Comparison of Two Approaches for Predicting Farmer Responses to Water Price Changes

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Agenda

- Case study area and research question
- Residual imputation approach
- Calibrated agricultural production function approach
- Results

Case study area: Aggitis River Basin, northern Greece

- Small river basin located in northern Greece
- 15 irrigation water use locations
- 15 crop types, including 3 subsidized crops
  - 14 irrigated crops (2 subsidized)
  - 1 dryland crop (subsidized)
- Data from 2007
- No volumetric pricing in 2007 (or now)

Research question

- How might agricultural water use change with the introduction of volumetric pricing?
- Two approaches:
  - Residual imputation approach
  - Calibrated agricultural production function approach

Residual imputation (RI) approach: Overview

- Approach based on Young (2005), Determining the Economic Value of Water
- Assume that willingness to pay for water is equal to change in land rent resulting from irrigation
- Land rent is assumed to equal 1/3 net return
- Net return = Revenue – Variable costs – Fixed cost
- Change in land rent due to irrigation is equal to:

  land rent – land rent for dryland agriculture on the same land

Revenue

- Revenue = Area * Yield * Crop price + Subsidy

Variable costs

- Variable costs equal to sum of costs of:
  - Fertilizer
  - Pesticides
  - Seeds
  - Fuel
  - Labor
  - Irrigation O&M
  - Groundwater pumping
  - Borrowing over the growing season

Fixed costs

- Fixed costs equal to sum of:
  - Annualized establishment costs for perennial crops
  - Annualized capital costs

Approach for predicting changes in water demands

for i = 1 to N

if $pw \leq WTP_i$

$A_i = A\_obs_i$

else

$A_i = 0, A_{dryland} = A_{dryland} + A_i$

Where

i = crop index, N = number of crops

pw = water price, WTP_i = willingness to pay for crop i

A_i = area of crop I, A_obs_i = observed area of crop i

$A_{dryland}$ = dryland crop area

Calbrated agricultural production function approach: Overview

- Approach based on Howitt (1995), A calibration method for agricultural economic production models, Journal of Agricultural Economics
- Production is assumed to be described by a constant-elasticity-of-substitution (CES) production function with constant returns to scale
- Land cost function is assumed to a quadratic function with increasing returns to scale
- Production function and land cost function parameters are parameterized using shadow values associated with observed land and water use

CES production function

- CES production function includes three arguments: land, water, and one other input representing the sum of other fixed and variable inputs

$$y = \alpha * (\beta_1 * x_1{}^{\gamma} + \beta_2 * x_2{}^{\gamma} + \beta_3 * x_3{}^{\gamma})^{\frac{1}{\gamma}}$$

Where

y = crop production (tonnes)

1=land, 2=water, 3=all other inputs

$\alpha, \beta_1, \beta_2, \beta_3$ = calibration parameters

$\gamma = \frac{\sigma - 1}{\sigma}$, σ = elasticity of substition

Calibration of CES production function

- Assume marginal product of land equal to observed unit land cost plus shadow value of observed land constraint

$$p_i * \frac{\partial y_i}{\partial x_1} = \lambda_i + \lambda_{land} + c_{land}$$

- Assume marginal product of water equal to observed unitwater cost OR shadow price associated with observed water constraint

$$p_i * \frac{\partial y_i}{\partial x_2} = \lambda_{water}\ or\ c_{water}$$

- Constant returns to scale assumption and observed production provide two additional equations→four equations, four unknowns

Calibration of quadratic land cost function

- Assume quadratic function with increasing returns to scale

$$c\_land_i = {}^1\!/_2 * b_i * {x_{1i}}^2 + a_i * x_{1i}$$

- Assume shadow value associated with observed land constraint is equal to difference between marginal and average land cost

$$\lambda_i = c\_land_i{}' - \overline{c\_land_i}$$

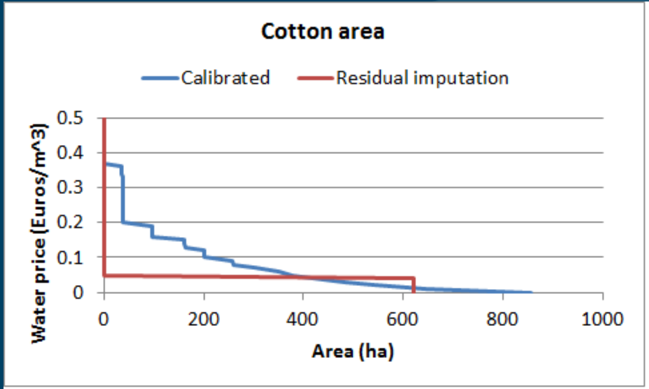
- Observed production provides an additional equation→two equations, two unknowns

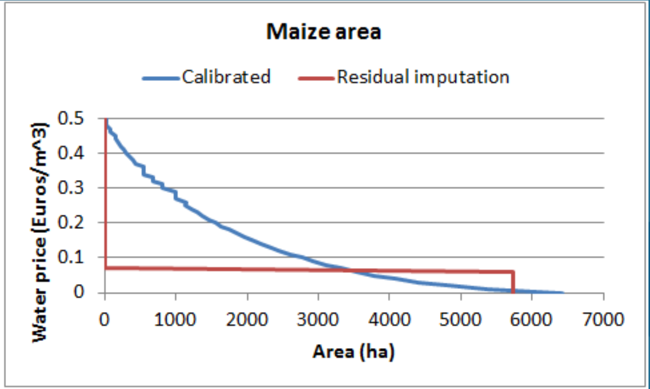
Predicting changes in crop water demands

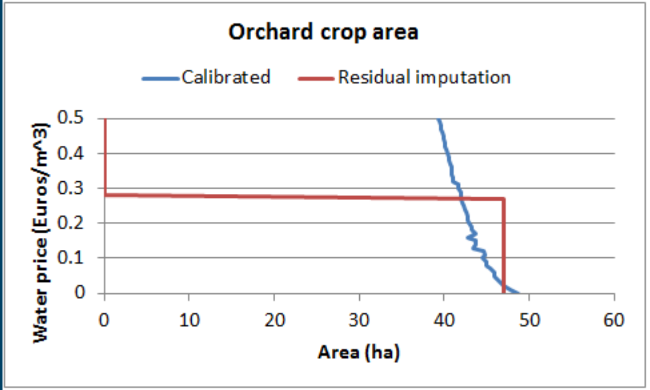
$$\max \sum_{i}^{N} y_i = \alpha_i * (\beta_{1i} * {x_{1i}}^{\gamma} + \beta_{2i} * {x_{2i}}^{\gamma} + \beta_{3i} * {x_{3i}}^{\gamma})^{\frac{1}{\gamma}}$$
$$- {}^{1}/_{2} * b_i * {x_{1i}}^{2} - a_i * x_{1i}$$
$$- pw * x_{2i}$$
$$- c_{other} * x_{3i}$$

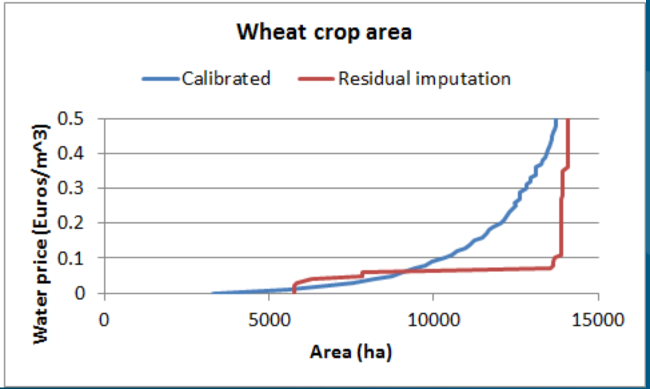
- At observed water prices, solving the optimization problem above will reproduce observed land and water use without constraints

Comparison of land use at one location

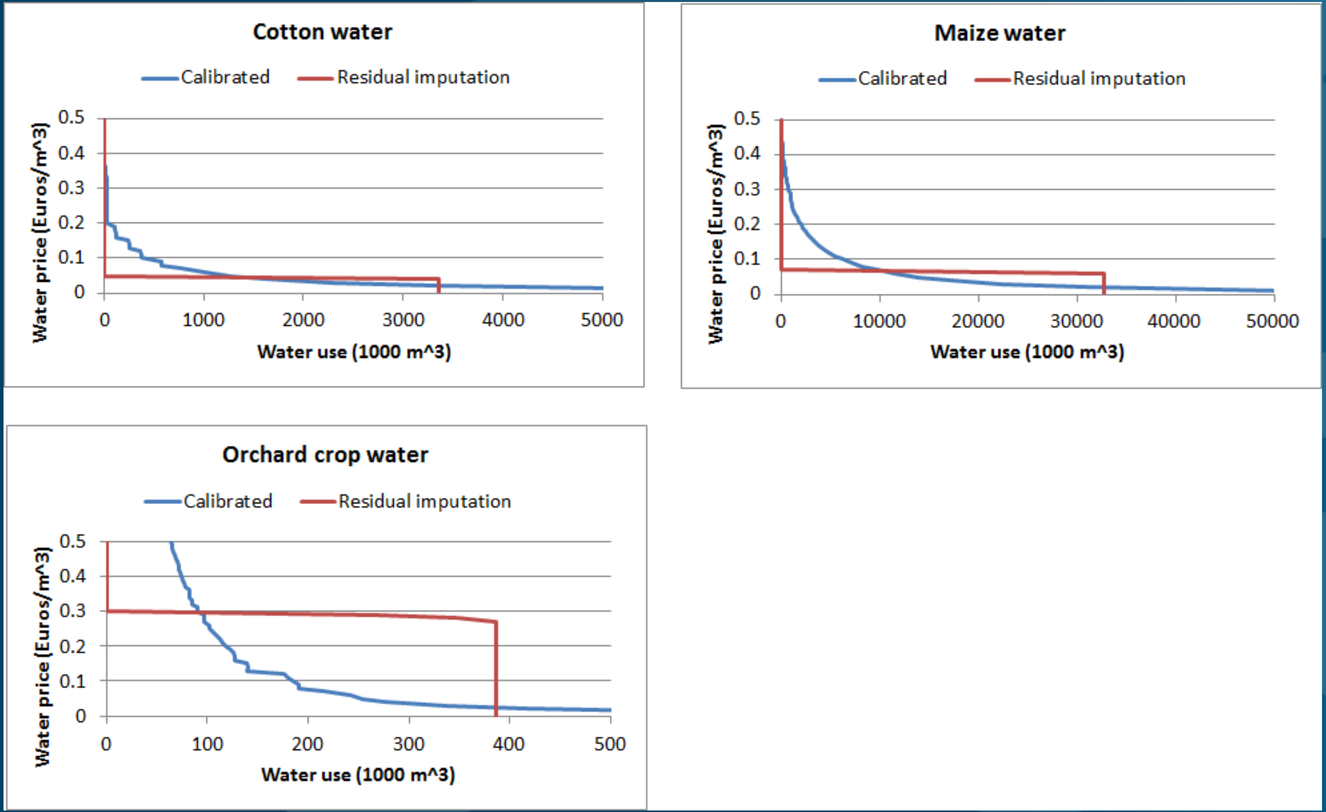








Comparison of water use at one location



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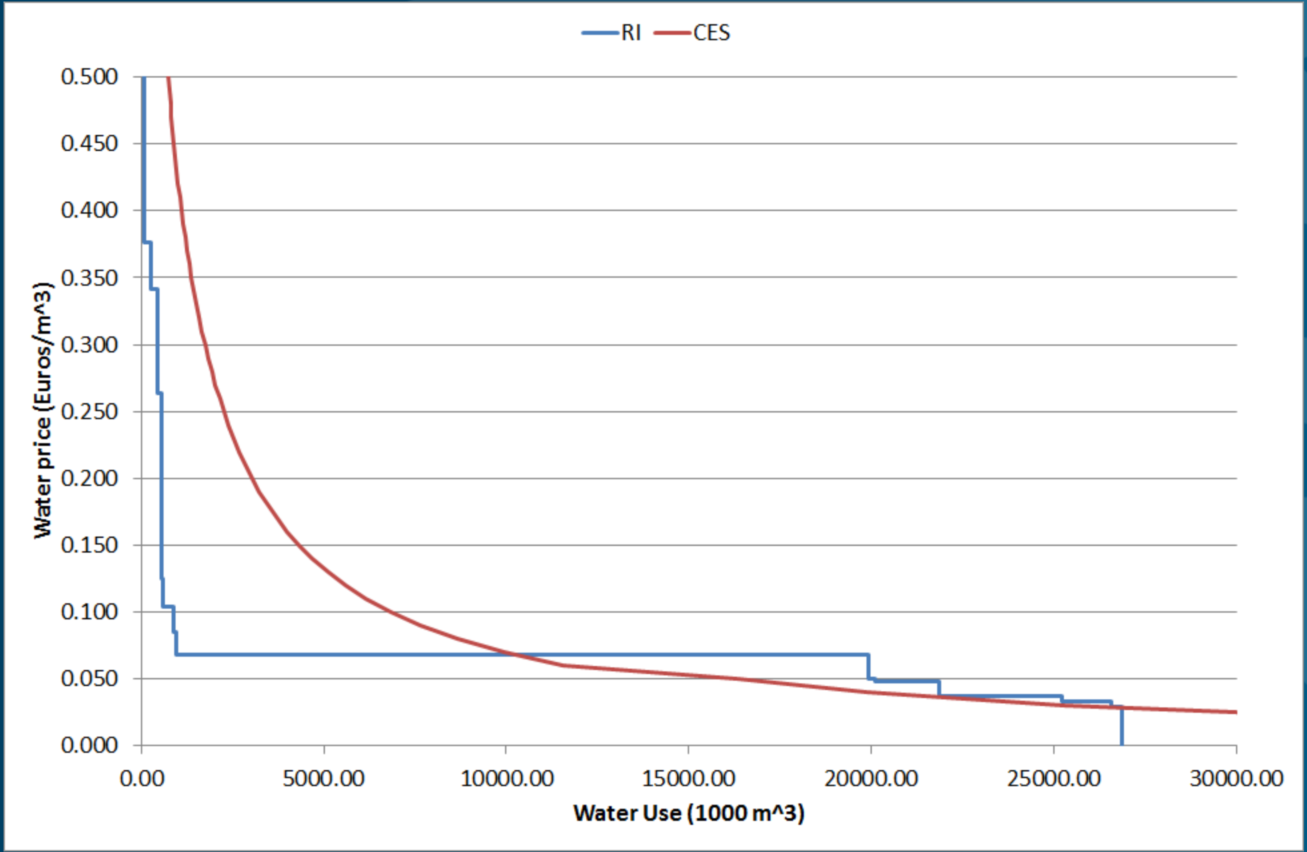

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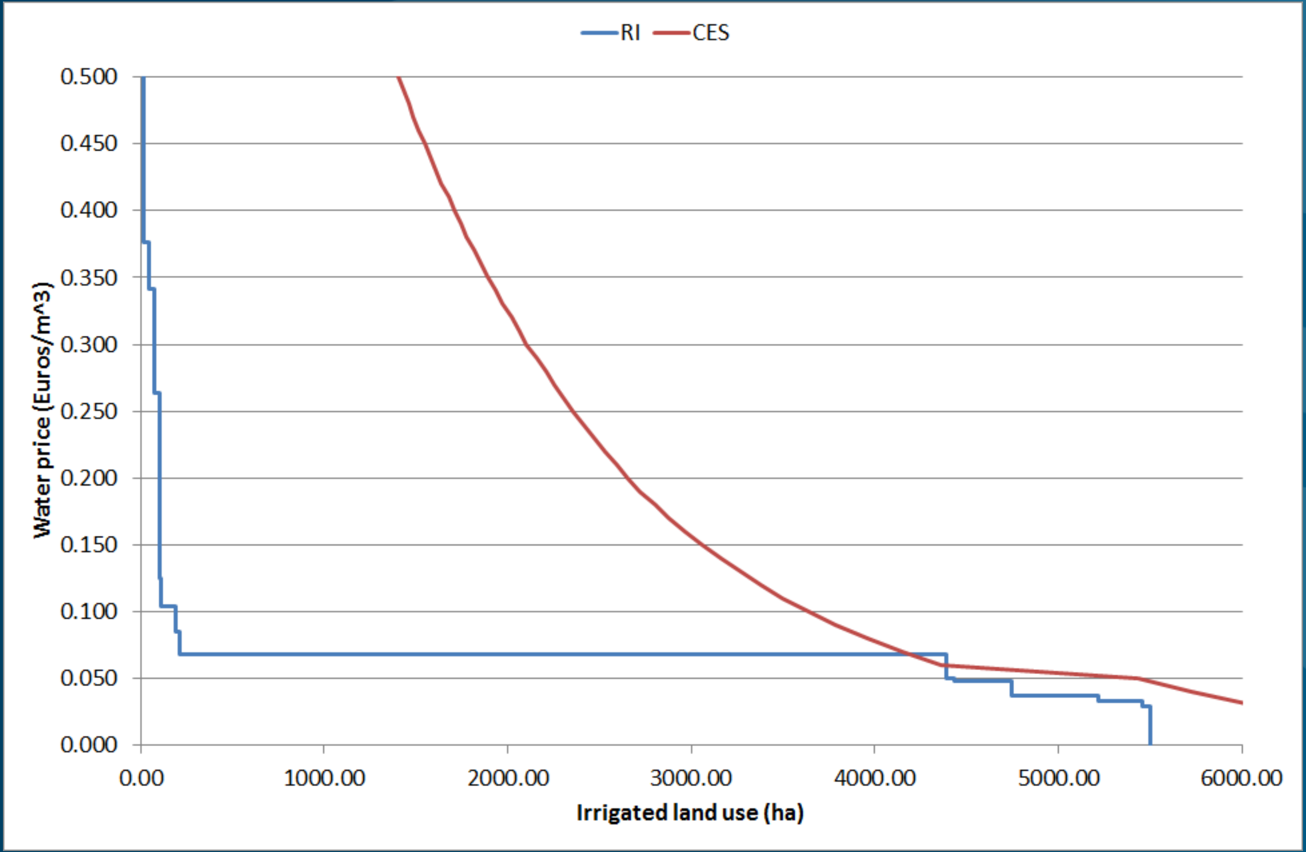
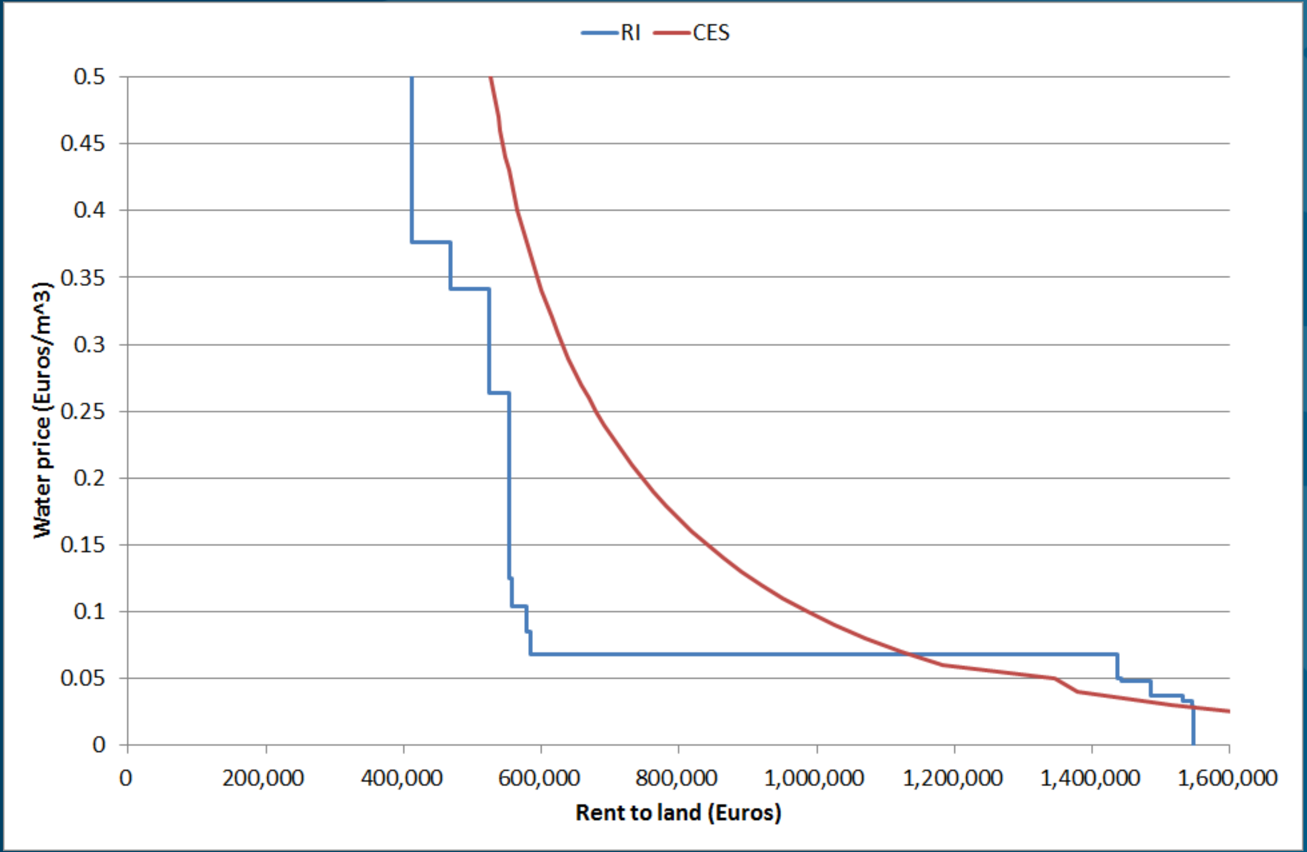
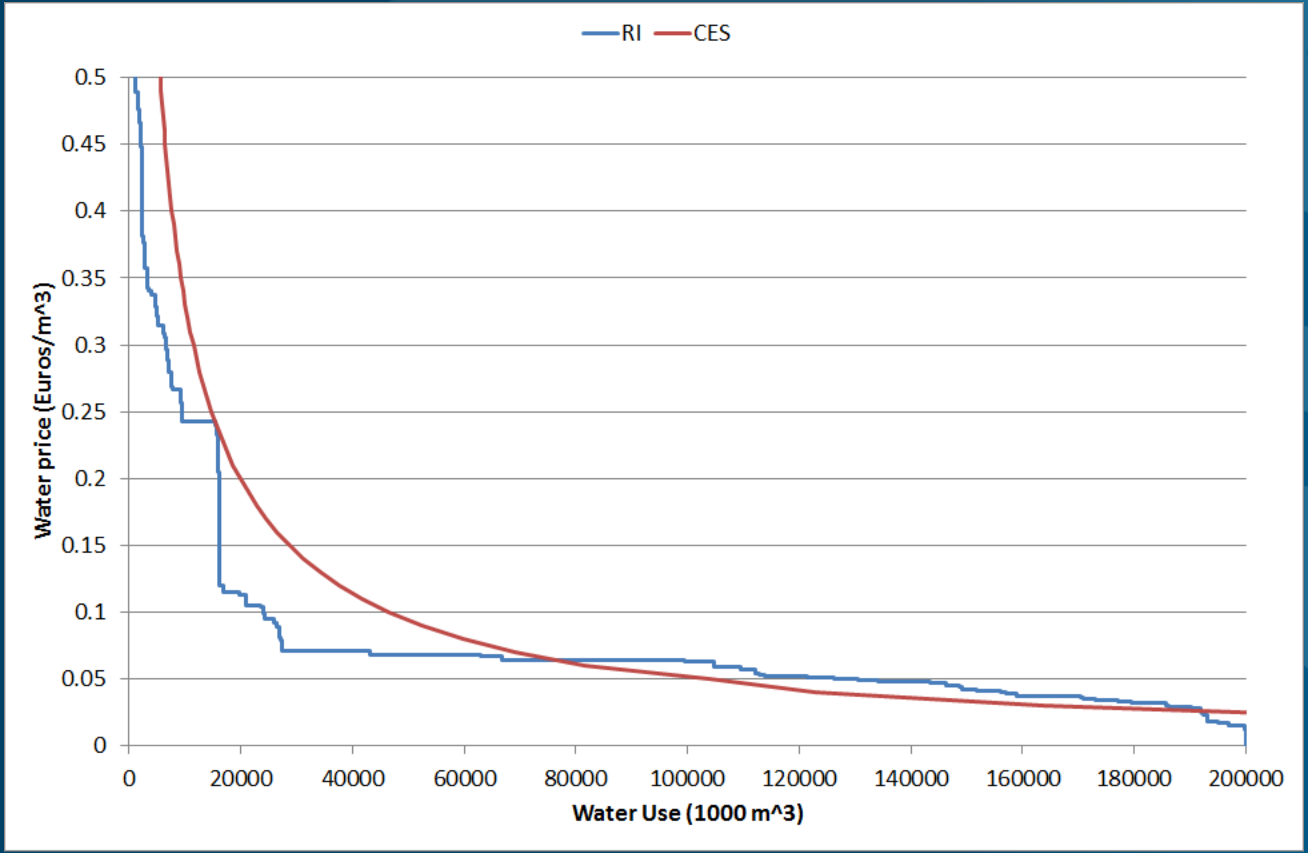


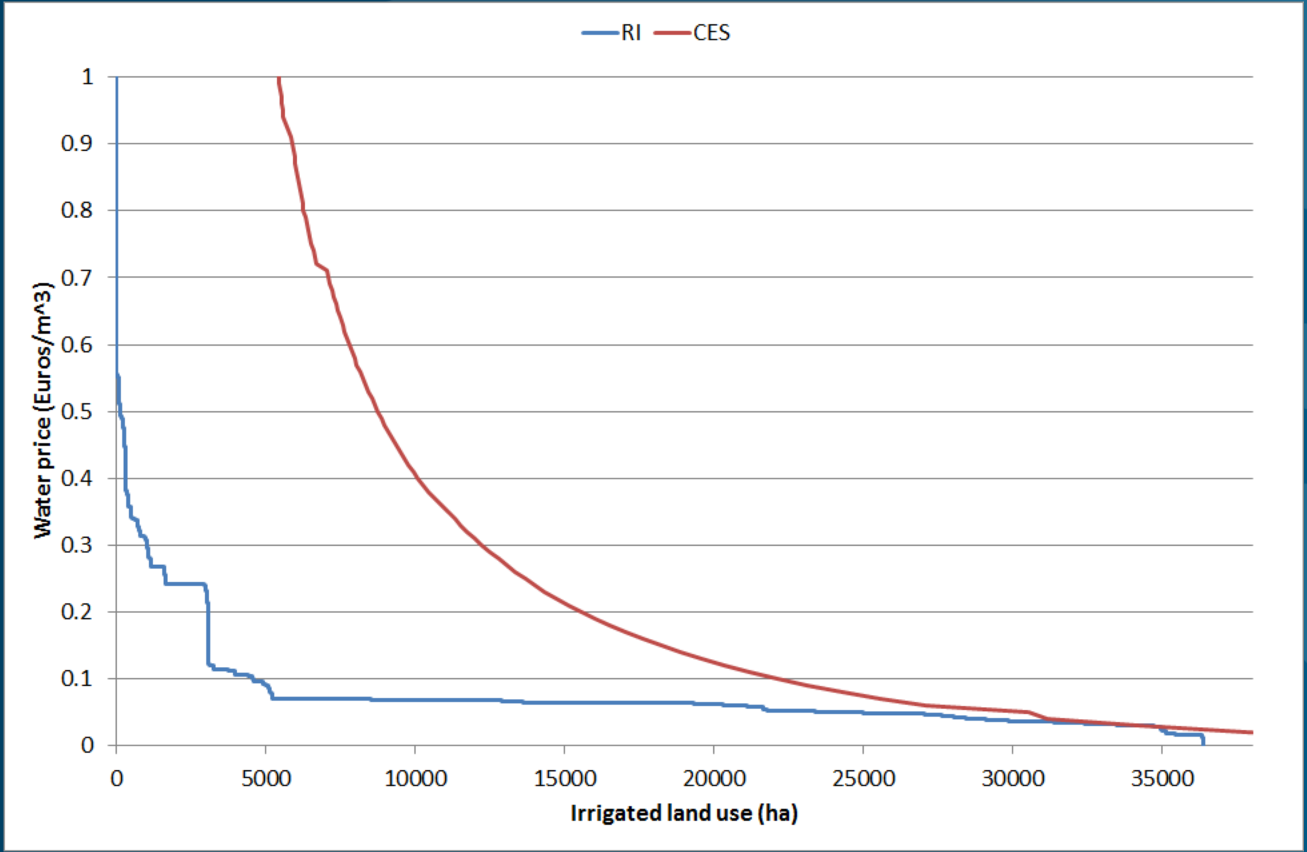
Comparison of irrigated land rent at one location



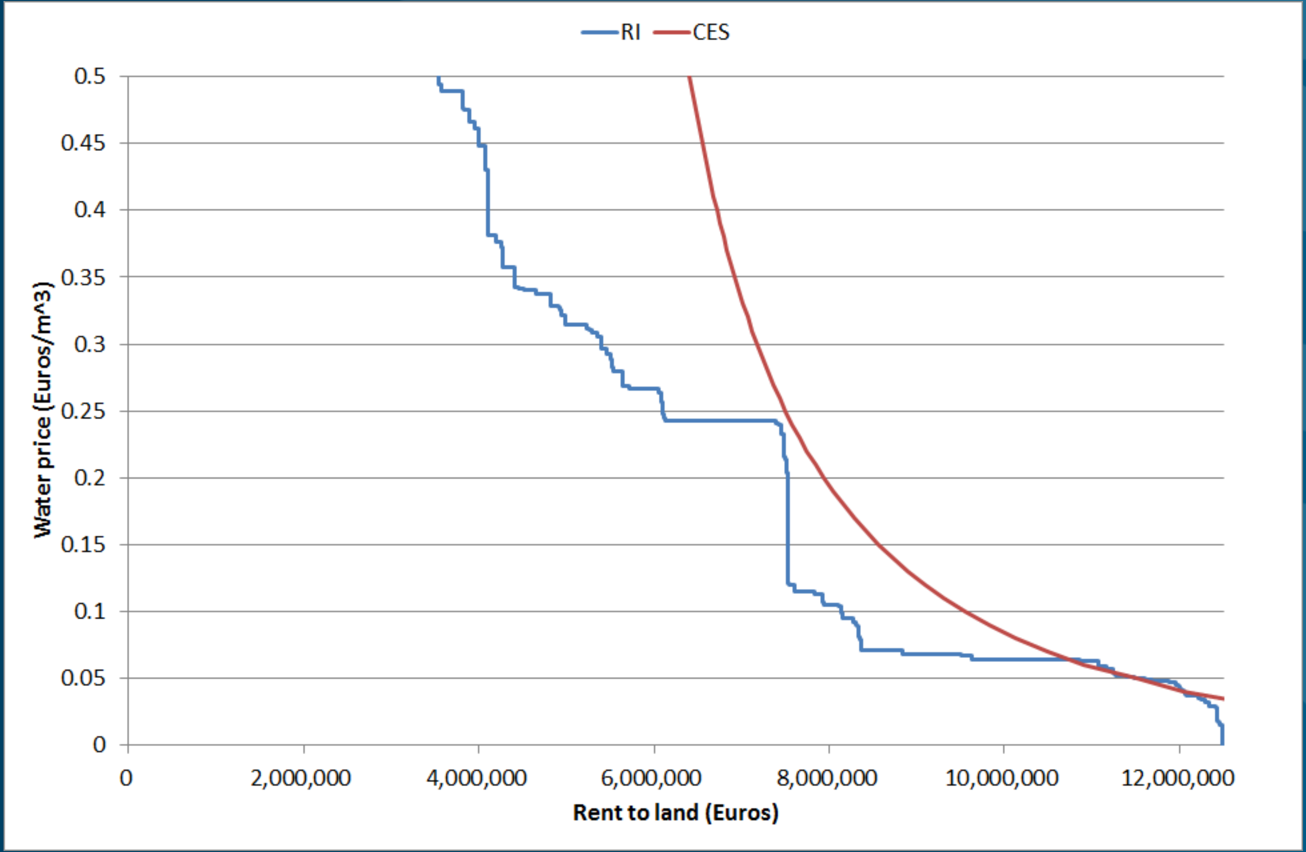
Comparison of water use at basin scale



Comparison of land use at basin scale



Comparison of irrigated land rent at basin scale



Conclusions

- Simplified RI approach and calibrated approach predict similar responses to introduction of volumetric water pricing
- Calibrated approach does not predict conversion of low-value crops to high-value crops as water prices increase because of constraints embedded in calibration of production and land cost functions
  - May also be the result of including a dryland crop in the model
- Calibrated models may not be appropriate for making predictions about farmer behavior under new policy conditions


THANK
YOU!