Water pollution management under information asymmetry: The case of protecting a drinking water reservoir by means of coalition projects

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Personal Motivation

- *When most of the authors of this paper were growing up in the 1960s, dam lakes, ponds and rivers they knew were good for swimming. One could drink water from many natural springs not only in mountains and forests but also at margins of fields and in small towns and villages.*

- *Later, in the 1970s and 1980s, they witnessed a step-by-step rapid deterioration of the water quality.*

- *Major improvement has been observable since the 1990s, so they believe to live to experience a high quality of the waters again.*

- *They want to promote the idea that the Czech Republic is a clean country located in important European watersheds, which tends to continue in the effort after with new strategies*

Problem Solved

- In the new strategy, smaller basins are targeted in more detail - drinking water reservoirs, waters used for swimming purposes, and areas important for increasing biodiversity

- Deals with relatively small territories - it might make sense to create coalitions of polluters and implement common protection projects

- The number of theoretically possible coalitions is huge ($2^n - 1$ coalitions; n = number of subjects)

- It is necessary not to include the evidently non-efficient options

- Understand information asymmetry between subject-polluters and authority; especially in cases when public financial support is provided

- *similar idea - "[Mississippi River Basin Healthy Watersheds Initiative](...)", where rather than working with individual polluters dispersed across the rural landscape - work with many cooperating polluters-farmers located in selected, high-priority watersheds (Perez 2014) (???)*

Model

- The model of reverse combinatorial auctions is used

- There is one buyer – authority – „buying" pollution reduction; and multiple sellers – polluters offering pollution reduction for some costs

S_1 S_2 S_m

B
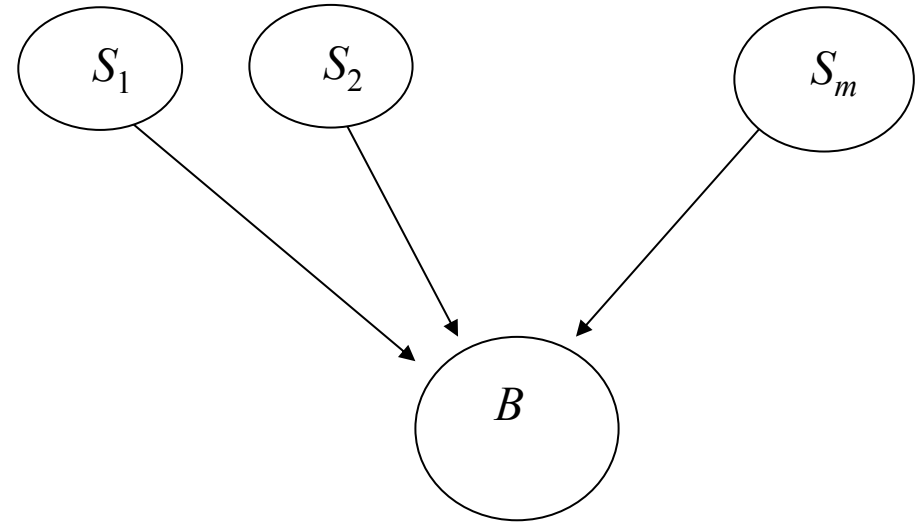
Model - continue

- The basic reverse combinatorial auction model can be formulated as follows (Cramton et al. 2006):

- Subject to $\displaystyle\sum_{h=1}^{m} \sum_{C \subseteq R} c_h(C)y_h(C) \rightarrow \min$

$$\sum_{h=1}^{m} \sum_{C \subseteq R} y_h(C) \geq 1, \quad \forall j \in R,$$

$$y_h(C) \in \{0,1\}, \quad \forall\, C \subseteq R, \quad \forall h, h = 1, 2, \ldots, m.$$

- The standard model is used to find the optimal solution for the „purchase" of a combination of items in an auction.
- In our problem, the model is used to find the optimal coalition structure of projects.
- The objective function expresses the desire to minimize costs tor achieving the target

Vrchlice reservoir – situation, problems

- Vrchlice reservoir build in 1973 as a sole source of drinking water for region with 55,850 inhabitants

- Total area of Vrchlice river basin 97.6 km^2

- Precipitation has increased; increase in the number of rainstorms; increases the danger to the reservoir from dispersed pollution sources;

- Especially **phosphorus** is more intensively transported into the reservoir and contributes to excessive proliferation of green algae and cyanobacteria

- Organoleptic quality deterioration during vegetation periods, manganese and nitrite pollution at the end of vegetation periods, and episodic increases in ammonia content (pollution) are the most important **problems faced by the drinking water treatment plant**

- 26 municipalities contributing to the pollution (map)

The Water Supply Reservoir Vrchlice – the Watershed
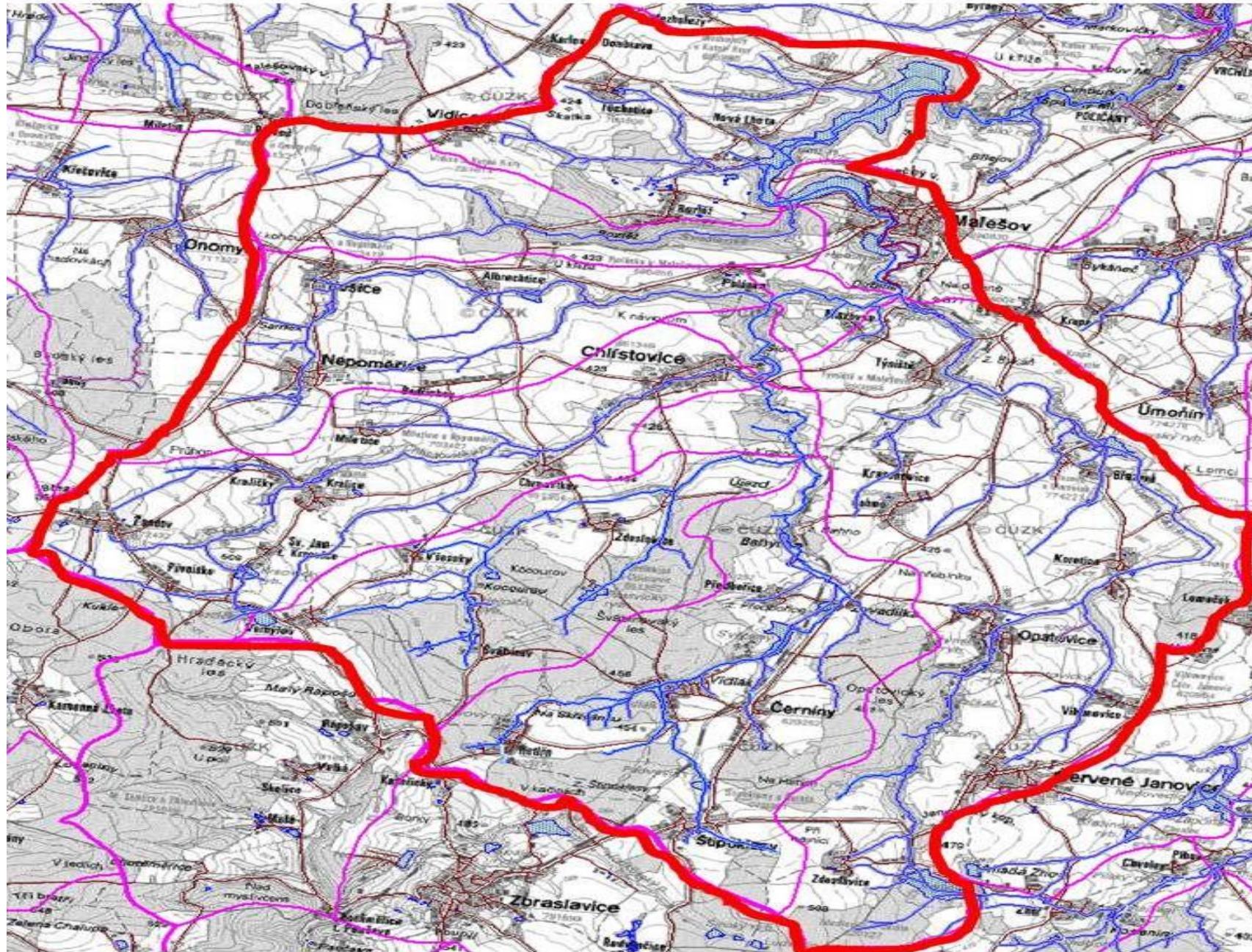
Vrchlice reservoir – situation, problems

- The initial protection of the reservoir was based on legislation valid in the 1960s-80s.
- The central planning system applied universally established regime rules to water sources without any significant differentiation of their actual importance to the water quality in a given source

- Current approaches - much more effective to combine reduced size of protection zones with other legislative instruments
- New proposal for the scope and mode of the protection zones of the Vrchlice reservoir has been elaborated (for assessment pursuant to Section 30 of Act no. 254/2004 Coll.)

Vrchlice reservoir - solution

- 121 potential projects entered the calculation

(26 individuals, 25 two-member coalitions, 26 three-member coalitions, 35 four-member coalitions, 1 five-member coalition, 1 six-member coalition, 4 seven-member coalitions, 2 eight-member coalitions, 1 nine-member coalition)

- Experts estimated the (investment) costs of all these 121 projects

Calculating optimal solution

- Optimal structure of suggested solutions was calculated (promoting coalition solutions):
- **1 four-member coalition:** (Korotice, Č. Janovice, Opatovice I, Krasoňovice)
- **2 three-member coalitions**: (Chlístkovice, Chroustkov, Kralice); (Vidice, Roztěž, Malešov)
- **2 two-member coalitions**: (Černíny, Předbořice); (Nepoměřice, Košice)
- **12 (remain as) individual projects**: Hetlín, Zavadilka, Zdeslavice, Pivnisko, Žandov, Maxovna, Albrechtice, Týniště, Miletice, Štipoklasy, Březová, Tuchotice

- **17 projects in the optimal structure**
- **Costs of the optimal structure = 207 milion** CZK (USD 10 milion)
- **Costs of individual projects solution = 270 mil**. CZK
- = 63 mil. CZK **saving (= 23 %) !!!**

The Watershed of the Reservoir Vrchlice
- The most effective assembled polluters -
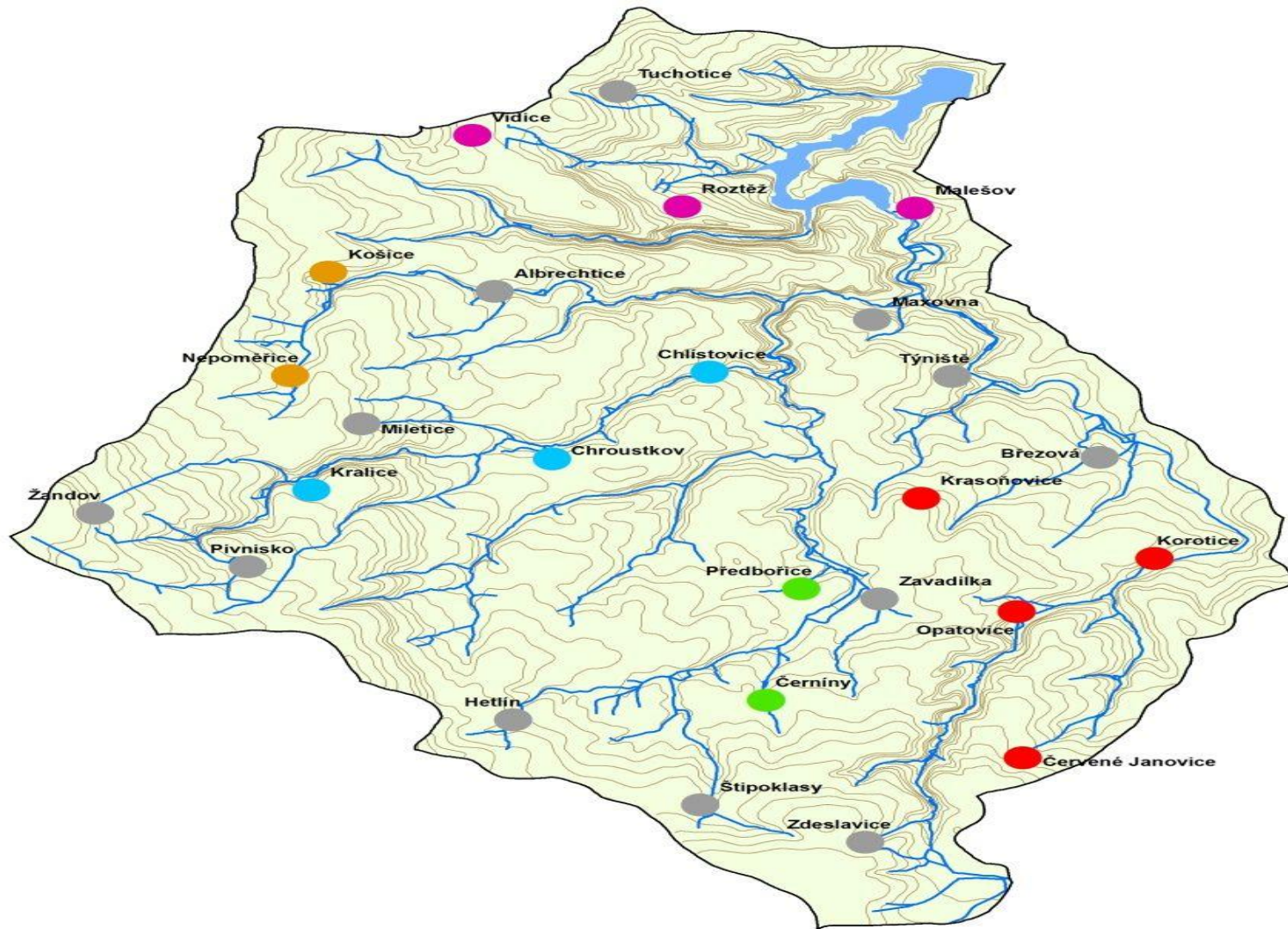
Laboratory experiment

- Pre-test the behavior of the subjects-municipalities within the current Czech legislative-institutional framework
- Sub-segment (four-coalition) from Vrchlice basin was taken for the experiment

- Information asymmetry exists between the authority and the polluters
- The authority offers financial support to wastewater treatment plants
- The polluters negotiate with each other and submit proposals to the authority at the end of the negotiation
- Each player/subject is faced two incentives:
(i)   to save on the investments of the municipality they represented and
(ii)   to participate in a project that would receive the subsidy
 – they knew that only 50% of the projects would be supported
- show-up fee to all + surplus to succesful projects

Estimated investment costs of projects (CZK thousand)

Project no.	Project title	WWTP	Sewerage	Other facilities	Total costs	Remarks
Individual projects						
1.	A	4000	2500	None	6500	
2.	B	10,000	6250	None	16,250	
3.	C	14,000	12,500	2500	29,000	pumping station for a hamlet
4.	D	18,000	14,750	None	32,750	
Coalition projects						
1.	AB	14,000	8750	5000	27,750	extra piping
2.	BC	18,000	18,750	5000	41,750	pumping station
3.	CD	22,000	28,000	15,000	65,000	bridge over a brook, pumping station
4.	ABC	23,000	23,000	4000	50,000	pumping station
5.	BD	20,000	39,000		59,000	
6.	BCD	26,000	28,000	15,000	69,000	bridge over a brook
7.	ABCD	28,000	30,000	15,000	73,000	

Computed results

- Coalition (common) project ABCD should be proposed for implementation

- The total costs are N = 73 mil. CZK

- Brings a saving of CZK 11.5 mil. compared to the implementation of individual projects, which is a common practice

Experimental results – Czech students

Experiment group no.	Coalition structure (project group)	Total costs	Total subsidy	Investment A	Investment B	Investment C	Investment D
1	(AB), C, D	89,500	64,525	1650	4800	8700	9825
2	(ABCD)	73,000	49,560	1900	4140	7800	9600
3	(ABCD)	73,000	49,405	195	4875	8700	9825
4	(ABCD)	73,000	49,726.5	1657.5	4831	6960	9825
5	(ABCD)	73,000	47,650	1950	4875	8700	9825
6	(ABCD)	73,000	53,650	1850	2000	5700	9800
7	(ABC),D	82,750	60,350	1600	4300	7000	9500
8	(ABCD)	73,000	48,000	1700	4800	8700	9800

Lab Experiment Powder Brook – China students

Group No.	Created coalition structure	Total costs	Total subsidies	Investor A	Investor B	Investor C	Investor D
1	A,(B+C+D)	75500	60500	1000	4000	7000	8500
2	A,(B+C+D)	75500	51000	1700	4500	8500	9800
3	(A+B+C+D)	73000	47900	1900	4800	8600	9800
4	(A+B+C+D)	73000	50000	500	4500	8500	9500
5	(A+B+C+D)	73000	51400	1600	7000	5000	8000

Conclusions

- The model can be used for finding/computing the optimal (costs-effective) solution in the case the data are available (we trust the experts)

- It can be used for calculating the optimal solution when testing various institutional settings in laboratory experiments (useful in situations where there is strong information asymmetry between authority and polluters)

Coalition solutions:

- (i) bring significant cost-saving comparing to individual projects;

- (ii) may also have potential economic effects over time in the form of enabling downwarding shifts of abatement costs (when environmentally oriented technological progress brings new solutions and, a smaller number of WWTPs would enable a faster and easier implementation of these innovations)

- Useful also for developing countries

Thank you for your atention