Research Demonstration: The Impacts of Irrigation Costs on Irrigation Demand

AECN 396/896-002

Objective

Understand the impact of pumping cost on groundwater use for irrigated agriculture

Data

Well-level groundwater use observed annually in Eastern Colorado

Data

```
(data <- readRDS("final_data_CO.rds") %>%
  dplyr::select(site_no, year, pumpingAF, pc, precip, et, gpm, REA, tier))
```

```
##                site_no year pumpingAF       pc    precip       et       gpm REA tier
##    1: 393510102431000 2013    308.17 3.612525 12.204731 37.17223 1489.3279 Y-W    2
##    2: 393510102431000 2011    358.25 1.888933 14.921268 34.40002 1403.8981 Y-W    3
##    3: 393510102431000 2015    364.01 2.885766 18.779538 32.68950 1489.3279 Y-W    3
##    4: 393510102431000 2016    391.91 2.396533  9.724415 34.12479 1489.3279 Y-W    3
##    5: 393510102431000 2014    244.08 3.445902 15.590560 34.93238 1489.3279 Y-W    2
##   ---
## 5924: 393630102454000 2011    200.34 3.365769 14.094496 34.53151  743.3990 Y-W    2
## 5925: 393630102454000 2013    265.91 2.466798 12.204731 37.26833  835.3989 Y-W    3
## 5926: 393630102454000 2012    246.91 1.792938  5.866145 43.65690  730.0590 Y-W    3
## 5927: 393630102454000 2015    177.45 4.519144 19.055128 32.71948  772.9989 Y-W    2
## 5928: 393630102454000 2016    197.94 2.937017  9.645674 34.14341  842.7288 Y-W    3
```

- `site_no`: well id
- `year`: year
- `pumpingAF`: groundwater use (acre-feet)
- `pc`: pumping cost ($/acre-feet)
- `precip`: total precipitation (inches) during the growing season
- `et`: total evapotranspiration (inches) during the growing season
- `gpm`: well yield (gallons per minute)
- `REA`: energy supplier name
- `tier`: price tier (explained later)

Exploratory Data Analysis

Econometric Model (univariate)

$$W = \beta_0 + \beta_1 IC + v$$

- W: irrigation amount
- IC: irrigation cost
- v: error term.

Endogeneity: Omitted Variable Bias

$$W_{i,t} = \beta_0 + \beta_1 IC_{i,t} + v_{i,t}$$

Question

What is in v? Are they going to cause bias on β_1 estimation?

Endogeneity: Omitted Variable Bias

$$W_{i,t} = \beta_0 + \beta_1 IC_{i,t} + v_{i,t}$$

Question

What is in v? Are they going to cause bias on β_1 estimation?

- soil type
- well yield
- precipitation

Econometric Model (multi-variate)

$$W_{i,t} = \beta_0 + \beta_1 IC_{i,t} + \beta_2 WY_{i,t} + \beta_3 Precip_{i,t} + \beta_4 ET_{i,t} + \varepsilon_{i,t}$$

- W: irrigation amount
- IC: irrigation cost
- WY: well yield
- $Precip$: total precipitation during the production season
- ET: total evapotranspiration during the production season
- ε: error term

Can Individual (well) Fixed Effects help?

Endogeneity

Declining block rate pricing

Supplier	Year	Price 1	Price 2	Price 3	Threshold 1	Threshold 2
Highline	2,011	0.1592	0.1185	0.0727	300	600
	2,012	0.1626	0.1261	0.0727	300	600
	2,013	0.1347	0.0981		400	
	2,014	0.1347	0.0981		400	
	2,015	0.1347	0.0981		400	
	2,016	0.1152	0.0981		400	
Y-W	2,011	0.2107	0.0973	0.0496	500	1,000
	2,012	0.2206	0.1019	0.0520	500	1,000
	2,013	0.2206	0.1019	0.0520	500	1,000
	2,014	0.1071	0.0972	0.0814	500	1,000
	2,015	0.1071	0.0972	0.0814	500	1,000
	2,016	0.1384	0.1016	0.0676	500	1,000

Threshold 1 and 2 refer to the threshold electricity uses (kwh/HP) over which the users move on to the next tier. For example, for a farmer served by Highline who has a pump of 100 HP, the farmer would be at the second tier after using 40,000 kwh.

Endogeneity

Declining block rate pricing

Supplier	Year	Price 1	Price 2	Price 3	Threshold 1	Threshold 2
Highline	2,011	0.1592	0.1185	0.0727	300	600
	2,012	0.1626	0.1261	0.0727	300	600
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	2,016	0.1384	0.1016	0.0676	500	1,000

Example

A well in Highline's service area with 100 HP will be on the second price tier after using 40,000 kWh.

Endogeneity

Declining block rate pricing

Supplier	Year	Price 1	Price 2	Price 3	Threshold 1	Threshold 2
Highline	2,011	0.1592	0.1185	0.0727	300	600
	2,012	0.1626	0.1261	0.0727	300	600
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	2,016	0.1384	0.1016	0.0676	500	1,000

Endogeneity?

Would this cause bias in estimating β_1?

Fixed-Effects estimation

Location	Year	P	Q	Ql
Chicago	2,003	75	2.0	10
Chicago	2,004	85	1.8	10
Peoria	2,003	50	1.0	5
Peoria	2,004	48	1.1	5
Milwaukee	2,003	60	1.5	7
Milwaukee	2,004	65	1.4	7
Madison	2,003	55	0.8	6
Madison	2,004	60	0.7	6

(individual) Fixed Effects Estimation

- Including individual (cross-sectional units) dummies (here, they are wells represented by `wdid`) in the model
- This is equivalent to do within-transformation of the data (deviation from the individual means) and then regress deviation on deviation
- What the within-transformation does is to effectively divide the observations into groups (wells) and you look at variations within each of the groups (wells observed over time).
- Since including individual dummies are equivalent to the within-transformation approach, that means including individual (well) dummies also effectively divides the observations into groups (wells) and you look at variations within each of the groups (wells observed over time).

Fixed Effect Estimation (in general)

key

Including dummies variables effectively divide the observations into groups and you look at variations within each of the groups

Beyond individual (well) FEs

wdid	year	pumpingAF	pc	tier	pump_hp
4,905,044	2,012	250.07	1.843734	3	75
	2,013	218.01	2.399341	3	75
	2,014	149.69	3.755891	3	75
	2,015	174.95	4.548531	2	100
	2,016	215.48	3.163381	3	100
4,905,049	2,011	159.82	3.555504	2	100
	2,012	232.43	1.900167	3	100
	2,013	175.85	3.963672	2	100
	2,014	138.14	3.780853	2	100
	2,015	102.94	4.165940	1	100
	2,016	92.98	5.929217	1	100

Beyond individual (well) FEs

Question

- Does including individual dummies (well fixed effects) help?

Beyond individual (well) FEs

Question

- Does including individual dummies (well fixed effects) help?
- Does including well-tier dummies (well-tier fixed effects) help?

Beyond individual (well) FEs

Question

- Does including individual dummies (well fixed effects) help?
- Does including well-tier dummies (well-tier fixed effects) help?
- Does including well-tier-hp dummies (well-tier-hp fixed effects) help?