Demand for Groundwater and Water Pricing Policy in China

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Motivation

- In northern China, declining availability of water for agriculture is creating a crisis
- China's past response to water shortage: Supply augmentation.
  - Infrastructure construction---dams, reservoirs.
  - South-north water transfer.
  - Except for pumping costs, GW was free for irrigation uses
- Recently: switch to management on the demand side.
  - Resorting to water pricing policies that aim at providing incentives to conserve water.

Motivation

- However, many questions need to be answered before policies can be made.
- Will farmers be responsive to price signals?
- In addition, water price reform has been mostly targeted at surface water, instead of groundwater.
- Some of the major grain production areas (and some of most water short areas) rely mostly on groundwater resource.
- Objective: analyzing and understanding the effects of GW water prices on GW water saving.

Research Approach

- Background: Describe groundwater problems in the study area.
- Farmers' response to groundwater problems.
- Effect of changes in water prices.

The Background

Water resource problems in Henan and Hebei

Data: 2004 Northern China Water Resource Survey (2004 NCWRS)

- *Household survey*
  - randomly selected 185 households in Henan and Hebei province
  - 173 households were surveyed in 2001
  - household characteristics: education, asset, off-farm income etc.
- *Crop level data:*
  - two plots each household
  - Irrigation: amount of water used, times of irrigation, length of irrigation irrigation technology, amount of water payment, quantity other inputs (labor, fertilizer, herbicide, plastic shielding etc.
- *Complementary questionnaires:* village leader, well/ canal manager
  - Characteristics of the village's water resource: depth of water.
  - Water application: amount and scheduling
  - Pump size, pump type, volumne of water pumped per hour, etc.

Groundwater is an important source of irrigation (year 2004)

	Total sown area (mu)	% of irrigated sown area	Among irrigated sown area, % irrigated by			% of non-irrigated sown area
			Surface water	**Ground water**	Conjunctive	
Total	2182	87.7%	17.7%	**68.8%**	13.5%	12.3%
Hebei	912	82.5%	15.0%	**79.4%**	5.7%	17.5%
Henan	1270	91.4%	19.4%	**62.0%**	18.6%	8.6%

Source: 2004 NCWRS

Notes: So from now on, focus on Groundwater

Groundwater issue 1: Declining water levels

Changes in groundwater level	Decline	Constant	Increase
Percentage of villages (%)	**89**	8	3

Total sample size: 80 villages in Hebei Province

Source: 2004 NCWRS; 2001-2004 CWIM .

Note: across all of northern China it is less severe, but still serious

Groundwater issue 1: Declining water levels

A. Total decline in water level between 1995 and 2004 (m)

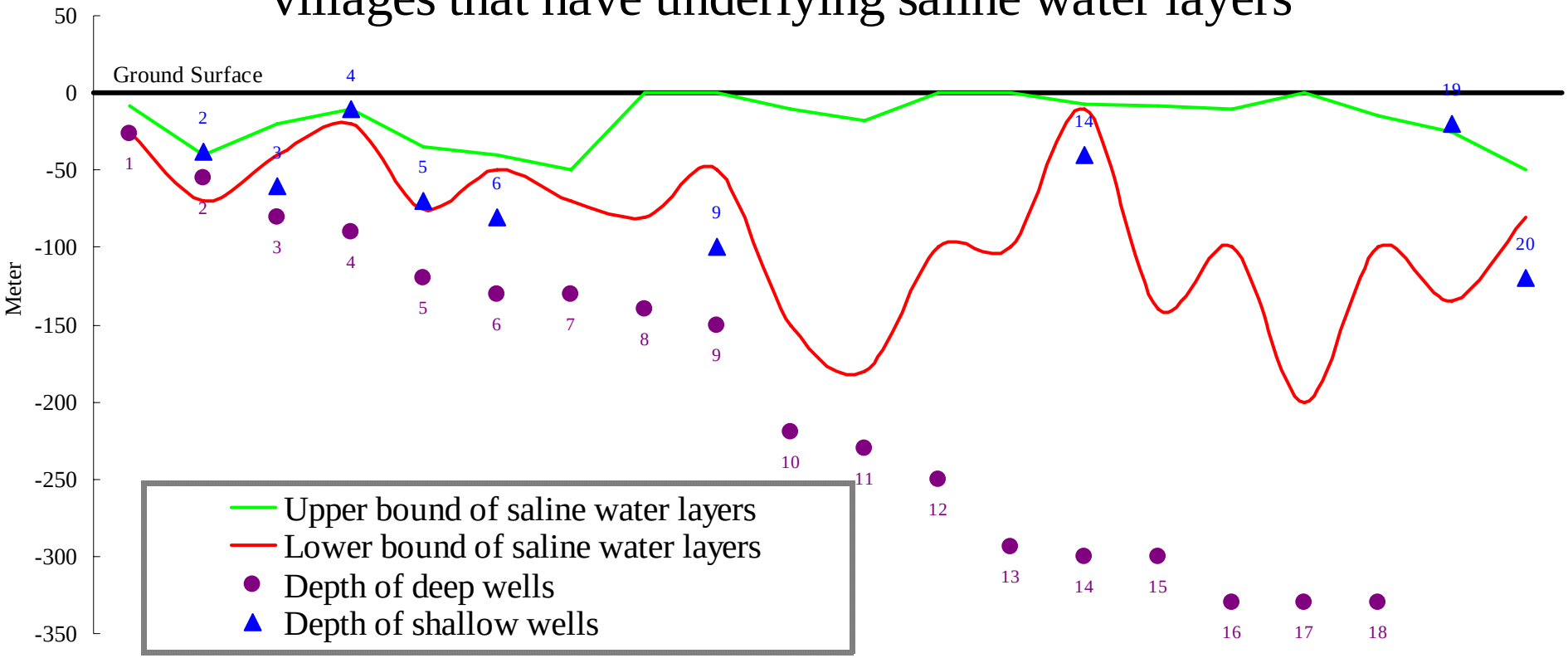
	Mean	Min	Max
Hebei Province	11.7	2	88
Shallow aquifer	5.8	2	28
Deep aquifer	25.6	5	88

B. Rate of decline in Hebei Province

Rate of decline (m/yr)	0-1	1-2	2-3	> 3
Percentage of village (%)	71	16	2.5	10.5

Groundwater issue 2: Other problems caused by declining groundwater levels – water quality.

The position of saline water layers and wells in the villages that have underlying saline water layers



Evidence from our data that decline in groundwater levels cause increase in the salinity level of fresh groundwater

- 19% villages have a saline water layer.
- Leaders in 24% of these villages think the saline water layer is moving.

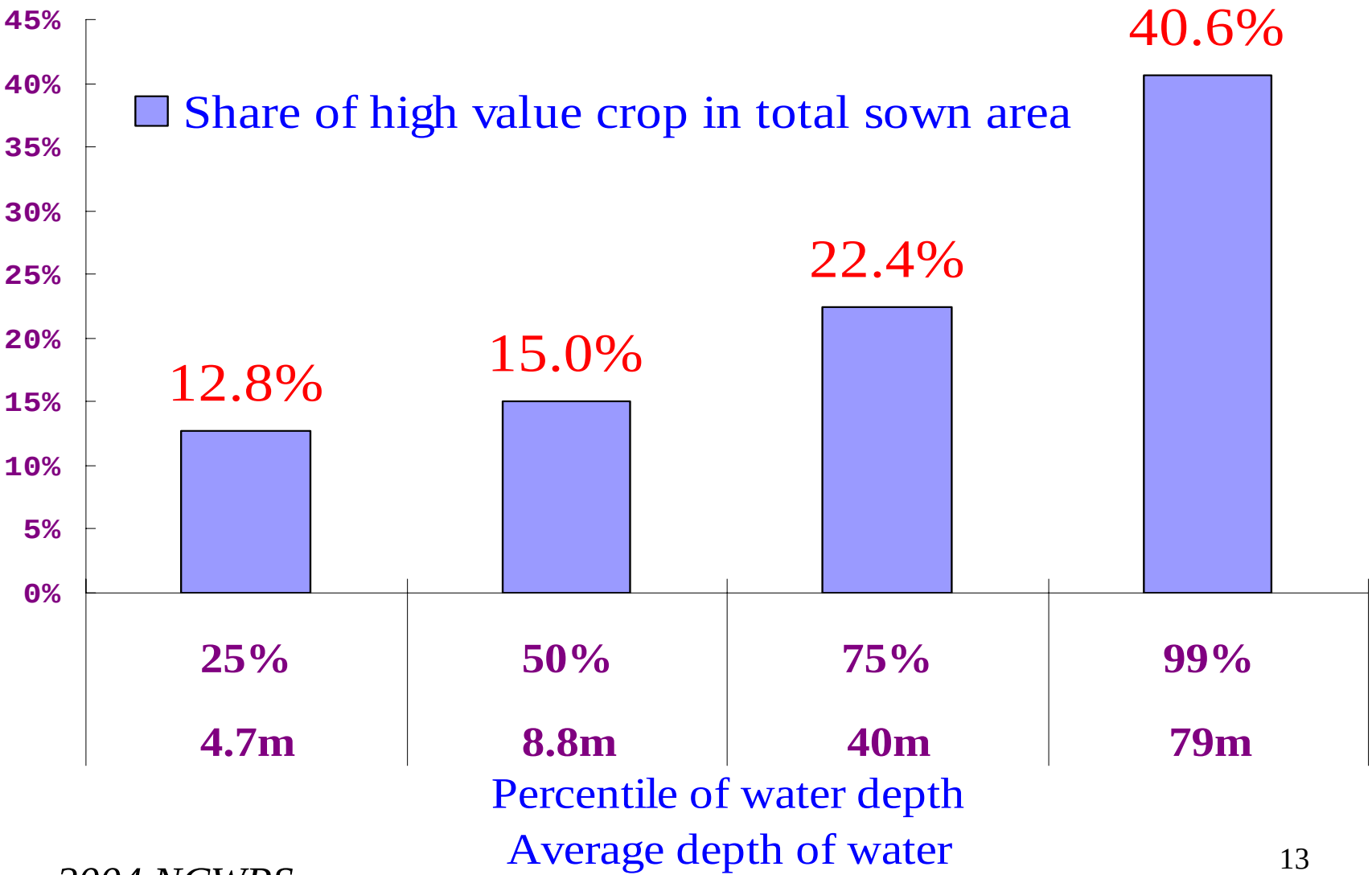
Average decline of water level between 1995 and 2004 (meters)	
In villages that leaders do not believe saline water layer moves	11
In villages that leaders believe saline water layer moves	20

Farmers' response at the intensive margin

Reduction in: water use / mu

Percentile of water depth	Average water depth (m)	Volume of applied water (m^3/mu)
25%	4.4	**513**
50%	6.7	**306**
75%	24.6	**257**
99%	77.5	**150**

Farmer's response at the extensive margin: Changing cropping pattern



Source: 2004 NCWRS

Other responses

- Adopting water saving technology: See Amelia's presentation.
- Shift in institutions in organizing water resource use. For example, emergence of groundwater market.

- Common property problem.
- Farmers' responses are far from being enough to solve the groundwater problems.
- Water policies are in need to further induce water conservation.
- How effective would be water pricing policies?

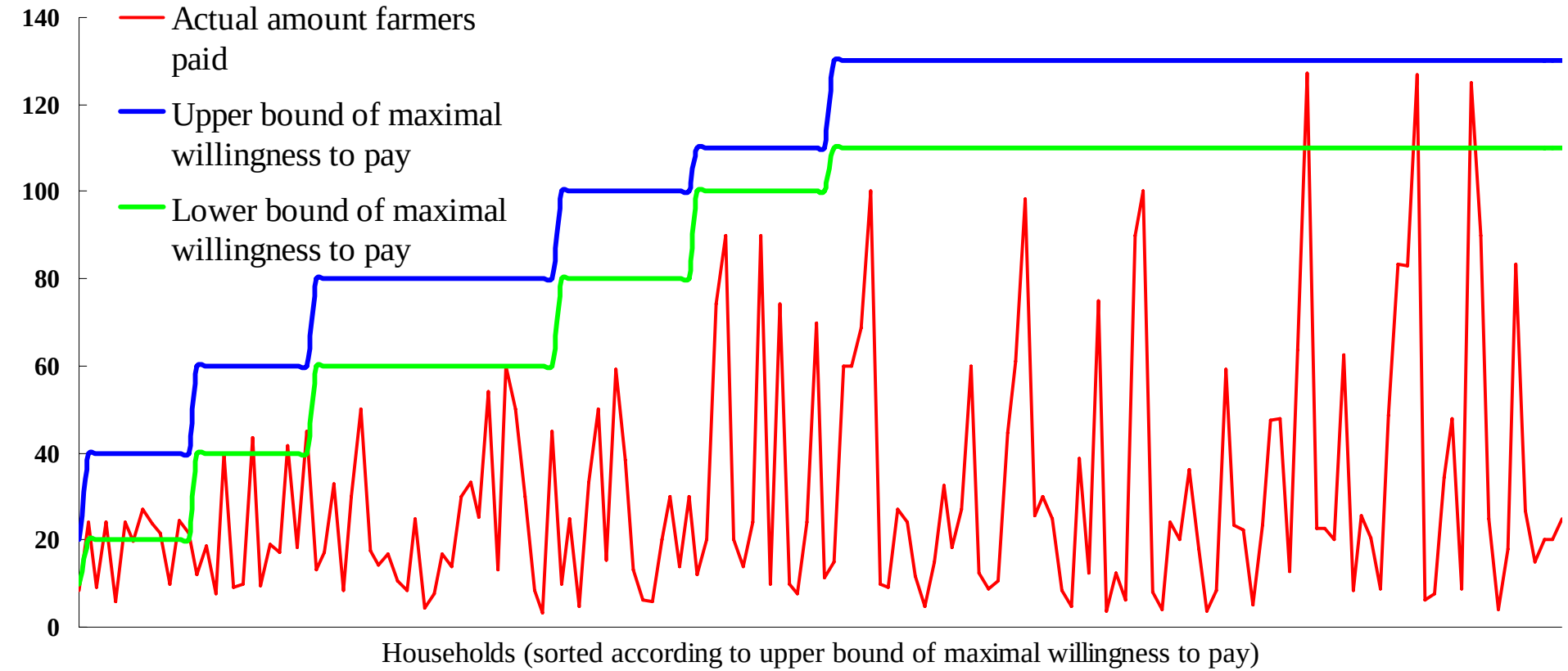
How much farmers are paying for groundwater when irrigating wheat?

Percentile of water depth	Average water depth (m)	Average cost of water (yuan/m^3) (Mostly cost of energy, plus service fee in some areas)
25%	4.4	**0.096**
50%	6.7	**0.084**
75%	24.6	**0.201**
99%	77.5	**0.414**

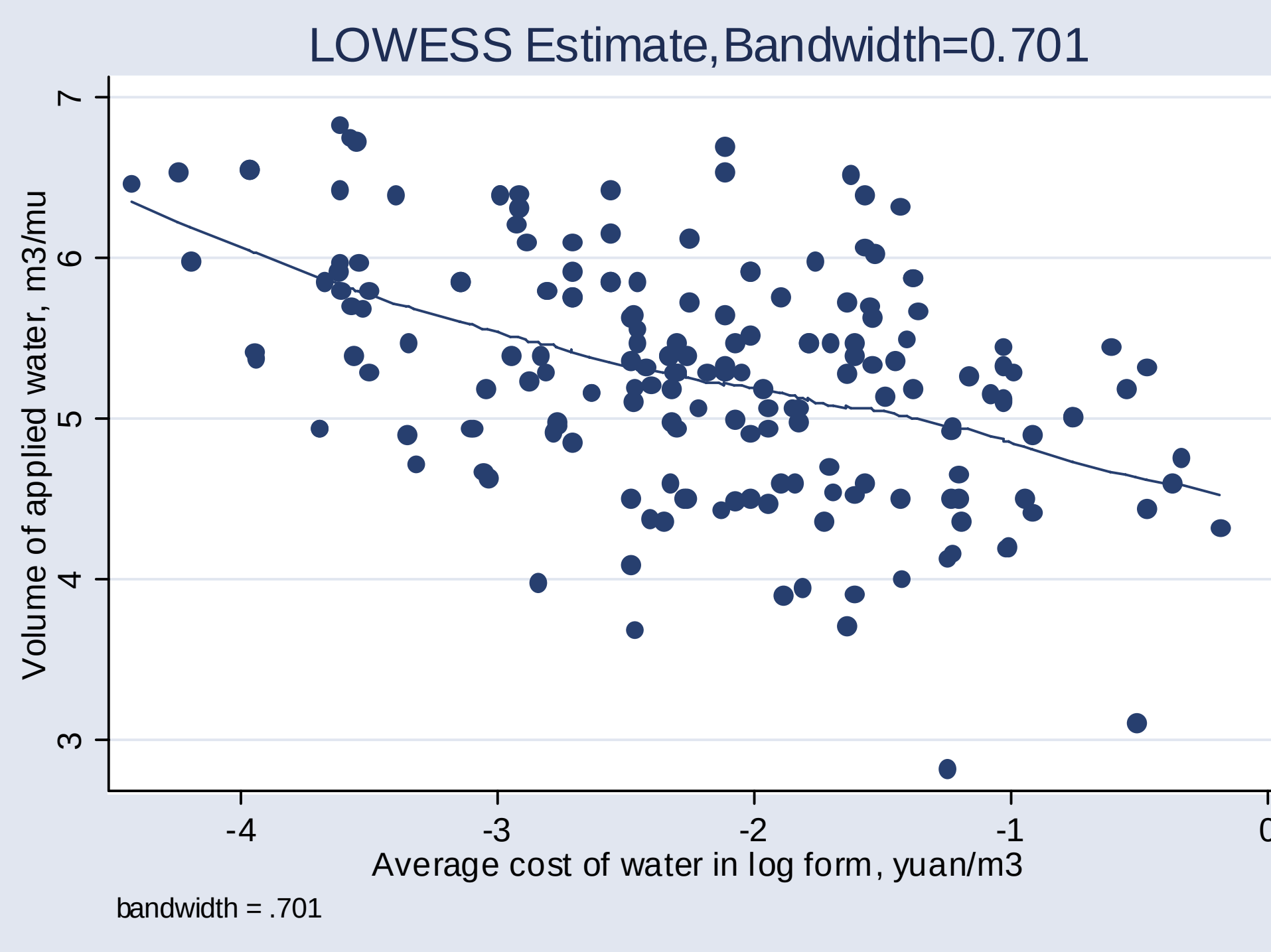
Comparison: The average of surface water price in north China ranges between 0.03- 0.1 yuan/m^3.

(source: 2002 Water Price Survey, Ministry of Water Resource; 2003 China Institute of Water Resource and Hydropower Research)

Actual amount paid for water and willingness to pay
(Wheat irrigated by groundwater; Yuan/Mu)



The difference between actual amount paid by farmers and the maximum of their willingness to pay for water ranges from **3 to 127 yuan/mu**.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Volume of applied water, m3/mu
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Average cost of water in log form, yuan/m3
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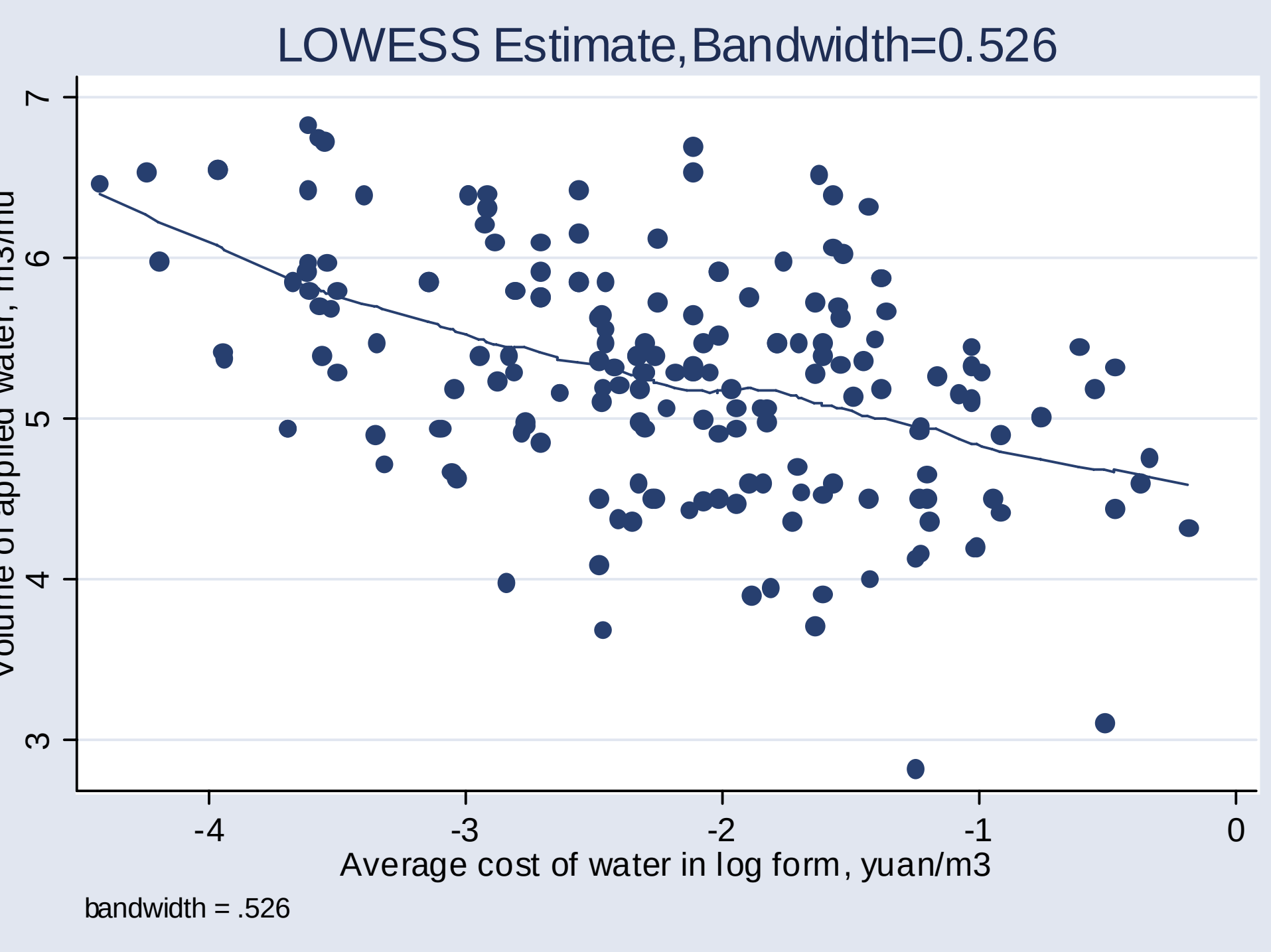
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Average cost of water in log form, yuan/m3
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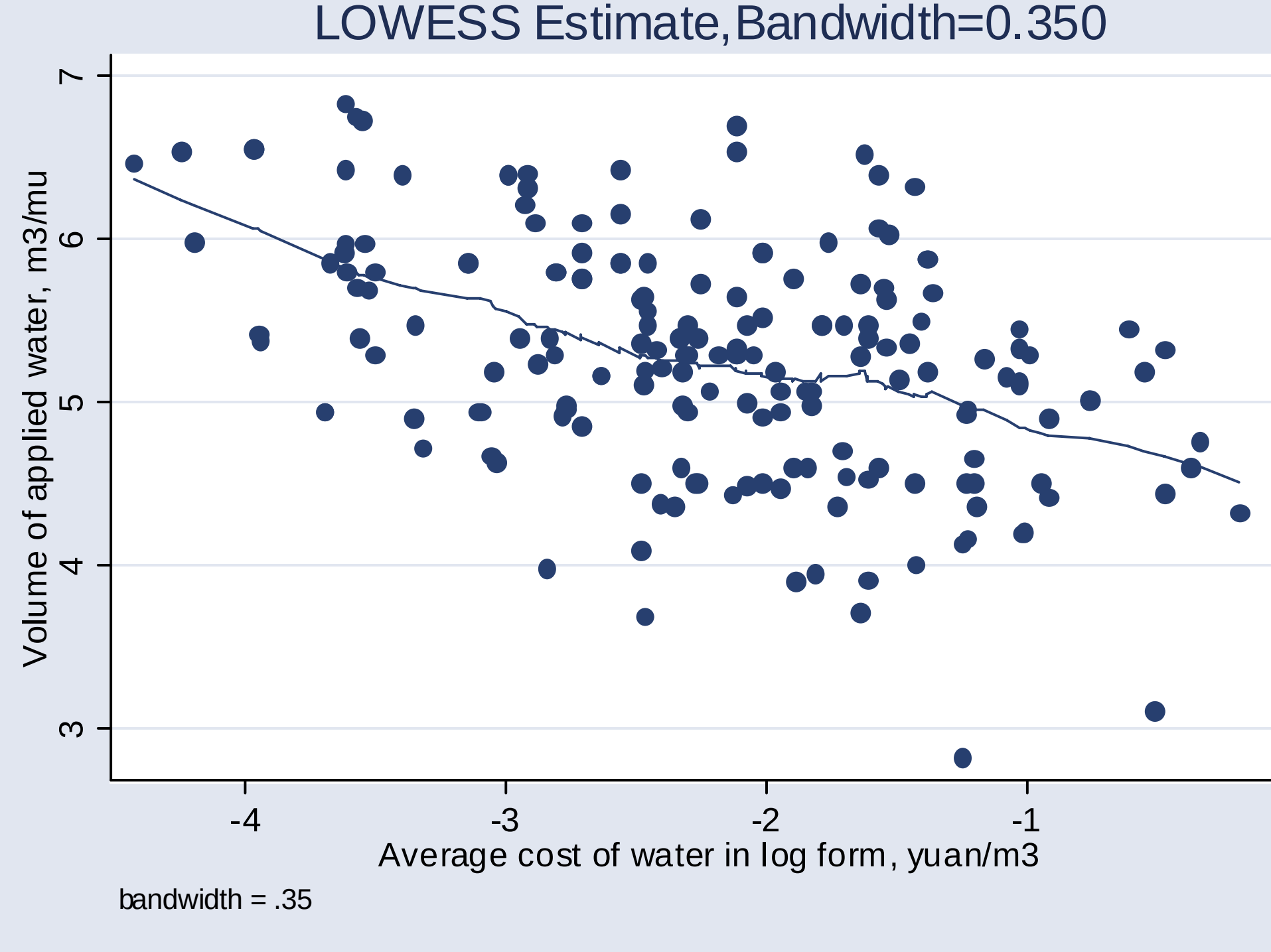
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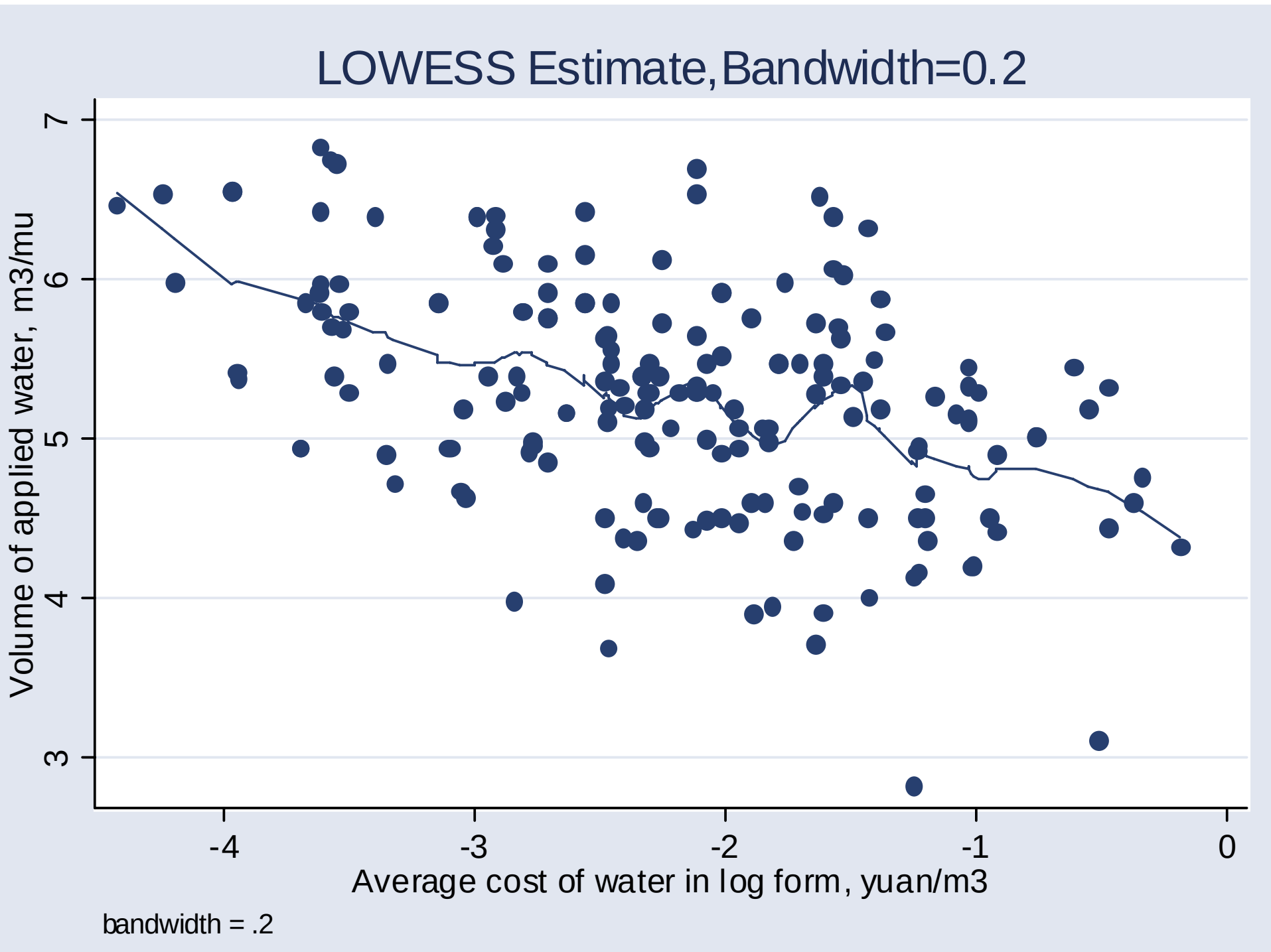
bandwidth = .35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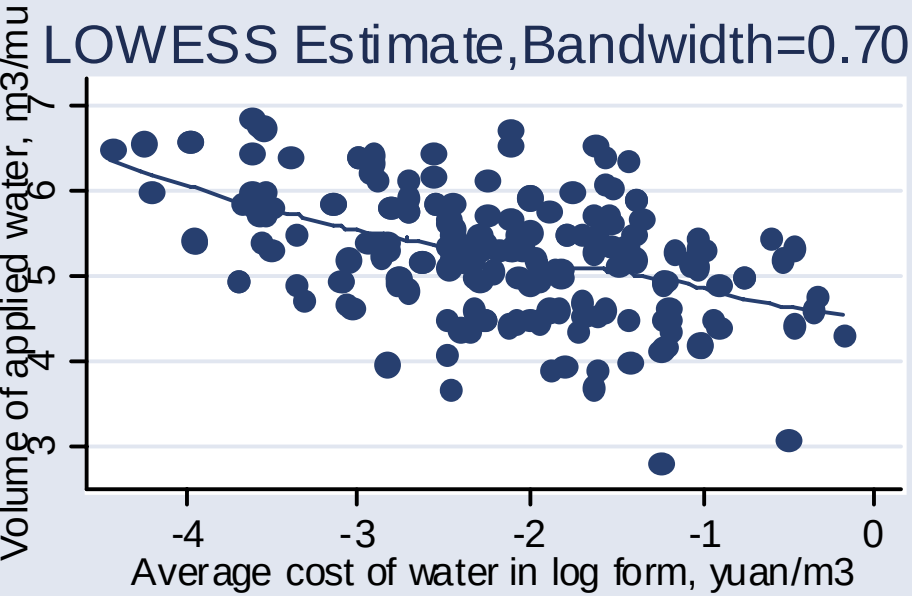
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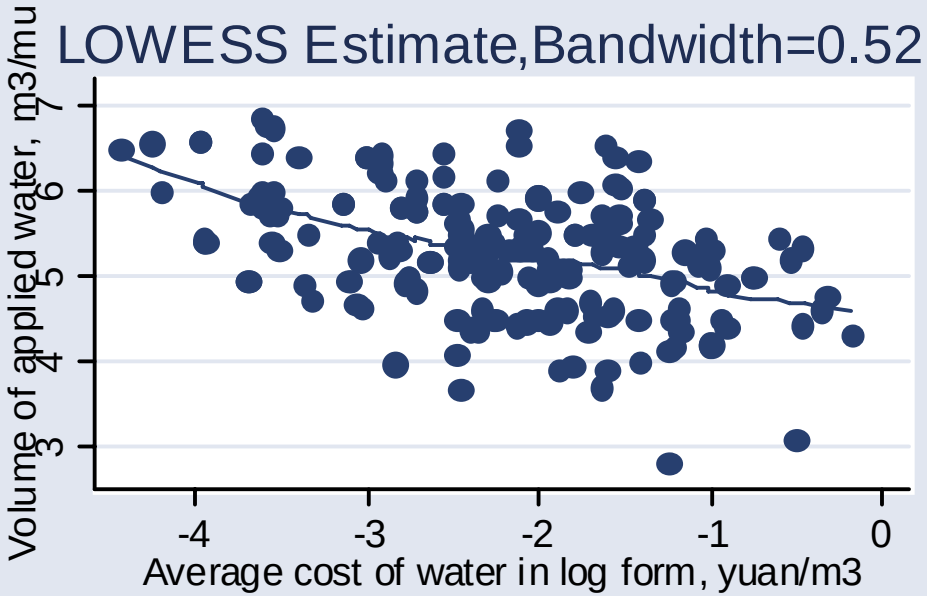
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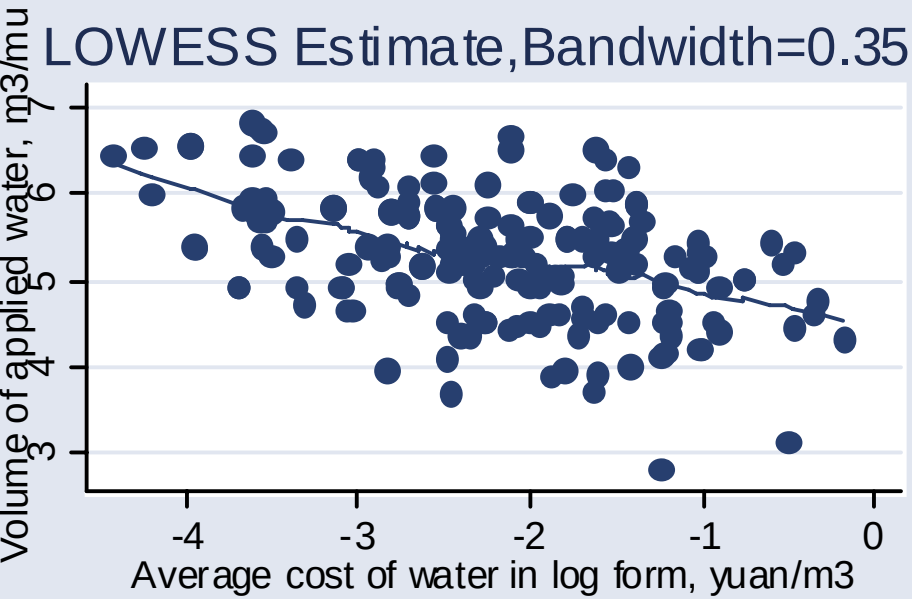
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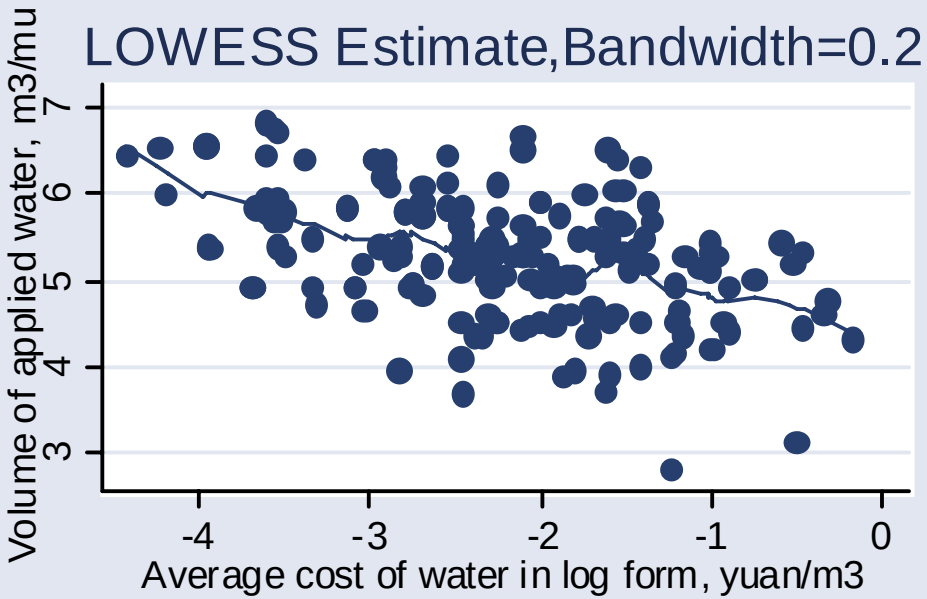
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Average cost of water in log form, yuan/m3
bandwidth = .2

Parametric estimation

- Add covariates to control for other factors that may affect water demand.
  - Plot characteristics: soil type; topography; plot size; distance of plot from house; distance to the outlet of wells; irrigation technology used.
  - Household characteristics: average years of education; number of labor; whether have off-farm income; level of household assets
  - Regional: use county dummies in fixed effect model to control factors such as rainfall.

Estimation results

Regress log (quantity of water) on log (cost of water)	Price elasticity of groundwater demand
OLS	**-0.41*** **
Fixed effect at the county level	**-0.36*** **
Instrumentalize cost of water with water depth	**-0.35*** **
Other functional form	
Log-inverse quadratic elasticity (Strauss and Thomas,1995)	**-0.37** **

*** significant at 1%; ** significant at 5%.

Comparison to USA

Elasticity	Region	Source
-0.07 ~ -0.17	790 counties in 16 western USA states Groundwater	Ogg & Gollehon (1989)
-0.03 ~ -0.10	Northwest, Central Plains, Southern Plains, Southwest Groundwater and Surface water	Moore, Gollehon and Carey (1994)

Conclusion

- Relatively more responsive than the farmers in USA, but still in the inelastic range
- Large increase in water prices (in terms of energy price or tax on groundwater use) would be required to induce water conservation.
- In regions of inelastic water demand, other policy instruments may need to be designed in addition to pricing schemes to meet the goal of water conservation.

Future research

- Include times series data to analyze the response at extensive margin– changing cropping pattern.
- Move to programming approach: PMP to characterize farmers' behavior and incorporate dynamic adaptations in the long run, that is, another extensive margin- land allocation (e.g., stop cultivating at all).
- Feasibility of water pricing reform:

➢ Monitoring water use and enforcing fees costly in rural China: millions of small scale farmers

➢ Mechanism design (Smith and Yacov, 1997).

- Welfare effect of water pricing reform: farmer's income; revenue collected by water authorities.