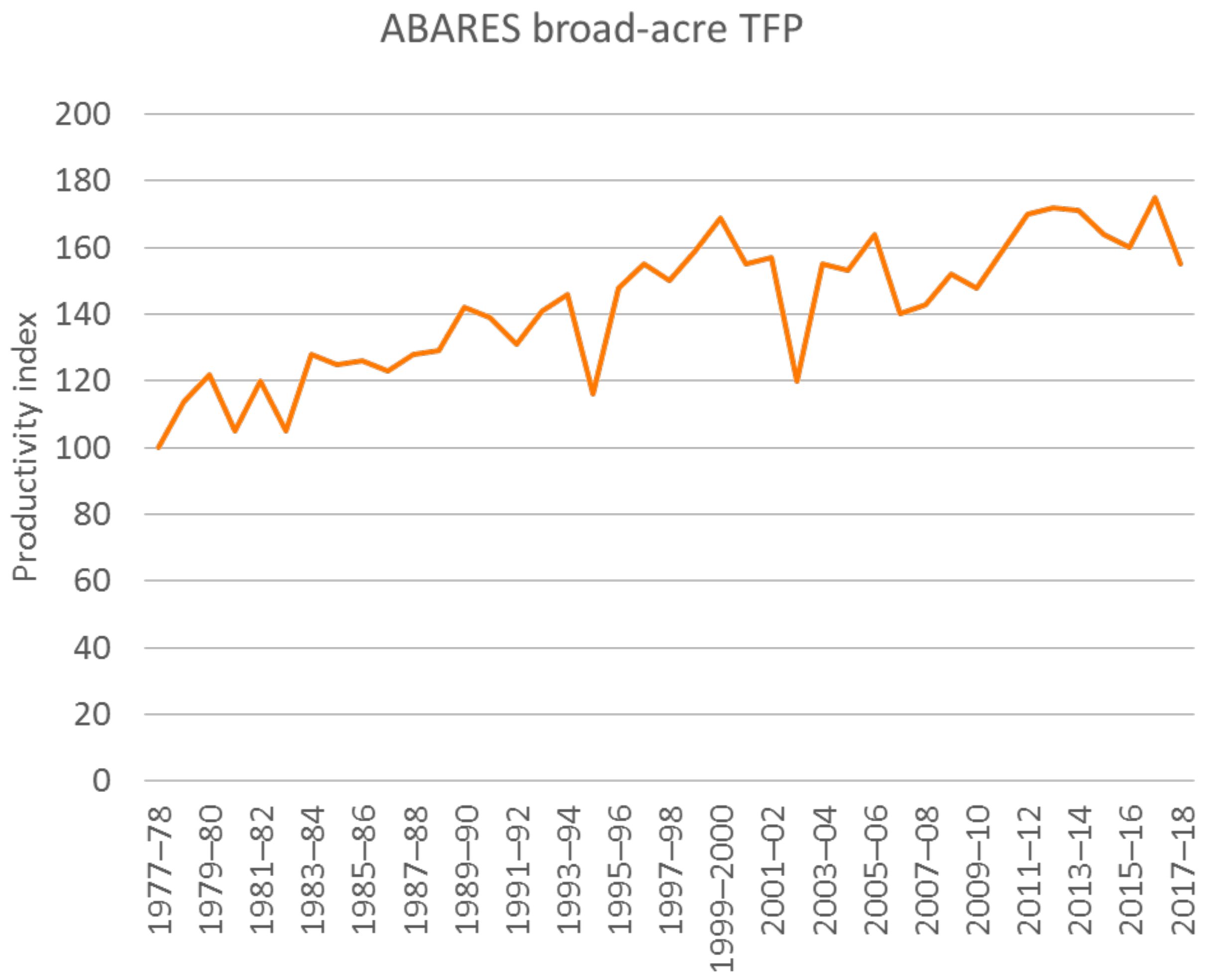
- Why adjust for climate?

  - Actual productivity improvement obscured by seasonal volatility

- (ABARES) TFP productivity growth increased by 9.1% in 2016-17, followed by a decline of 12.2% in 2017-18 (coinciding with favourable and unfavourable climate conditions respectively).
- ABS agricultural MFP increased by 25.6% in 2016-17 and a decline of 7% in 2017-18 (ABS, 2018) – (now rebased).

  - Implications for policy makers and statistical users.

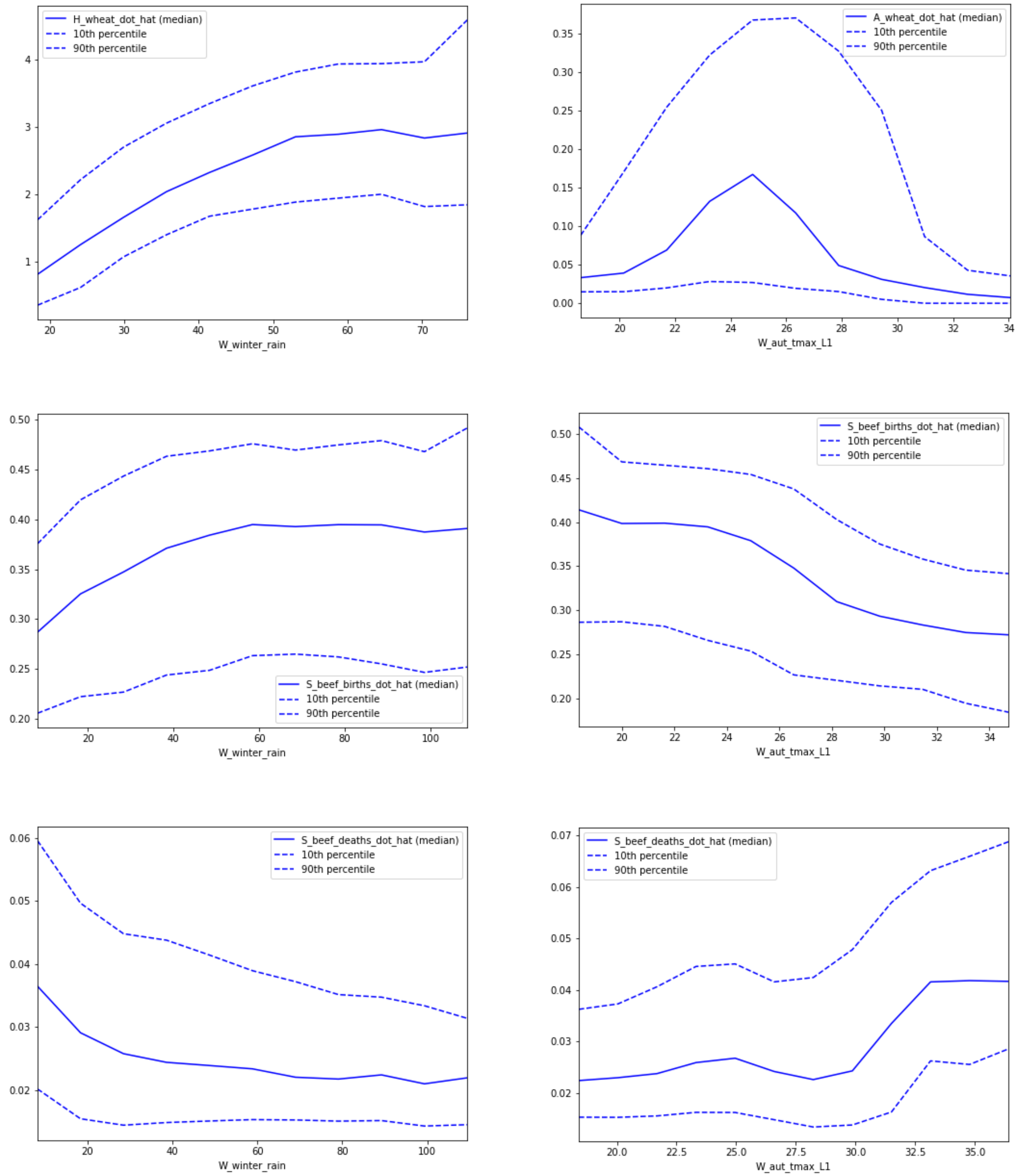
  - Future climate (BoM state of climate) = decreases in rainfall in southern Aus, more time in drought, hotter, increase in intense heavy rainfall



Source: ABARES

Climate effect

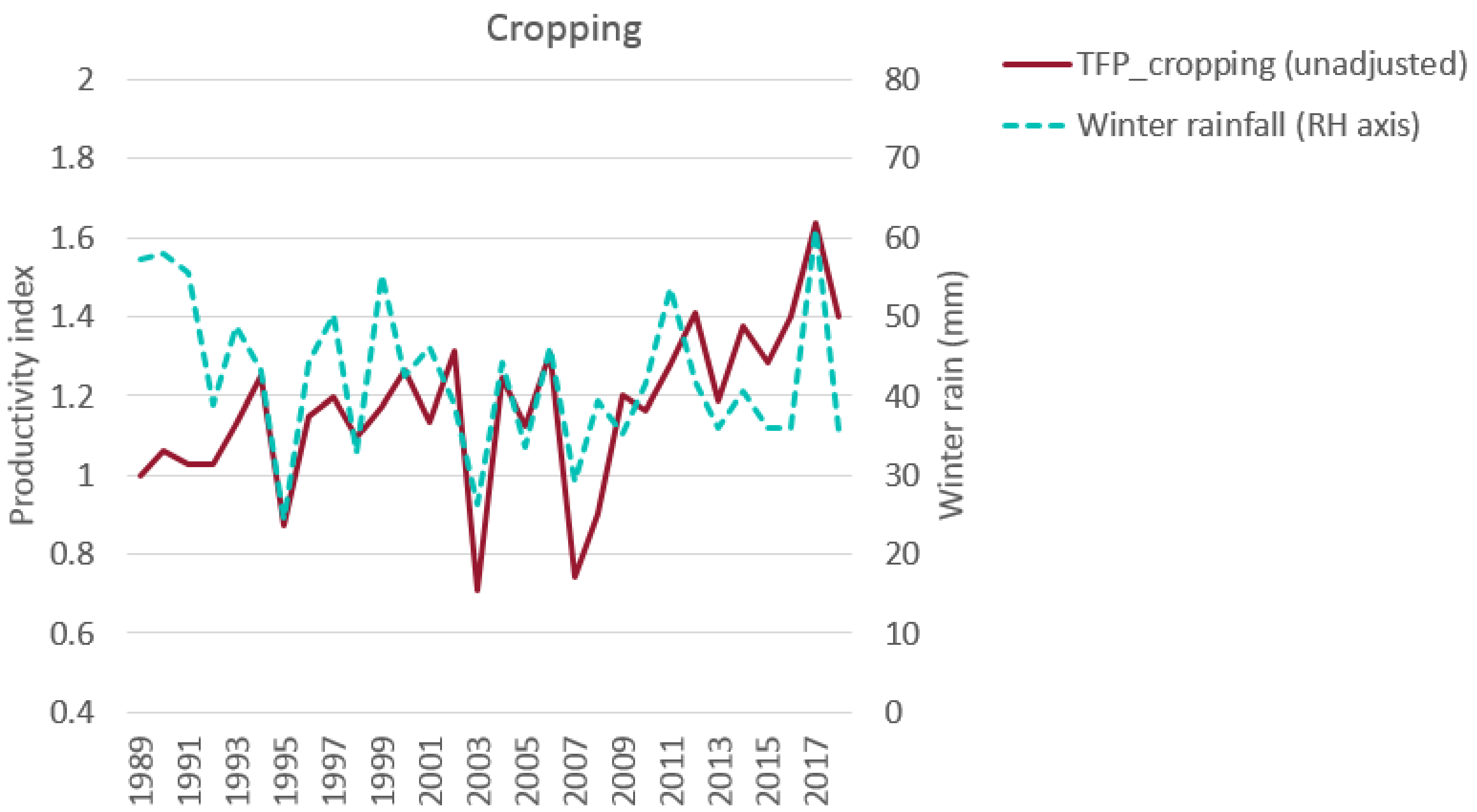
- Model response to growing season rainfall (cropping) and Autumn avg. max. temp. (livestock)



The relationship between TFP and climate

- TFP is exposed to seasonal variability
  - Cropping is highly sensitive to winter rainfall

Cropping TFP (UNADJUSTED) and average winter rainfall, 1989 to 2018

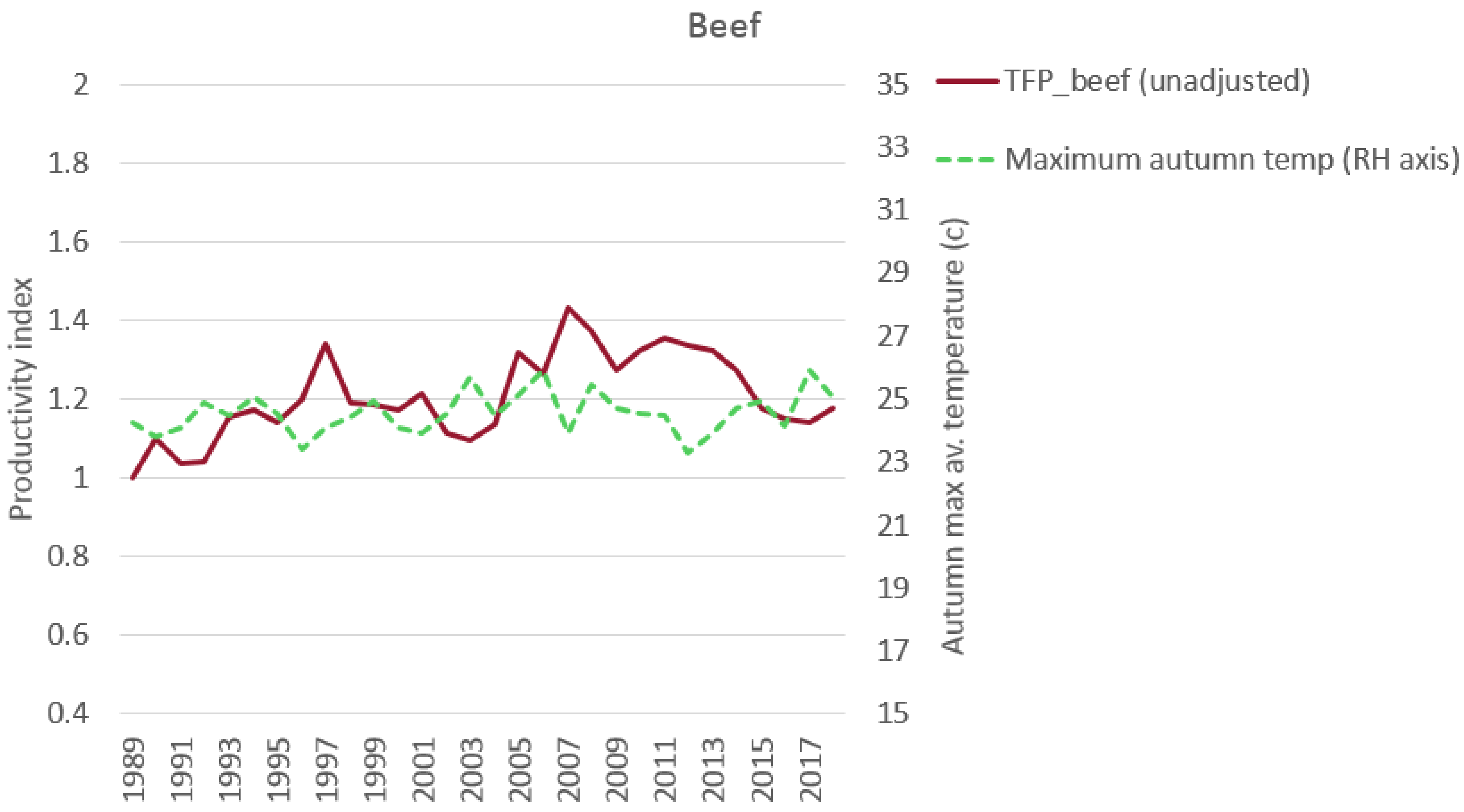


Source: Authors estimates and Hughes et al. 2019 (farmPredict)

The relationship between TFP and climate

- TFP is exposed to seasonal variability
    - Livestock less sensitive, but stocking (births/deaths) impacted by autumn temperature

Beef TFP (UNADJUSTED) and autumn temperature, 1989 to 2018

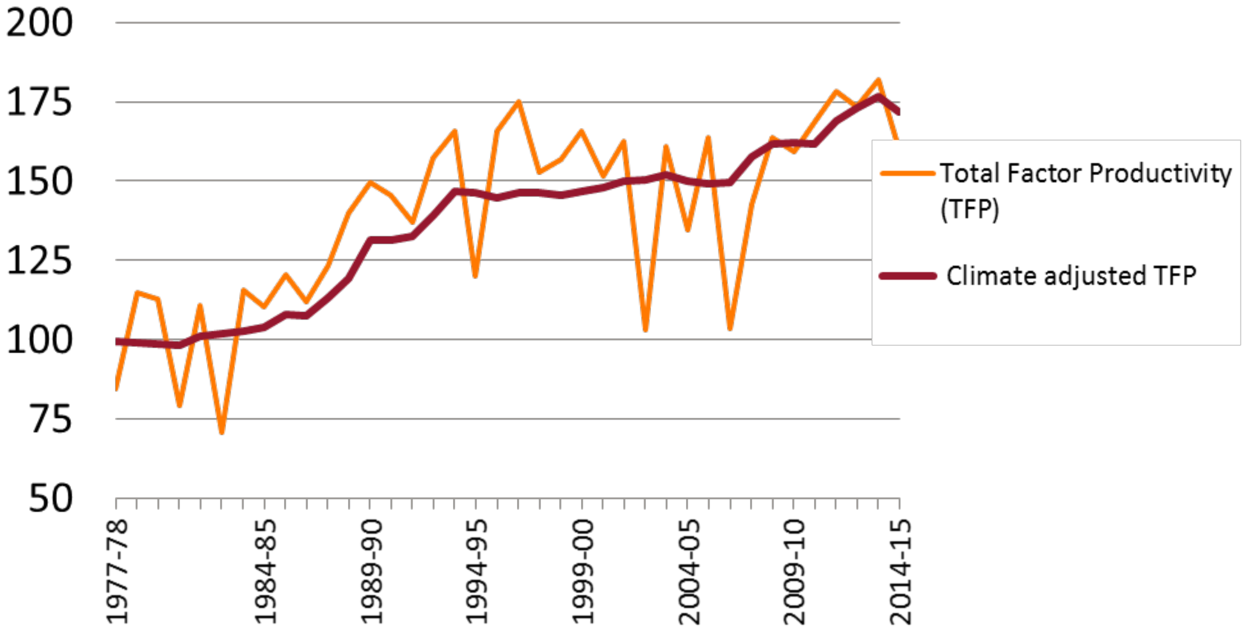


Source: Authors estimates and Hughes et al. 2019 (farmPredict)

Previous work – climate adjusted cropping TFP

- Climate adjusted cropping TFP (Hughes et al. 2017)
  - Short term volatility largely explained by seasonal variation
  - Climate conditions for cropping deteriorating
  - Crop farmers adapting

Climate adjusted TFP for the Australian broad-acre cropping industry, 1977-78 to 2014-15



Hughes, N, Lawson, K & Valle, H 2017, *Farm performance and climate: Climate-adjusted productivity for broadacre cropping farms*, Canberra, April.

Climate adjusted TFP approach

Previous approach

$TFP_{it} = f(W_{it}, t)$ — Fit regression model of farm-level TFP against climate and other controls

$TFPCA_{it} = \frac{1}{s}\sum_s f\,(W_{is}, t)$ — Simulate TFP for range of climate years *s* and take average

New approach

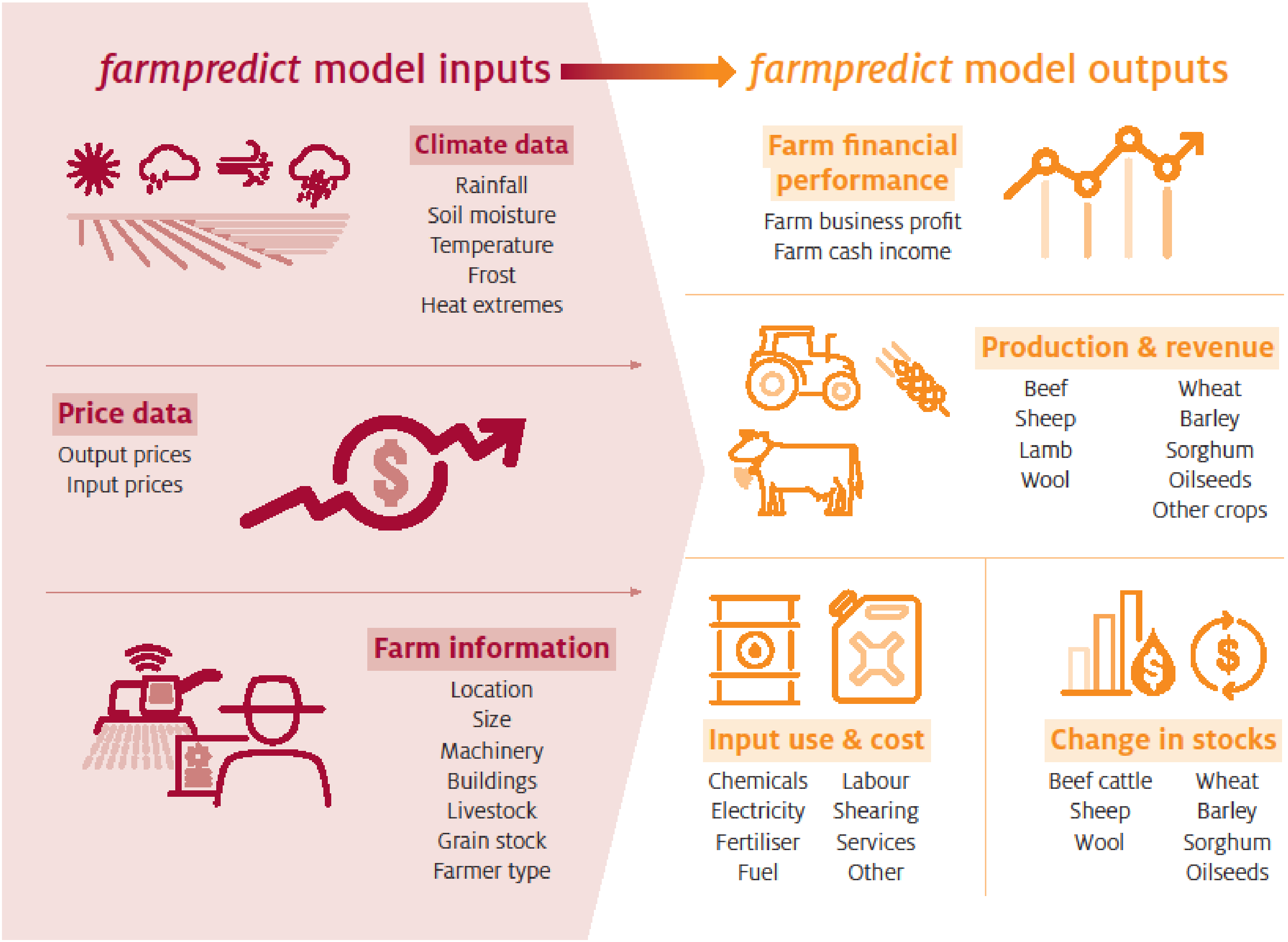
$\boldsymbol{Q}_{it,}\boldsymbol{V}_{it} = \boldsymbol{f}(W_{it}, K_{it}, t)$ — *farmpredict* (outputs and variable inputs as a function of climate, fixed inputs and other controls)

$\boldsymbol{Q}_{its,}\boldsymbol{V}_{its} = \boldsymbol{f}(W_{is}, K_{it}, t)$ — Simulate outputs and inputs under a range of climate years *s*

$TFPCA_{it} = \frac{1}{s}\sum_s g\,(\boldsymbol{Q}_{its}, \boldsymbol{V}_{its})$ — Compute TFP using index formula *g* for every climate year *s* and take average

farmpredict

- **Data driven**
  - Farm production / financial data
  - Site specific climate data
- **Micro-simulation statistical model**
  - Series of input demand and output supply functions
  - Similar to 'dual' (reduced form) production models
- **Machine learning estimation**
  - Gradient boosted regression tree
  - Multi-target stacking
  - Cross validation
- **Farm level simulation**
  - Climate, price, technology, scale



Hughes, N. Soh, W. Y., Boult, C., Lawson, K., Donoghoe, M., Valle, H. and Chancellor, W., 2019, ***farmpredict:* A micro simulation model of Australian farms**, ABARES working paper, Canberra

Data and variables

- TFP input and output
  - Follows ABARES TFP index structure
- Unbalanced panel
  - 1989-2018
  - 54 analysis variables for TFP

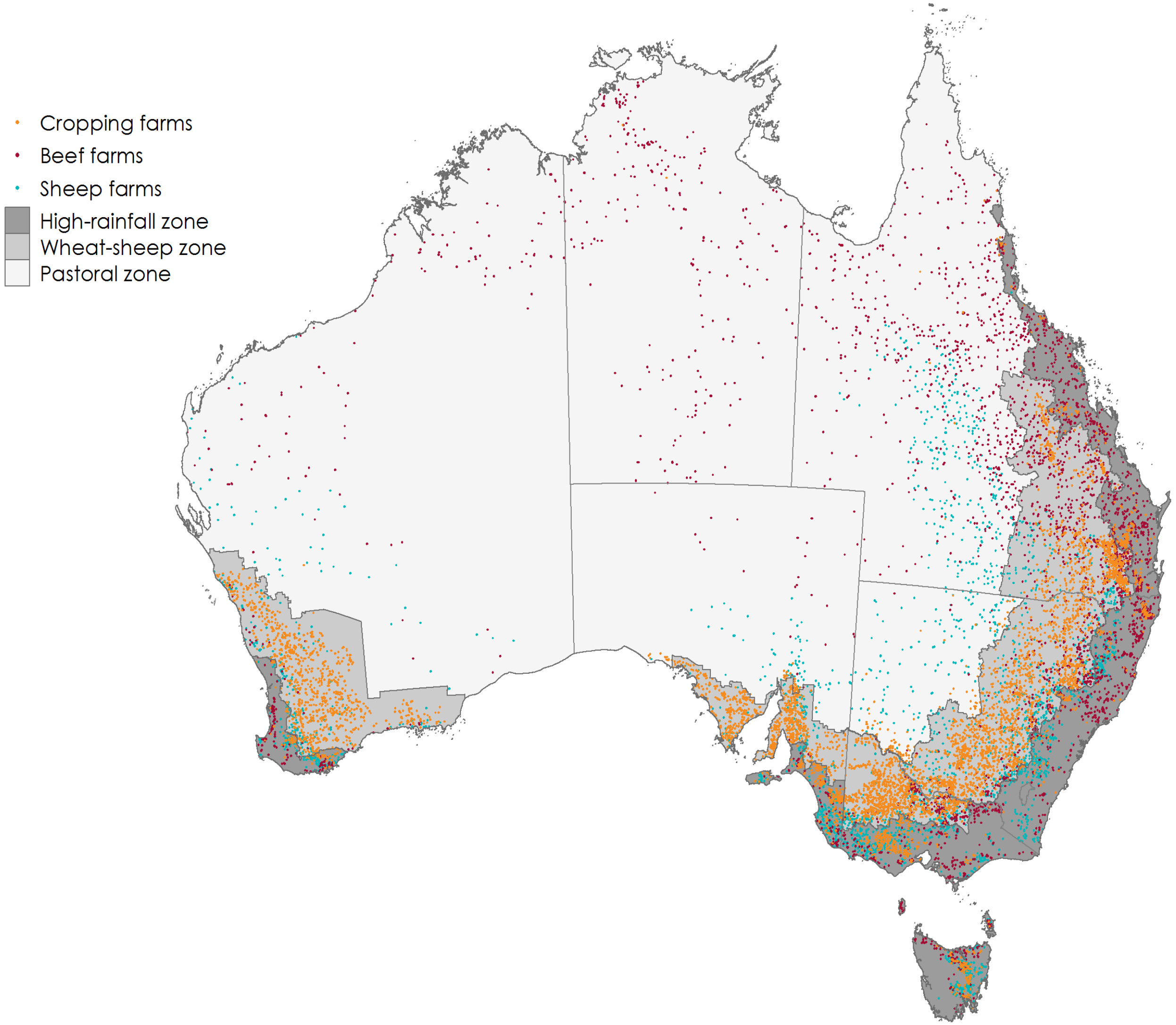
Total factor productivity variables

	Output quantity	Output price	Source
1	Beef cattle output	Beef farm price (index)	farmpredict
2	Sheep output	Sheep farm price (index)	farmpredict
3	Wool produced (Kg.)	Wool price (index)	farmpredict
4	Prime lamb sold (no.)	Lamb price	farmpredict
5	Wheat harvested (t)	Wheat farm price (index)	farmpredict
6	Barley harvested (t)	Barley farm price (index)	farmpredict
7	Sorghum harvested (t)	Sorghum farm price (index)	farmpredict
8	Oilseeds harvested (t)	Oilseeds farm price (index)	farmpredict
9	Other crops sold (index)	Other crop price (index)	farmpredict
10	Other revenue ($)	Other revenue price (index)	farmpredict
	Input quantity	**Input price**	**Source**
1	Fertiliser (index)	Fertiliser price (index)	farmpredict
2	Fuel, oil and grease (index)	Fuel, oil and grease price (index)	farmpredict
3	Crop and pasture chemicals (index)	Crop and pasture chemicals (index)	farmpredict
4	Other materials (index)	Other materials (index)	farmpredict
5	Services (index)	Other services (index)	farmpredict
7	Family labour (index)	Constant (index)	farmpredict
8	Hired labour shearing (index)	Hired labour shearing (index)	farmpredict
9	Other costs (index)	Other costs (index)	farmpredict
10	Beef input	Beef farm price (index)	farmpredict
11	Sheep input	Sheep farm price (index)	farmpredict
12	Beef capital	Beef cattle value in herd (real) ($)	AAGIS
13	Sheep capital	Sheep value in herd (real) ($)	AAGIS
14	Other livestock capital	Other livestock slaughter price (index)	AAGIS
15	Land area (ha.)	Land value (real) ($)	AAGIS
16	Buildings and improvements	Fixed improvements (real) ($)	AAGIS
17	Equipment and machines	Plant and equipment (real) ($)	AAGIS
	Classification variables		
1	Farm number (unit identifier)		farmpredict
2	Year (YYYY)		farmpredict
3	Weight		farmpredict
4	State (1=NSW, 2=VIC, 3=QLD, 4=SA, 5=WA, 6=TAS)		farmpredict
5	Industry (1=Cropping, 2=Mixed crop-livestock, 3=Sheep, 4=Beef, 5=Sheep-beef)		farmpredict

[1] *Beef cattle output=beef cattle receipts+increase in herd size*
[2] *sheep output=sheep receipts+increase in flock size*
[3] *Beef input=expenditure on beef cattle+decrease in herd size*
[4] *Sheep input=expenditure on sheep+decrease in flock size*
[5] *Land value=total average capital-(average livestock capital value+average value of crops and wool on hand+average leased plant and equipment capital value+average non leased plant and equipment capital value+operators house value+farm fixed improvements value)*

Data and variables

- Wheat sheep zone
  - Mostly large scale cropping
- High rainfall zone
  - Mostly small scale livestock (where rainfall is too high for cropping and land is too expensive)
- Pastoral zone
  - Mostly large scale livestock (where rainfall is too low for cropping)



Data and variables

- Site specific climate data
  - AWAP and AWRA-L (5km grid)
  - SILO and BoM based on nearest weather station

Climate variables used in *farmpredict*

	Climate variables	Unit	Source
1	Rainfall volume	Mm	AWAP
2	Average maximum temperature	Degrees C	AWAP
3	Average minimum temperature	Degrees C	AWAP
4	Root zone soil moisture	Index (0-1)	AWRAL
5	Exposure to frost (days below 2C)	Days	SILO
6	Heat accumulation (growing degree days)	Degrees C	SILO
7	Exposure to high temperatures	Degrees C	SILO
8	Rainfall volatility (Gini coefficient)	Index	SILO
9	Rainfall volatility	Index	SILO
10	Exposure to hail storms	Index (0-1)	BoM

[1] Australian Water Availability Project
[2] Australian Water Resources Assessment Landscape
[3] Scientific Information for Land Owners
[4] Bureau of Meteorology

Method for climate scenario simulation

- Method outlined in Hughes et al. 2019 ‘*farmpredict*’
- *Non-parametric machine learning with gradient boosted regression tree algorithm (xgboost) and multi-target stacking (two stage regression)*

Generates farm level predictions for multiple dependent variables Y_{it} as a function of a large number of explanatory variables:

$$X_{it} = \{P_t, K_{it}, S_{it}^{op}, W_{it}, Z_{it}\}$$

Where P_t are price indexes for each output and input,
K_{it} are the quantity of capital input,
S_{it}^{op} are the opening quantities of stock s,
W_{it} are weather indicators, and
Z_{it} are a collection of control variables (Hughes et al. 2019).

Method for climate scenario simulation

- Target variables (outputs Q, revenue R, variable inputs V, costs C and closing stocks S^{cl}) can then be predicted by using explanatory variables (Fixed inputs K, opening stocks S^{op}, prices P, climate W, and controls Z).

- Therefore, for farm i in period t, prediction of target variables:

$$\hat{Y}_{it} = \{Q_{it}, R_{it}, V_{it}, C_{it}, S_{it}^{cl}\}$$

Are a function of explanatory variables:

$$X_{it} = \{P_t, K_{it}, S_{it}^{op}, W_{it}, Z_{it}\}$$

Practical estimation

- Run climate scenarios on farm level data
  - farmpredict used to run simulated climate scenarios (1989, 1990…2018) to farm level panel data (30 panels)

- Run TFP model using each panel
  - TFP estimated 30 times (to produce TFP under climate scenario 1989 to 2018)

- Calculate average TFP index
  - An average of these 30 indexes is taken to derive TFP under average climate.

ABARES TFP indexes

- Fisher index
  - Geometric mean of Laspeyres and Paasche
- EKS (transitivity)
  - Desirable index number properties for transitivity and circularity
  - More information on ABARES TFP method [EKS Fisher index]from Zhao et al. (2012)

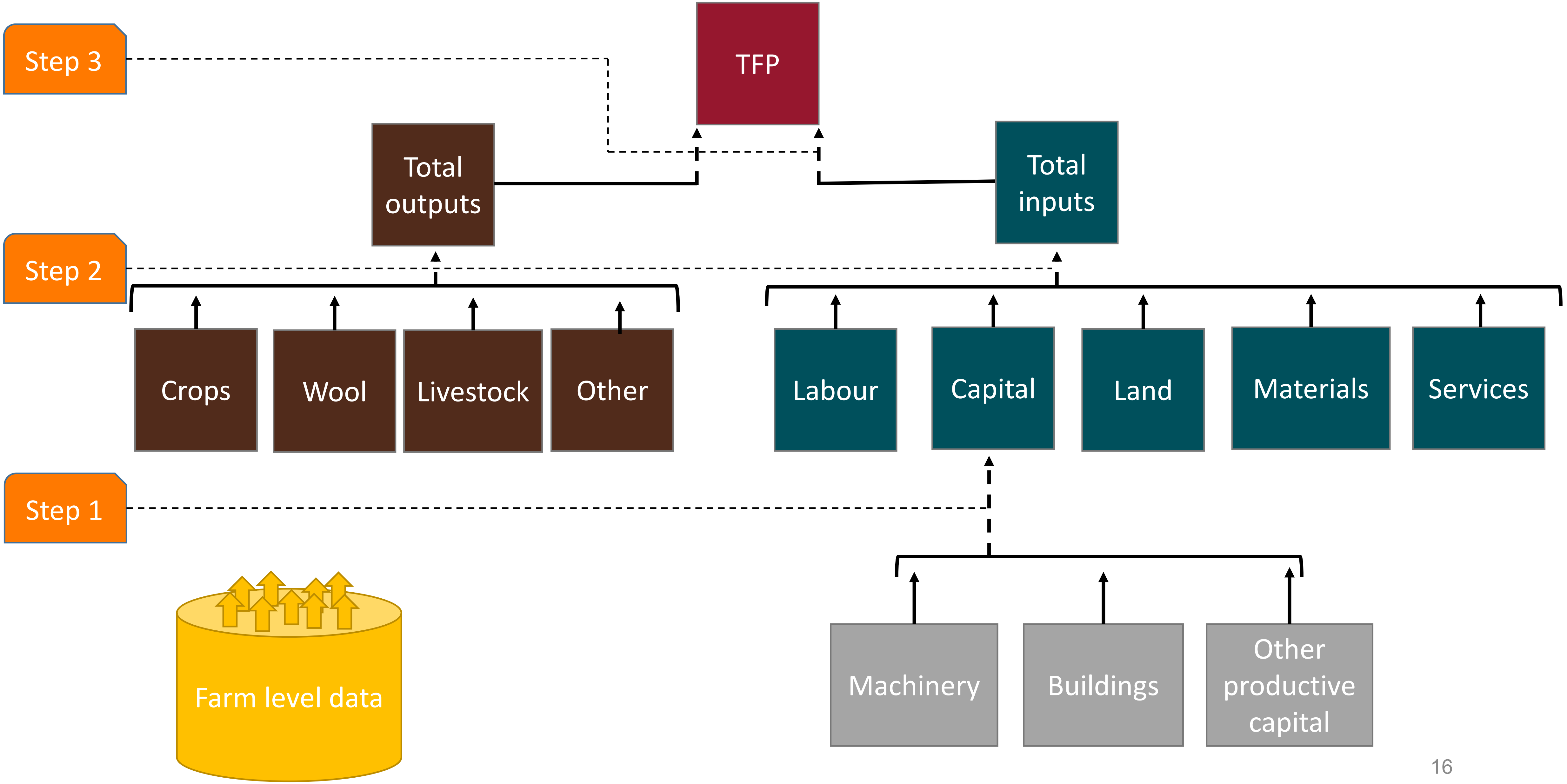
$$Q_{0t}^{F} = \sqrt{Q_{0t}^{L} Q_{0t}^{P}}$$

$$Q_{0t}^{L} = \frac{\sum_{i=1}^{N} p_{i0}\, q_{it}}{\sum_{i=1}^{N} p_{i0}\, q_{i0}} = \sum_{i=1}^{N} W_{i0} \frac{q_{it}}{q_{i0}}$$

$$Q_{0t}^{P} = \frac{\sum_{i=1}^{N} p_{it}\, q_{it}}{\sum_{i=1}^{N} p_{it}\, q_{is}} = \left\{\sum_{i=1}^{N} W_{it} \left(\frac{q_{i0}}{q_{it}}\right)\right\}^{-1}$$

$$Q_{AB}^{EKS} = \left(\prod_{r=1}^{N} Q_{AC}^{F}\, Q_{CB}^{F}\right)^{1/N}$$

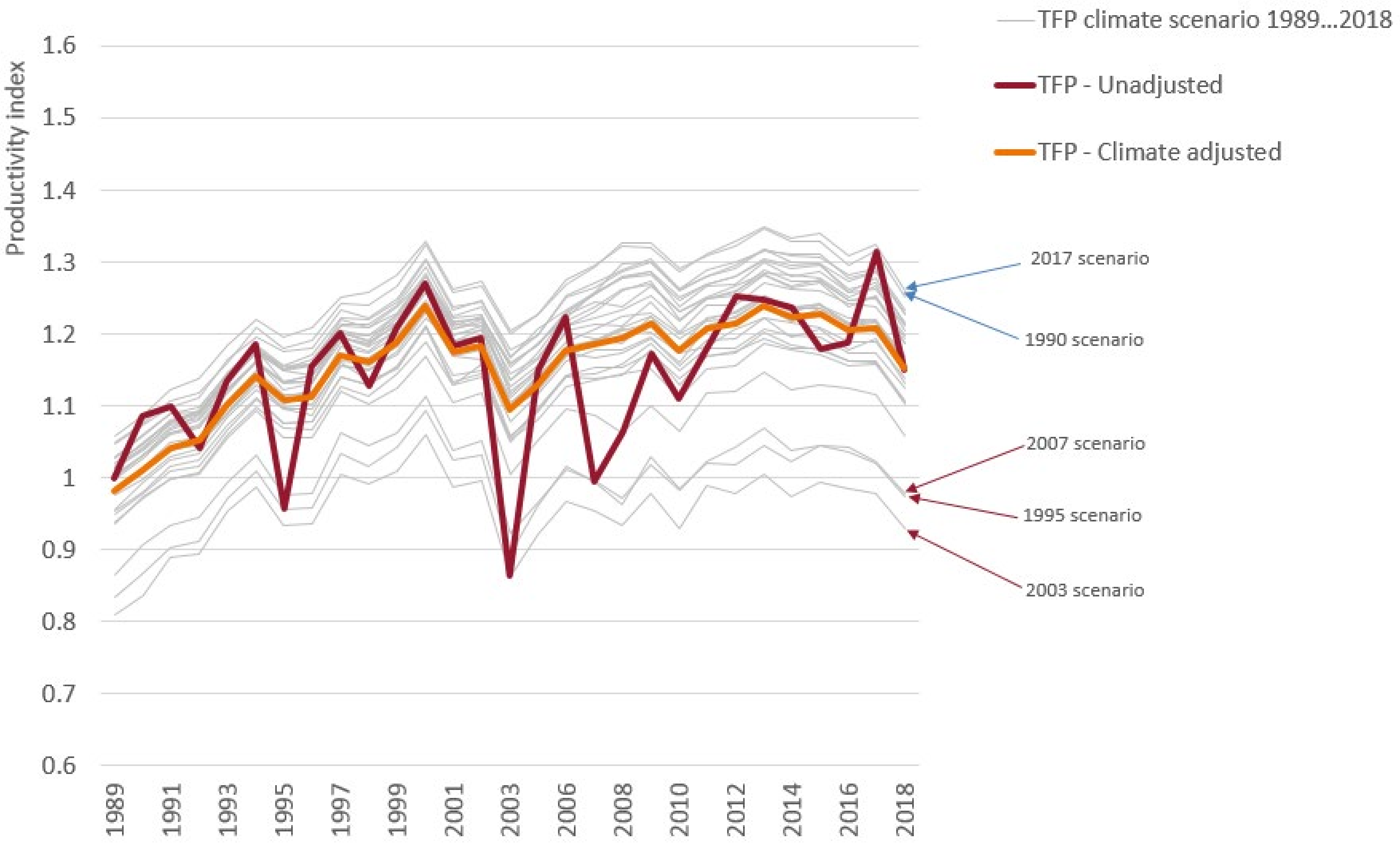
ABARES TFP measurement



Average climate

- Multiple climate scenarios
  - 1989…2018
- TFP under ‘average climate’
- Process repeated for all broad-acre industries

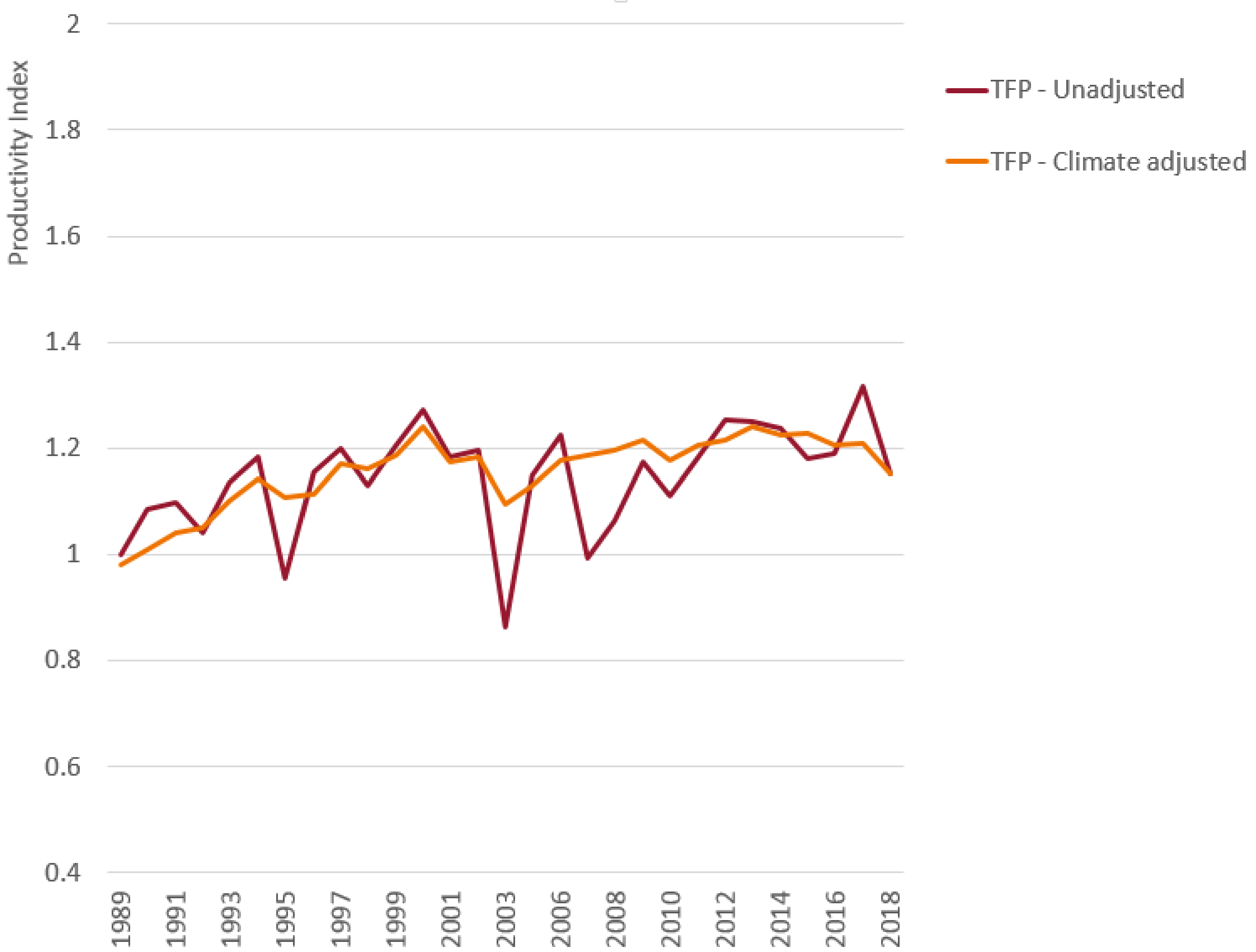
Construction of climate adjusted total factor productivity index, all broad-acre, 1989 to 2018



Results – all broad-acre

- Short term seasonal volatility largely smoothed
- Post-drought improvements in TFP

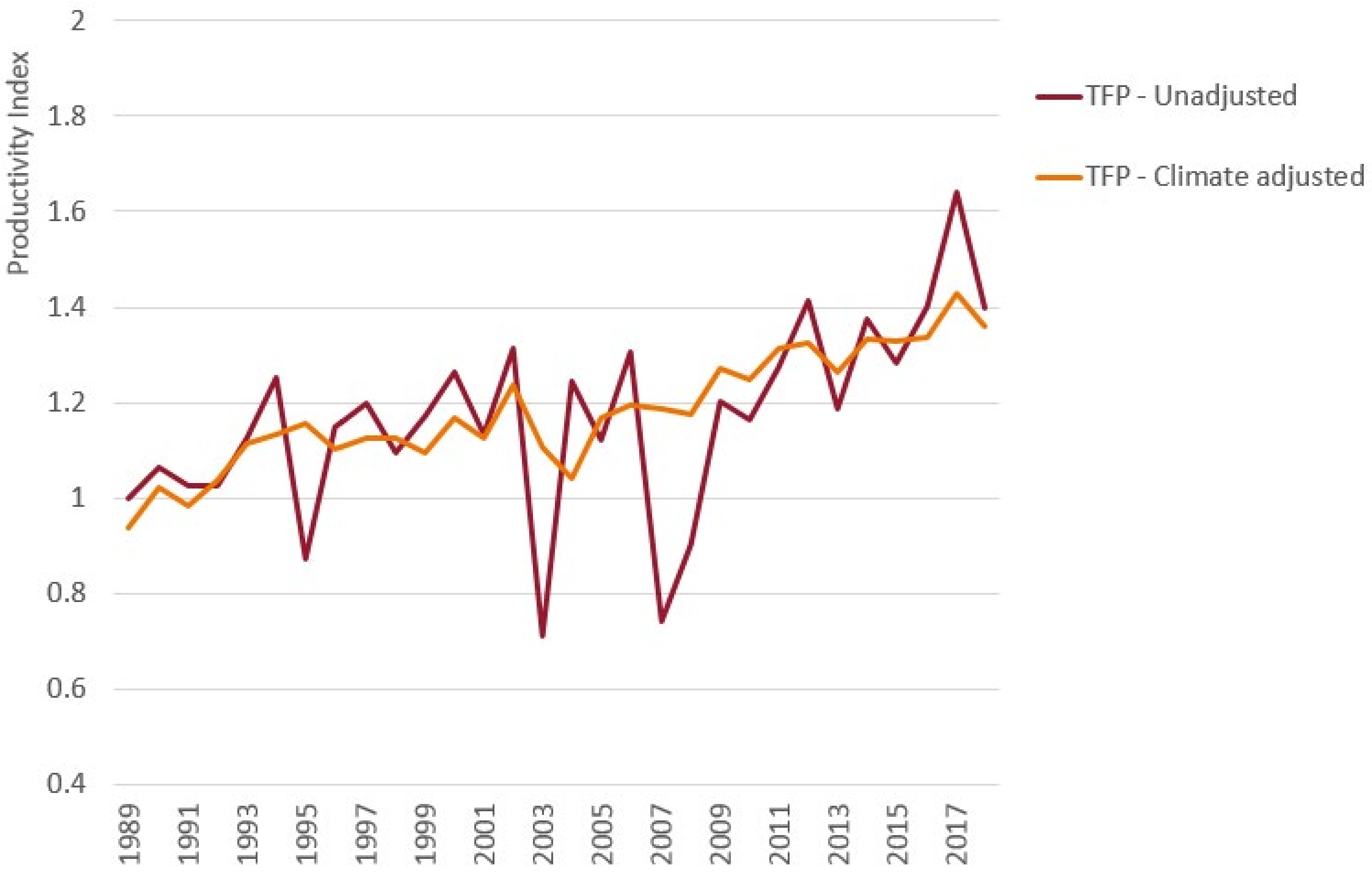
Total factor productivity, all broad-acre, 1989 to 2018



Results – Cropping

- Cropping sensitive to rainfall
  - Drought years (e.g. 2003, 2007)
  - High rainfall years (e.g. 2017)
- Climate adjusted TFP trend suggests adaptation

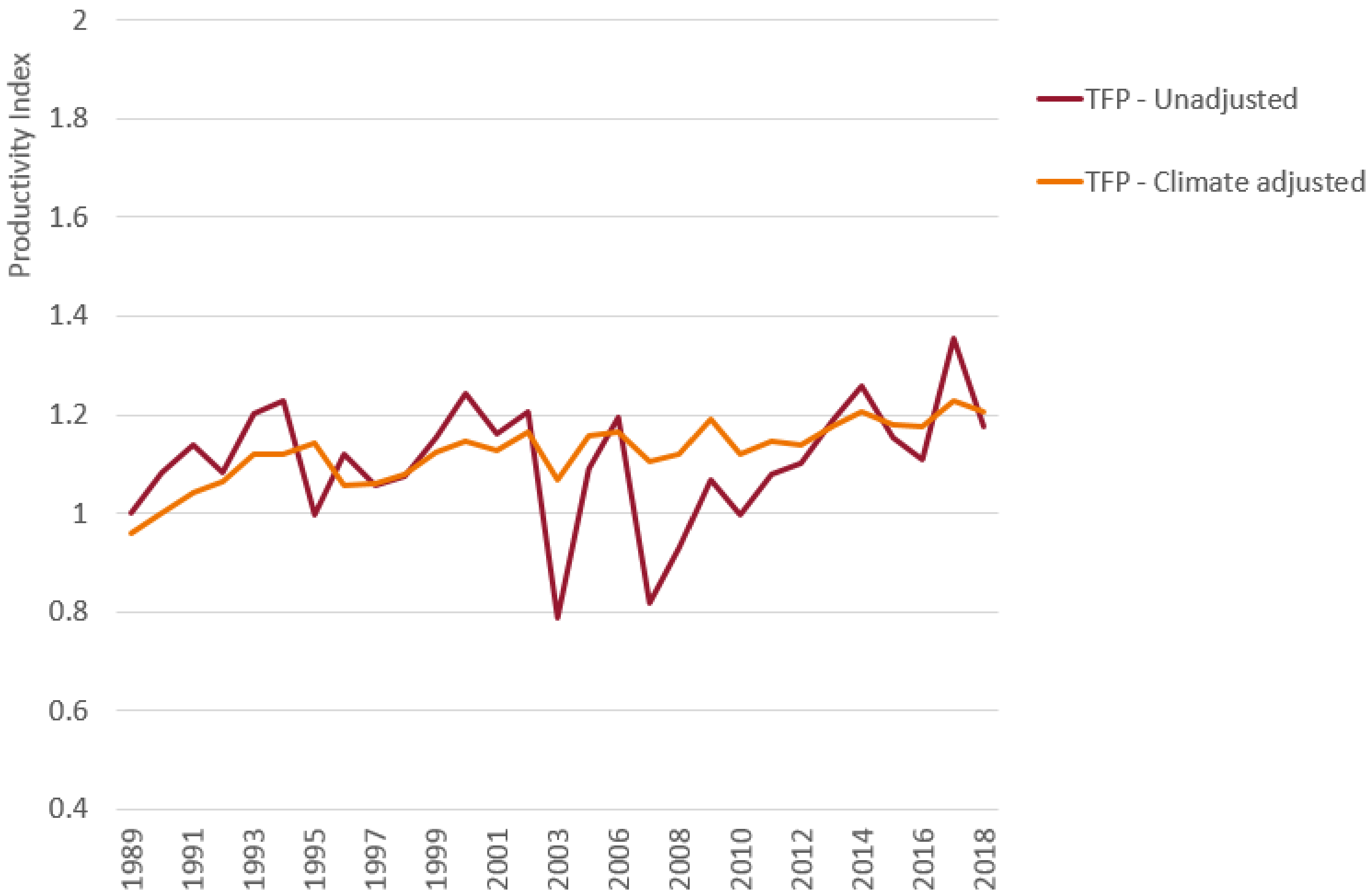
Total factor productivity, cropping farms, 1989 to 2018



Results – Mixed (crop / livestock)

- Mixed farms less exposed to climate variation
  - Diversification

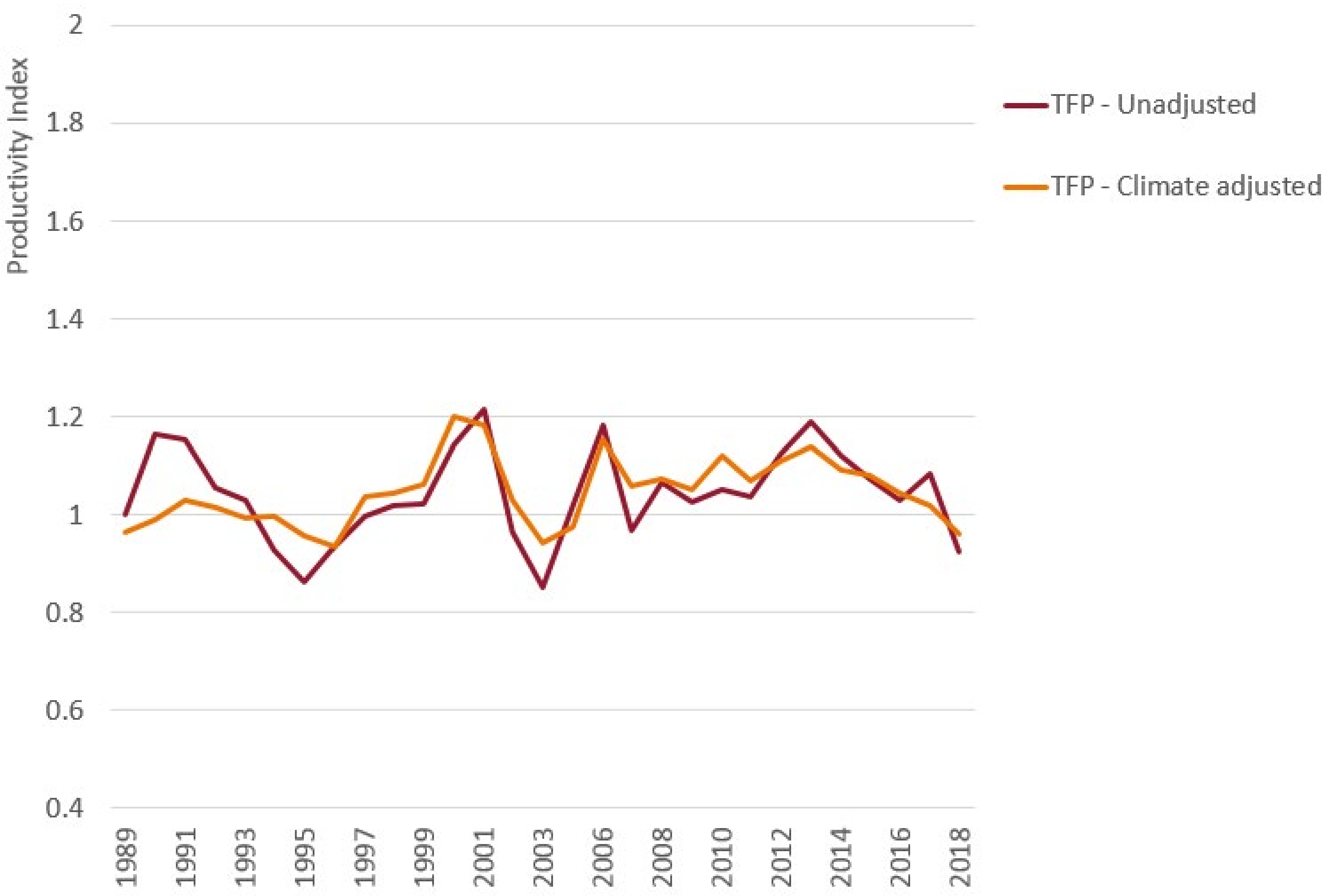
Total factor productivity, mixed cropping and livestock farms, 1989 to 2018



Results – Sheep

- Sheep farms appear less sensitive to climate
    - Structural break
    - Industry transformation

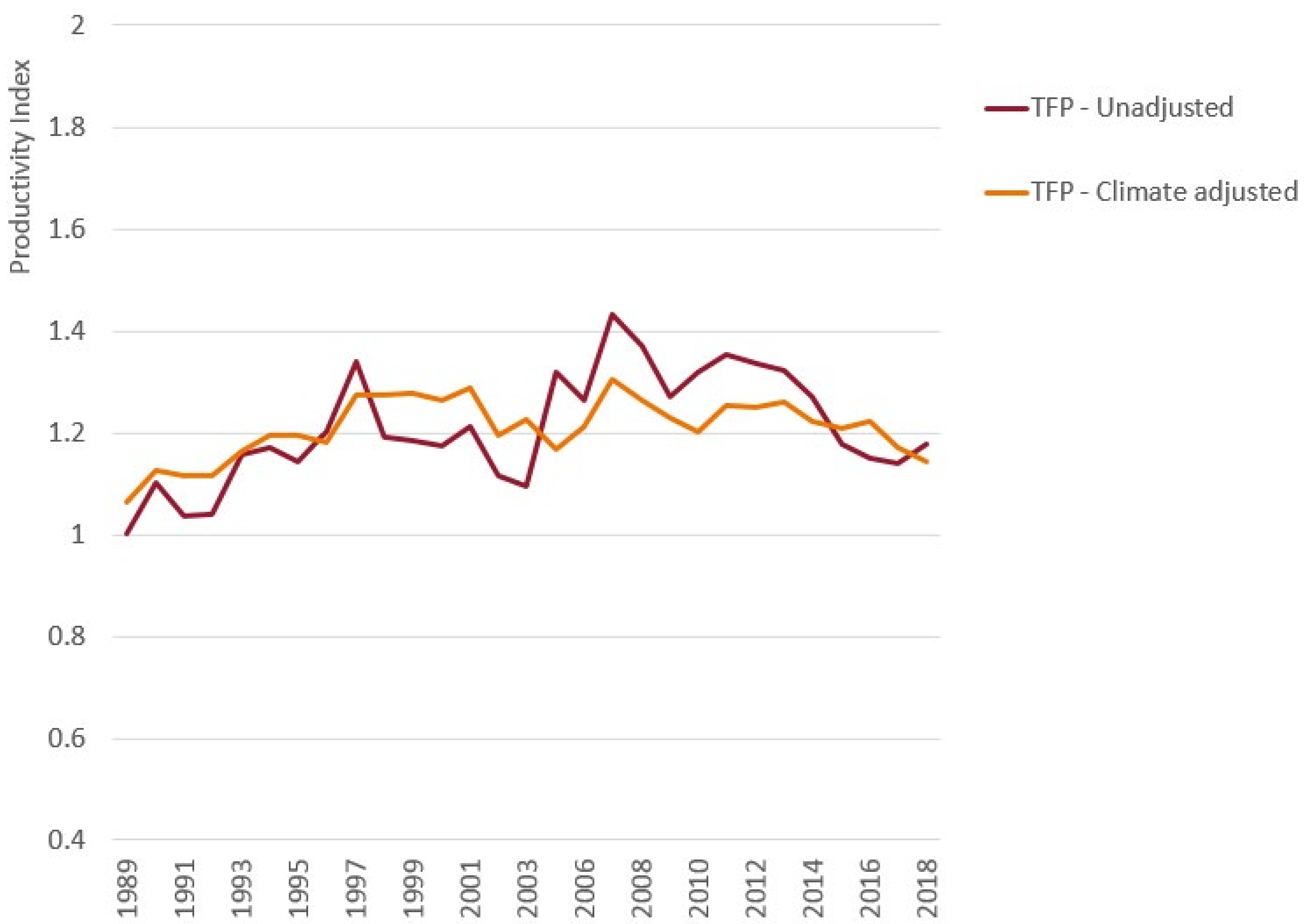
Total factor productivity, sheep farms, 1989 to 2018



Results – Beef

- Beef farms also appear less sensitive to climate
  - Relationship between temperature and stocking rate identified

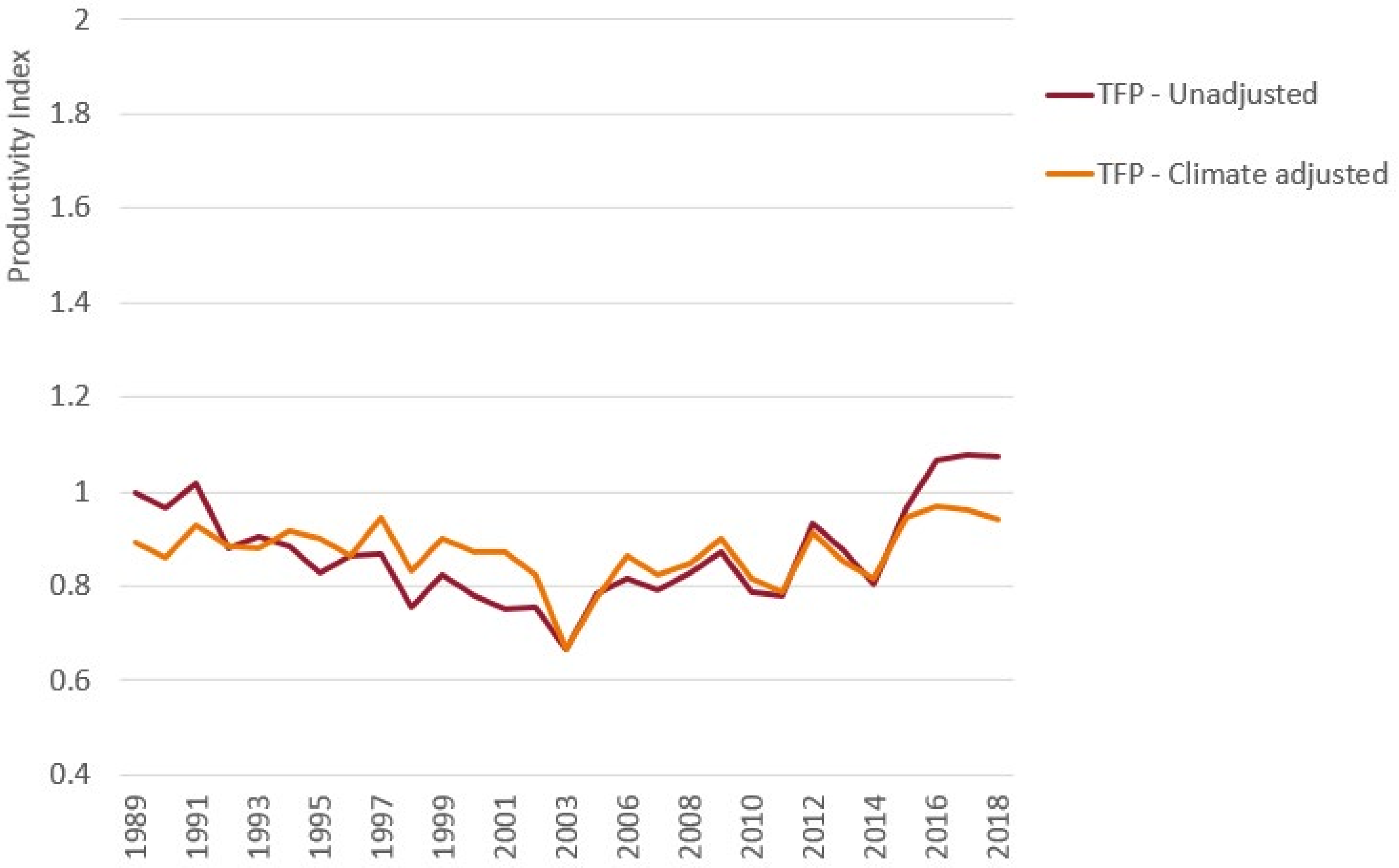
Total factor productivity, beef farms, 1989 to 2018



Results – Mixed (sheep/beef)

- Beef-sheep
  - Little climate effect
  - Volatile group, farms switching in and out.

Total factor productivity, mixed sheep-beef farms, 1989 to 2018



Future work

- Estimate climate adjusted TFP for dairy (different inputs and outputs compared to broad-acre).
- Look to publish climate adjusted TFP on annual basis.
- Climate adjusted state level TFP estimates by industry

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Link to *farmpredict* working paper:
https://www.agriculture.gov.au/abares/research-topics/working-papers/farmpredict