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Enforcement of the Icelandic cod fishery:

– A two management control, two enforcement tool fishery –

A paper presented at the EAFE Workshop

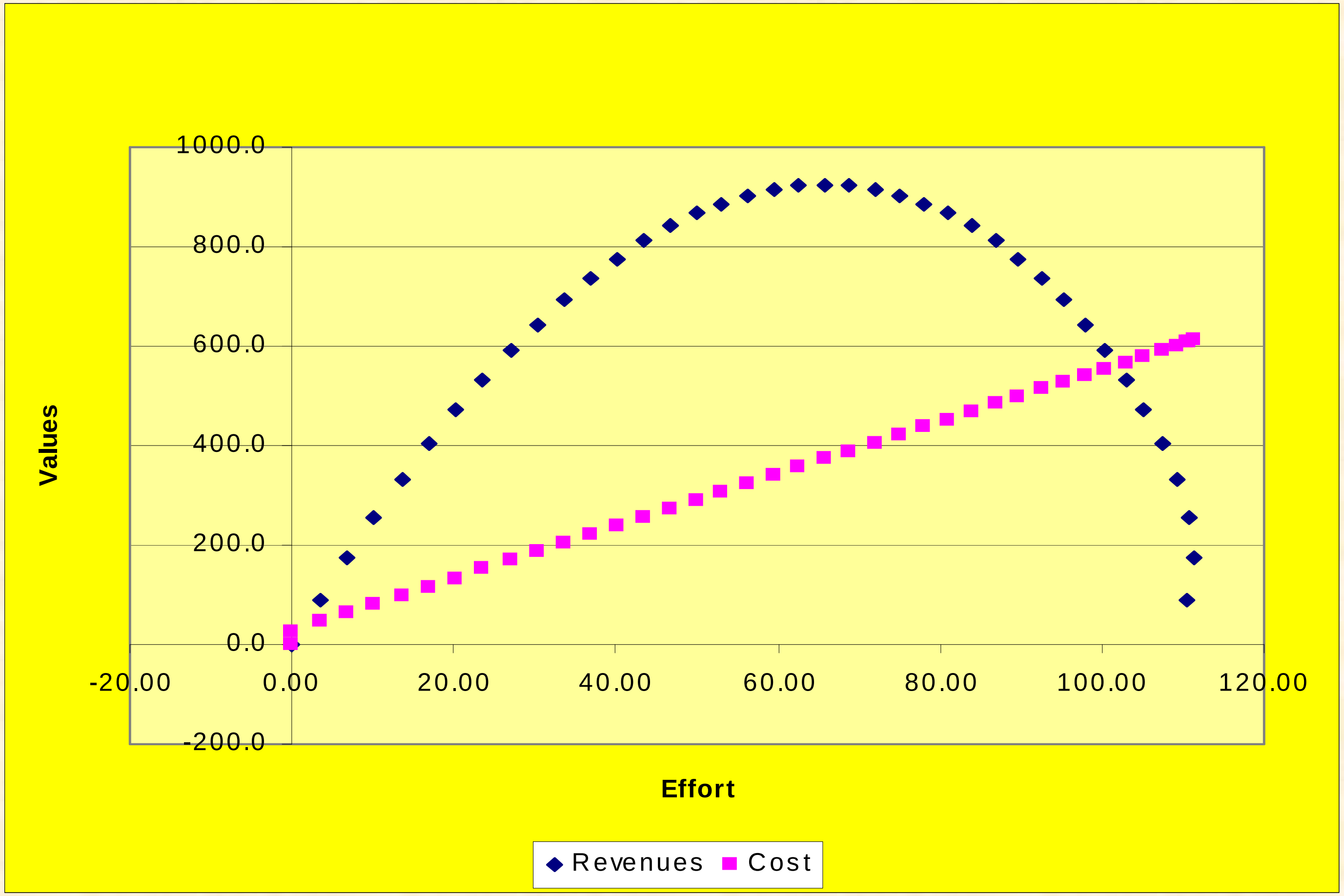
Fishery Governance and Cost of enforcement

Alghero, June 23-24, 2008

Background

- Icelandic cod fishery
  - Quite sizable (MSY ≈0.330 m.mt; landed value≈600-900 m.US$)
  - Currently depressed (biomass≈0.7 m.mt.; OSY≈1.2 m.mt)
  - Capitalistic fishery- profit maximizers
    - About 700 fishing vessels (some multi-purpose)
    - About 70 landing places
  - Managed on the basis of ITQs
    - Individual harvest restrictions
    - Also area/time/gear restrictions
  - Quite profitable (quota rental values 2-3 US$/kg)

Icelandic cod: Sustainble fishery



Enforcement Situation

- Enforcement agencies
  - The Fisheries Directorate (the key agency)
  - Assisted by the Coast Guard
- Two management tools
  - The quota constraint – the key management control
  - Fishing area/time/gear restrictions – mix of controls
- Two enforcement tools
  - Enforcement of harvest or quota
  - Enforcement of area/time/gear restrictions

Modelling the situation

Private Benefits

$$PB = B(q,\alpha;x) - f_1 \cdot \pi_1(e_1) \cdot (q-\overline{q})^2 - f_2 \cdot \pi_2(e_2) \cdot (\alpha - \overline{\alpha})^2$$

Social Benefits

$$SB = B(q,\alpha;x) - C(e_1,e_2) - \lambda \cdot (G(\alpha;x) - q)$$

Functional specifications

Profit function: $B(q,\alpha;x) = p \cdot q - c(\alpha) \cdot \frac{q^{\gamma}}{x}$

Cost coefficient: $c(\alpha) = a_0 + a_1 \cdot (\alpha - a_2)^2$

Biomass growth function: $G(x) = a \cdot \left(\frac{1}{1+(\alpha - \alpha^*)^2} \right) \cdot x - b \cdot x^2$

Functional specifications (cont.)

Probability function 1: $\pi_1(e_1) = \dfrac{e_1}{A_1 + e_1}$

Probability function 2: $\pi_2(e_2) = \dfrac{e_2}{A_2 + e_2}$

Cost of enforcement: $C(e_1, e_2) = c_0 + c_1 \cdot (e_1 + e_2) + c_2 \cdot (e_1 + e_2)^2$

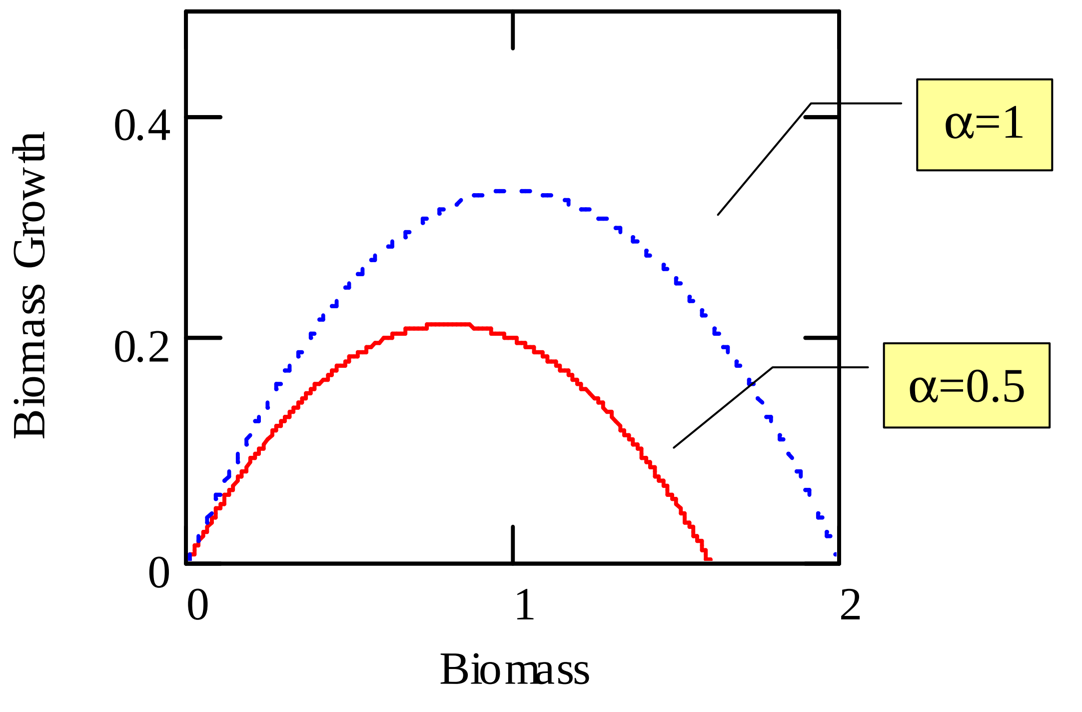
Empirical specifications

Parameters in the bio-economic model			
Parameters	Value	Estimation method	Source
Landings price, p	220 ISK/kg.	Econometric estimation	Agnarsson et al 2007
Fishing costs, a_0	100	Econometric estimation +adjustment	Agnarsson et al 2007 Authors
Fishing costs, a_1	60	Guesstimate	Authors
Fishing cost, a_2	0.5	Guesstimate	Authors
Fishing cost, γ	1.1	Econometric estimation	Agnarsson et al 2007
Biomass growth, a	0.6699	Econometric estimation	Agnarsson et al 2007
Biomass growth, b	0.3353	Econometric estimation	Agnarsson et al 2007
Biomass growth, α*	1	Normalization	Authors
Base year biomass	715.000 mt	Biological estimate	Marine research Institute 2007
Shadow value of biomass, λ	150 ISK/kg	Bio-economic estimate	Agnarsson et al 2007 Arnason et al. 2007.

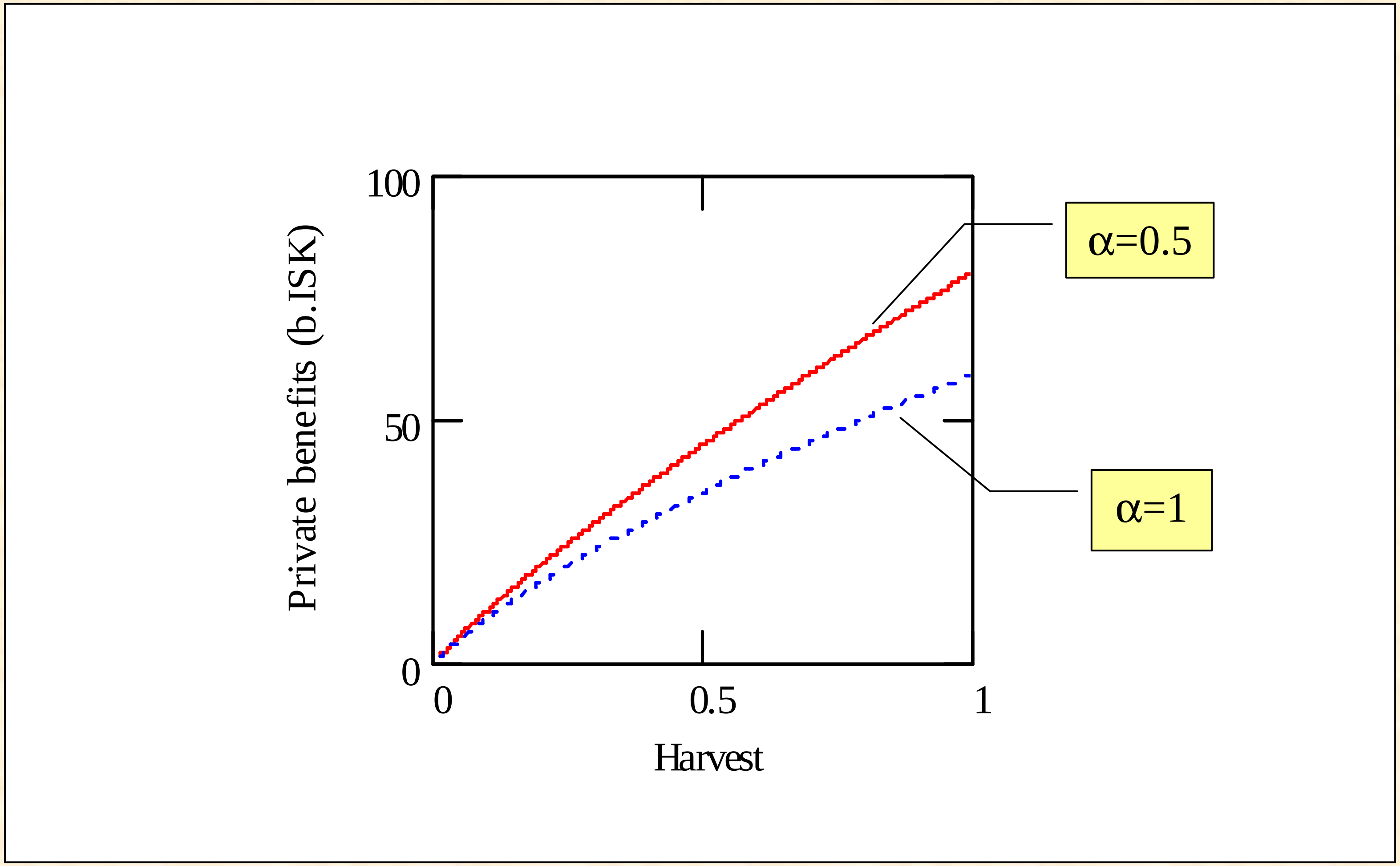
Empirical Specifications

Enforcement parameters		
Parameters	Value	Source
Probability function, A_1	0.0678	Estimated in project
Probability parameter, A_2	0.0136	Estimated in project
Fining parameter, f_1	1476 ISK/kg	Estimated in project
Fining parameter, f_2	40.9	Estimated in project
Enforcement costs, c_0	0.0663 b.ISK	Estimated in project
Enforcement costs, c_1	0.185 b.ISK/effort unit	Estimated in project
Enforcement costs, c_2	$0.578 \cdot 10^{-5}$ b.ISK/(effort unit)^2	Estimated in project

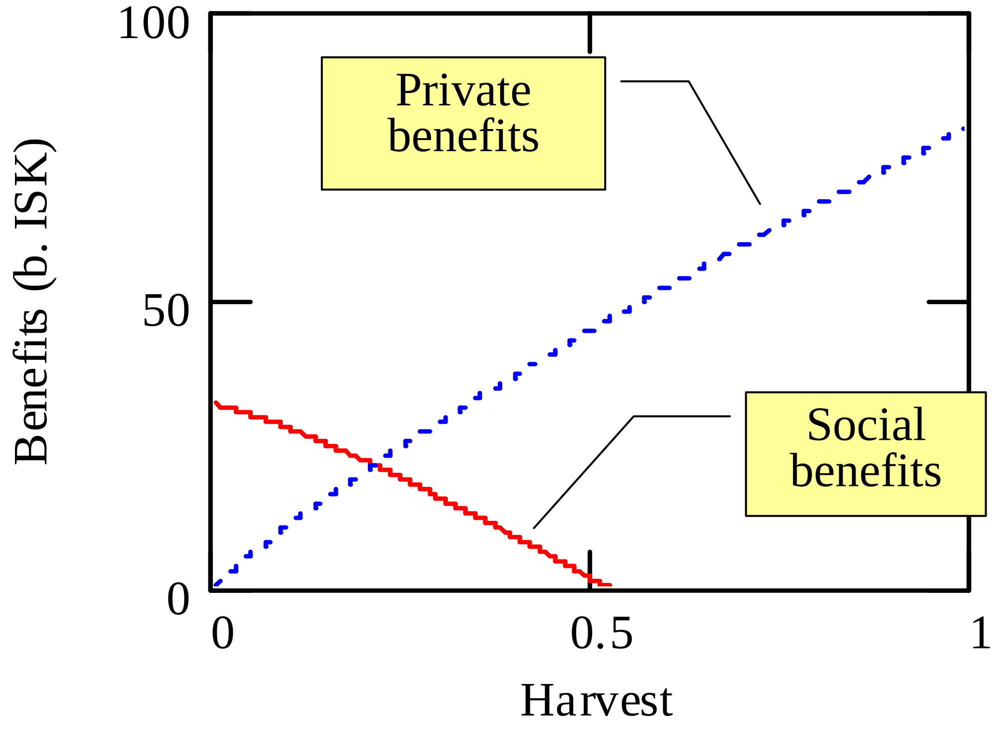
Biomass growth
(million metric tonnes)



Profit function

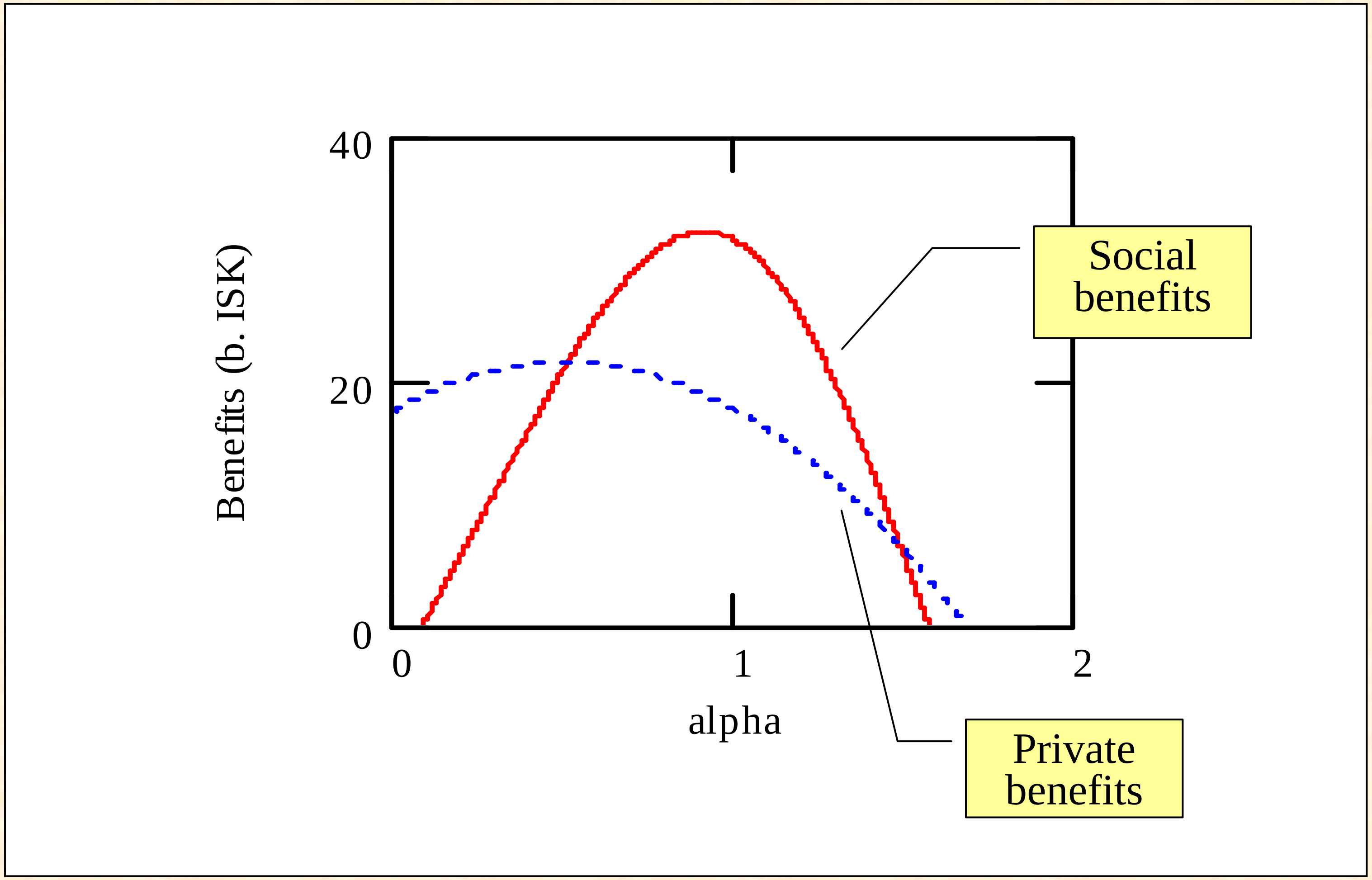


Benefits from harvest
(α=0.5)



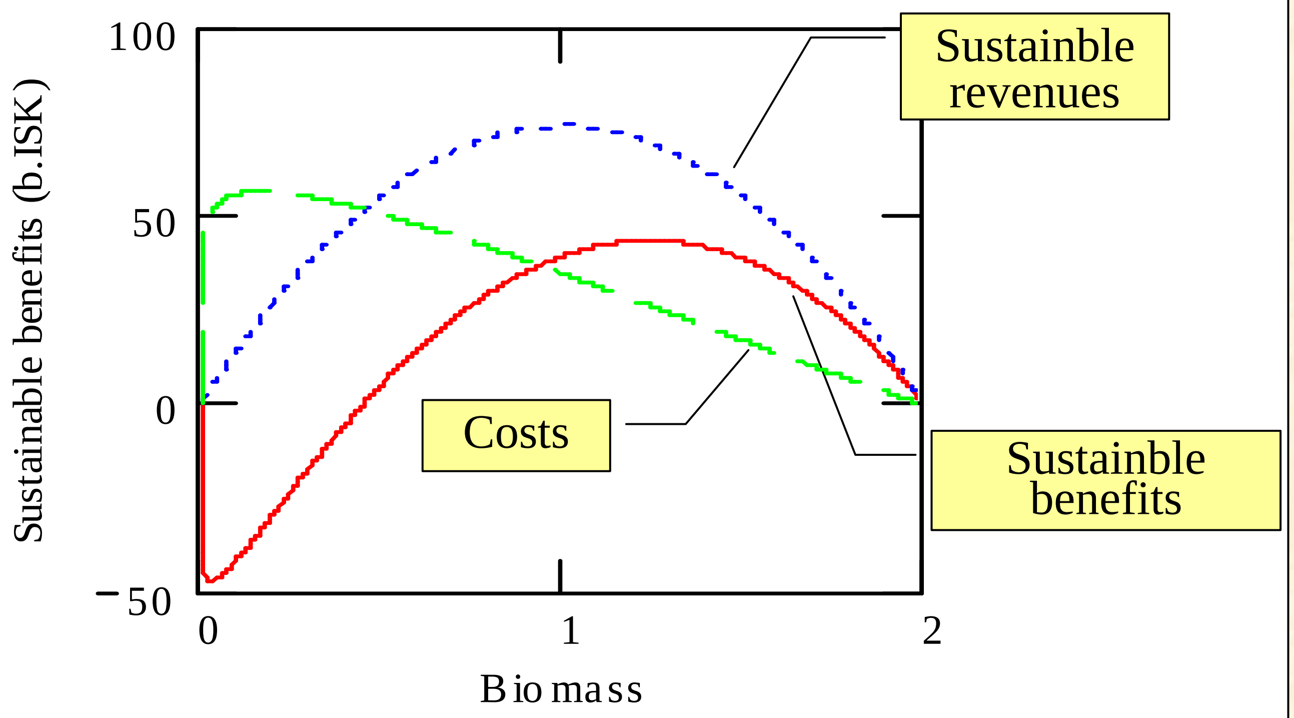
Benefits from alpha

(Harvest=0.215)

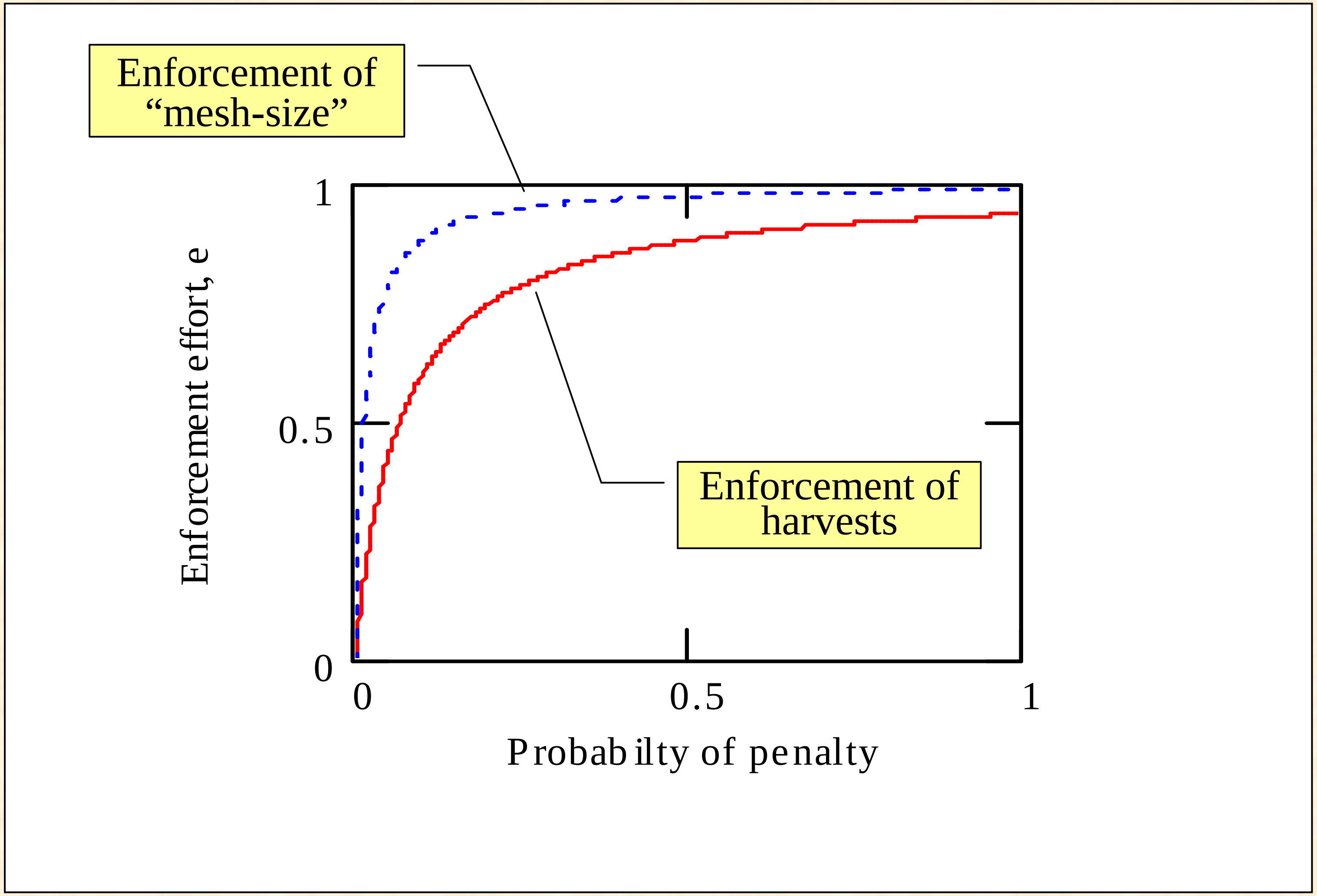


Sustainble benefits

(α=0.1)



Probability of penalty



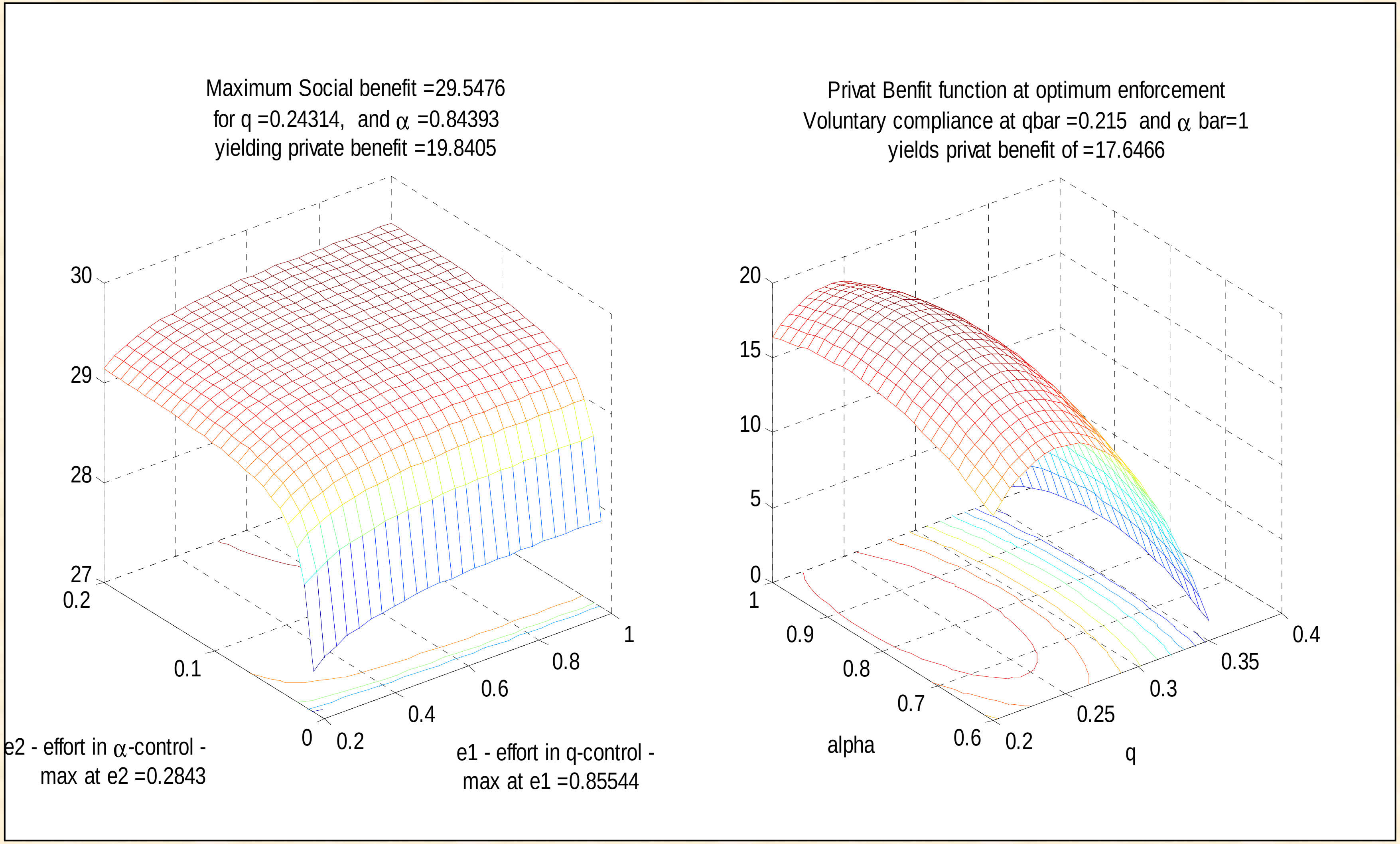
Results

Enforcement situation	Enforcement e_1	e_2	Harvest q	Mesh-size α	Private benefits (b.ISK)	Social benefits (b.ISK)
No enforcement	0	0	0.600* (+179%)	0.5 (-50%)	52.3	-6.0
Optimal enforcement	0.855	0.284	0.243 (13%)	0.884 (-16%)	19.8	29.5
Voluntary compliance	0	0	0.215 (0%)	1.0 (0%)	17.6	31.5

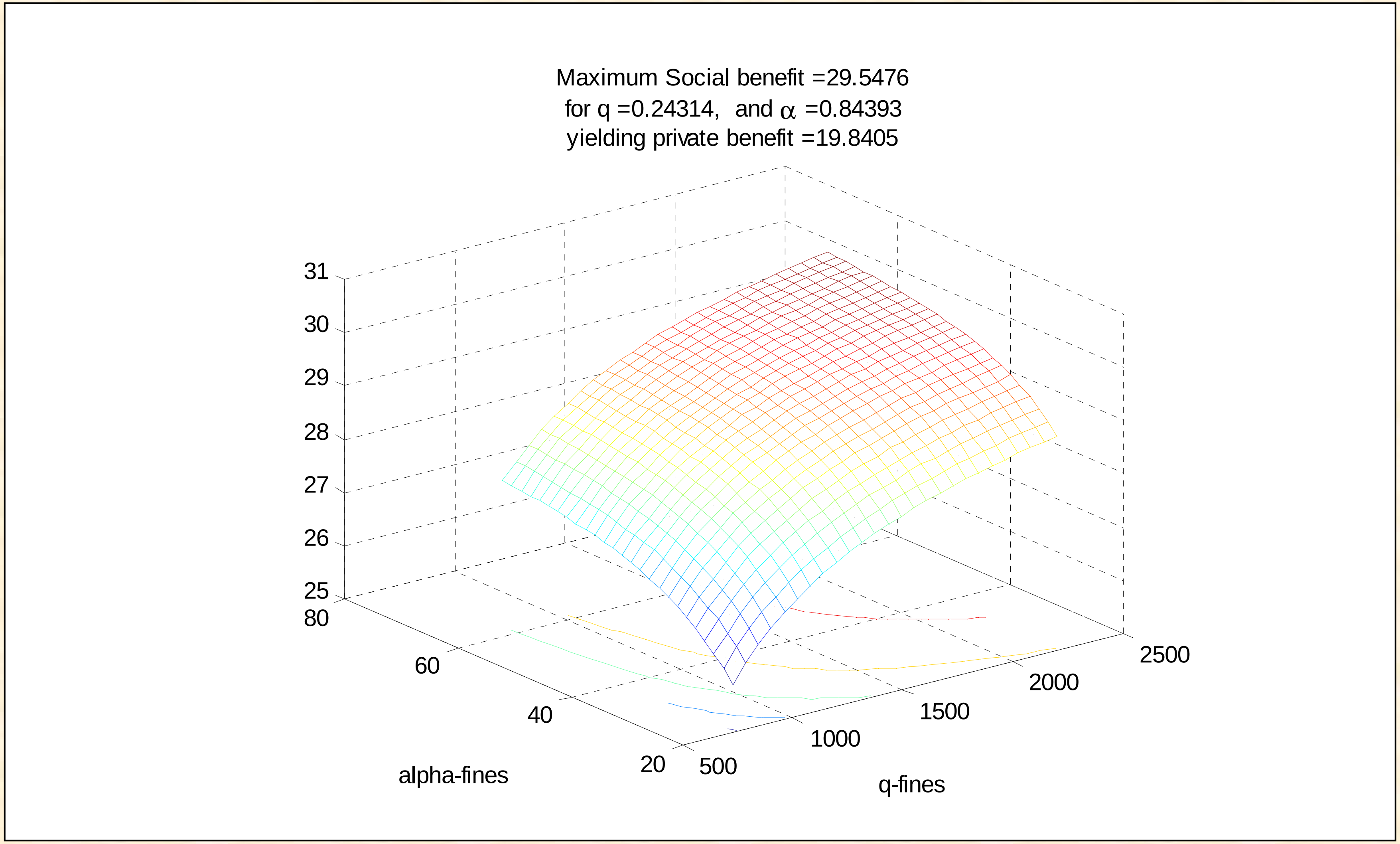
* The harvesting capacity level.

Numbers in parentheses indicate deviations from the management measures $q=0.215$ and $\alpha=1$

Optimizing surfaces



Sensitivity to fines



Sensitivity analysis

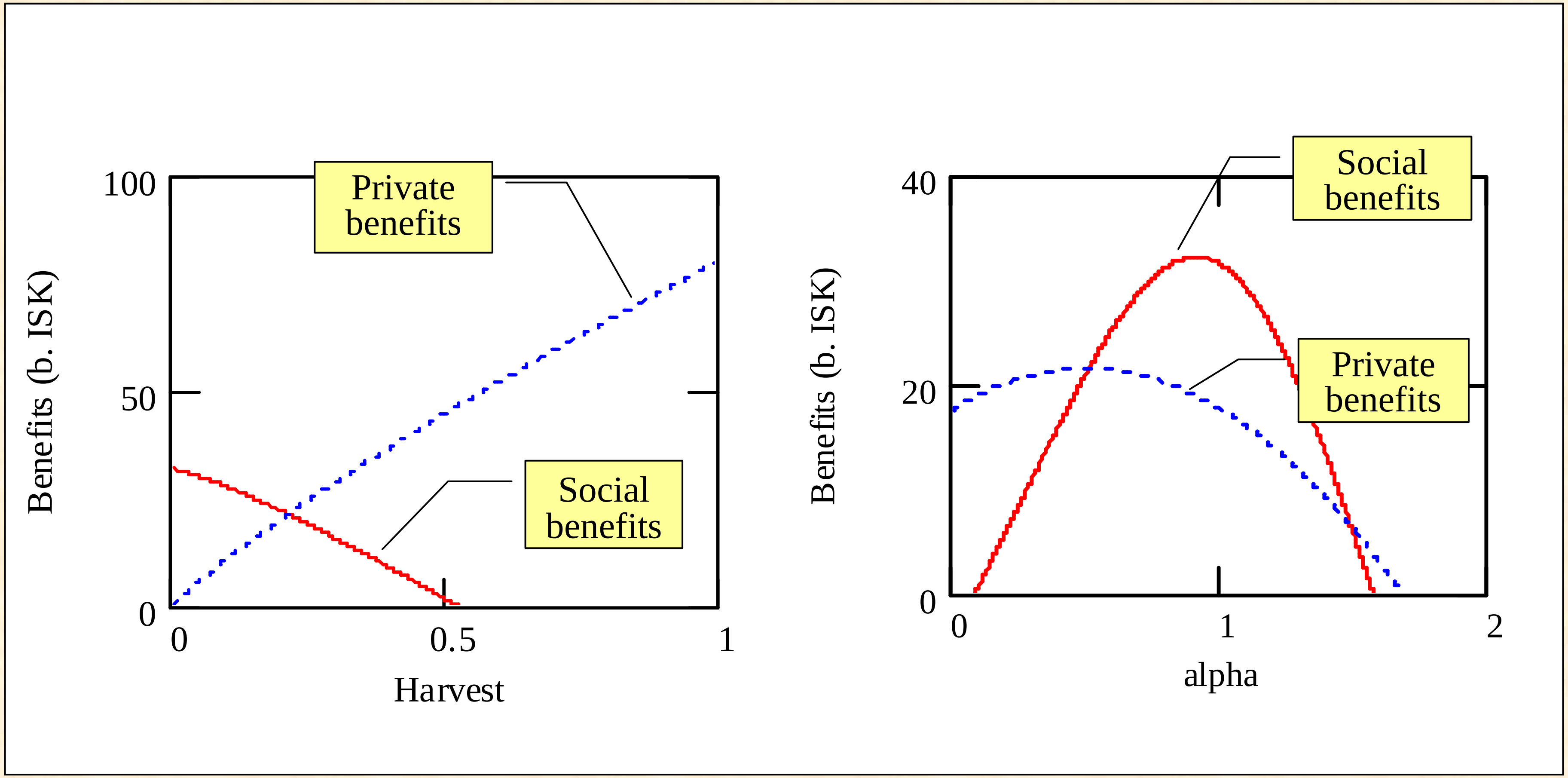
			Social benefits (B.ISK)	Private benefits (B. ISK)	Harvest q	Mesh-size α	Enforcement effort, e_1	Enforcement effort, e_2
Reference points								
Optimal enforcement			29.548	19.8405	.2431	.8439	.8554	0.2843
Voluntary compliance			31.463	17.6466	.2150	1.000	0	0
Parameters								
	Value	Base value						
Fine, f_q	1600	1476	29.715	19.760	.2411	.8449	.8221	.2818
Fine, f_q	1400	1476	29.431	19.897	.2446	.8433	.8777	.2862
Fine, f_q	3000	1476	30.918	19.025	.2290	.8846	.5901	.1599
Fine, f_α	30	40.9	29.082	20.139	.2437	.8098	.8729	.3641
Fine, f_α	50	40.9	29.738	19.668	.2428	.8637	.8456	.2290
E. cost c_1	0.1	0.185	29.659	19.808	.2426	.8455	1.163	.3838
E. cost c_1	0.3	0.185	29.432	19.874	.2437	.8424	.6725	.2250
Biomass x	0.9	0.715	39.003	26.520	.2536	.8634	.8089	.3124
Biomass x	.5	0.715	10.801	6.984	.2224	.8136	.5607	.2314

Findings

1. Application of enforcement theory to real fisheries enforcement situations is quite feasible
   - *N* actions and *M* enforcement tools
   - Data is the main constraint
2. Benefits of enforcement may be great compared to the costs
   - Depends on the fishery and the fisheries management system
3. Optimal enforcement complicated
   - Few simple rules of thumb


END

Figure 3



100
50
0
Benefits (b. ISK)
Private benefits
Social benefits
0
0.5
1
Harvest
40
20
0
Benefits (b. ISK)
Social benefits
Private benefits
0
1
2
alpha