Droughts, Deluges, and (River) Diversions: Valuing Market-Based Water Reallocation
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Environmental Reading Group

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Reseach Question

This paper studies

- value of water
- value of water trade and reallocation

By

- recovering parameters from an agricultural production model
- conducting a counterfactual analysis

Data

Firm $\times$ Year $\times$ Crop Panel Data, from 2007-2015

- Survery on water trading in the southern Murray-Darling Basin (sSMB), water ownership, input choice, output levels
- Sutralian Bureau of Meteorology (BOM), rainfall, temperature, evaporation
- state government: regulatory records of regional water allocation caps
- Murray-Darling Basin Authority (MDBA): water trading data on trasaction prices and trade flows

Summary statistics

TABLE 1—WATER RIGHTS, TRADING, AND PRICES

	$N \times T$	Mean	St. dev.	q10	q25	q50	q75	q90
Panel								
Total irrigation, ML	2,059	679.0	1,377.1	18	70	210	641.9	1,564.6
Permanent rights, nominal ML	2,059	876.4	1,246.6	74.8	160	406	1,084	2,257.1
Permanent rights, realized ML	2,059	519.1	815.9	31.5	84	231.8	600.5	1,268.9
Buy annual water, $\{0, 1\}$	2,059	0.321	0.467	0	0	0	1	1
Volume bought, ML	661	288.7	462.2	20	40	100	320	736
Sell annual water, $\{0, 1\}$	2,059	0.199	0.399	0	0	0	0	1
Volume sold, ML	409	135.3	155.7	20	42	90	160	300
Buy entitlements, $\{0, 1\}$	976	0.092	0.289	0	0	0	0	0
Entitlements bought, nominal ML	90	251.7	528.4	1.9	8.5	50	250.2	522.5
Sell entitlements, $\{0, 1\}$	976	0.154	0.361	0	0	0	0	1
Entitlements sold, nominal ML	150	298.2	499.9	2.9	20	130.5	356.8	702.5
Within								
Ever trade annual water rights, $\{0, 1\}$	1,094	0.600	0.490	0	0	1	1	1
Ever buy annual water rights, $\{0, 1\}$	1,094	0.407	0.491	0	0	0	1	1
Ever sell annual water rights, $\{0, 1\}$	1,094	0.271	0.444	0	0	0	1	1
Ever buy and ever sell, $\{0, 1\}$	1,094	0.078	0.268	0	0	0	0	0
Annual trade frequency	656	0.829	0.248	0.500	0.600	1	1	1
Annual buy frequency	656	0.535	0.432	0	0	0.500	1	1
Annual sell frequency	656	0.349	0.434	0	0	0	1	1
Annual buy and sell frequency	656	0.055	0.204	0	0	0	0	0
Market								
Annual regional water price, AU$/ML	2,059	234.5	198.9	24.6	55.0	160.3	338.7	621.9
Transaction-level water price, AU$/ML	80,599	227.3	252.8	40	62	123	309	500
Transaction-level volume, ML	80,599	100.8	275.3	7	15	40	100	200

statistics.png

Reduce Form Evidence

TABLE 2—ANNUAL WATER TRADING DECISIONS AND RAINFALL

	Dependent variable: Buy, $\mathbf{1}\{\Delta_{it} > 0\}$			
	(1)	(2)	(3)	(4)
Panel A. Annual purchases				
$\ln(net\_rainfall_{it})$	−0.162	−0.059	0.00002	−0.143
	(0.032)	(0.034)	(0.035)	(0.050)
$\ln(water\_endowment_{it})$	0.006	0.019	0.022	−0.080
	(0.010)	(0.010)	(0.010)	(0.026)
Year fixed effects	✓	✓	✓	✓
Region fixed effects		✓	✓	
Region × year fixed effects			✓	
Farm fixed effects				✓
Observations	2,059	2,059	2,059	2,059
Adjusted R^2	0.111	0.139	0.184	0.397
	Sell, $\mathbf{1}\{\Delta_{it} < 0\}$			
Panel B. Annual sales				
$\ln(net\_rainfall_{it})$	0.141	0.029	−0.00003	0.063
	(0.030)	(0.031)	(0.032)	(0.037)
$\ln(water\_endowment_{it})$	0.040	0.026	0.023	0.044
	(0.009)	(0.009)	(0.009)	(0.023)
Year fixed effects	✓	✓	✓	✓
Region fixed effects		✓	✓	
Region × year fixed effects			✓	
Farm fixed effects				✓
Observations	2,059	2,059	2,059	2,059
Adjusted R^2	0.084	0.126	0.165	0.459

form evidence.png

Model

- In year t, firm i produces crop c for hectares of land K_{ict}, with irrigation volumes W_{ict}, and other inputs X_{ict} including labor and total materials. Effective rain water is $R_{ict} = (E^R_{ict} - E^V_{ict})K_{ict}$.
- Output is given by

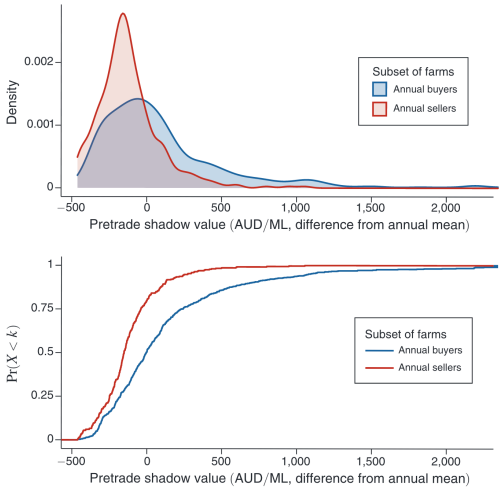
$$
\begin{aligned}
Q_{ict} &= e^{\omega_{ict}+\varepsilon_{ict}} F_c\left(W_{ict}, X_{ict}, K_{ict}, R_{ict}\right) \\
&\equiv e^{\omega_{ict}+\varepsilon_{ict}} \left[\alpha_c\left(W_{ict} + \vartheta_c R_{ict}\right)^{\frac{\sigma_c-1}{\sigma_c}} + \left(1-\alpha_c\right) K_{ict}^{\frac{\sigma_c-1}{\sigma_c}}\right]^{\frac{\sigma_c}{\sigma_c-1}\beta_{cW}} \prod_{j\in\{L,M\}} \left(X^j_{ict}\right)^{\beta_{cj}},
\end{aligned}
$$

Estimation Results

	Perennial (1)	Annual irrigated (2)	Annual nonirrigated (3)	Dairy (4)
Irrigation				
Average irrigation-output elasticity $E\left[\frac{\partial \ell_c}{\partial w}\right]$	0.246	0.206	0.230	0.164
	(0.037)	(0.029)	(0.061)	(0.051)
Interquartile range of $\frac{\partial \ell_c}{\partial w}$ *across* i, t	[0.207, 0.301]	[0.151, 0.265]	[0.222, 0.240]	[0.104, 0.209]
Tenth to ninetieth percentile range	[0.141, 0.326]	[0.087, 0.297]	[0.215, 0.245]	[0.075, 0.263]
Water-land aggregator				
Scale coefficient, β_{cW}	0.631	0.526	0.311	0.782
	(0.047)	(0.070)	(0.097)	(0.043)
Irrigation share, α_c	0.599	0.513	—	0.385
	(0.046)	(0.016)		(0.125)
Land share, $1 - \alpha_c$	0.401	0.487	0.409	
	(0.046)	(0.016)	(0.007)	
Rainwater coefficient, ϑ_c	1.081	1.048	0.591	0.148
	(0.151)	(0.163)	(0.007)	(0.245)
Elasticity of substitution, σ_c	1.575	1.451	3.211	
	(0.199)	(0.218)	(1.137)	
Other factors				
Labor elasticity, β_{cL}	0.352	0.201	0.335	0.147
	(0.016)	(0.015)	(0.027)	(0.007)
Materials elasticity, β_{cM}	0.186	0.404	0.558	0.110
	(0.008)	(0.021)	(0.030)	(0.003)
Feed share, α_F				0.615
				(0.125)
Pasture-feed elasticity of substitution, σ_F				3.331
				(2.161)
Returns to scale, $\sum_j \beta_{cj}$	1.169	1.131	1.204	1.039
	(0.050)	(0.081)	(0.088)	(0.043)
J-statistic	0.969	1.103	1.456	1.004
Adjusted R^2	0.807	0.797	0.802	0.876
Observations	510	170	208	254

results.png

Shadow Value



value.png

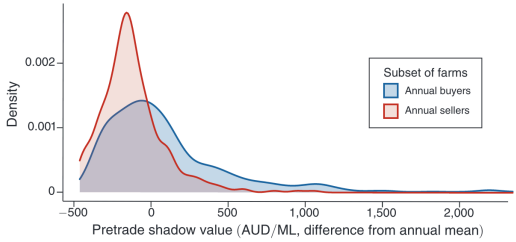
Trade from Low to High

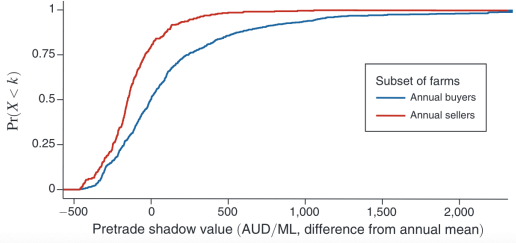
TABLE 4—WATER TRADING DECISIONS AND ESTIMATED PRODUCTIVITY

	Dependent variable:							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Buy annual allocations								
Productivity, $\hat{\omega}_{it}$	0.059		0.071		0.069		0.078	
	(0.019)		(0.020)		(0.018)		(0.030)	
Productivity innovation, $\hat{\xi}_{it}$		0.086		0.102		0.078		0.147
		(0.028)		(0.030)		(0.028)		(0.039)
Lagged productivity, $\hat{\omega}_{i,t-1}$		0.031		0.045		0.044		0.065
		(0.027)		(0.028)		(0.025)		(0.042)
Panel B. Sell annual allocations								
Productivity, $\hat{\omega}_{it}$	−0.032		−0.033		−0.036		−0.012	
	(0.018)		(0.018)		(0.018)		(0.026)	
Productivity innovation, $\hat{\xi}_{it}$		−0.039		−0.029		−0.016		−0.038
		(0.029)		(0.030)		(0.031)		(0.040)
Lagged productivity, $\hat{\omega}_{i,t-1}$		−0.053		−0.032		−0.037		−0.051
		(0.023)		(0.024)		(0.022)		(0.044)
Year fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Region fixed effects			✓	✓	✓	✓		
Region × year fixed effects					✓	✓		
Farm fixed effects							✓	✓
Observations	2,059	976	2,059	976	2,059	976	2,059	976
Adjusted R^2	0.116	0.148	0.146	0.181	0.190	0.236	0.401	0.443

and productivity.png

Marginal Value of Trade





value of trade.png

Gains from Trade I

- First, calculate pre-trade irrigation $W_{ict}^q = W_{ict} - \Delta_{ict}$,
- Then, calculate profit

$$\Pi_{it}(W_{it}) = \max_{X_{it}} \sum_c P_{ict} e^{\omega_{ict}} F_c(W_{ict}, X_{ict}, K_{ict}, R_{ict}) - P_{X,it} \cdot X_{ict} - \Gamma_{it}^W(W_{it})$$

, and profit from gain is

$$GFT_t = i \sum_i \Pi_{it}(W_{it}) - i \sum_i \Pi_{it}(W_{it}^q)$$

, then calculate the sum of discounted value over 2007-2015

$$GFT = \sum_t \delta_t GFT_t$$

Gains from Trade II

$GFT = 2.3$ billion AUD.

from trade.png

TABLE 5—REALIZED GAINS FROM WATER TRADING

	Gains from trade			Reallocation	
	Percent	Percent, traders	AUD/ML	Realloc (percent)	Traders (percent)
Annual	0.051	0.091	338.52	0.133	0.51
	[0.016, 0.071]	[0.037, 0.127]	[−21.23, 467.53]	[0.117, 0.148]	[0.48, 0.53]

Hetergeneity in Gains from Trade

See paper