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THE ARCTIC UNIVERSITY OF NORWAY

Use and non-values in applied bioeconomic model

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What do we want to achieve in this paper?

- Broader bioeconomic model than purely fisheries
- Ecosystem-based – include habitat
- Ecosystem services – include non-use values of habitat

=> Combine valuation and bioeconomic modelling for more holistic model of marine ecosystem services

Source: Institute of Marine Research, Bergen

Model of endogenous habitat change

- Fishery-habitat interaction:
  - Growth
  - Cost

- Two gear types:
  - Destructive (i.e. destructive to habitat)
  - Non-destructive

- Habitat is non-renewable - Cold-water corals (CWC)

Dynamic optimization without the non-use for the habitat

$$PVNB = \int_0^\infty e^{-\delta t}\left[\left(p - c_1(X,H)\right)h_1 + \left(p - c_2(X,H)\right)h_2\right]dt$$

a) Habitat is preferred

$$\frac{dX}{dt} = F(X) - h_1 - h_2$$

$$\frac{dX}{dt} = F(X, \underline{H}) - h_1 - h_2$$

b) Habitat is essential

$$\frac{dH}{dt} = -\alpha h_1$$

Non-renewable habitat

F(X,H) is the stock growth
X is the biomass of fish stock
H is the habitat
h_i is harvest (*i* harvesters; 1 and 2)
c_i is unit cost of harvest
p is unit price of harvest
α is the coefficient of habitat destruction perpetrated by harvest type 1
δ is the discount rate

Optimal management rules

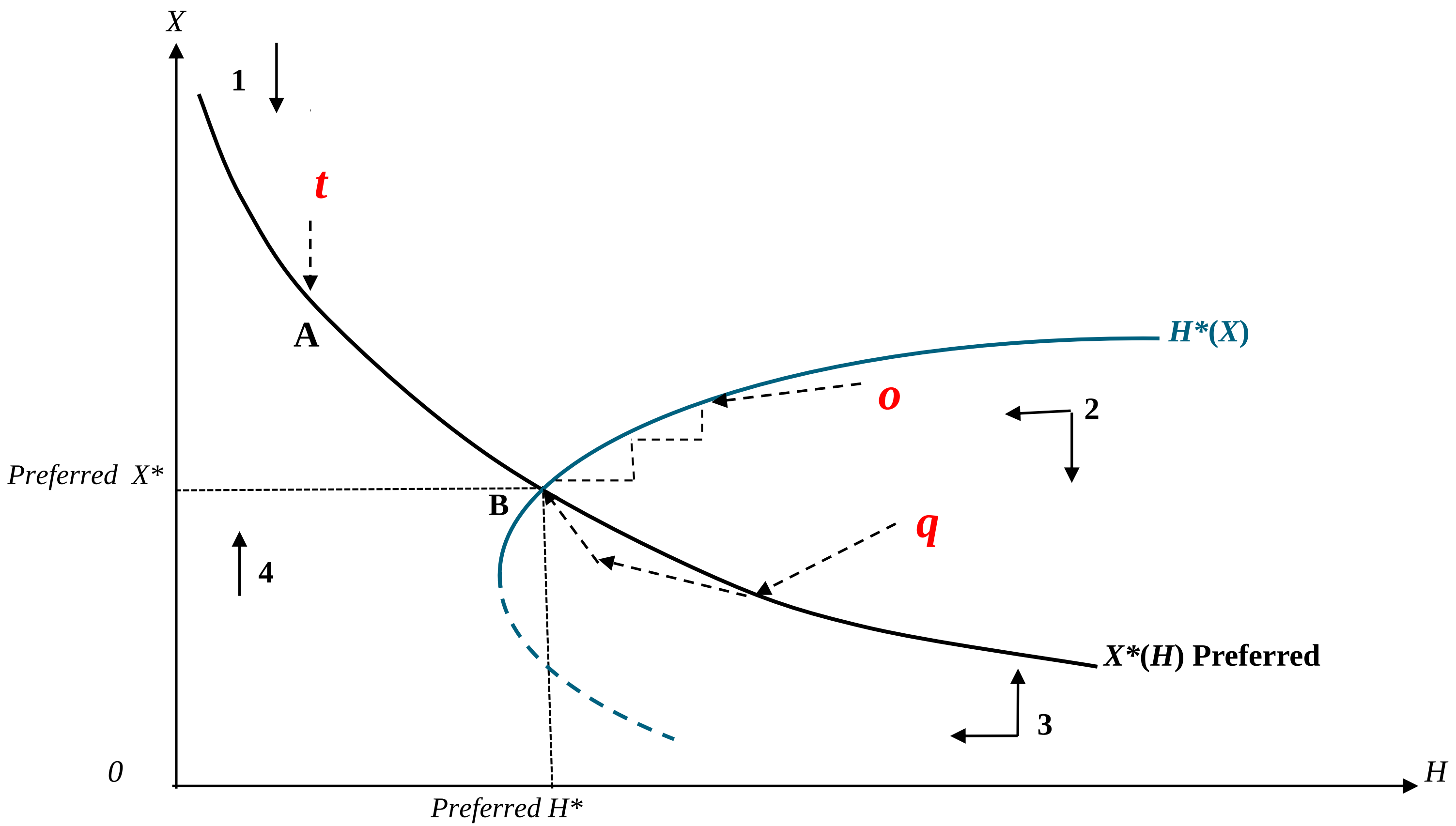
Preferred habitat

$$\delta = F_X(X^*) + \frac{-c_{2X}F(X^*) + \left(c_{2X} - c_{1X} + \alpha c_{2H}\right)h_1}{\left(p - c_2(X^*, H)\right)}$$

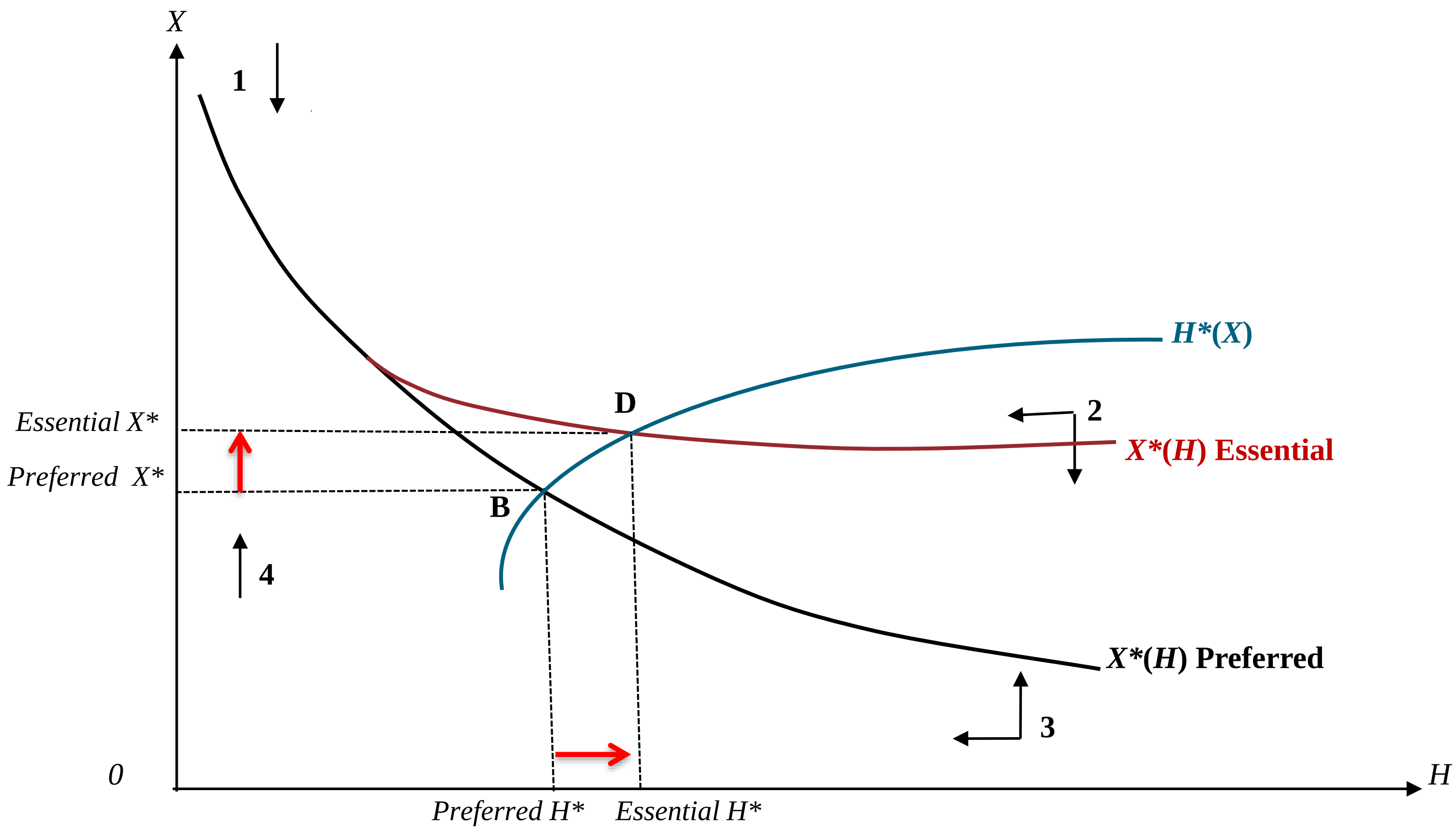
$$\delta = \frac{\left(c_{2X} - c_{1X}\right)F(X) + \left(c_{1X} - c_{2X} - \alpha c_{2H}\right)h}{\left(c_2(X, H^*) - c_1(X, H^*)\right)}$$

$$h = h_1 + h_2$$

Steady state analysis – preferred model



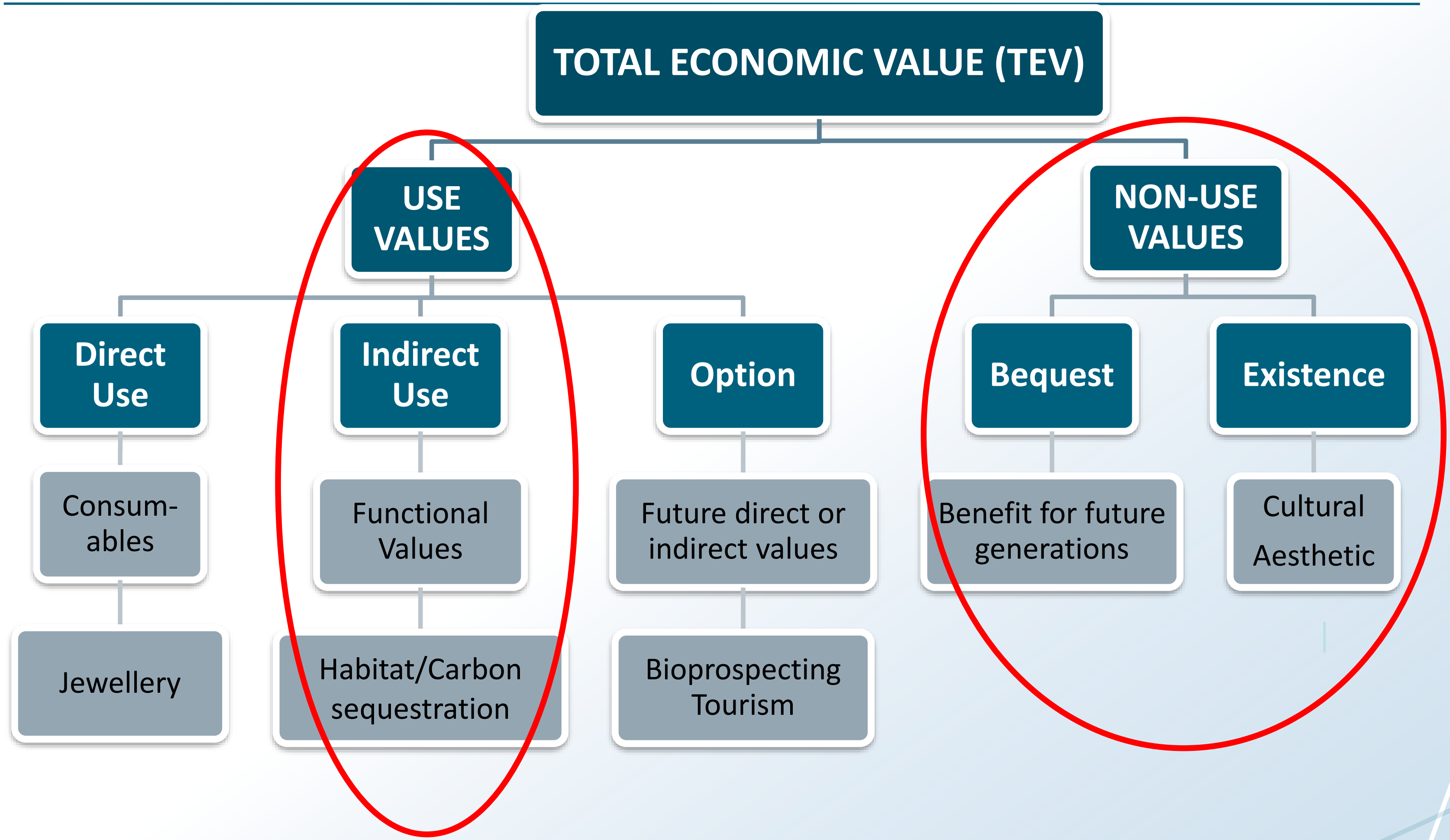
Steady state analysis – preferred and essential models



So far CWC only serves as habitat provider….

What about services that the habitat (e.g. CWC) may provide?

Components of TEV associated with CWC



How to manage fisheries when taking into account these values?

Adding non-fishery values $V(H)$:

$$PVNB = \int_0^\infty e^{-\delta t}\left[\left(p - c_1(X,H)\right)h_1 + \left(p - c_2(X,H)\right)h_2 + V(H)\right]dt$$

Habitat is preferred

$$\frac{dX}{dt} = F(X) - h_1 - h_2$$

$$\frac{dH}{dt} = -\alpha h_1$$

Nonrenewable habitat

F(X,H) is the stock growth
X is the biomass of fish stock
H is the habitat
h_i is harvest (i harvesters; 1 and 2)
c_i is unit cost of harvest
p is unit price of harvest
α is the coefficient of habitat destruction perpetrated by harvest type 1
δ is the discount rate
V(*H*) is the non-use value function

Optimal management rules

Preferred habitat

$$\delta = F_X(X^*) + \frac{-c_{2X}F(X^*) + \left(c_{2X} - c_{1X} + \alpha c_{2H}\right)h_1}{\left(p - c_2\left(X^*, H\right)\right)}$$

$$\delta = \frac{\left(c_{2X} - c_{1X}\right)F(X) + \left(c_{1X} - c_{2X} - \alpha c_{2H}\right)h + \alpha V_H}{\left(c_2(X, H^*) - c_1(X, H^*)\right)}$$

$$h = h_1 + h_2$$

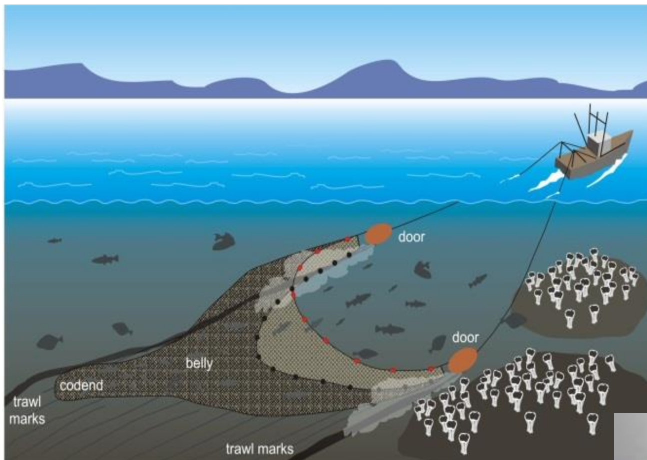
Data for simulation

- Applied fisheries modelling:
  - Norway - very good fisheries data on costs and benefits.
- But then how can we get data for non-use value function for habitat?
  - Stated preference – choice experiment

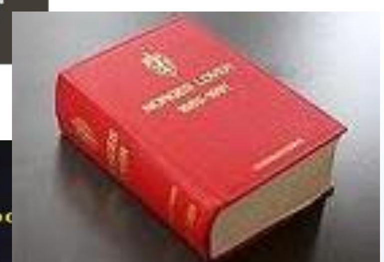
Attitudes and willingness to pay for protection

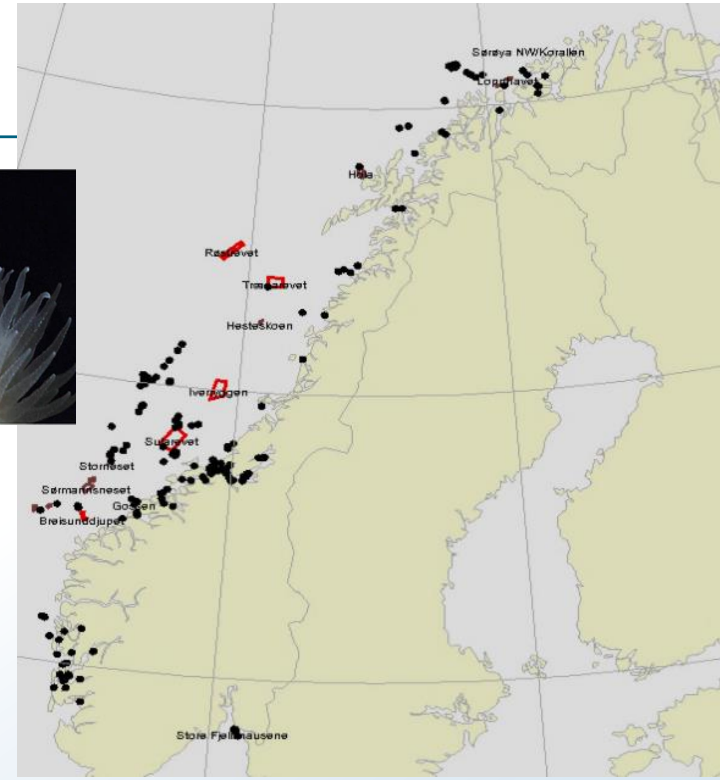
How do we capture this?

Bottom trawling may have damaged 30-50 % of CWC in Norway



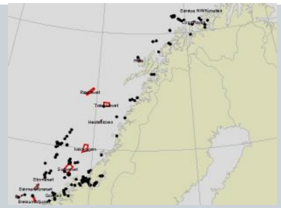
(after Christen, 1999)





- Slow growing; 4-25mm/year
- 2,445 km^2 protected
- Not allowed to damage on purpose

DISCRETE CHOICE EXPERIMENT

		Alternative 1	Alternative 2	Alternative 3 (no change)
Size of protected areas		5.000 km^2	10.000 km^2	2.445 km^2
Attractive for industry		Attractive for oil/gas	Attractive for fisheries	To some degree for both
Importance as habitat for fish		Not important	Important	To some degree
Cost per household per year to protect more cold water coral areas		100 kr/year	1000 kr/year	0
I prefer				

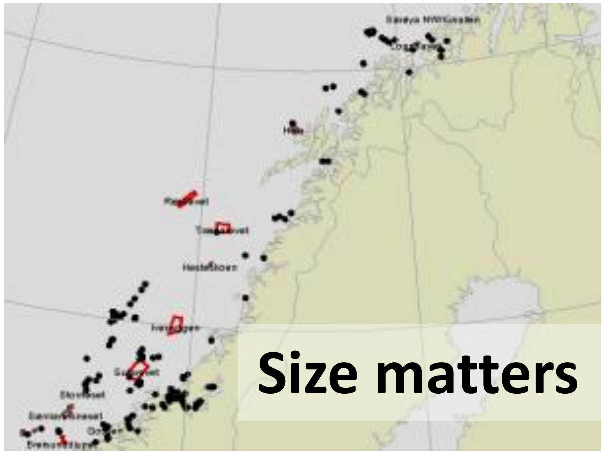
22 municipalities * 20 participants * 12 choice cards = 4800 choices

- average willingness to pay to protect more cold water coral
- preferences for what factors should be emphasised

Marginal willingness to pay (EUR) using GMXL model

Attributes	Mean (standard error)	Standard deviation (standard error)
SQ (ASC)	-172.13***	379.91***
	(25.73)	(31.58)
size (1 000 km^2)	-2.47	5.86*
	(2.96)	(03.08)
*oil/gas*size*5	-16.13	114.72***
	(13.51)	(14.29)
*oil/gas*size*10	6.78	135.61***
	(13.83)	(16.93)
*fishing*size*5	-7.77	106.27***
	(13.49)	(13.07)
*fishing*size*10	41.885***	138.24***
	(14.83)	(13.60)
*habitat*size*5	142.785***	153.55***
	(13.29)	(13.96)
*habitat*size*10	162.878***	145.75***
	(15.61)	(14.49)
cost	26.73***	68.95***

People willing to pay, but…



Recall the optimal management rule

$$\delta = F_X(X^*) + \frac{-c_{2X} F(X^*) + \left(c_{2X} - c_{1X} + \alpha c_{2H}\right) h_1}{\left(p - c_2\left(X^*, H\right)\right)}$$

$$\delta = \frac{\left(c_{2X} - c_{1X}\right) F(X) + \left(c_{1X} - c_{2X} - \alpha c_{2H}\right) h + \alpha V_H}{\left(c_2(X, H^*) - c_1(X, H^*)\right)}$$

But what functional form does *V*(*H*) have, if it exists?

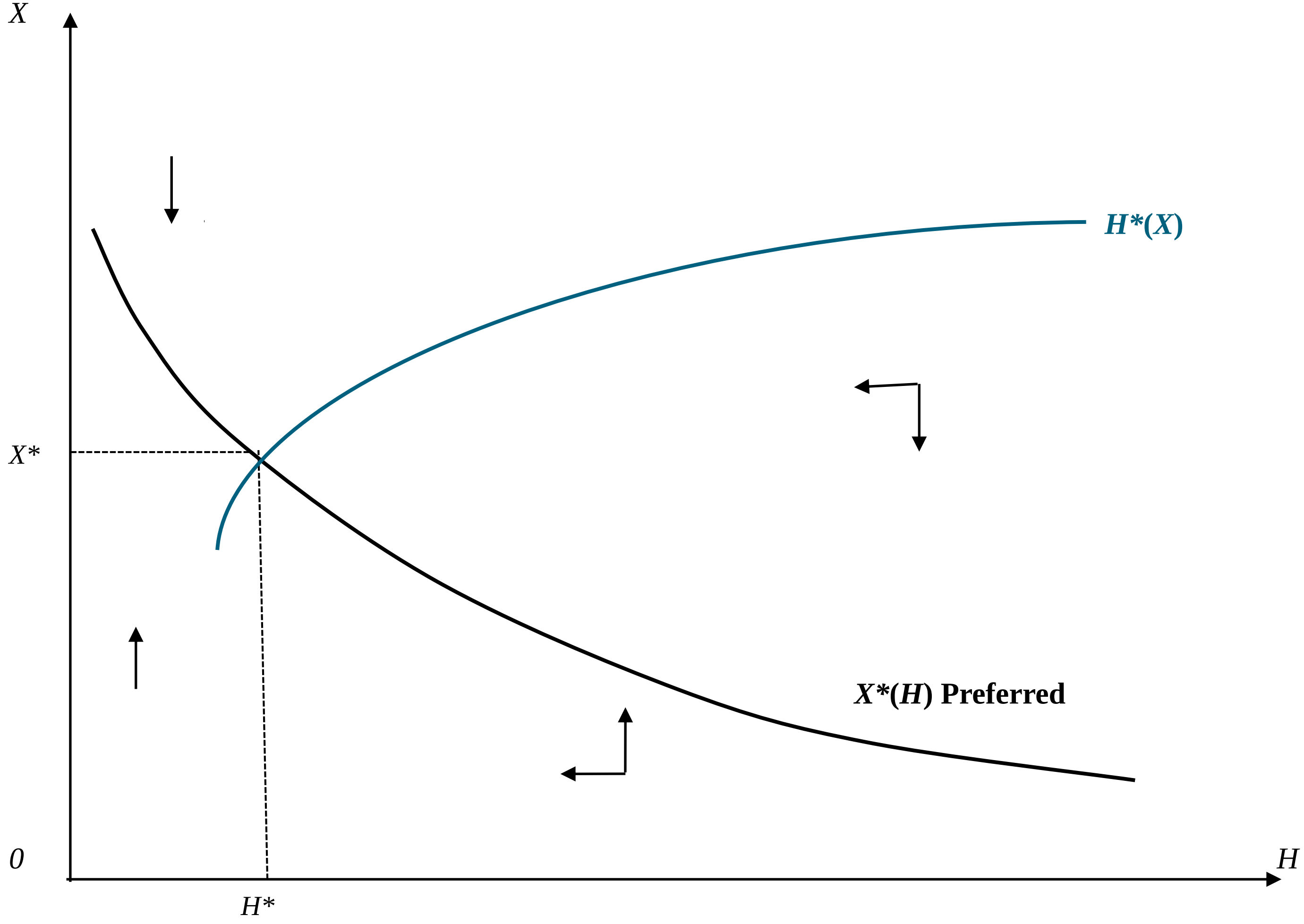
$$V(H) = b \log\left(H\right) + \gamma$$

Non-use value

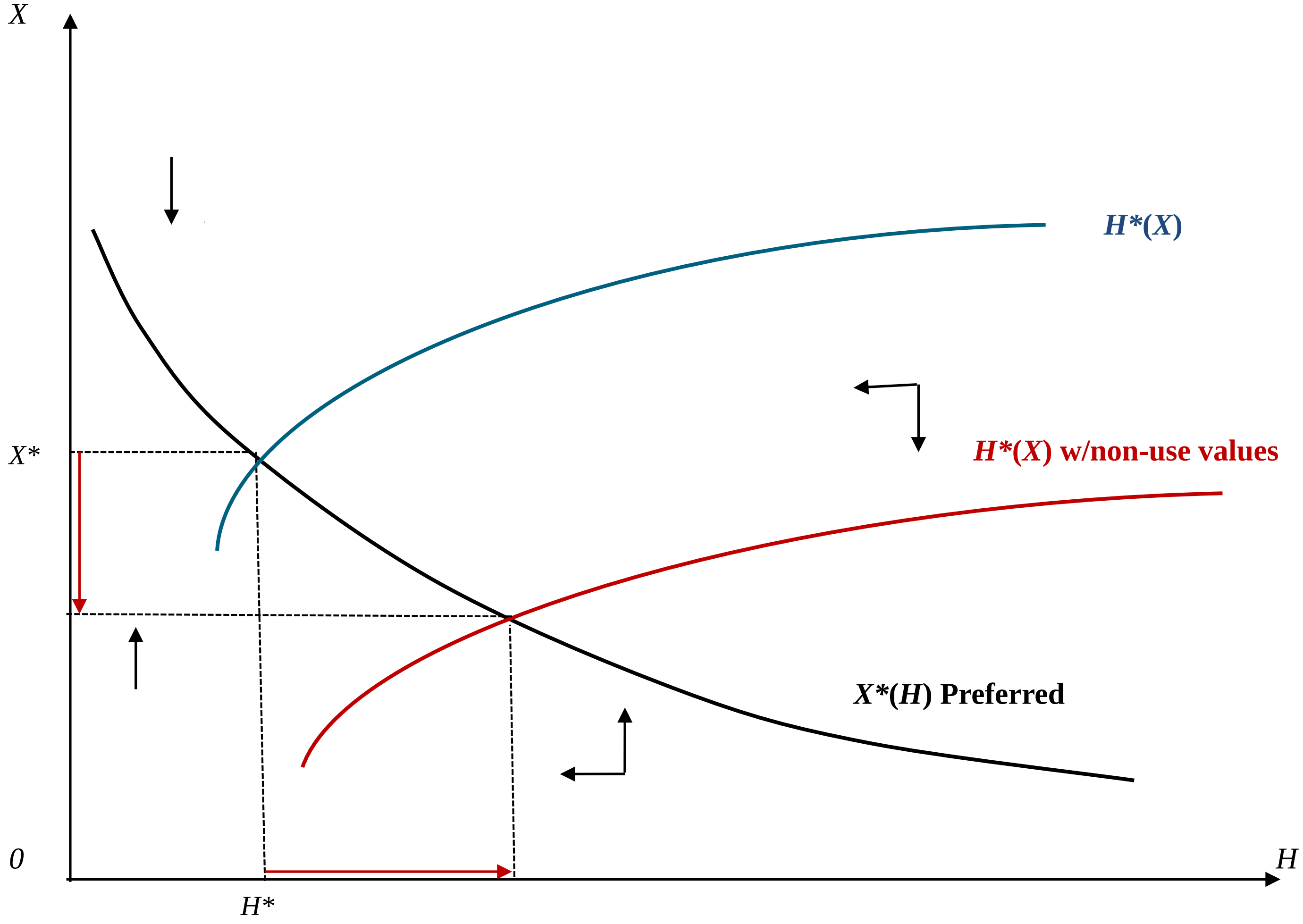
$$R^2 = 0.9545$$

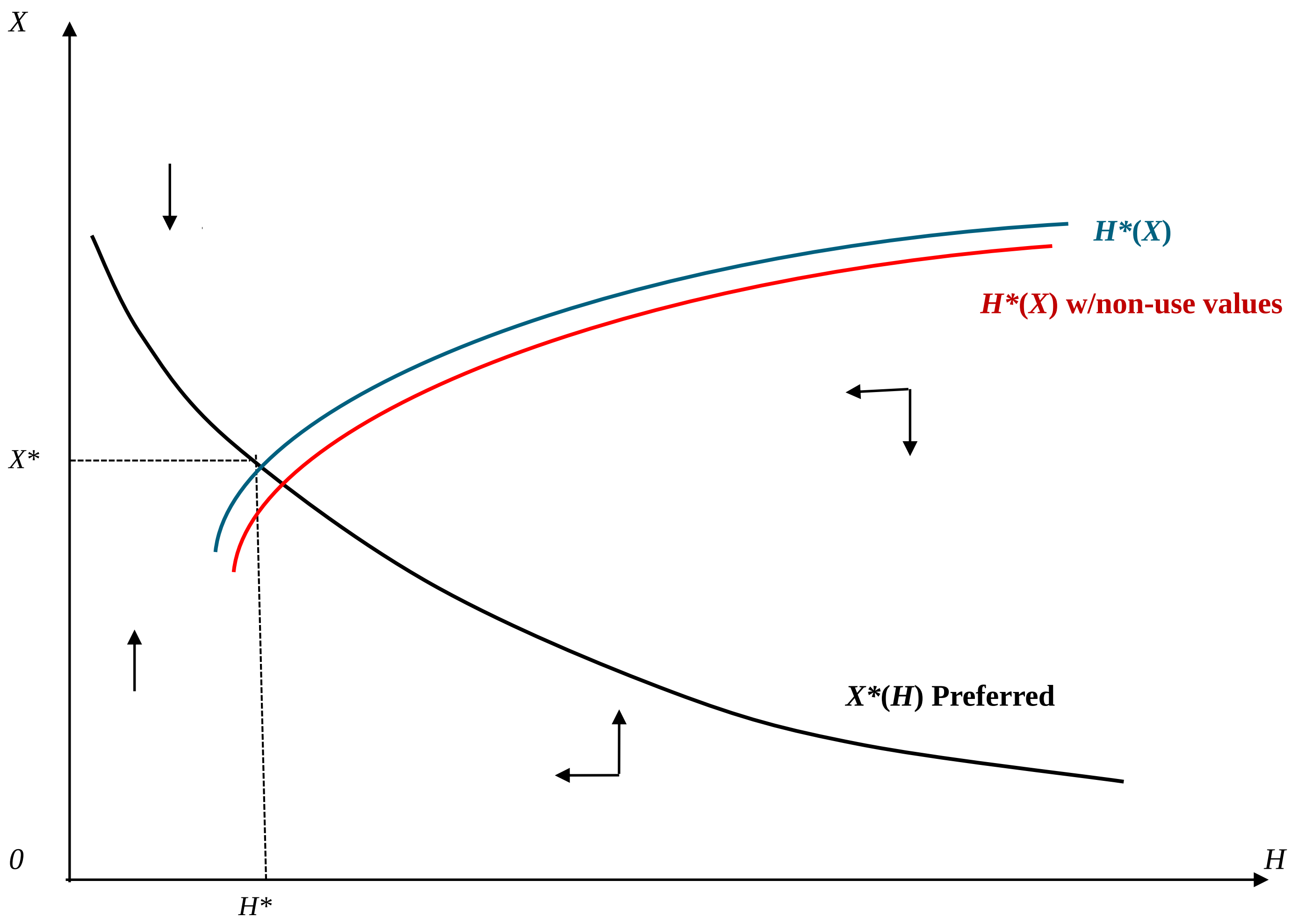
Parameter	Measure	Source/explanation
δ	0.05	Eide & Heen (2002); EC (2008)
r	0.6	Armstrong (1999)
α	0.00000001	Guesstimate
K	4500000	ICES (2014)
w_1	18 400 861	Anon (2010, 2011, 2012, 2013)
w_2	2332078	Anon (2010, 2011, 2012, 2013)
q_1	0.0011832	Anon (2010, 2011, 2012, 2013)
q_2	0.0000692	Anon (2010, 2011, 2012, 2013)
h_1	0	Equilibrium requirement
h_2	670000	Assumed close to MSY
p	10246.6	Fisher's Sale Org. (2010, 2011, 2012, 2013)
b	1266.7	Valuation study data
H	2 349 460	Statistics Norway (2014)

Steady state analysis – Preferred model for CWC and North East Arctic cod fishery data



Steady state analysis – Preferred model for CWC and North East Arctic cod fishery data and non-use values




X
X*
0
H*
H
H*(X)
H*(X) w/non-use values
X*(H) Preferred

10% increase in	WITHOUT NON-USE VALUES				WITH NON-USE VALUES			
	L^*	X^*	% change in L^*	% change in X^*	L^*	X^*	% change in L^*	% change in X^*
Baseline	1.50295	3282040	NA	NA	1.52091	3268020	NA	NA
δ	1.42050	3344350	-5.5	1.9	1.4356	3331110	-5.6	1.9
r	1.31484	3453830	**-12.5**	5.2	1.32529	3443240	**-12.9**	5.4
α	1.51653	3271430	0.9	-0.3	1.53668	3256210	1.0	-0.4
K	1.16525	3832100	**-22.5**	**16.8**	1.17495	3820010	**-22.7**	**16.9**
w_1	1.51568	3272100	0.8	-0.3	1.53569	3256910	1.0	-0.3
w_2	1.62999	3298660	8.5	0.5	1.64740	3285860	8.3	0.5
q_1	1.49317	3289680	-0.7	0.2	1.50960	3276850	-0.7	0.3
q_2	1.39146	3260850	-7.4	-0.6	1.41039	3245290	-7.3	-0.7
h_2	2.07632	2955050	**38.1**	**-10.0**	2.13133	2932810	**40.1**	**-10.3**
p	1.37867	3271370	-8.3	-0.3	1.39405	3258720	-8.3	-0.3
b	1.50295	3282040	NA	NA	1.52274	3266580	0.1	0.0
g	1.50295	3282040	NA	NA	1.52231	3266920	0.1	0.0
Households	1.50295	3282040	NA	NA	1.52274	3266580	0.1	0.0

Conclusions

- We broaden existing bioeconomic models to go beyond pure fisheries.
  - Derive optimal management rules.
- We conduct stated preference to estimate the non-use value and use that in the model.
- We perform sensitivity analyses on optimal rules.

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