Agricultural Water Allocation Efficiency in a Developing Country Canal Irrigation System

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Evidence Action

Preview

- Research question:

  "Is water being allocated efficiently in canal irrigations systems?"

- Data:
  - Doesn't exist!
  - Irrigation system in Pakistan (Southern Punjab)
  - Two vital bits of data:
    - Production survey (post-season)
    - Water measurement survey (in-season)

Preview

- Method:
  - Economic tests of efficiency in allocation:
    - Using traditional measures
    - Improved measures (volumetric)
    - Adding (some) nuance (conveyance efficiency plays a role)

- Results:
  - Allocation is inefficient (even when adjusting for conveyance efficiency)
  - Re-allocation provides substantial gains (13% – 14%)

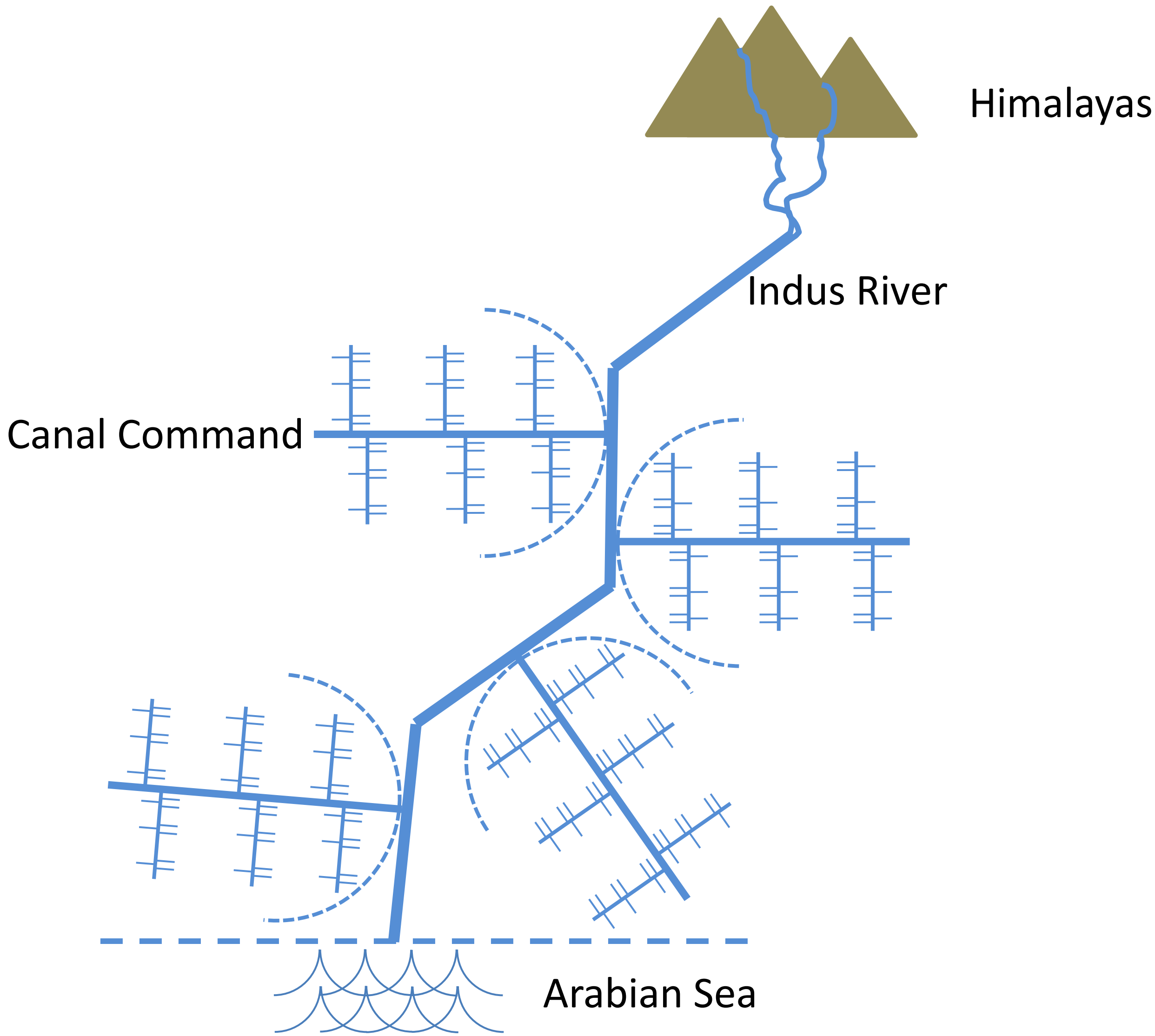
Why do this?

- Hydro-economic models are poorly founded
- This work provides a firm basis for basin-scale modeling
- Improved climate change analysis

Context

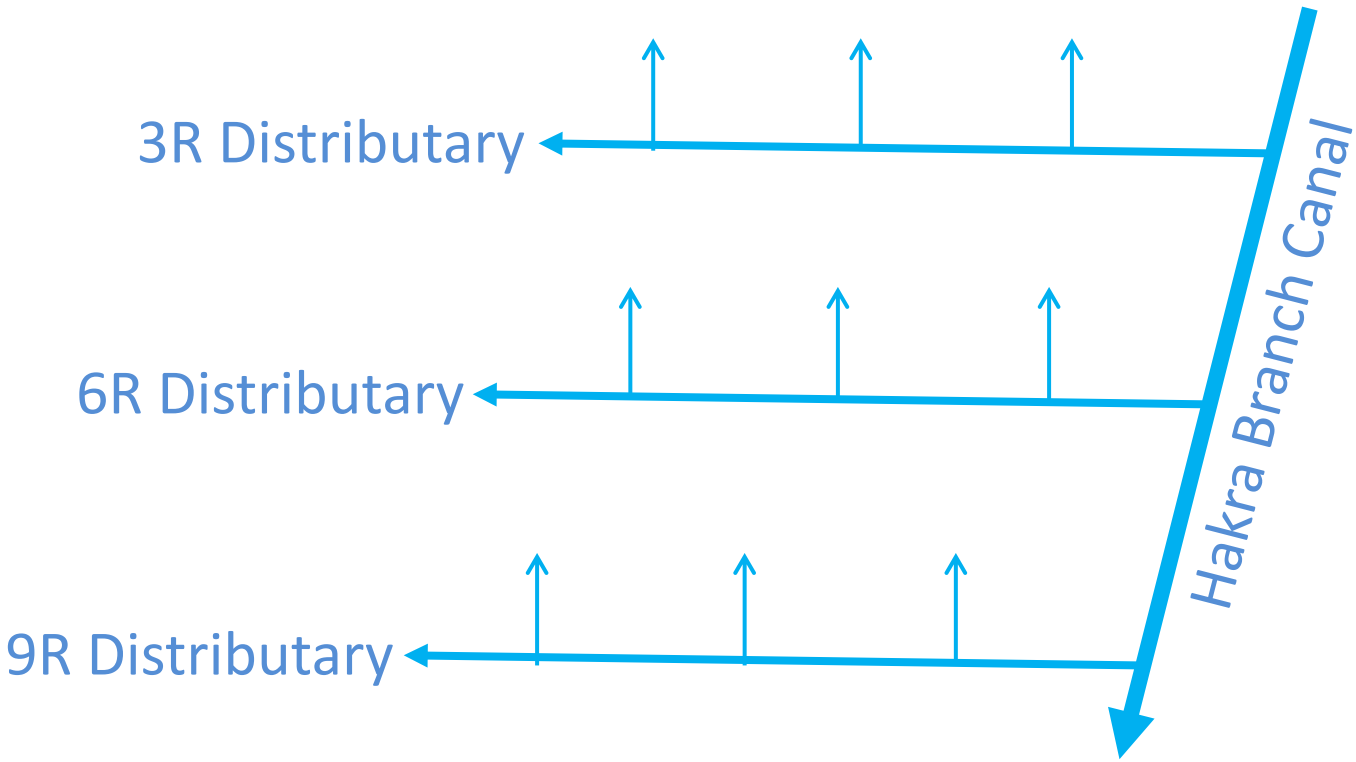
- Location: large scale irrigation works in Pakistan
- Hakra Branch Canal
- Chose three secondary canals and a majority of outlets in each of the secondary canals

Context



Context

- Hakra Branch Canal – what it looks like



Context

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Context

- Institutionally, controlled by the irrigation department up to outlet
- Farmers manage tertiary canals
- Discharge in the primary canal means discharge in the tertiary canals
- *Warabandi* – fixed schedule of gate openings and closings

Data

- In-season water measurement:
  - Standard stream discharge measurement protocols
  - Measured discharge at outlets
  - Sample of 200 outlets across three secondary channels
  - **“Traditional” measures**

Data

- Post season production survey:
    - Followed up with post-season agricultural production survey
    - Sampled 363 farmers
    - Sampled farmer at head middle and tail reaches (of both primary and secondary canals)
    - Use of GPS to match farmers to outlets

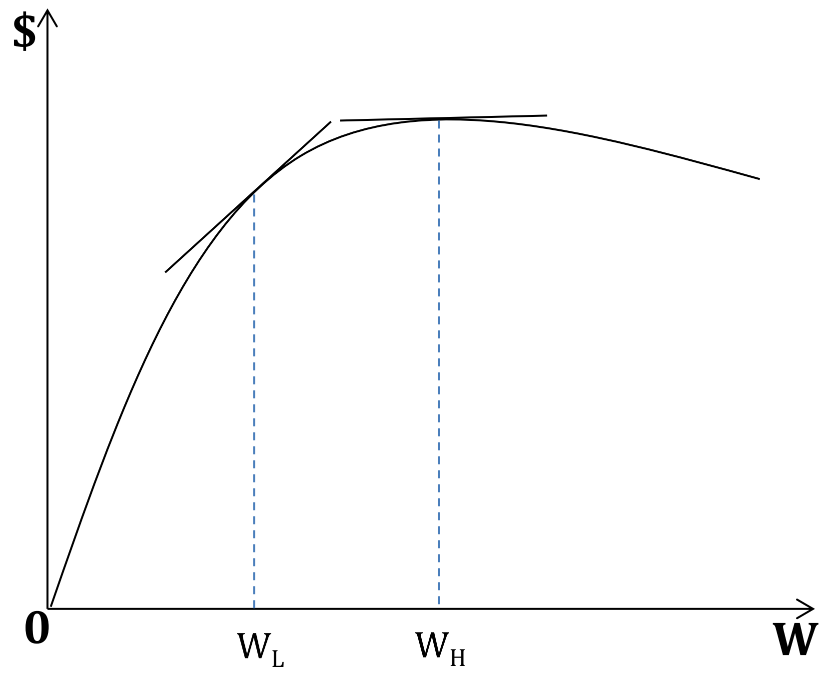
Theory

- What does economic theory tell us?
- Basic rule that emerges:

$$\frac{\partial B_1(w_1)}{\partial w_1} = \frac{\partial B_2(w_2)}{\partial w_2}$$

- How do we test this?
- One idea: estimate a concave form for the net benefits function
- If we are able to detect a concave form, it implies inefficient allocation
- Assume: irrigation water received is exogenous

The Test



Results

- Some evidence on exogeneity of canal water

VARIABLES	(1) HHSize	(2) Adults	(3) Working Members	(4) HeadOf HH Education	(5) Sons Educated	(6) Daughters Educated
CanalWater/Acre	-0.0142	-0.0123	0.0122	-0.00106	0.000347	-0.000734
	(0.0589)	(0.0416)	(0.0193)	(0.0260)	(0.00113)	(0.00300)
Constant	9.492***	6.104***	2.400***	3.311***	0.959***	0.950***
	(0.491)	(0.306)	(0.151)	(0.196)	(0.0129)	(0.0208)
Observations	334	334	334	334	334	334
R-squared	0.000	0.000	0.001	0.000	0.000	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results

- Some evidence on exogeneity of canal water

VARIABLES	(7) Management Experience (years)	(8) Overall Agricultural Experience (years)	(9) Contact With Agricultural Extension	(10) Formal Sector Loans	(11) Winter Crop BasedOn Summer Outcomes
CanalWater/Acre	-0.0566	-0.269	0.00271	-0.00211	0.000256
	(0.126)	(0.172)	(0.00567)	(0.00439)	(0.00575)
Constant	18.61***	30.14***	0.418***	0.219***	0.487***
	(0.958)	(1.181)	(0.0422)	(0.0344)	(0.0431)
Observations	334	334	334	334	334
R-squared	0.001	0.010	0.001	0.001	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results

- Some results using “traditional” farmer reported water use measures

	(1)	(2)	(3)
VARIABLES	NR/Acre	NR/Acre	NR/Acre
TurnsReceived/Acre	2,008		
	(1,773)		
(TurnsReceived/Acre)^2	88.99		
	(106.9)		
TurnTime/Acre		-0.239	
		(0.314)	
(TurnTime/Acre)^2		7.77e-06	
		(7.07e-06)	
Depth x *Turns/Acre*			342.2
			(615.1)
(Depth x *Turns /Acre)^2*			22.83
			(20.98)
Controls	*Yes*	*Yes*	*Yes*
Constant	3,562	6,170	1,724
	(7,645)	(8,547)	(7,560)
Observations	334	334	334
R-squared	0.190	0.117	0.176

Robust standard errors in parentheses
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Results

- Some results using in-season measured farmer water use

VARIABLES	(1) NR/Acre	(2) NR/Acre	(3) NR/Acre	(4) NR/Acre
CanalWater/Acre	1,984***	2,280***		
	(666.7)	(678.0)		
(CanalWater/Acre)^2	-52.81*	-66.81**		
	(31.64)	(31.95)		
CanalWater/Acre_Spl_a_i			2,536***	
			(690.3)	
CanalWater/Acre_Spl_a_ii			-1,855**	
			(793.2)	
CanalWater/Acre_Spl_b_i				1,425***
				(381.1)
CanalWater/Acre_Spl_b_ii				-2,190*
				(1,216)
Controls	*No*	*Yes*	*Yes*	*Yes*
Constant	5,161	-10,872	-10,224	-8,096
	(6,133)	(8,882)	(8,816)	(8,518)
Observations	334	334	334	334
R-squared	0.169	0.197	0.188	0.196

Robust standard errors in parentheses
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Results

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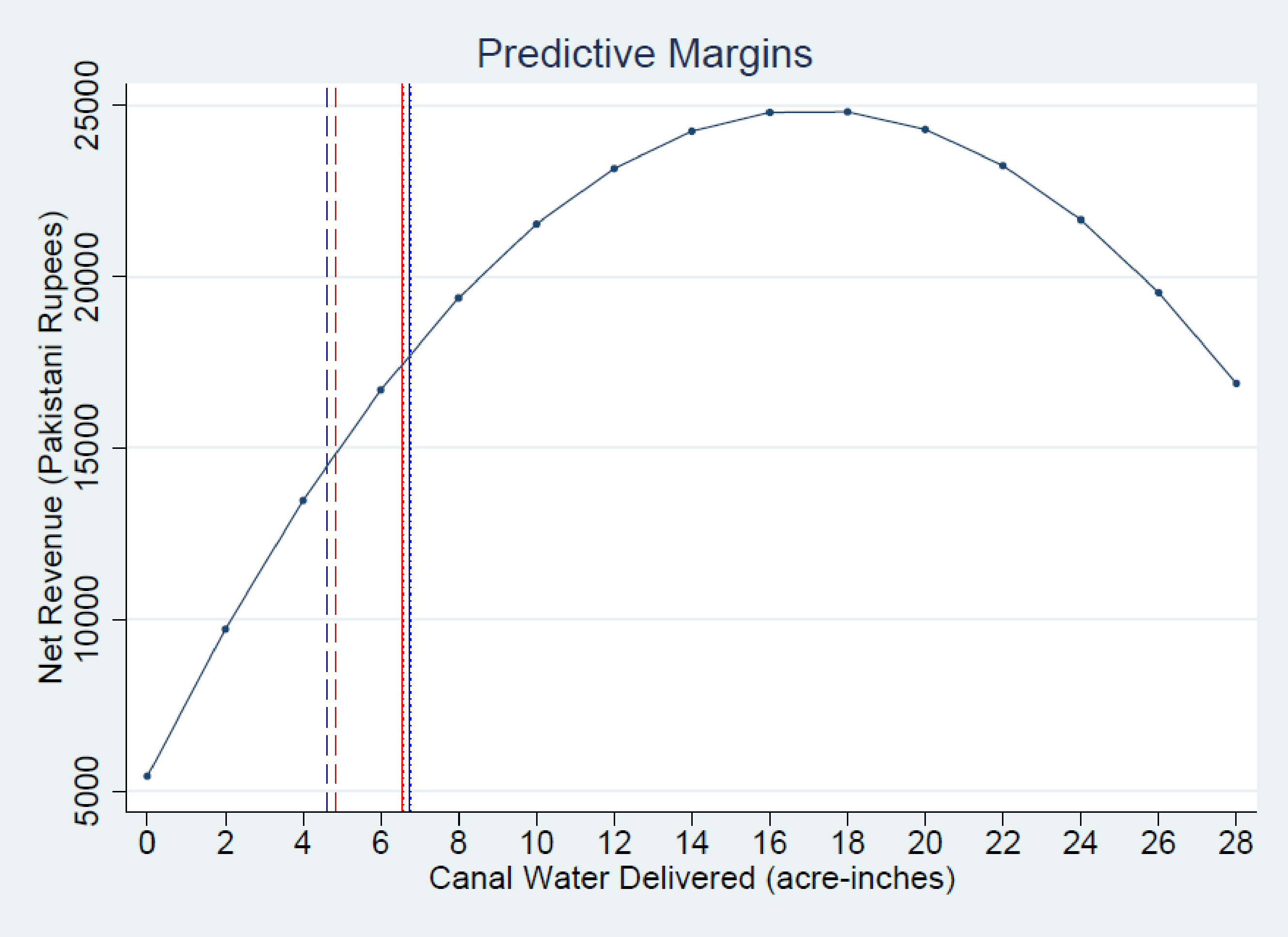

Results

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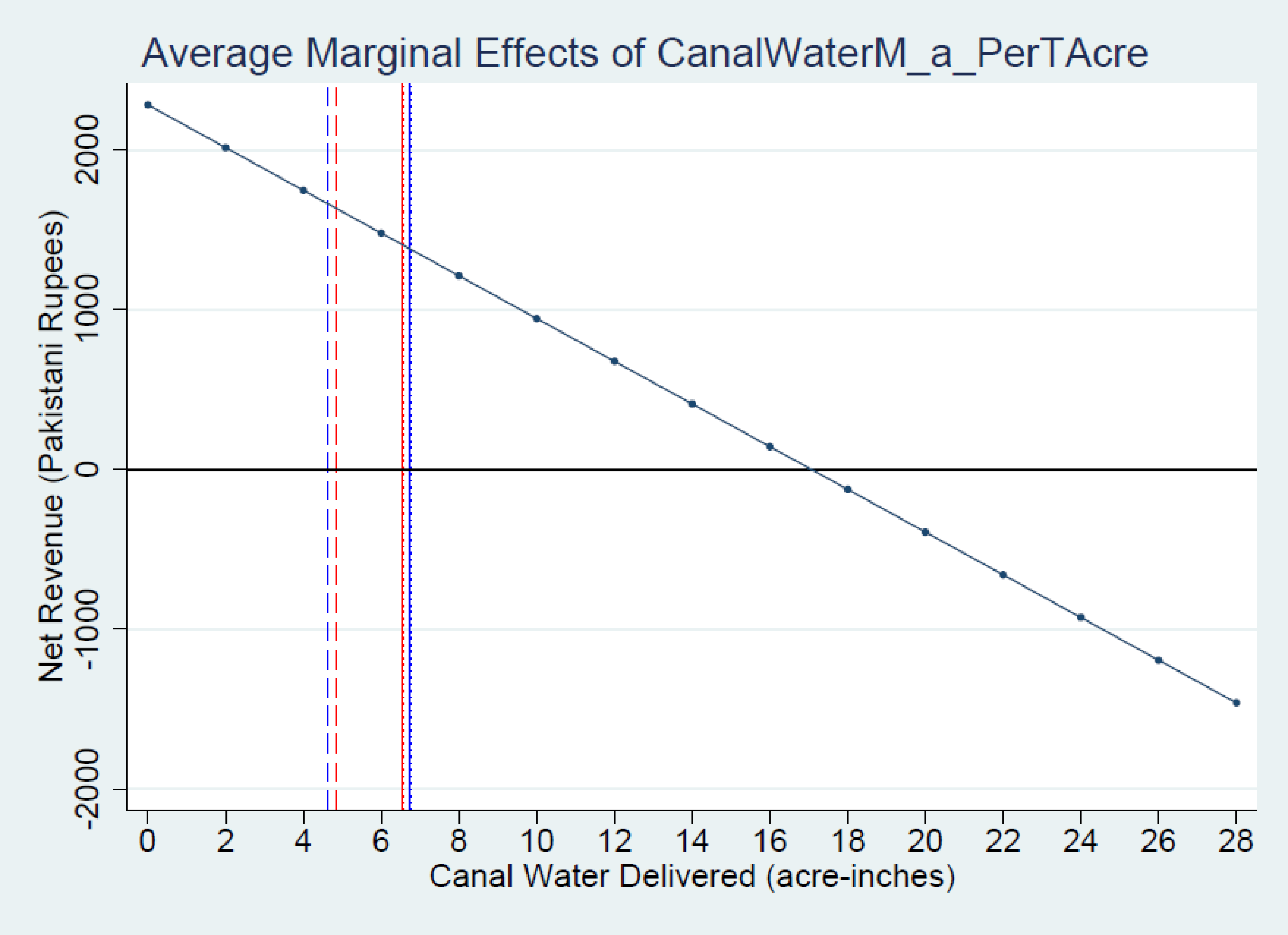
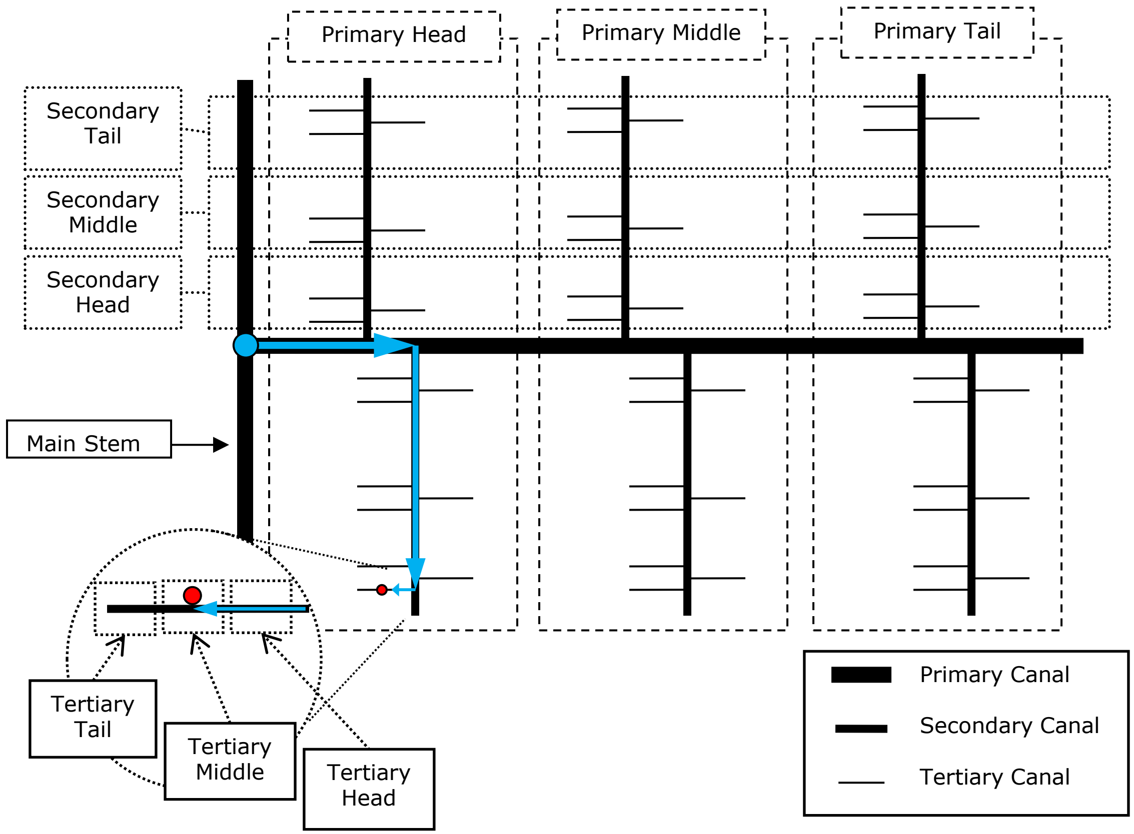


Results

- Second cut: need to account for conveyance efficiency (CE)
- How is this calculated?



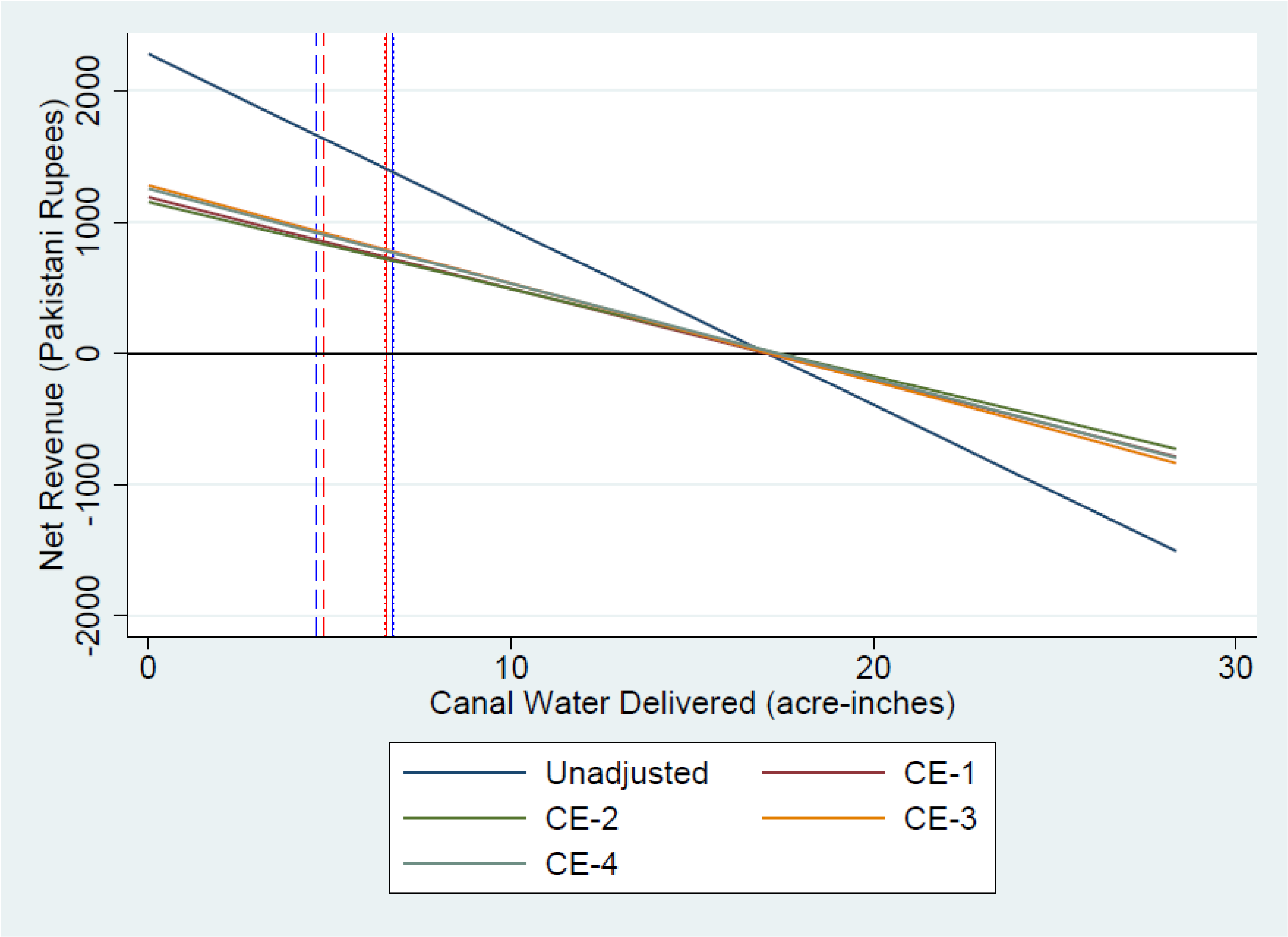
Results

- New rule that emerges:

$$\frac{\partial B_1(w_1)}{\partial w_1}.z_1 = \frac{\partial B_2(w_2)}{\partial w_2}.z_2$$

- Must adjust water delivered for losses in canal system
- Cannot rely on a simple test of concavity (non-linearity) anymore
- Have to actually derive marginal net revenues and adjust for CE
- Second-order polynomial is most conducive to this

Results


Net Revenue (Pakistani Rupees)
2000
1000
0
-1000
-2000
0
10
20
30
Canal Water Delivered (acre-inches)
Unadjusted
CE-1
CE-2
CE-3
CE-4

Results

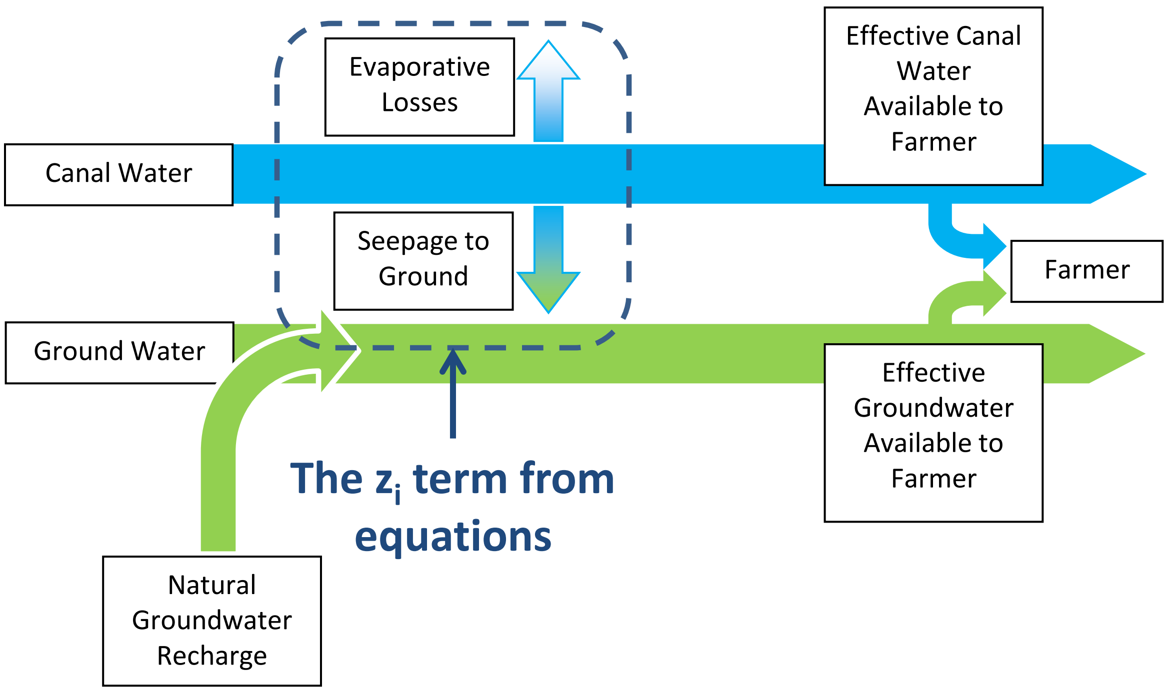
- Welfare calculation – does reallocation help?*

Adjustment for Conveyance Efficiency	*Efficient Allocation* Total Net Revenues (Rupees)	*Existing Allocation* Total Net Revenues (Rupees)	Gain (Rupees)	Gain (%)	Total Water Available (acre-inches)
Unadjusted	3143083	3649434	506351	13.87%	2437.477
CE-1	3143083	3625869	482786	13.32%	3643.949
CE-2	3143083	3606963	463880	12.86%	3679.264
CE-3	3143083	3614624	471541	13.05%	3366.882
CE-4	3143083	3606052	462969	12.84%	3393.224

* Sample not representative of HBC nor other canal commands

What next?

- Groundwater, groundwater, groundwater



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