Productivity and Farm Size in Australian Agriculture:

Reinvestigating the returns to Scale

Yu Sheng, Katarina Nossal and Shiji Zhao

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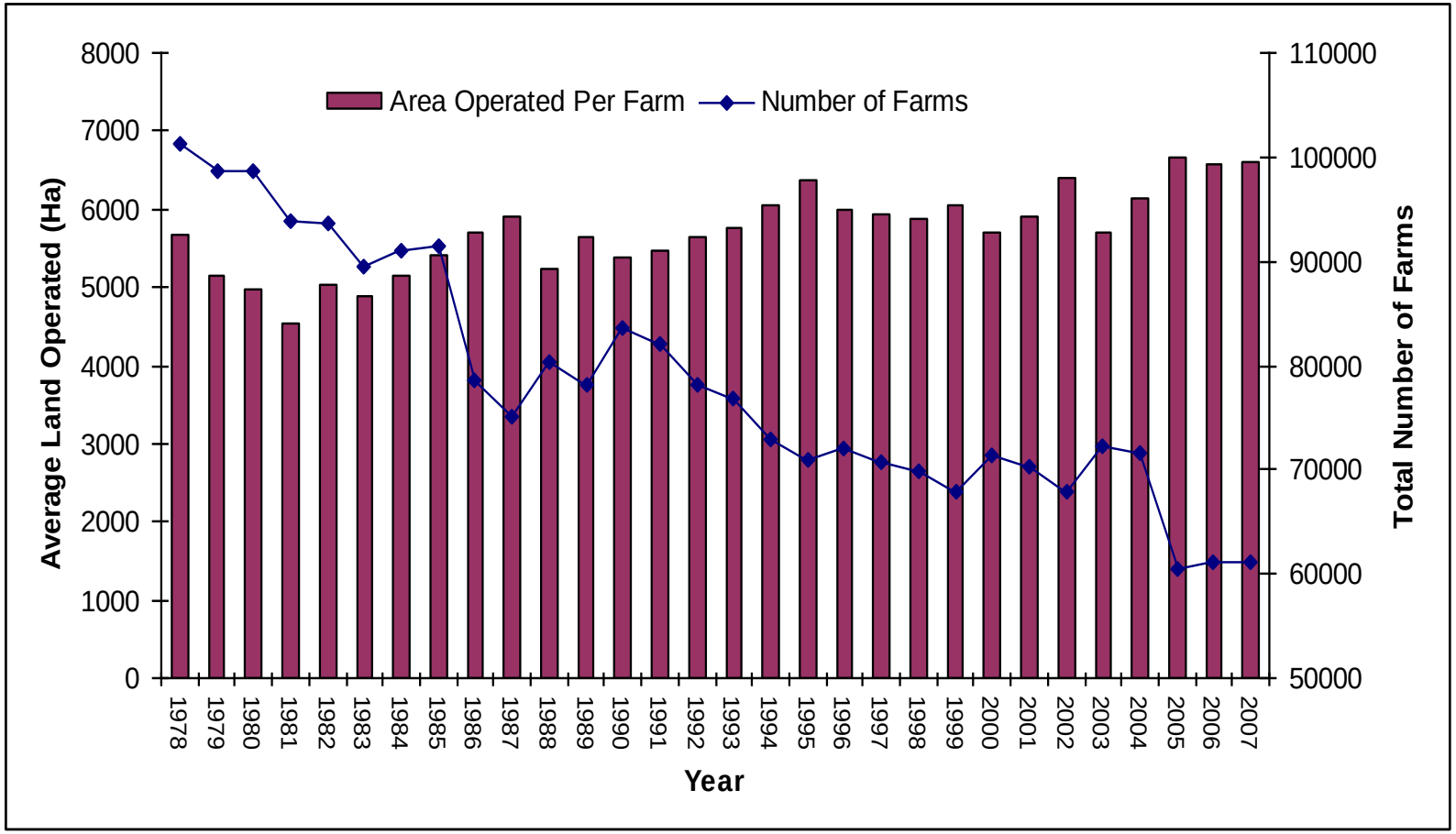
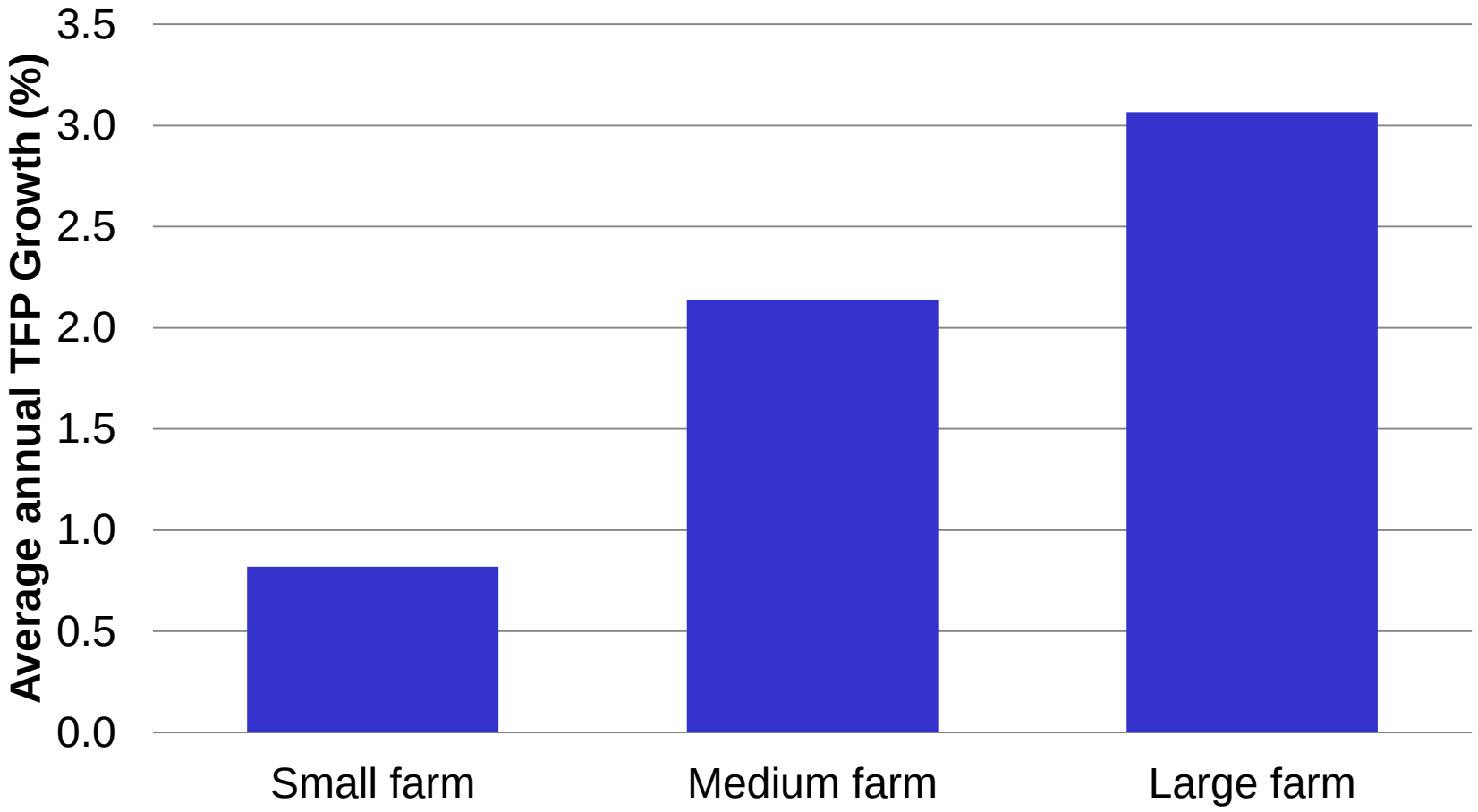
Background

- The average size of broadacre farms in Australia has increased rapidly
  - Number of farms declined from 117,000 in 1977-78 to 58,000 in 2006-07
  - Average farm area increased from 5002 ha in 1977-78 to 6500 ha in 2006-07.
- Average farm productivity and profitability increased with operating size over the period1977-78 to 2006-07

Number of broadacre farms and average land area operated



Productivity growth by farm size: 1977-78 to 2006-07



Research questions

- How do large farms achieve higher productivity than smaller farms?
  - Increasing returns to scale (IRS) is widely used to explain disparities between farm size and performance
    - Knopke et al. (2000), PC (2005), Cattle (2006), Cattle and White (2007)
- Do IRS apply to Australian farming sector?
  - ‘Returns to scale’ vs. ‘Returns to size’
  - Role of production technology (input mix)

Objectives

- Explore the impact of farm size on productivity performance
- Test for ‘economies of scale’ and the heterogeneity of production techniques used in farms of different size
- Assess the implications for ongoing structural adjustment in Australian agriculture

Theoretical Framework

- Increasing returns to scale:
  - A one percent increase in producers' inputs (proportionally) may lead to more than one per cent of increase in their output

- Three potential assumptions:
  - Farms are both profit maximisers and cost minimizers
  - Production technique is homogeneous
  - Proportional increase in outputs exceeds that of inputs

Theoretical Framework

We assume that

$$Y = Af(X) \qquad X = (Land, Labor, Capital, Materials)$$

A general representation of variations in output associated with a proportional increase in inputs (k)

$$f(kX) = G[k, X/|X|, f(X)]$$

Due to Chamber (1985), we have

$$Y = Af(kX_0) = A \cdot k^{H(X/|X|)} \cdot f(X_0)$$

Theoretical Framework

- Profit maximization

$$\partial \ln Y / \partial \ln k = H(X / | X |)$$ where

$$H(X / | X |) = \gamma + a \cdot h(X / | X | -1)$$

- Cost minimization

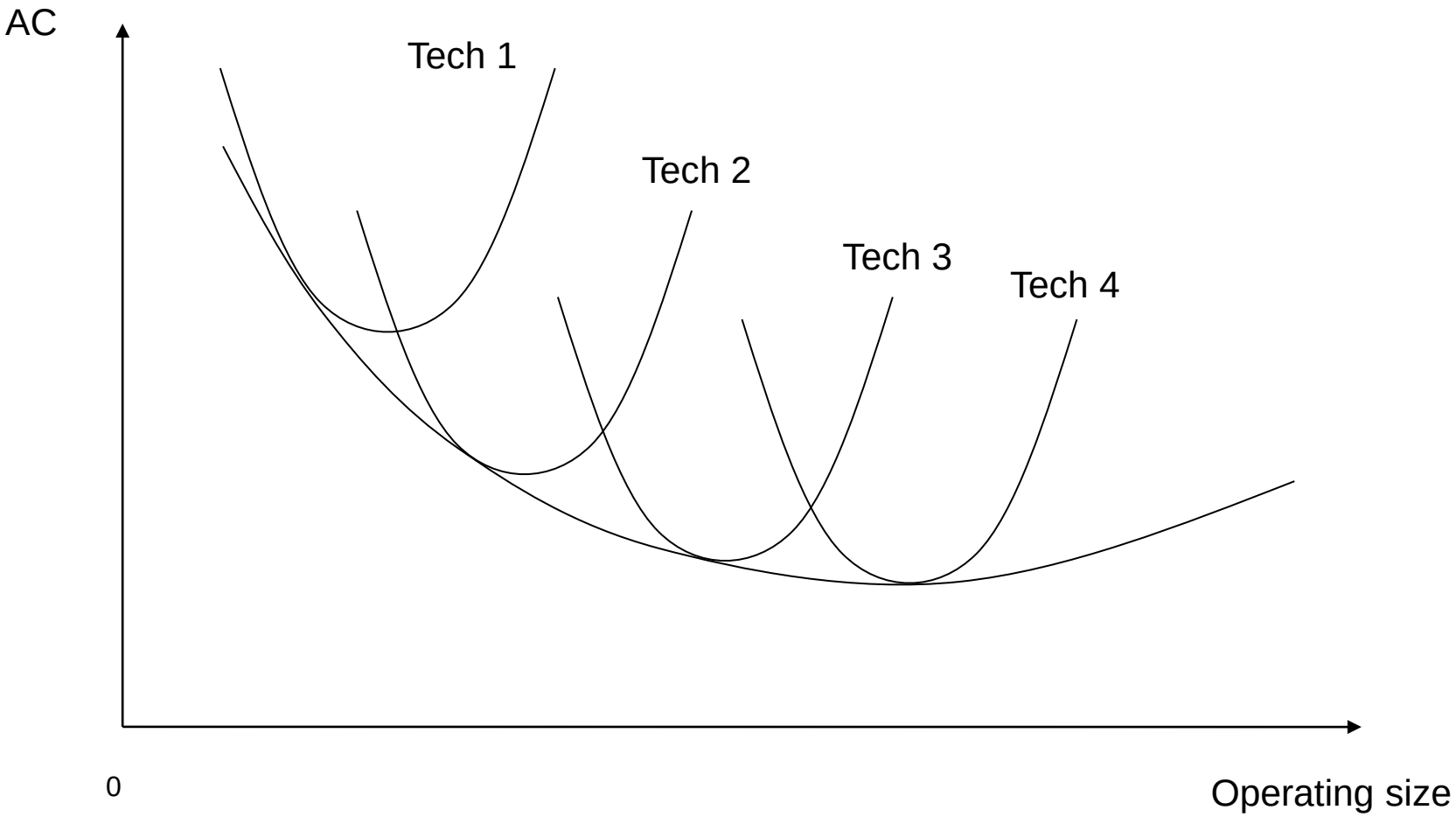
$$\partial \ln Y / \partial \ln TC = AC / MC = \eta^{-1}$$

Using “duality rule”, we have

$$\gamma + a \cdot h(X / | X | -1) = \eta^{-1}$$

- **returns to scale = returns to size *only if the production technologies are ray-homogenous***

Relationship between average costs and farm size



Empirical hypothesis

- Estimate the impact of size on the productivity

$$d\ln Y_{it} = \beta_0 + \beta_1 d\ln Land_{it} + \beta_2 d\ln Labour_{it} + \beta_3 d\ln Capital_{it} + \beta_4 d\ln Materials_{it} + \beta_5 dDM_{it} + \beta_6 dDL_{it} + \sum \theta_t D\_Year_t + \sum \vartheta_r D\_Region_r + \sum \kappa_i D\_Industry_i + u_i + \varepsilon_{it}$$

  - First-differencing, panel data techniques
- Identify returns to scale under homothetic production technology
- Test for heterogenous production technology among farms of different size groups
- Robustness checks (Cobb-Douglas vs. Translog, industry-level exercise, IRTS at the farm level)

Data source

- Australian Agricultural and Grazing Industry Survey
  - Broadacre industry (with 5 farm types)
  - Un-balanced panel: 1977-78 to 2006-07
  - Number of observations: 34,915
- Input and output indexes estimated using Fisher quantity index methods
- Farm size – small, medium and large – based on dry sheep equivalents (DSE)

Farm size and productivity

	Ordinary least squares	First differencing	Panel (random effects)	Panel (fixed effects)
Dependent variable: ln output				
ln_land	0.039***	0.076***	0.016***	0.032***
	(0.004)	(0.014)	(0.003)	(0.007)
ln_labour	0.124***	0.108***	0.218***	0.171***
	(0.014)	(0.020)	(0.014)	(0.014)
ln_capital	0.361***	0.237***	0.315***	0.232***
	(0.011)	(0.017)	(0.009)	(0.008)
ln_materials	0.389***	0.163***	0.299***	0.192***
	(0.020)	(0.022)	(0.022)	(0.022)
Medium_sized_dummy	0.293***	0.198***	0.315***	0.226***
	(0.011)	(0.014)	(0.010)	(0.011)
Large_sized_dummy	0.482***	0.441***	0.582***	0.464***
	(0.019)	(0.024)	(0.015)	(0.017)
Number of observations	35 916	23 650	35 916	35 916
R-square	0.811	0.266	0.834	0.305
Estimated return to scale (RTS)	0.913	0.584	0.849	0.627
Chow test value (Chi 2)	60	139	224	366
H0: IRTS and CRTS (Wald Test at 1 % level)	**Rejected**	**Rejected**	**Rejected**	**Rejected**

Results

- Productivity increases with farm size
  - Coefficients in front of large and medium size dummy variables are positive and significant at 1 per cent level.
  - Robustness check finds consistent results for individual broadacre farm types
- Endogeneity problem related to farm-specific factors
  - First differencing and panel (with fixed effects) results are more reliable;

Returns to scale

	Ordinary least squares	First differencing	Panel (random effects)	Panel (fixed effects)
Dependent variable: ln_output				
ln_land	0.082***	0.090***	0.056***	0.040***
	(0.004)	(0.017)	(0.004)	(0.007)
ln_labour	0.163***	0.119***	0.278***	0.199***
	(0.015)	(0.021)	(0.018)	(0.015)
ln_capital	0.386***	0.230***	0.335***	0.228***
	(0.012)	(0.017)	(0.010)	(0.008)
ln_materials	0.444***	0.170***	0.349***	0.207***
	(0.021)	(0.023)	(0.024)	(0.023)
Number of observations	35 916	23 650	35 916	35 916
R-square	0.798	0.244	0.815	0.274
Estimated return to scale (RTS)	1.075	0.609	1.018	0.675
Chow test value (Chi 2)	8	100	9	251
H0: IRTS and CRTS (Wald Test at 1% level)	**Not rejected**	**Reject**	**Not rejected**	**Reject**

Note *, ** and *** indicate that coefficients are significant at the 10 per cent, 5 per cent and 1 per cent levels respectively.

Returns to scale

- Increasing returns to scale *does not* explain the productivity difference between large and small farms
- Constant or a mild decreasing return to scale is more evident
  - Robustness checks
    - consistent across individual broadacre farm types
    - estimation with the trans-log function also support this finding.

Table 3 Heterogeneous production technique

Dependent variable: ln_output	OLS	First differencing	Panel (random effects)	Panel (fixed effects)
ln_land	0.063***	0.062***	0.022***	0.009
	(0.006)	(0.016)	(0.007)	(0.009)
ln_labour	0.096***	0.111***	0.163***	0.118***
	(0.018)	(0.024)	(0.017)	(0.017)
ln_capital	0.387***	0.260***	0.357***	0.277***
	(0.015)	(0.022)	(0.012)	(0.012)
ln_materials	0.385***	0.150***	0.342***	0.204***
	(0.025)	(0.026)	(0.026)	(0.027)
Medium_sized_dummy	0.169***	0.234***	0.268***	0.251***
	(0.018)	(0.026)	(0.018)	(0.021)
Large_sized_dummy	0.381***	0.466***	0.541***	0.487***
	(0.021)	(0.036)	(0.024)	(0.028)
Medium_sized_dummy × ln_land	-0.060***	0.028**	-0.012*	0.022**
	(0.007)	(0.011)	(0.007)	(0.009)
Medium_sized_dummy × ln_labour	0.084***	0.002	0.052*	0.051*
	(0.027)	(0.030)	(0.027)	(0.026)
Medium_sized_dummy × ln_capital	-0.080***	-0.059***	-0.067***	-0.063***
	(0.019)	(0.022)	(0.015)	(0.016)
Medium_sized_dummy × ln_materials	-0.041	0.015	-0.050	0.001
	(0.038)	(0.041)	(0.036)	(0.034)
Large_sized_dummy × ln_land	-0.041***	0.026*	-0.008	0.031***
	(0.007)	(0.015)	(0.008)	(0.012)
Large_sized_dummy × ln_labour	0.091***	-0.027	0.116***	0.103***
	(0.023)	(0.034)	(0.029)	(0.027)
Large_sized_dummy × ln_capital	-0.116***	-0.087***	-0.072***	-0.070***
	(0.018)	(0.025)	(0.018)	(0.018)
Large_sized_dummy × ln_materials	0.065**	0.070*	-0.074*	-0.027
	(0.033)	(0.038)	(0.042)	(0.039)
Constant	-0.156***	-0.020	-0.268***	-0.277***
	(0.027)	(0.042)	(0.023)	(0.031)
Number of observations	35 916	23 650	35 916	35 916
R-squared	0.813	0.268	0.835	0.308

Note *, ** and *** indicate that coefficients are significant at the 10 per cent, 5 per cent and 1 per cent levels respectively.

Homothetic vs. non-homothetic production technology

- Returns to scale and returns to size diverge
- Production technology is non-homothetic
  - Technologies differ significantly according to size
  - Larger farms have a relatively high elasticity of land and labour, but relatively low elasticity of capital

Conclusions

- Larger farms have higher productivity than smaller farms
  - Advanced production technology rather than increasing return to scale
- Small farms are less able to change production technology
  - technologies not suitable?
  - limited capital, skills, information?
- Improving productivity
  - Not simply about ‘getting big’
  - Need a willingness/ability to shift resource allocation
  - Need innovation adoption





Thank you and Questions?

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