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A micro econometric approach to total factor productivity estimation: A case study of Australian vegetable farms

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Economic Measurement Group (EMG)

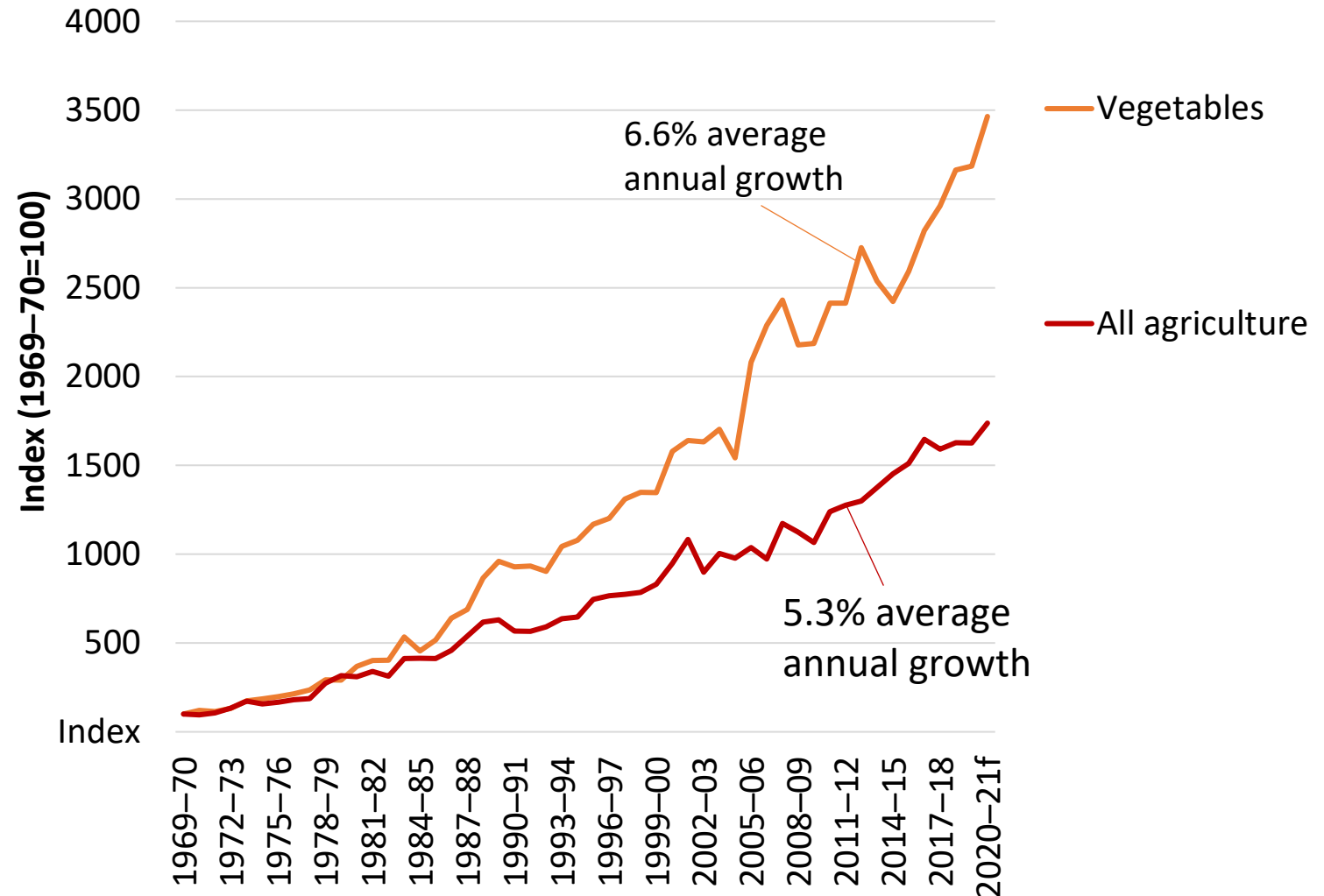


Research by the
Australian Bureau of Agricultural and Resource Economics and Sciences

Background

- Vegetable industry is relatively small however is growing quickly and becoming increasingly important
- It has some additional measurement challenges
- Rarely researched, likely due to data limitations and heterogeneous outputs

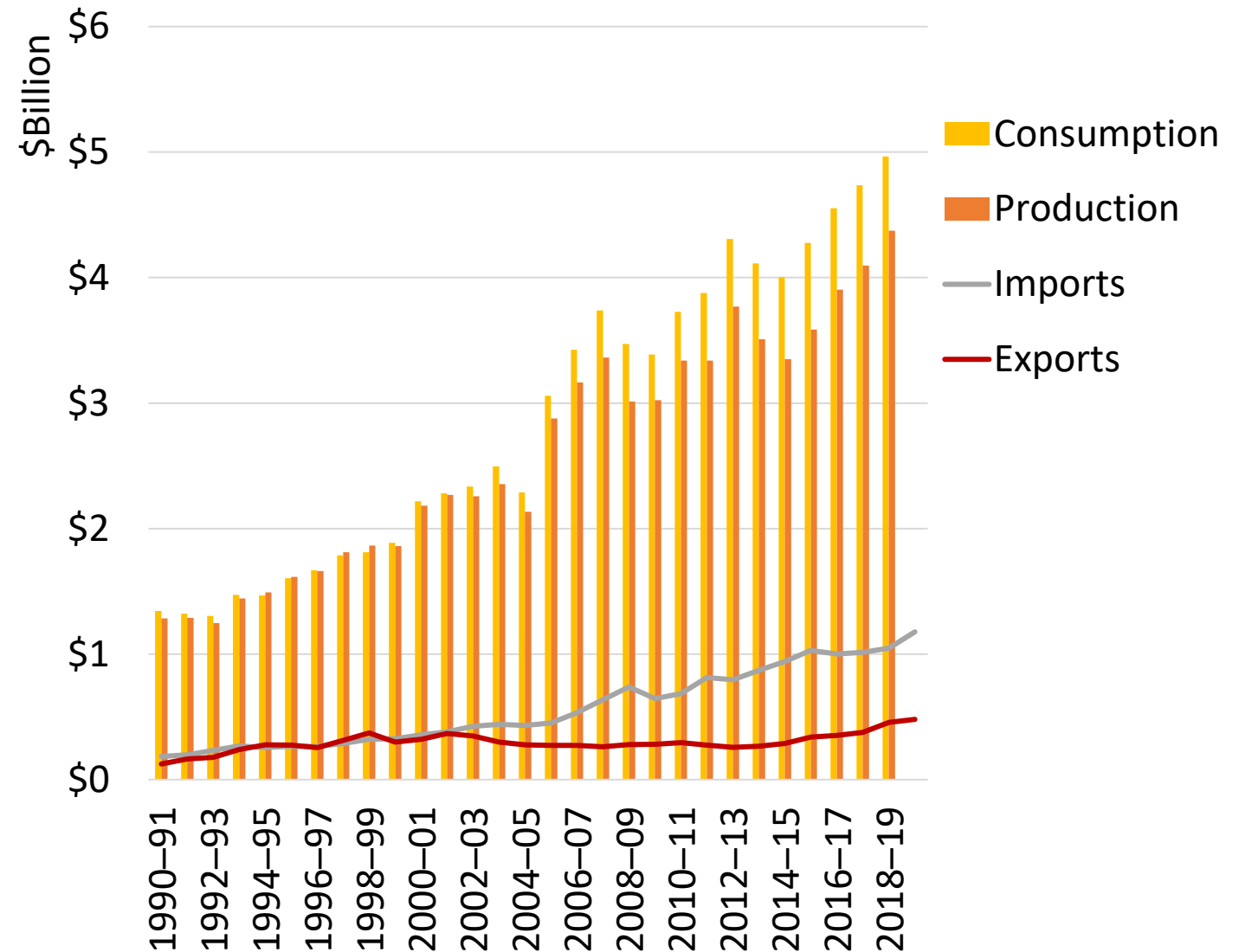
Growth in the nominal gross value of production by industry, Australia, 1969–70 to 2020–21



Motivations

- No existing estimates of Australian vegetable industry productivity + ABARES has the data
- The vegetable industry has grown at a faster rate than the overall agricultural sector
- It is an important industry that largely supplies the fresh food domestic market
- It presents unresolved measurement challenges

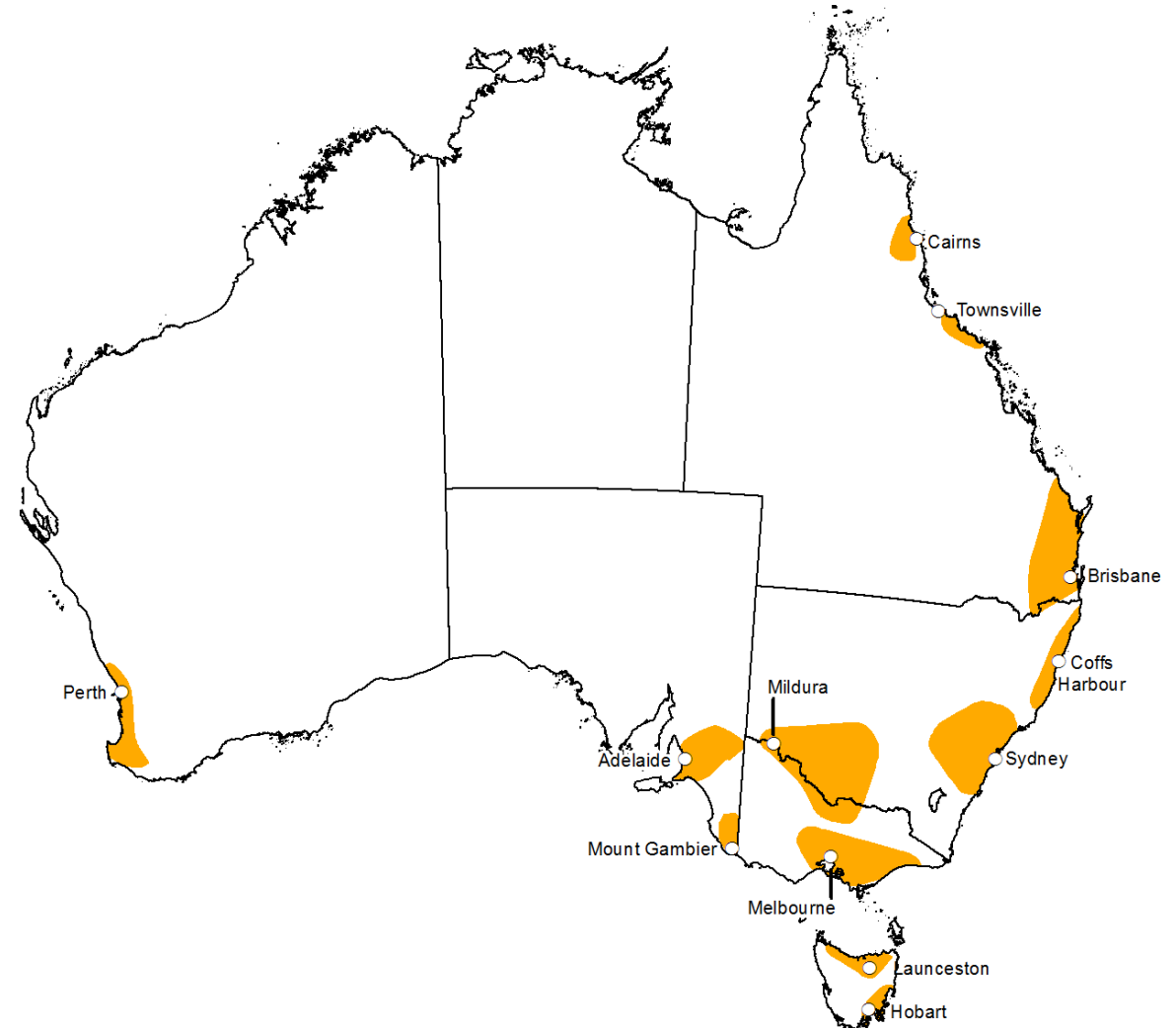
Vegetable production, consumption, and trade, 1990-91 to 2019-20



Data

- Sample of 300 vegetable farms surveyed each year from 2006 to 2016
- The final data set is an unbalanced panel of 2,853 observations, consisting of 1,151 unique farms
- The survey collected:
 - Financial, physical and socioeconomic characteristics
 - Vegetable production types, business receipts and costs, labour use, debts and assets.

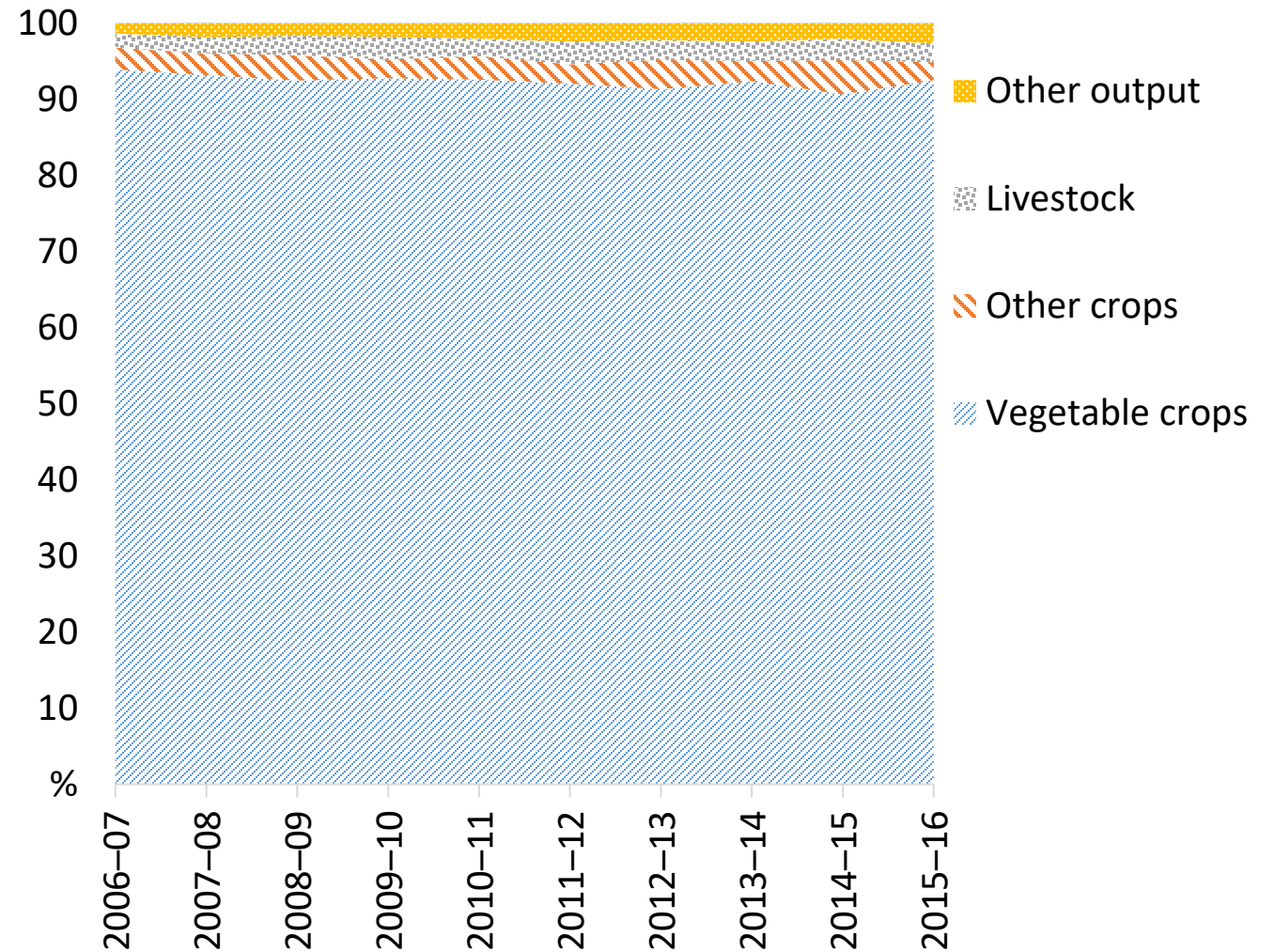
Location of vegetable growing farms surveyed



Outputs

- 18 vegetable categories (includes 1 category for 'other')
- Sample farms mainly produce vegetables (over 90% of output)
- Prices are matched to each vegetable category (to aggregate outputs).

Share of total output, by type of output:
2006-07 to 2015-16



Price

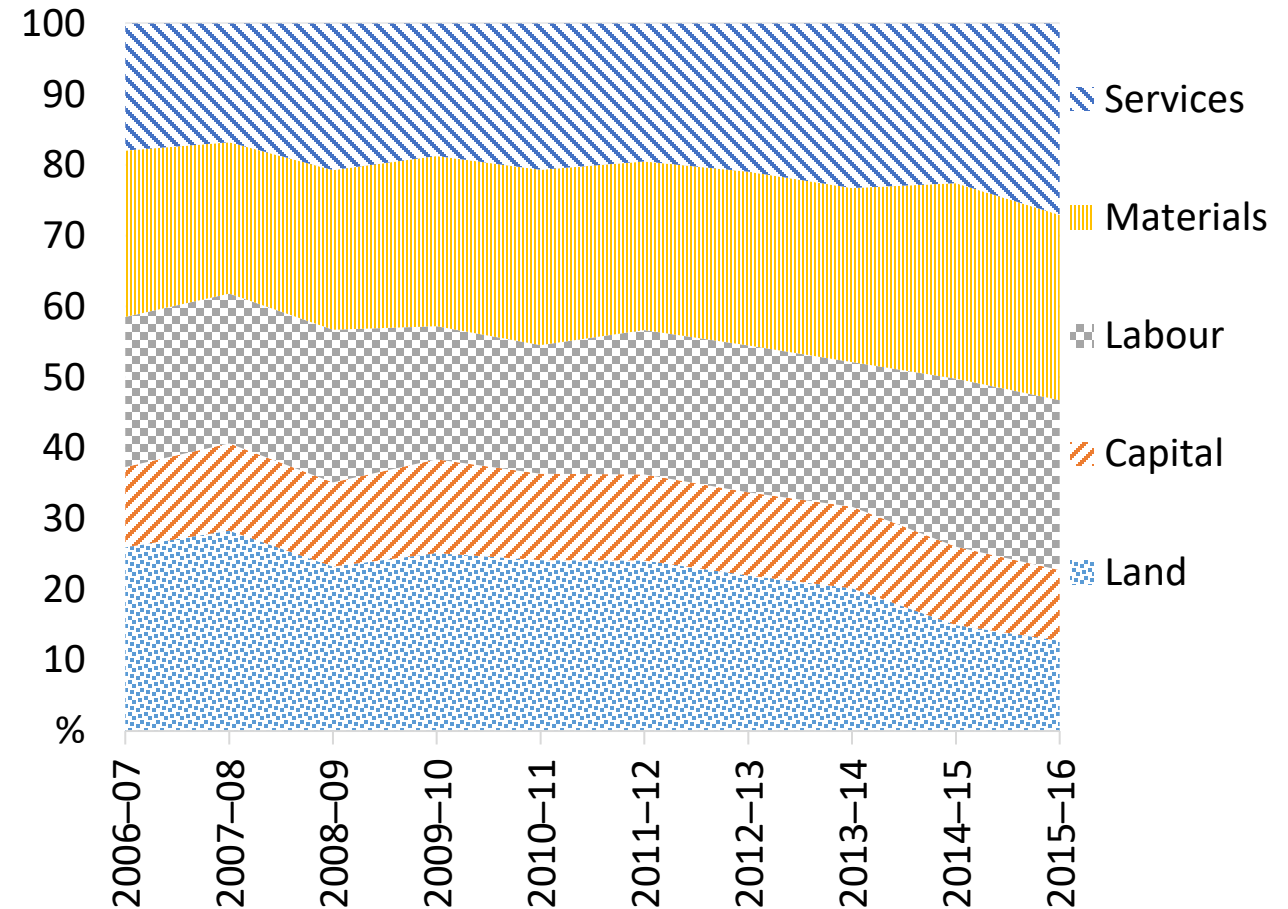
- Production for each of the 18 vegetable types is matched with an output price
- Price data from the Melbourne wholesale fresh fruit and vegetable market (rather than direct prices).
- Weekly price data for over 130 categories of fresh fruit and vegetables since 2001 (table)
- To control for variation in the price due to differences in size, quality and packaging, the data for each crop was standardised across these categories
- There can be significant variation in the price of vegetables within each financial year and vegetable farms can produce multiple crops within the same year
- ‘Other vegetables’, price constructed from 56 vegetable crops using a Jevon’s index

Variable	Description and examples
Week	The week ending for which the data is representative.
Crop	Examples include lettuce, tomatoes and potatoes.
Variety	For example, varieties of lettuce include cos, coral green, butter and ice-berg.
Grade	Information intended to reflect the quality of the crop. For example, eggplants and tomatoes are differentiated in terms of their production system such as glasshouse, hydroponic and outdoor. Typically, this information is missing.
Pack	Packaging information. For example, carton, tray, bag, deck and bunch. Typically, the packaging includes information about weight as well. For example, 12kg carton and 30L tray.
Region	Where the crop was sourced from—interstate or imported from overseas.
Price	Expressed in dollars per pack.

Inputs

- Inputs are categorised into 5 types—land, labour, capital, materials and services and measured in quantity or volume terms.
- Vegetable input data is expressed in value terms, such as expenditure on fertiliser or value of farm buildings and structures.
- Value measures are converted into volume measures by applying representative price indexes.
- Many of these indexes have no spatial variation

Share of total inputs, by type of input: 2006–07 to 2015–16



Input variables

Input type	Specific inputs	Data items
Land (including water entitlements)	Land	Average area operated in the financial year
	Water	Water entitlements owned by the farmer
Capital	Buildings and other farm improvements	Farm buildings excluding operator's house, water supply structure and fencing. Structural improvements including water supply infrastructure, fencing and yards.
		Real depreciation cost of buildings and other farm improvements
	Plant and machinery	Plant and equipment owned by the operator.
		Plant and equipment leased by the operator.
		Real depreciation of plant and equipment
	Beef cattle	Real value of beef cattle on hand
	Sheep	Real value of sheep on hand
	Other livestock on hand	Real value of other livestock on hand such as dairy cattle, pigs and horses
	Beef cattle purchased	Real cost of purchasing beef cattle
	Sheep purchased	Real cost of purchasing sheep and lambs
Other livestock purchased	Real cost of purchasing other livestock	
Labour	Hired labour	Weeks worked on farm by hired permanent and casual workers
	Owner operator and family labour	Total weeks worked on farm by owner operator and family members
Materials	Seed	Real costs of seed
	Fodder	Real costs of fodder
	Fertiliser	Real cost of fertiliser
	Crop chemicals	Real costs of crop and pasture chemicals, such as pesticides and herbicides
	Fuel	Real costs of fuel, oil and grease
	Livestock materials	Real costs of livestock materials such as dips and drenches
	Electricity	Real costs of electricity
	Other materials	Materials used to pack fruits and other crops, tree and vine replacements, purchase of water for livestock, wool packs, livestock agisted off-farm and materials not elsewhere included (for example, vermin control and protective clothing).
Services	Contract services	Real cost of plant hire and non-capital development contracts such as mustering, harvesting
	Rates and taxes	Real costs of rates paid including drainage and water.
	Administrative services	Real costs of accountancy, banking and legal services
	Repair and maintenance of structures	Real cost of repair for building and structure (for example, fences)
	Repair and maintenance of equipment	Real cost of repair for equipment (for example, tractors)
	Motor vehicle	Real costs for vehicle registration and third party insurance
	Insurance	Real costs of insurance for crops, livestock, buildings, improvements, motor vehicles and workers compensation
	Veterinary	Real cost of veterinary services including artificial insemination
	Other services	Advisory services, crutching, shearing, stores and rations paid to workers, travelling and entertaining expenses, tree and vine crops packed off-farm for sale.

Other variables

- Control variables and variables that are expected to have influenced vegetable productivity (Z_{it}).

Variable	Label	Units	Mean	Std. Dev.	Minimum	Maximum
RAIN	Rainfall	Millimetres (mm)	774.8	370.2	84.4	> 2,500
MINT	Minimum temperature	Degrees Celsius (°C)	11.2	3.0	4.9	20.7
MAXT	Maximum temperature	Degrees Celsius (°C)	22.7	3.4	14.7	31.7
AGE	Age of farmers (or his/her spouse)	Years (yrs)	54.1	11.2	26	90

Variable	Interpretation	% of sample
HYDRO	Farms using Hydroponics (1=Yes, 0=Otherwise)	8.8
UCOVER	Farms operating Undercover (1=Yes, 0=Otherwise)	9.6
CORP	Corporate farms with a hired manager (1=Yes, 0=Otherwise)	1.8
MIX	Farms growing more than one vegetable (1=Yes, 0=Otherwise)	51.7
Farmers highest education attainment:		
- HIGH	High School (1=Yes, 0=Otherwise)	27.9
- TRADE	Trade apprenticeship (1=Yes, 0=Otherwise)	13.5
- UNI	University (1=Yes, 0=Otherwise)	14.2



Method

- Parametric approach where the aggregate output is related to the five aggregate inputs through a specific functional form (Cobb-Douglas production function).

$$Y_{it} = F(X_{it}, Z_{it}, T_t)$$

- Y_{it} is the level of real gross output of i th farm observed in year t
- X_{it} is a vector of five aggregate inputs (labour, capital, land, materials and services)
- Z_{it} is a vector of control variables and variables that are expected to have influenced vegetable production but should be removed from the measure of TFP
- T_t (time dummy) is an indicator of the state of technology, a measure of technical change, which varies over time.

Empirical model

Aggregate output 'Y' for farm 'i' at time 't'

Independent variables 'Z' for farm 'i' at time 't'

Error term

$$\ln Y_{it} = \delta_0 + \sum_{k=1}^K \beta_k \ln X_{kit} + \sum_{n=1}^N \gamma_n Z_{nit} + \sum_{m=1}^M \alpha_m T_{mt} + \varepsilon_{it}$$

Core inputs 'X'—land, labour, capital, materials and services—for farm 'i' at time 't'

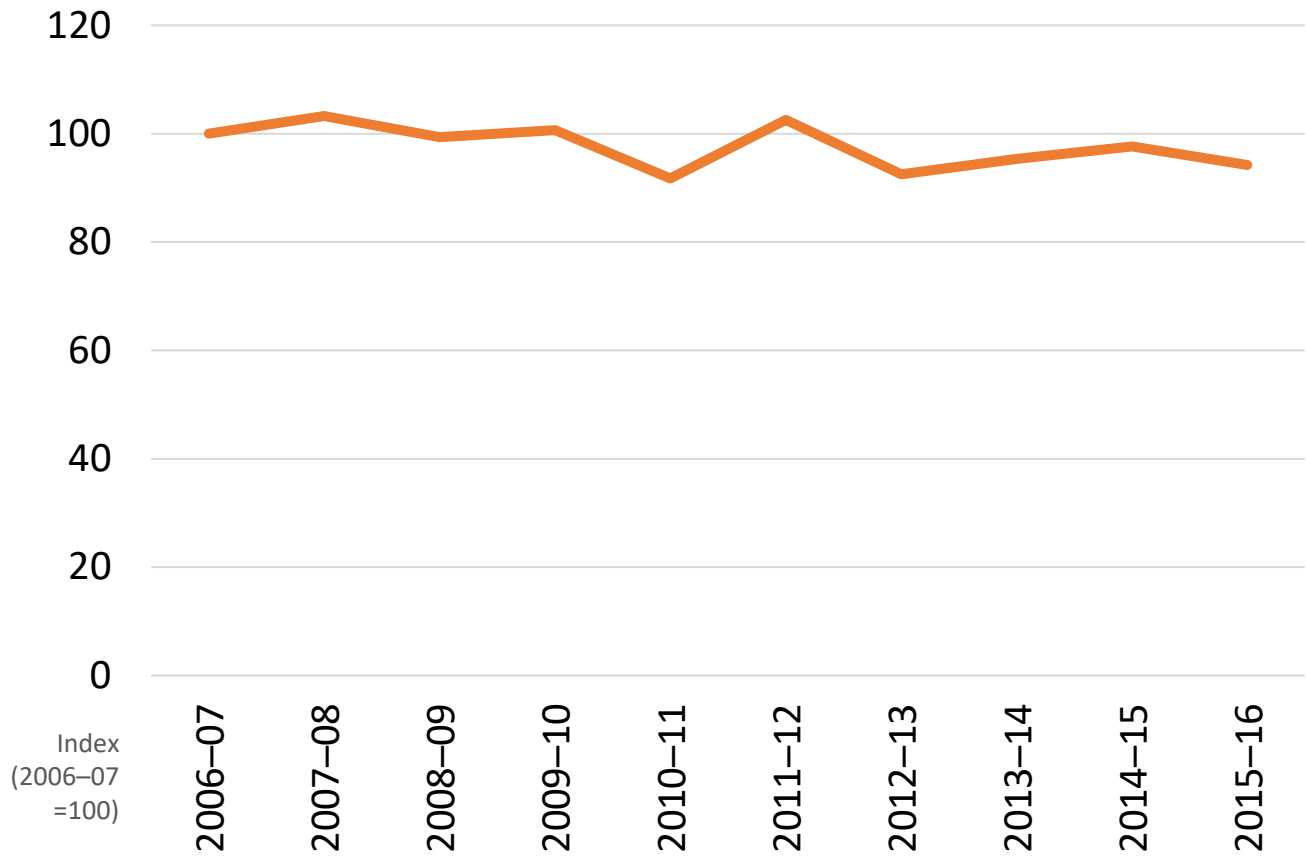
Year dummies 'T' which are 1 for farms in period 't' and 0 otherwise.



Results

- TFP in the Australian vegetable industry showed little change (-0.2%).
- Other farm productivity estimates have experienced limited productivity growth over this period (although they tend to be more volatile).

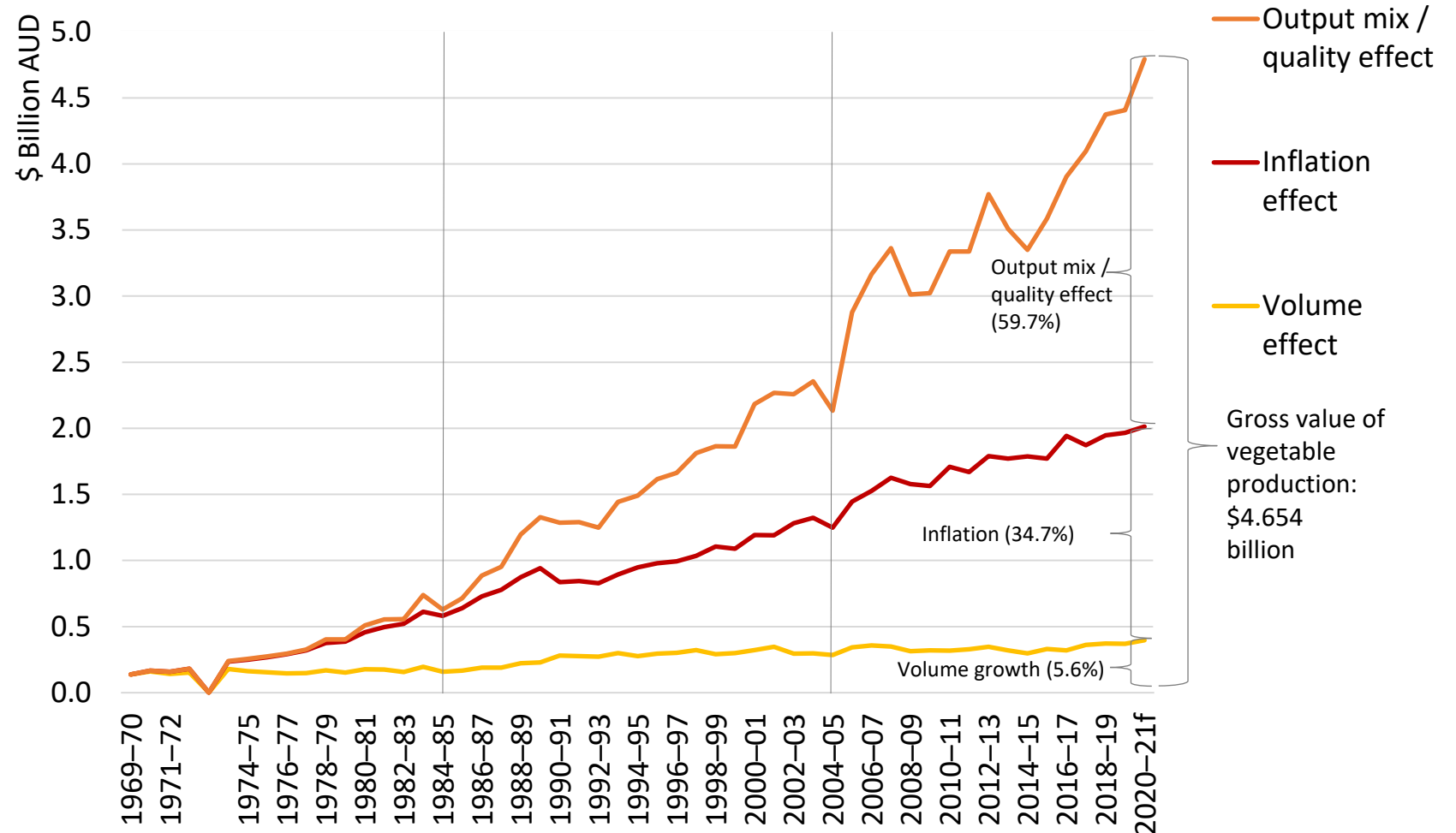
Total factor productivity growth: 2006-07 to 2015-16



Volume, inflation and quality improvements

Growth of the Australian vegetable industry: volume, inflation and output mix / quality improvement 1969-70 to 2020-21

- Between 1969-70 and 2020-21, nominal value of Australian vegetable industry increased by A\$4.65 billion (from A\$138 million to A\$4.79 billion).
- Product mix and quality improvements have been the main driver of growth (almost 60%)
- Aggregate price movements account for approximately 35% of output growth
- Increased production volume made up less than 6%



Some issues

- Some variables in Z_{nit} are not entirely exogenous
- Price matching issue for outputs
- Aggregate input price indexes
- Choice of method (we settled on the Cobb-Douglas production function)
- Absence of interaction terms
- Any others





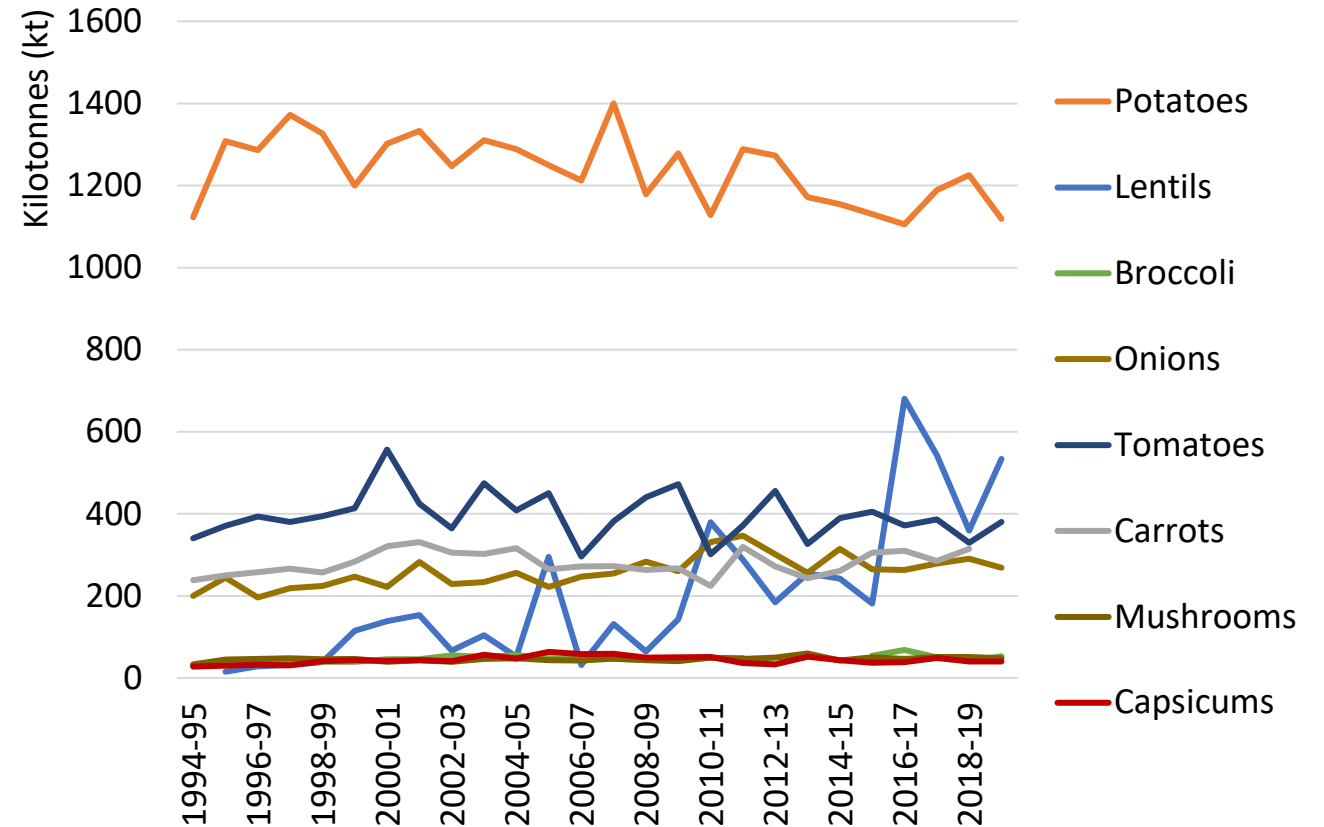
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Future improvements

- TFP estimates should be interpreted in conjunction with a analysis of quality change in the vegetable industry
- Collecting and analysing data on quality attributes of vegetable products should be the focus of future studies.
- Analyse the drivers of vegetable industry productivity
- Analyse difference in vegetable farms technology use

Production (Kt) by selected vegetable types, 1994-95 to 2019-20



Results

	Pooled		Random effect		Fixed effect
Inputs					
ln (Land)	.06	**	.11	***	.35 ***
ln (Capital)	.10	**	.20	***	.21 ***
ln (Labour)	.06	***	.06	***	.05 **
ln (Materials)	.54	***	.36	***	.17 **
Seasonal conditions					
Annual rainfall— <i>RAIN</i>	.05		.05		-.18
Annual rainfall squared— <i>RAIN</i> ²	-.05		-.02		.01
ln (Average annual <u>maximum</u> temperature)—ln (<i>MAXT</i>)	-.04		-.39		-1.41
ln (Average annual <u>minimum</u> temperature)—ln (<i>MINT</i>)	-.25		.08		.84
Production technologies					
Grow using hydroponics (dummy)— <i>HYDRO</i>	-.38	***	-.24	**	
Grow undercover (dummy)— <i>UCOVER</i>	-.24	*	-.25	***	
Corporate farm (dummy)— <i>CORP</i>	.14		-.08		
Grow more than 1 vegetable (dummy)— <i>MIX</i>	.02		.11	*	
Human capital					
Age of farm manager/operator— <i>Age</i>	-1.10		-1.29		
Age of farm manager/operator squared—(<i>Age</i>) ²	.48		.52		
Highest education is high school (dummy)— <i>HIGH</i>	.06		.05		
— trade apprenticeship (dummy)— <i>TRADE</i>	.05		.00		
— university degree (dummy)— <i>UNI</i>	-.04		-.03		
Financial year (dummy, 2006–07 financial year is the base)					
— 2007–08	.06		.03		-.02
— 2008–09	.03		.00		-.08
— 2009–10	-.01		.01		-.04
— 2010–11	-.10		-.08		-.18
— 2011–12	.02		.03		-.09
— 2012–13	-.09		-.08		-.16
— 2013–14	-.02		-.05		-.16
— 2014–15	-.02		-.02		-.12
— 2015–16	-.06		-.06		-.17
Intercept included?	Yes		Yes		No
State dummies included?	Yes		Yes		No
Year dummies included?	Yes		Yes		Yes
Main vegetable grown dummies included?	Yes		Yes		No
Control dummy for missing age data?	Yes		Yes		No
Number of observations (no.)	2,853		2,853		2,329