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Exploring the Relationship between Farm Size and Productivity

Evidence from the Australian Grain Industry

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Yu Sheng and Will Chancellor

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Introduction

The past three decades have witnessed a significant structural adjustment in agriculture throughout the world.

- The average farm size (in terms of both land usage and output) has increased in developed and developing countries;
- The industry has become more concentrated in some developed countries, with total output mainly produced by a few large farms;

Given observed productivity difference between farms of different size, this structural adjustment significantly contributes to industry-level productivity growth, through:

- resource reallocation from small and less efficient to large and more efficient farms;

However, small farms still play an important role in affecting agricultural production, making their productivity improvement a critical policy issue.

- A better understanding of the relationship between farm size and productivity will provide useful insights.

Introduction

Theoretically, farm size positively affects farm productivity because:

- Large farms are financially more capable of adopting new technology;
- Large farms are more likely to harvest the increasing returns to scale;
- Large farms usually face more favourable input and output prices;

However, empirical studies do not reach a consensus on a positive farm size-productivity relationship.

- Many researches find an ‘inversed’ productivity to size relationship especially in developing countries;
- Market distortions and measurement errors have been previously employed to explain the phenomenon, but they are not satisfactory;

Inconsistency between theory and empirics can be explained if farm productivity is linked to their resource capacity (e.g. size) for investment in efficient technology.

- Outsourcing capital services thus becomes a channel through which small farms obtain equal opportunity for productivity growth;

Introduction

This paper uses regression analysis with farm-level data in the Australian non-irrigated grain industry between 1989 and 2004 to:

- investigate the farm size-productivity relationship and its cross-regional disparity, and;
- link the productivity difference between farms of different size to the way that they obtain capital services (namely, self-own vs. contract);

The purpose is to:

- Provide empirical evidence on the positive farm size-productivity in Australian agriculture;
- Identify the impact of budget constraint (for investment) on productivity difference between farms of different size;
- Demonstrate the role of 'contract capital services' (or outsourcing) in helping to lift the productivity of small farms;

Introduction

Methodologically, we deal with the potential endogeneity problem by:

- Using a combination of first differencing (FD) and panel data fixed effect (FE) models to eliminate the time in-variant omitted variables, and;

- Control for a large number of time variant factors that jointly affect farm size and productivity: farm characteristics, management and farming practices and natural and market conditions;

Contributing to the literature, our study

- Provides supportive evidence for a positive farm size-productivity relationship and links the cross farm-size productivity difference to budget constraints for investment;

- Points out that outsourcing capital is an potential way for small farms to move towards the average productivity growth rate of the industry;

Policy implication: developing ‘contracting service market’ is an alternative way to resolve the small farm issue.

Background

The relationship between farm size and productivity is an important theoretical and empirical issue

- The positive farm size-productivity relationship in theory;
  - Diewert and Fox (2010), Berry and Cline (1979), Bhalla (1979);
- The ‘inversed’ farm size-productivity relationship in empirics
  - Sen (1962, 1966), Binswanger et al. (1995), Benjamin and Brandt (2002), Eastwood et al. (2010) and Carletto et al. (2013);
- Differences in the farm size-productivity relationship are observed between in developed and developing countries;

The phenomena calls for more sensible explanation and empirical evidence;

Background

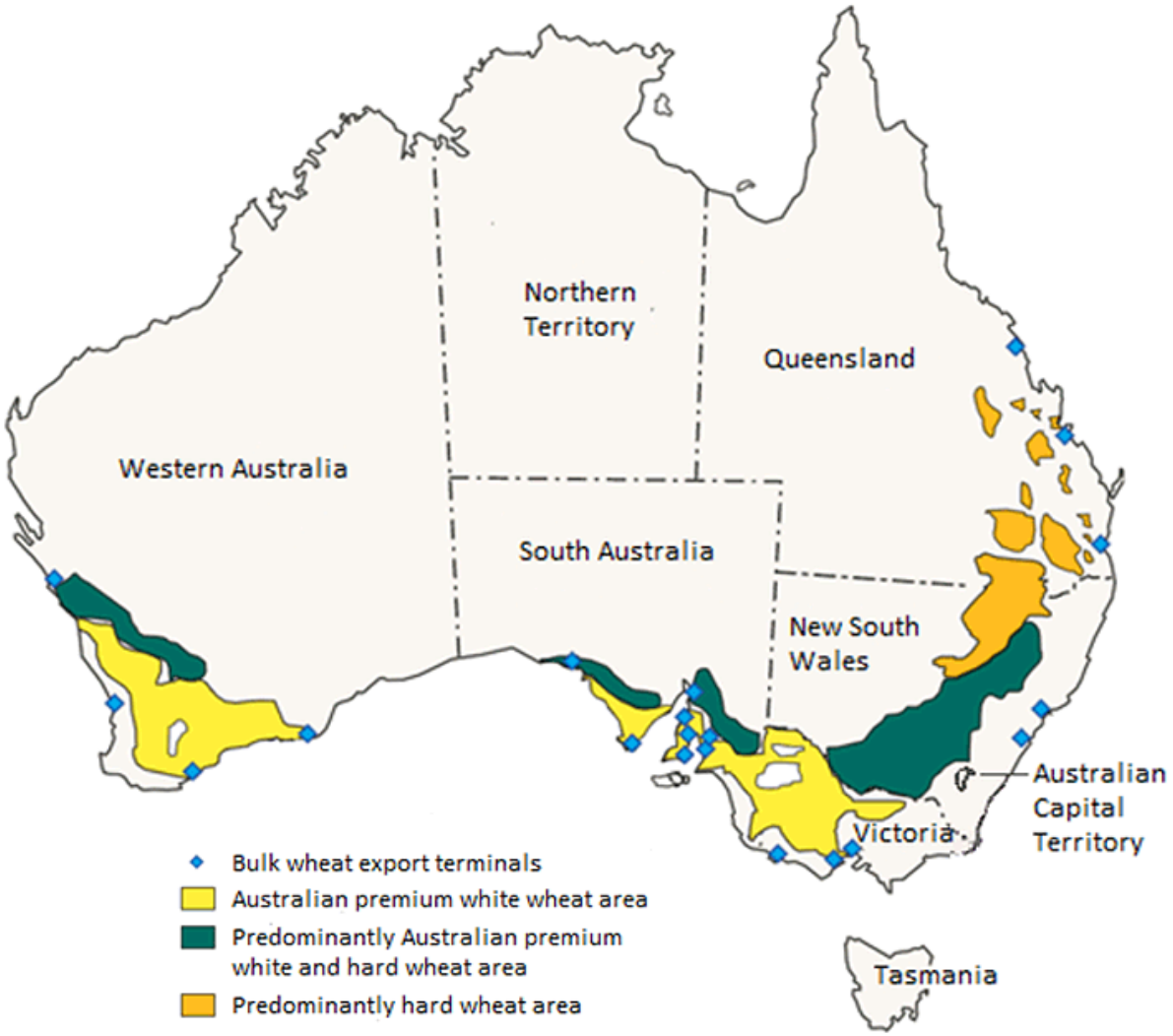
A critical issue in the empirical study on farm size-productivity relationship is the productivity measurement

- Partial factor productivity: yield and labor productivity;
    - Craig et al. (1997), Coellie and Rao (2005) and Ludena et al. (2007);
- Total factor productivity: regression vs. index method
    - Olley and Pakes (1995), Levinsohn and Petrin (2003), Wooldridge (2005) and ABBP (2007);
    - OECD FLA Meeting (2013);

Many factors that jointly affect farm size and productivity will also contaminate the farm size-productivity relationship;

- Farm owners education and experience;
- Natural endowment in soil and climate conditions;

Figure 1 Australian wheat growing regions



Source: ABARES

Background

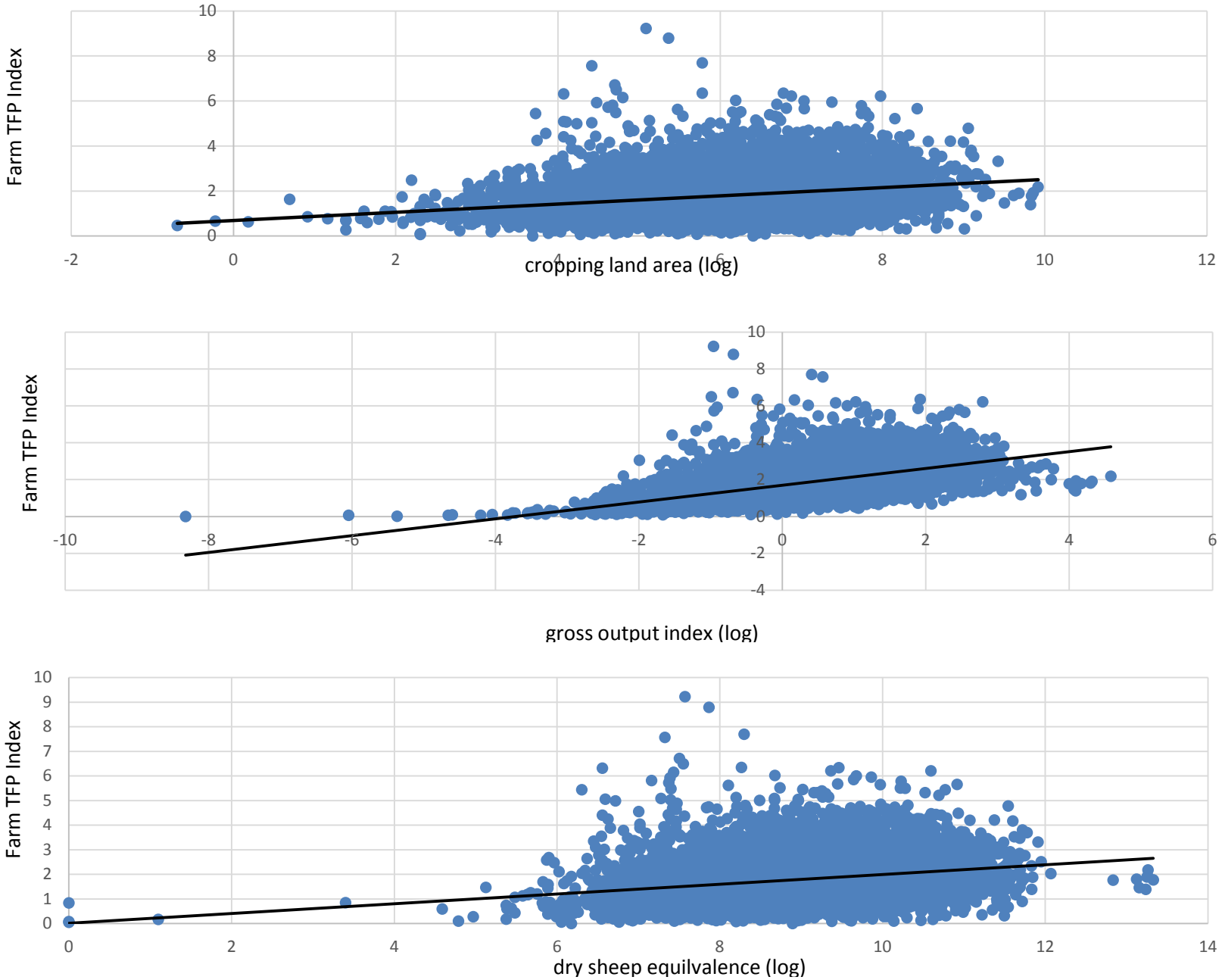
The farm size-productivity relationship in the Australian grain industry

- The grain industry is the largest non-irrigating farm sector in Australian agriculture;
    - Wheat, barley, sorghum, canola, cotton seeds etc.
- Productivity of the industry grew at 1.3 per cent a year since 1978;
- There are significant difference in productivity between large and small farms;

Previous studies found that farm size positively contributed to productivity growth: Kokic et al. (2006), Zhao et al. (2010), Sheng et al. (2015 & 2016).

- The adoption of technology and capital explains much of the productivity difference;

Figure 2 Farm size-productivity relationship in Australian grain industry



Empirical Model

Farm productivity is determined by size, when:

- controlling for other productivity determinants;
- accounting for time-invariant farm specific effects;

$$\ln TFP_{irt} = \alpha + \sum_{k} \beta^{k} \ln X_{irt}^{k} + \sum_{s} \gamma_{s} D\_Size_{is} + \sum_{t} \varphi^{t} D^{t} + \varepsilon_{irt}$$

Where:

TFP_{ijrt} is the TFP of ith farm operating in rth region at year t;

X_{irt}^{k} is a vector of farm characteristics that influence farm TFP;

D^{t} is a time dummy variables for year t, and $\varepsilon_{ijrt} = u_{ir} + \eta_{irt}$;

D_Size_{is} is the dummy for farm size;

Empirical Model

Incorporating the measure of 'plant and machinery hire into the baseline model

- Measure of farm using the contract service to replace self-owned investment;
- Interaction between farm size variable and the dummy for 'contracting capital service';

$$\ln TFP_{irt} = \alpha + \sum_k \beta^k \ln X^k_{irt} + \sum_s \gamma_s D\_Size^s_{irt} + \sum_s \theta_s D\_Size^s_{irt} * PH_{irt} + \lambda PH_{irt} + \sum_t \varphi^t D^t + \varepsilon_{irt}$$

Two null hypotheses are:

- Positive coefficient in front of PH_{irt} provides a measure of average effects of contract services on farm productivity;
- Negative coefficient in front of the inter-action terms provides a measure of marginal effects of contract services on farm size-productivity relationship;

Data Source

The data used in this paper is from three main sources:

- Australian Agricultural and Grazing Industry Survey (AAGIS): regional TFP measures;
- The Queensland University and the government of Queensland: soil moisture and land quality;
- Australian Nature Resource Management Survey: farm characteristics, farming practices etc.;

The data for all variables are collected and compiled at the farm level, in particular for control variables

- Farm characteristics;
- Management and farming practices;
- Natural and market conditions;

Descriptive Statistics

	Means
Farmer Characteristics	
Age	50.3
Education	
Missing (%)	6.6
Not reported (%)	0.2
No schooling (%)	6.9
1-4 year high school (%)	45.3
5-6 year high school (%)	25.6
TAFE (%)	7.2
Tertiary (%)	8.2
Crop specialist (%)	49.7
Crop-mixed (%)	50.3
Off farm income (%)	6.4
Family farm (%)	95.6
NSW (%)	27.2
VIC (%)	20.0
QLD (%)	13.9
SA (%)	20.0
WA (%)	18.9
Management and Farming Practices	
Land use intensity (%)	60.2
Crop specialisation (%)	63.6
Partners	4.1
Product diversity (%)	1.8
Management cost (%)	3.8
Natural and Market Conditions	
Moisture availability	75.5
Land gradient	2.0
Market risk	25790.9

Data Source

Farm TFP Measure

- TFP index is defined as the ratio of gross output over total inputs;
- Outputs and inputs are aggregated using the Fisher index formulas;
- The EKS formula is employed to resolve the transitivity issue;

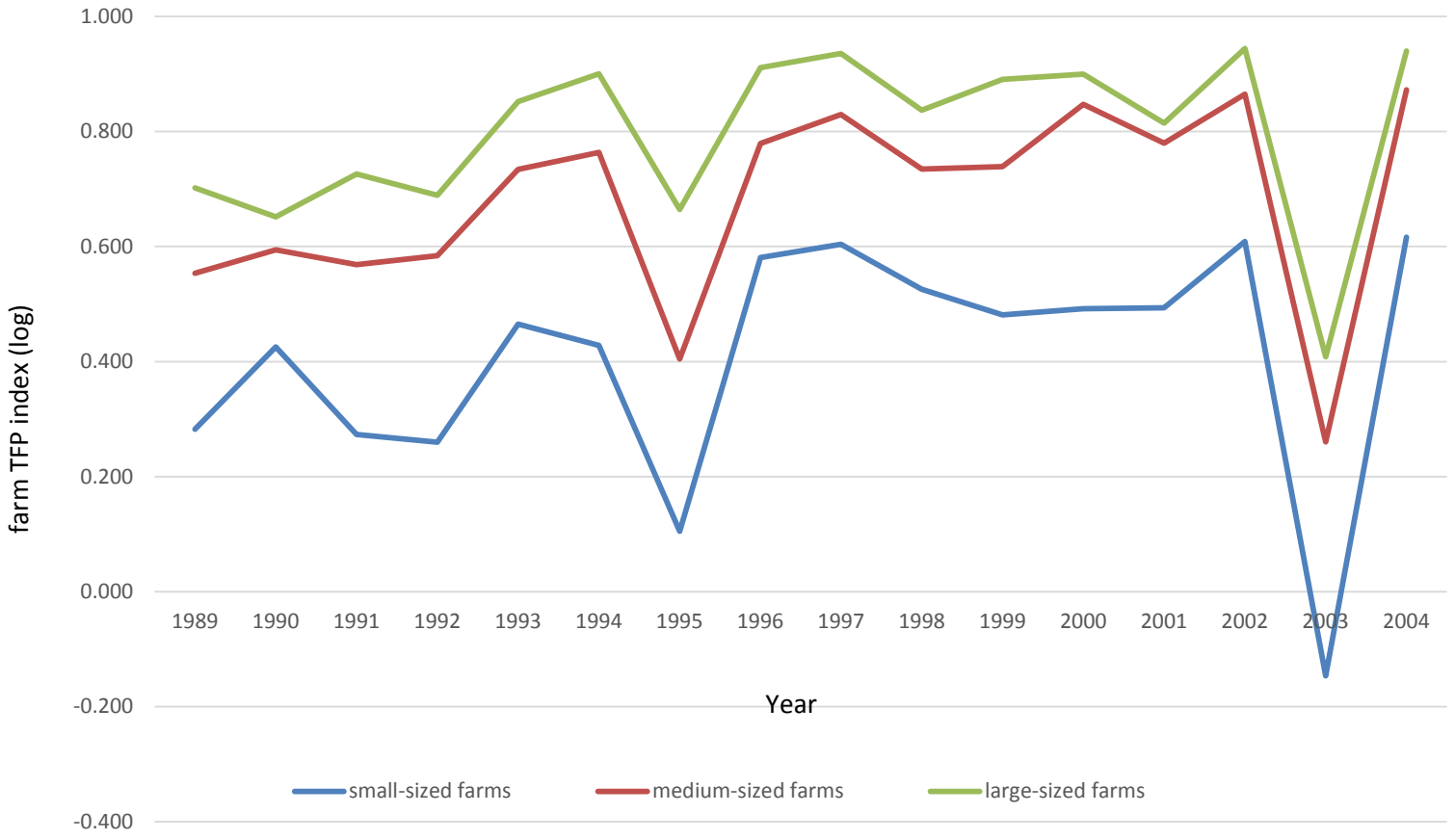
Farm size is measured by either by using continuous or groups of dummy variables

- By land areas, gross output index and dry sheep equivalence (total input measure/carry over capacity);

‘Contract capital’ is defined a dummy variable

- Taking ‘1’ if a farm uses hired plant and machinery services and ‘0’ otherwise.

Average farm TFP of different size: 1989-2004



Farm size positively affect productivity

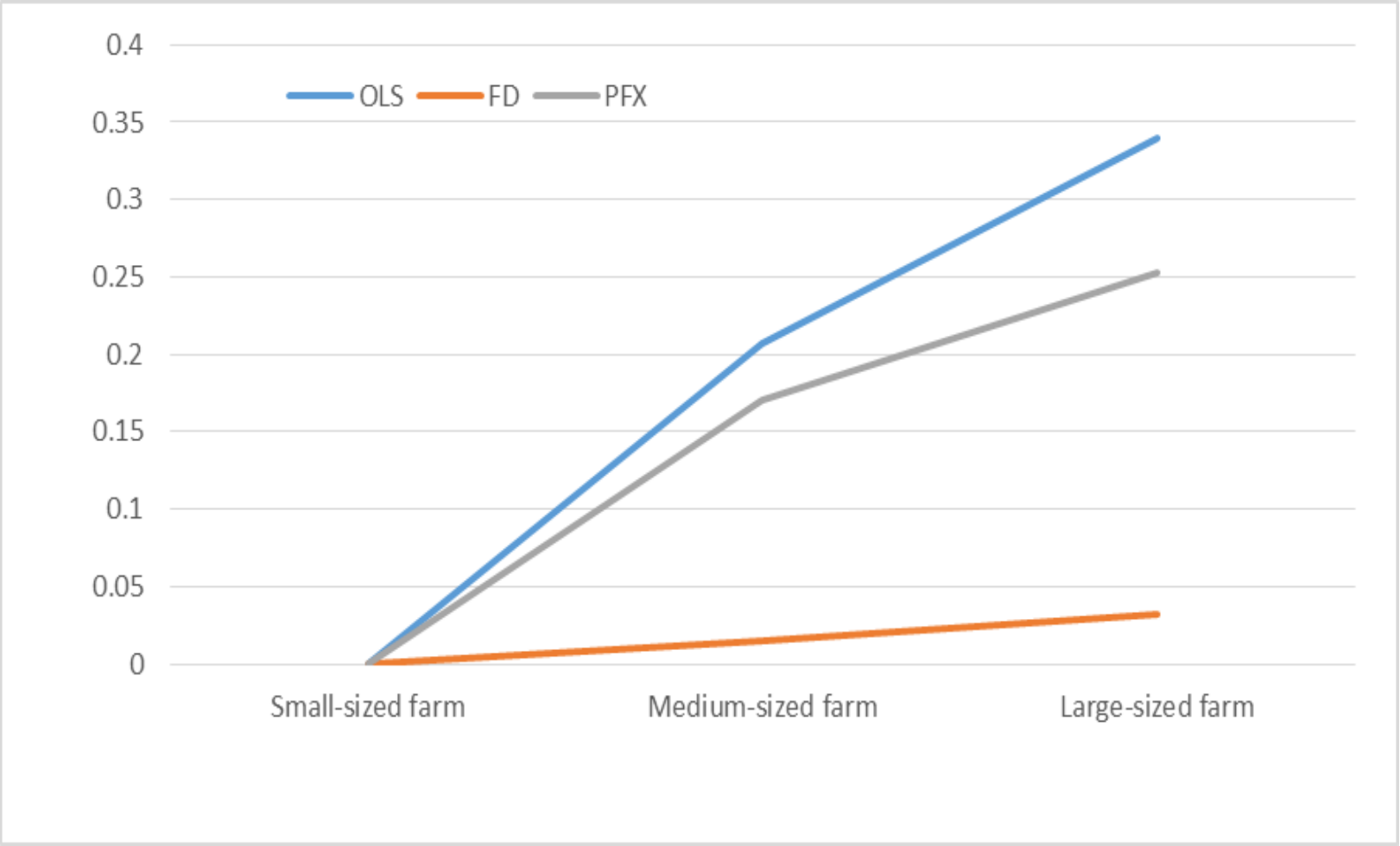
	OLS	FD	FE
Dependent variable: ln_farm_TFP			
ln_waterstress_index	0.450***	0.440***	0.443***
	(0.003)	(0.004)	(0.024)
ln_std_waterstress_index	-0.046***	-	-0.038
	(0.002)	-	(0.026)
ln_land_slope	-0.016***	-	-0.016
	(0.001)	-	(0.010)
operator age	0.009***	0.012***	0.004***
	(0.000)	(0.001)	(0.001)
operator age (square)	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
off-farm income	-0.115***	-0.074***	-0.122***
	(0.002)	(0.010)	(0.032)
Dummy_for_education0	0.112***	0.154***	0.135***
	(0.004)	(0.045)	(0.034)
Dummy_for_education1	0.276***	-0.003	0.136**
	(0.007)	(0.010)	(0.060)
Dummy_for_education3	0.064***	0.041***	0.062***
	(0.002)	(0.011)	(0.020)
Dummy_for_education4	0.106***	0.062***	0.082***
	(0.002)	(0.013)	(0.021)
Dummy_for_education5	0.113***	0.046***	0.086***
	(0.003)	(0.012)	(0.027)
Dummy_for_education6	0.178***	0.070***	0.142***
	(0.003)	(0.004)	(0.025)
ln_cropplanting_intensity	0.232***	0.153***	0.250***
	(0.001)	(0.004)	(0.011)
crop_specialisation	0.004***	0.151***	0.004***
	(0.000)	(0.003)	(0.000)

To be continued…

Farm size positively affect productivity (continued…)

	OLS	FD	FE
Dependent variable: ln_farm_TFP			
diversity	0.009***	0.007***	-0.013
	(0.002)	(0.000)	(0.018)
diversity2	0.002***	-0.010***	0.004
	(0.001)	(0.003)	(0.004)
d_ff	-0.181***	-0.002**	-0.112***
	(0.002)	(0.001)	(0.024)
labour_share_income	-0.032***	-0.190***	-0.047***
	(0.001)	(0.004)	(0.010)
partners2	0.002***	0.033***	0.004***
	(0.000)	(0.003)	(0.001)
manage_cost_share	-0.025***	-0.003***	-0.014**
	(0.001)	(0.000)	(0.006)
ln_risk_p	-0.007***	-0.025***	-0.030***
	(0.001)	(0.001)	(0.007)
Capital-Labour Ratio (logarithm)	-0.048***	-0.065***	-0.049***
	(0.001)	(0.002)	(0.006)
Dummy_for_Medium_Sized_Farms	**0.207*** **	**0.015*** **	**0.172*** **
	(0.001)	**(0.001)**	**(0.014)**
Dummy_for_Large_Sized_Farms	**0.304*** **	**0.032*** **	**0.253*** **
	(0.002)	**(0.002)**	**(0.021)**
Constant	-1.274***	0.036***	-0.963***
	(0.019)	(0.002)	(0.156)
Number of Observations	5969	3757	5969
R-squared	0.481	0.532	0.437

Large farms perform better than small farms in TFP



Impact of contracting plant and machinery on farm size-productivity relationship

	OLS	FD	FE
Dependent variable: ln_farm_TFP			
Capital-Labour Ratio (logarithm)	-0.048***	0.064***	-0.048***
	(0.001)	(0.002)	(0.006)
Dummy_for_Medium_Sized_Farms	0.220***	0.026***	0.223***
	(0.002)	(0.002)	(0.015)
Dummy_for_Large_Sized_Farms	0.318***	0.038***	0.363***
	(0.002)	(0.002)	(0.021)
Dummy_for_PlantHire	0.003*	0.022***	0.002**
	(0.002)	(0.002)	(0.001)
Interaction_Term_MediumFS	-0.036***	-0.019***	-0.041**
	(0.002)	(0.003)	(0.016)
Interaction_Term_LargeFS	-0.035***	-0.005	-0.024
	(0.002)	(0.004)	(0.017)
Number of Observations	5969	3757	5969
R-squared	0.524	0.618	0.5046

Impact of ‘outsourcing capital’: aggregate level

Capital hire of Plant and machinery (‘outsourcing’) improves farm TFP

- Coefficients in front the dummy for plant and machinery hire are positive and significant at 5-10 per cent level;
- Farm productivity increase with the use of ‘plant and machinery hire’ to replace the self-owned investment;

Plant and machinery hire (‘contract capital service’) is likely to reduce the productivity difference between small and medium sized farms

- Coefficients in front of the inter-action terms between farm size and the variable for ‘plant and machinery hire’ are negative and significant at 1-5 percent level;
- ‘Plant and machinery hire’ helps to lift the productivity of small farms;

Cross-regional disparity: Northern, Southern and Western

	Northern Region	Southern Region	Western Region
Dependent variable: ln_farm_TFP			
Capital-Labour Ratio (logarithm)	-0.018*	-0.046***	-0.054***
	(0.011)	(0.015)	(0.009)
Dummy_for_Medium_Sized_Farms	0.121***	0.256***	0.199***
	(0.028)	(0.027)	(0.014)
Dummy_for_Large_Sized_Farms	0.223***	0.385***	0.337***
	(0.034)	(0.038)	(0.020)
Dummy_for_PlantHire	0.010	0.005***	0.01***
	(0.040)	(0.001)	(0.001)
Interaction_Term_MediumFS	-0.030	-0.098***	-0.029
	(0.045)	(0.037)	(0.018)
Interaction_Term_LargeFS	-0.041	-0.025	-0.015
	(0.042)	(0.038)	(0.023)
Number of Observations	1130	1429	3376
R-squared	0.387	0.413	0.402

Northern grain region:

- tropical and subtropical climate;
- high inherent soil fertility;
- yield depends upon conservation of soil moisture from subtropical rainfall;
- substantial enterprise size;
- diversity in crop choice, need for new crops, e.g. pulses;
- premium on high-protein wheats for export and domestic markets;
- high-potential yields; and
- competition with cotton.

Southern grain region:

- temperate climate;
- relatively infertile soils;
- yield depends upon reliable spring rainfall;
- smaller enterprise size;
- diverse production patterns and opportunities;
- large and diverse domestic market;
- phase farming innovator; and
- shift in intensive livestock production and demand for feed grains to this region.

Western grain region

- Mediterranean climate;
- low soil fertility;
- yield depends upon good winter rains as spring rainfall is generally unreliable;
- large enterprise size;
- narrower range of crop options;
- export market dominant, domestic market smaller;
- leader in grain storage practice; and
- transport advantage to SE Asia.

Impact of ‘outsourcing capital’ by regions

Explanation for the regional variations relating to the impact of ‘outsourcing’ on farm productivity, as well as the farm size-productivity relationship can be explained by: natural and social condition, culture in farming system.

- Farmers in the Western region:
    - Large land scale; predictable weather condition and lower soil quality; modern and specialised farming system (newly equipped plant and machinery);
- Farmers in the Northern region:
    - Small land scale; unpredictable weather condition and lower soil quality (diversified output mix); family farm system (respecting independency);
- Farmers in the Southern region:
    - Small land scale; predictable weather and good soil quality; shared farming system

Conclusions

We investigate the farm size-productivity relationship in Australian grain industry between 1978 and 2004

- Using an unbalanced panel farm-level data;
- Allowing for difference in farm characteristics, farming practices and natural and market conditions;

We find that a positive relationship between farm size and productivity, variations exist between regions.

'Outsourcing' positively contribute to farm productivity level and is likely to reduce the productivity difference between small and medium sized farms, even when:

- The capital-labor ratio and other productivity determinants are well controlled;
- In particular, the effects are significant in southern region;

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Questions and Comments

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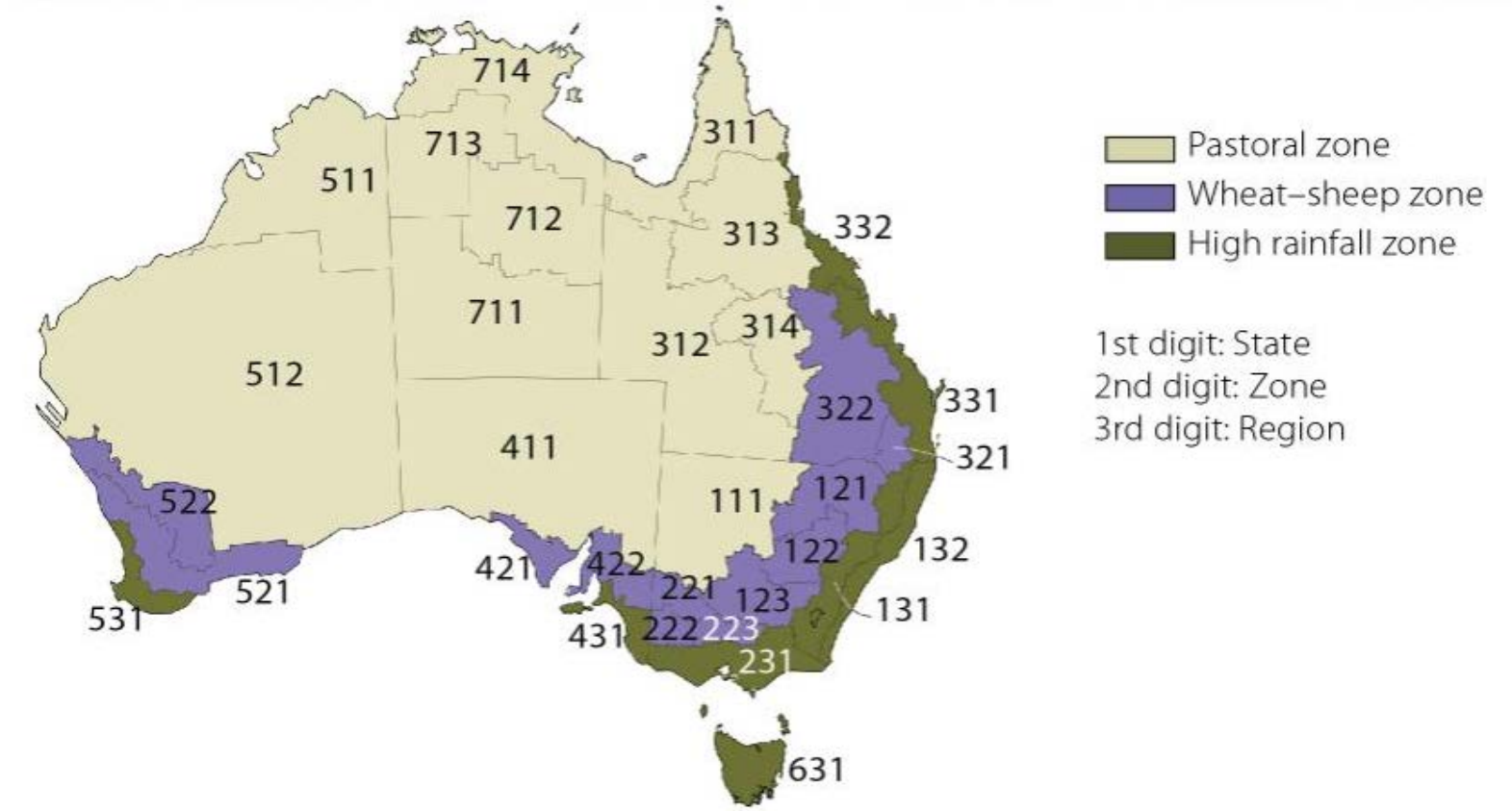
AAGIS Farm Survey in Australia



Weather Data

Water availability measure:

- The index is measured 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

Figure 3 weather information match