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Economics of the Global Marine Fishery: Changes between 2004 and 2012

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Background

- Fisheries are globally important economic activity
- Fisheries economics predicts huge waste in common property/pool fisheries
  - Various empirical studies support that
  - But global estimates missing
- WB and FAO organized a study in 2006
  - Kelleher, Willmann & Arnason
- Results published in 2009; “Sunken Billions”
  - Estimate for 2004: $51 billion; $\alpha_{0.95}$=[26,73] b.$

- In 2014, World Bank commissioned a “Sunken Billions” update (Jim Anderson)
- Work conducted 2014-15
  - Collaboration with FAO, UCSB & CEA (bottoms-up micro approach)
- Report submitted in August 2015
  - WB still preparing the official report

Methodological considerations

- The global marine fishery
  - Thousands of different fisheries
  - Very limited and unreliable data
  - ⇒ Data poor situation!
- Approach: Aggregation; One single fishery
  - Disadvantages: Huge simplification
    - ⇒ Aggregation errors, gloss over differences
  - Advantages: Robust, manageable, transparent

Model

(Condensed form)

$$x(t+1) - x(t) = G(x(t)) - Y(e(t), x(t))$$

$$\pi(t) = P(x(t)) \cdot Y(e(t), x(t)) - C(e(t))$$

Four basic functions:

- Biomass growth: $G(x)$,
- Harvesting: $Y(e,x)$,
- Price of catch: $P(x)$,
- Cost of effort: $C(e)$

Biomass growth

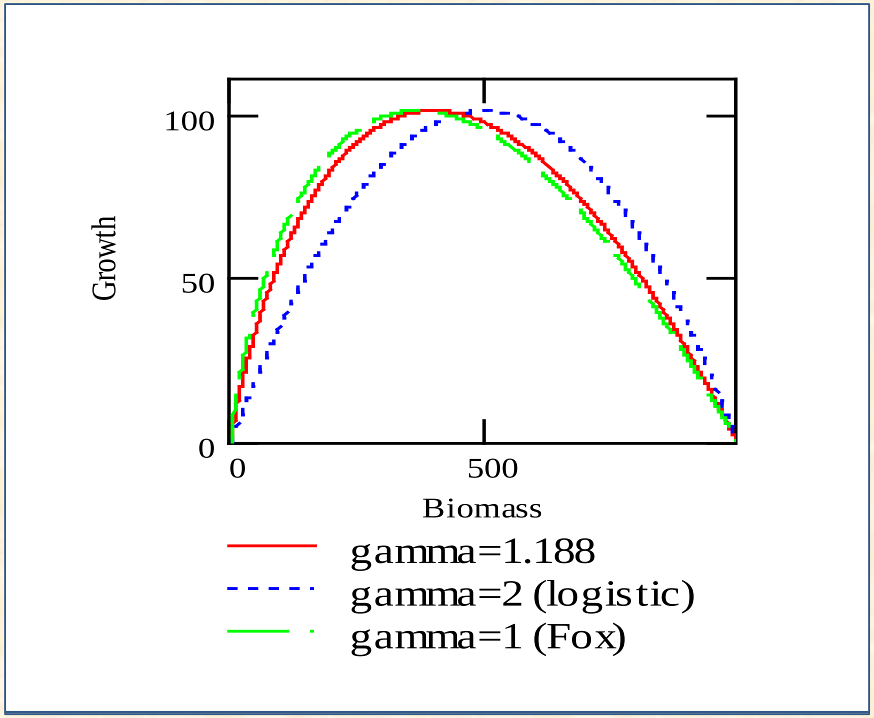
Pella-Tomlinson: $G(x) = \alpha \cdot x - \beta \cdot x^{\gamma}$

Pella-Tomlinson parameter: γ

$\gamma = 2 \Rightarrow$ Logistic

$\gamma \to 1 \Rightarrow$ Fox

$2 > \gamma > 1 \Rightarrow$ some other shape



The other functions

Harvesting function: $Y(e,x) = q \cdot e \cdot x^b$

Cost function: $C(e) = c \cdot e + fk$

Price function: $P(x) = a \cdot x^d$

Estimation of parameters

Severe lack of global data

- Time series: Global harvests (some on prices, fleets)
- Some estimates of global biological parameters
- Quality/reliability poor

∴ Typical data poor situation

Estimation procedure

Mix of empirical data and model implictions

$\dot{x}$

Empirical data

	Symbol	Unit	Value
Parameters			
Maximum sustainable yield	*msy*	Million mt.	102.0
Biomass carrying capacity	*xmax*	Million mt.	980.0
Pella-Tomlinson exponent	γ	None	1.188
Schooling parameter	*b*	None	0.71
Elasticity of demand w.r.t. biomass	*d*	None	0.22
Base year variables (2012)			
Landed volume	*y*	Million mt	79.7
Landings price	*p*	US$/kg	1.26
Net biomass growth	$\dot{x}$	Million mt	8.0
Profits	π	Billion US$	3.0

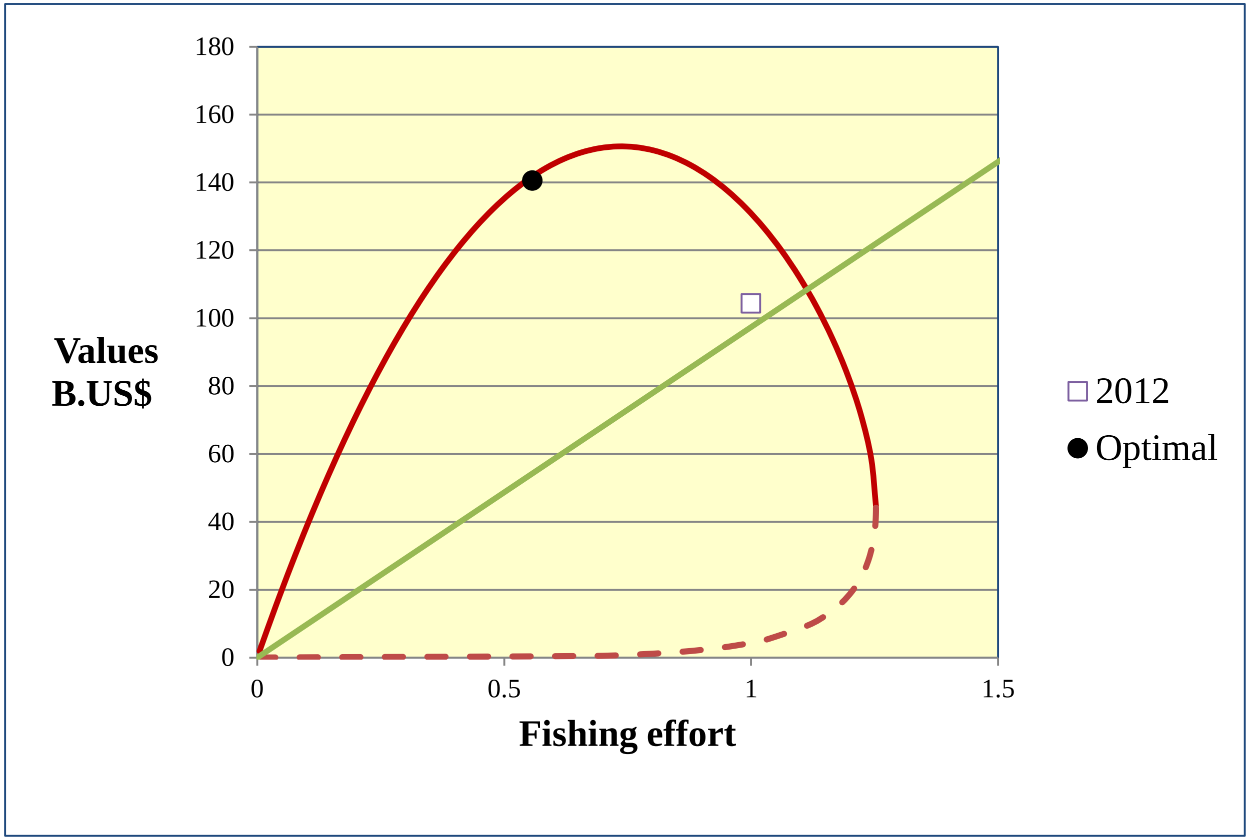
Model structure (Formulae to calculate parameters)

Unknowns	Estimation formulae
α	$\hat{\alpha} = \left(\frac{msy}{xmax}\right) \cdot \left(\frac{\gamma^{\frac{\gamma}{\gamma-1}}}{\gamma - 1}\right)$
β	$\hat{\beta} = \left(\frac{msy}{xmax^{\gamma}}\right) \cdot \left(\frac{\gamma^{\frac{\gamma}{\gamma-1}}}{\gamma - 1}\right)$
q	$\hat{q} = \frac{y(t_0)}{e(t_0) \cdot x(t_0)^b}$
c	$\hat{c} = \frac{p(t_0) \cdot y(t_0) - \pi(t_0) - fk}{e(t_0)}$
a	$\hat{a} = \frac{p(t_0)}{\hat{x}(t_0)^d}$
$x(t_0)$	$\hat{G}(\hat{x}(t_0)) = y(t_0) + \dot{x}(t_0)$
$e(t_0)$	1

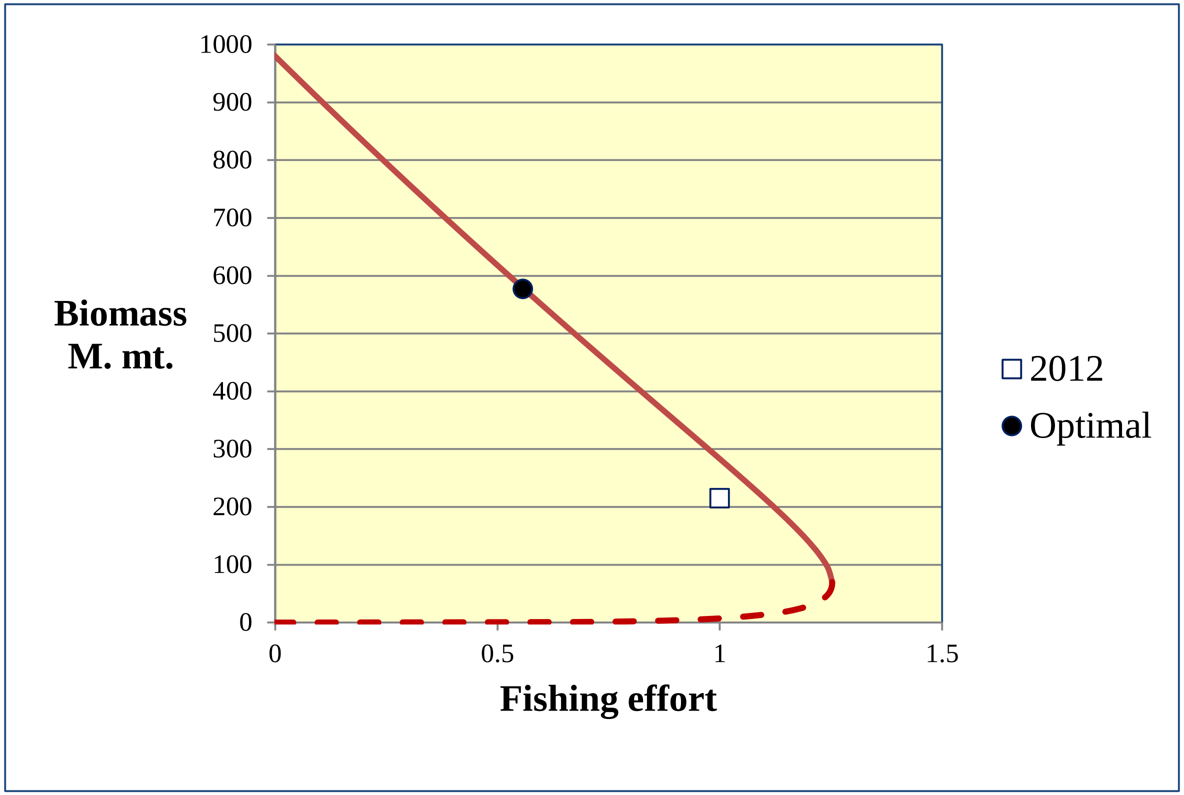
Model implied parameters & base year values

	Characterization	Values
Biological coefficients		
α	Intrinsic growth rate	**1.644**
β		**0.45**
Bio-economic coefficients		
q	Catchability	**1.76**
Economic coefficients		
c	Marginal cost parameter	**97.4**
fk	Fixed costs	**0**
a	Landings price parameter	**0.39**
Base year (2012) variables		
$e(2012)$	Fishing effort	**1.0**
$x(2012)$	Biomass	**214.9**

The sustainable fishery in 2012
(Effort-value space)



The sustainable fishery in 2012
(Effort-biomass space)

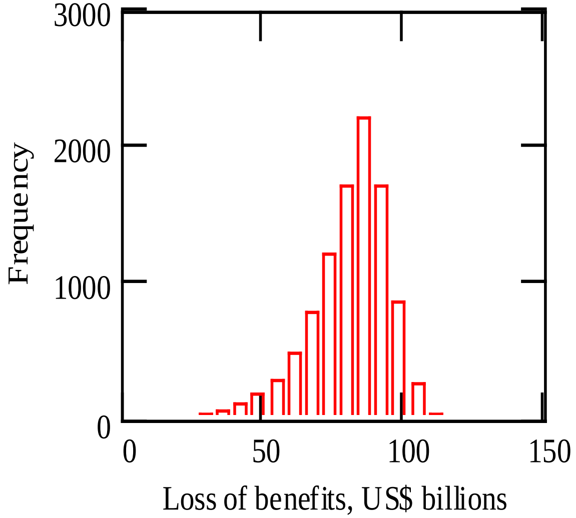


Global fishery 2012: Basic estimates

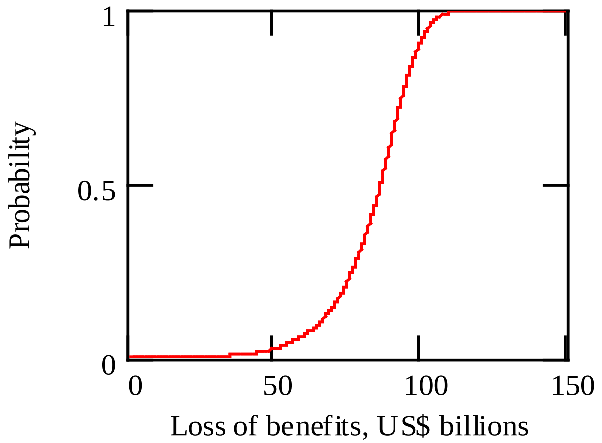
Variables	Units	2012 Base case	Optimal equilibrium	Difference	Optimal/ current
Biomass	m.mt	214.9	578.6	363.7	2.692
Harvest	m.mt	79.7	89.7	10.0	1.126
Effort	Index	1.000	0.557	-0.443	0.557
Land. Price	US$/kg	1.26	1.567	0.31	1.244
Revenues	B. US$	100.422	140.6	40.2	1.400
Costs	B.US$	97.422	54.3	-43.1	0.557
Profits	B.US$	3	86.3	83.3	28.767

Probability distribution of the estimated loss of attainable economic benefits

Density function



Distribution function



The Sunken Billions in 2012

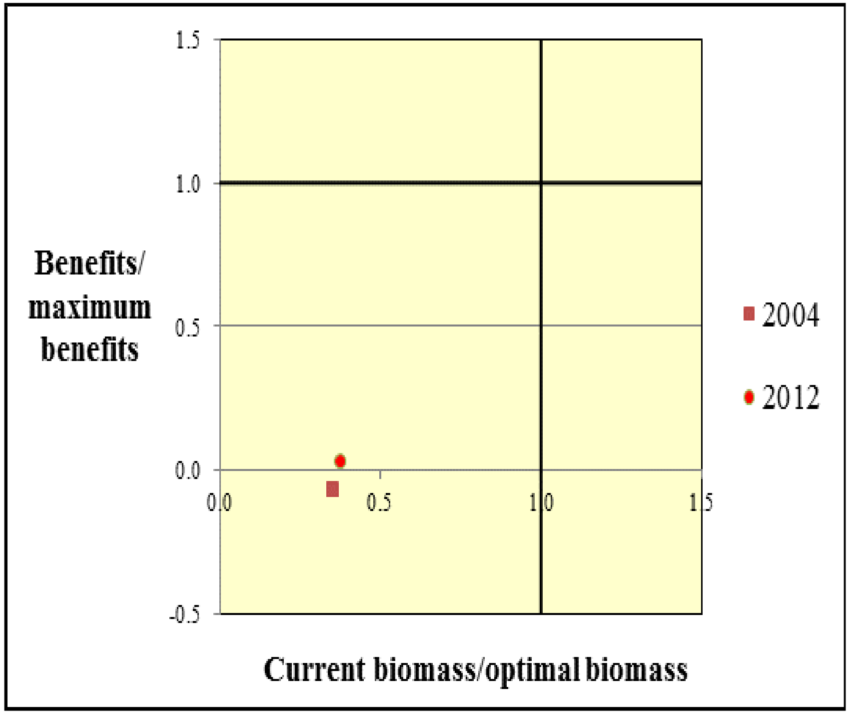
Point estimate: 83 B. US$*

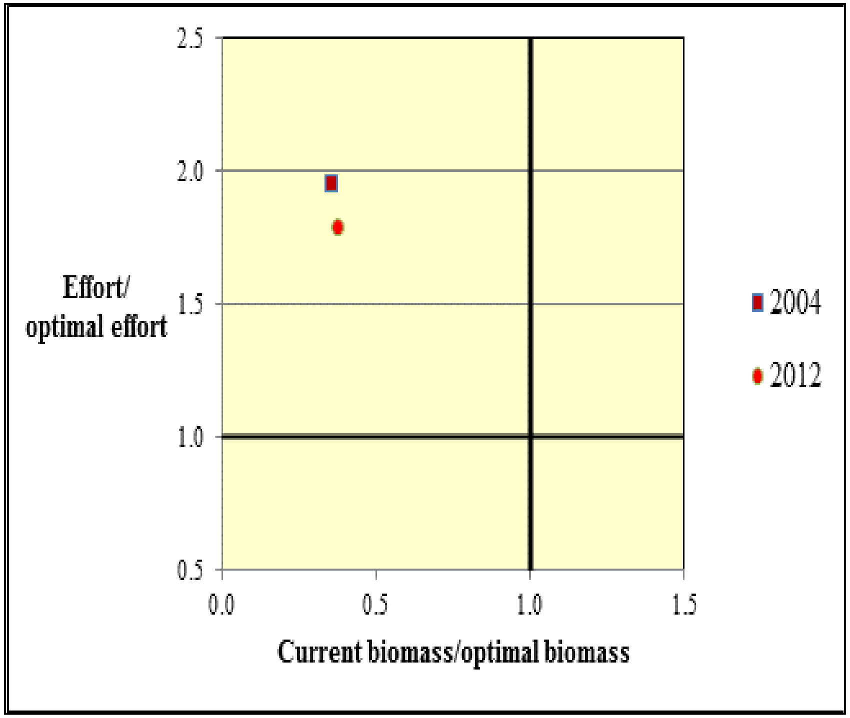
95% confidence interval: [50,105] B. US$

*Comparable figure in 2004 is: **87.5** B. US$

Evolution 2004 to 2012
(Kobe-diagrams)

Same model for both years, updated 2004 data

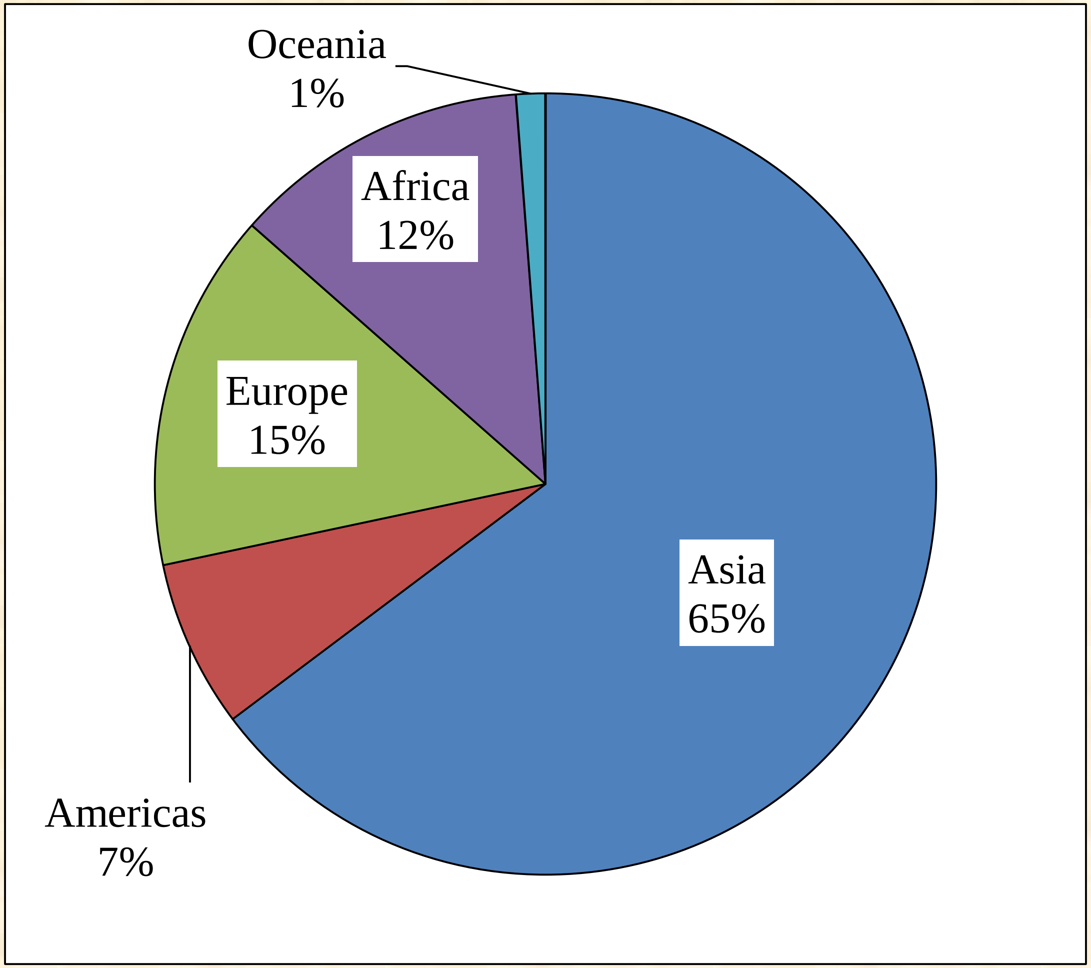




Continental results

- Same methodology
- Less reliability
  - Continental data less reliable
  - Much less scrutiny of the data and the results

Contributions to the “Sunken billions”



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Model unknowns

Nine parameters:

Biomass growth: α, β, γ

Harvesting: q, b

Cost: c, fk

Price: a, d

Two base year variables:

Biomass: $x(t_0)$

Fishing effort: $e(t_0)$

Estimation

Unknowns	Symbol	Basic for estimation
Biological coefficients		
Biomass growth function	α	Biological estimates of global *msy*, *xmax* & model structure
Biomass growth function	β	Biological estimates of global *msy*, *xmax* & model structure
Biomass growth function	γ	Global biological estimate
Bio-economic coefficients		
Harvesting function	q	Data on $y(t_0)$, $e(t_0)$ & model structure
Harvesting function	b	Bio-economic estimates
Economic coefficients		
Cost function	c	Data on $y(t_0)$, $e(t_0)$, $\pi(t_0)$ & model structure
Cost function	fk	Zero by long run theory
Price function	a	Data on fish prices & model structure
Price function	d	Data on fish prices, estimates of impact of larger stocks
Base year variables		
Biomass	$x(t_0)$	Estimated *msy*, *xmax*, $\dot{x}(t_0)$, data on $y(t_0)$ & model structure
Fishing effort	$e(t_0)$	Unity by normalization

The stochastic specifications

Input data	Type of distribution	Point estimate	Standard deviation*
Maximum sustainable yield, *msy*	Log-normal	102	0.03
Carrying capacity, *xmax*	Log-normal	980	0.15
Biomass growth, $\dot{x}(t^*)$	Normal	8.0	4.0
Landings, $y(t^*)$	Log-normal	79.7	0.01
Net profits, $\pi(t^*)$	Normal	3.0	3.0
Landings price, $p(t^*)$	Log-normal	1.26	0.04
Pella-Tomlinson exponent, γ	Log-normal	1.188	0.2**
Schooling parameter, *b*	Log-normal	0.71	0.05
Elasticity of landings price, *d*	Normal	0.22	0.02

* For lognormal distributions, the standard deviation may be interpreted as an approximate percentage deviation

** The stochastic γ is defined as $\gamma=1+u$, where u is the stochastic variable

The Costello bottoms-up approach

Data on 4.373 fisheries ≈ 77% of global catch volume
Just conservation, no price gains
Estimated gains

Profits: $ 74 B.	SB: $ 83 B. [50-105]
Biomass: 531 m.mt.	SB: 364 m.mt
Harvest: 26 m.mt.	SB: 10 m.mt.

Totally different approach (micro-based)
But, similar “ballpark” results

Change from current to optimal

	Asia	Americas	Europe	Africa	Oceania	Sum
Biomass, m.mt	176.6	59.7	69.7	29.8	7.1	342.9
Harvest, m.mt	3.0	1.1	3.0	1.9	0.3	9.3
Effort, index	-0.52	-0.26	-0.34	-0.51	-0.19	NR
Price US$/kg	0.40	0.10	0.25	0.52	0.13	NR
Revenues, B. US$	22.4	2.8	7.7	6.6	0.6	40.2
Costs, B.US$	-32.4	-3.0	-4.9	-3.8	-0.4	-44.4
Net economic benefits B.US$	54.8	5.9	12.5	10.4	1.0	84.6