Real Option Value of Climate Policy in Regional IAM

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Modeling climate policy under uncertainty

- Initially selected policy will be corrected in the future;
- Modeling learning:
  - Complicated framework;
  - Assumption regarding learning;
- Modeling cost of adjustment;
- Adjustment = dynamic hedging;

Methodology

Why Real Options?

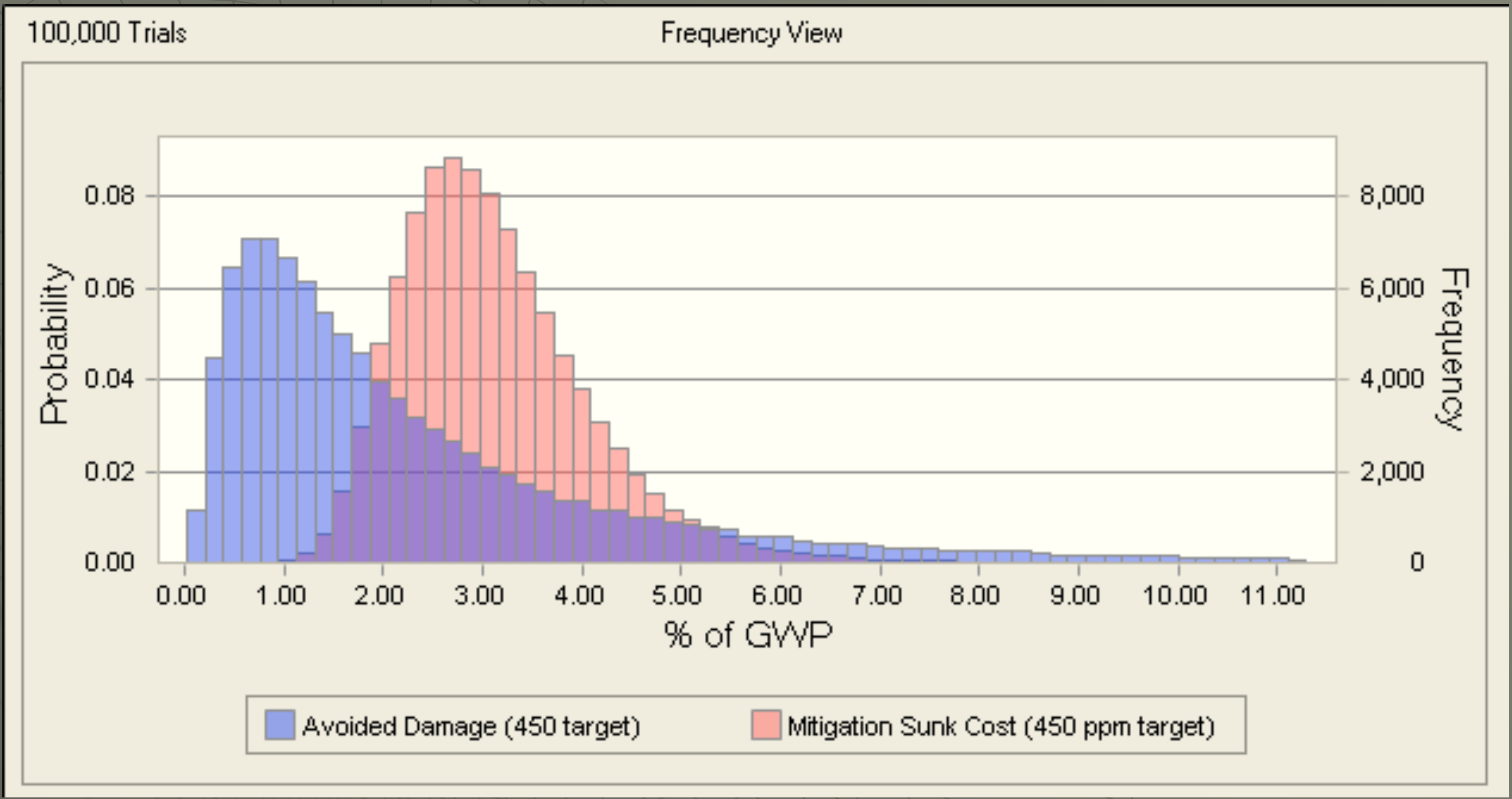
Dynamic Hedging

Numerical Solution

Why Real Option Value?

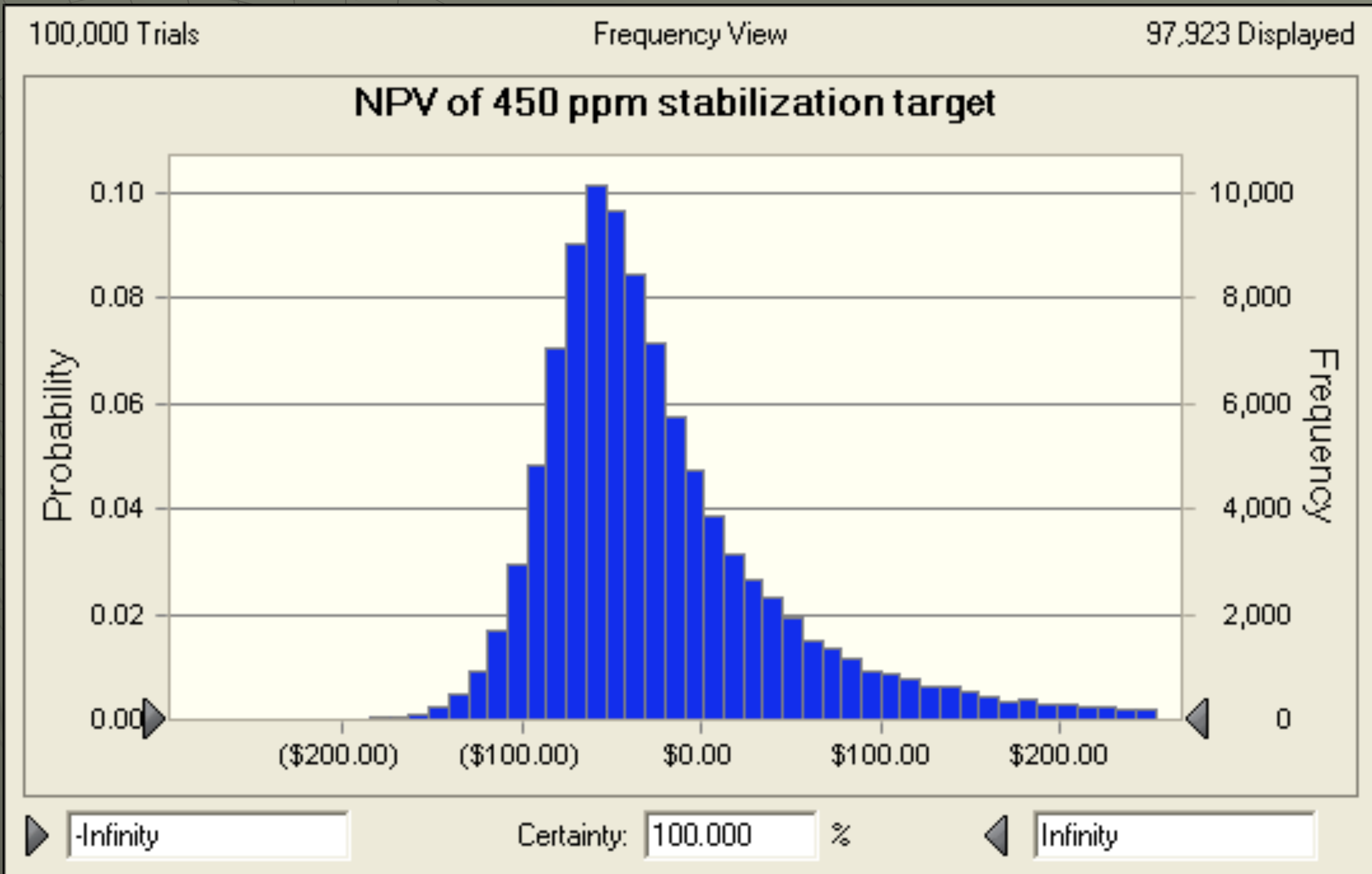
- Damage Variance > Cost Variance
- Damage Skew > Cost Skew
- NPV Ignores Relative Distribution Profile
- In NPV, Discount Rate drives Stringency
  - Tail skimming is a more useful debate than SDR
  - Tail skimming is essentially dynamic hedging
- Geo-engineering is an inherent Put Option
- Policy Flexibility highlighted by ROA Framing

At Median - 450 Target Uneconomic



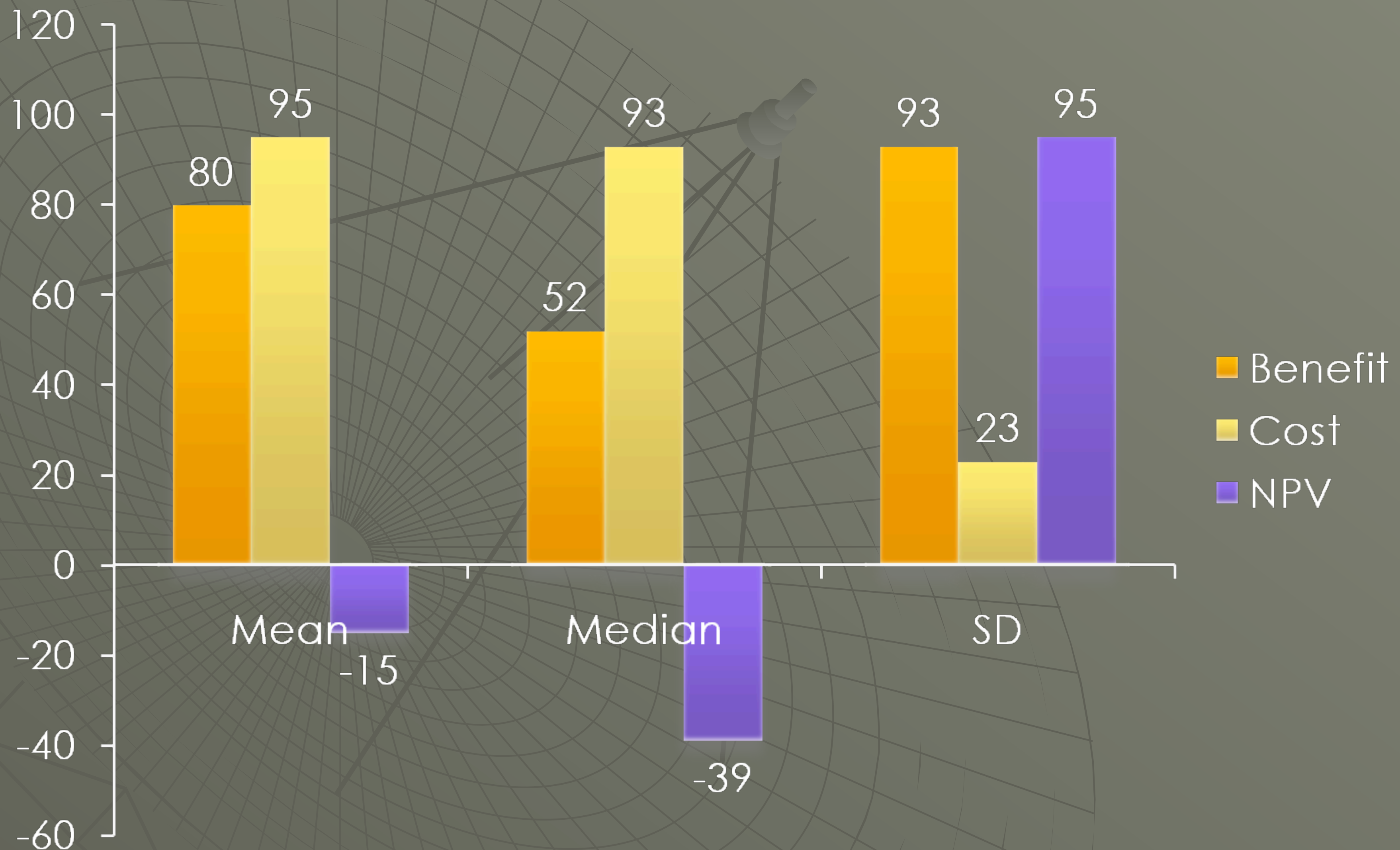
NPV Stringency Choice:

Perversely, well above median without tail skimming



NPV SD Indicates Need for New Tool

Monte Carlo simulation, discounted to 2010 in $ trillion



ROV Pricing of an Emissions Target

- Cost of each emission target includes:
  - Optimization period damages attributed to the emission pathway
  - Anticipated abatement cost to keep emissions on that pathway
  - (*note: selected target may be adjusted later*)
- To emit targeted carbon, society “shorts” adaptation
  - To hedge, society buys a call option on adaptation services
  - So “hedging cost” of the call option is added to direct policy costs
- Risk free damage = expected damage + call value
- Initial target:
  - Minimize anticipated direct plus hedging costs
  - Hedging portfolio may include calls on both abatement & adaptation
- Conceptually different from traditional IAM approach
  - Higher production vs. productivity loss from climate change
  - Society is buys back damages via adaptation cost

Dynamic Climate Hedging

- Initial target:
  - Concentration target C_0 selected
    - based on best knowledge of cost and benefits distribution
  - $Z'(C_0) - D'(C_0) = ROVD'(C_0) - ROVZ'(C_0)$
    - Δ marginal expected value = Δ marginal option value
- New knowledge = New concentration target
  - Feedbacks in the climate system greatest unknown
- Selected policy may be sticky
  - Built-in flexibility very beneficial
    - Low cost offsets
    - Strategic allowance reserve (set aside upfront)

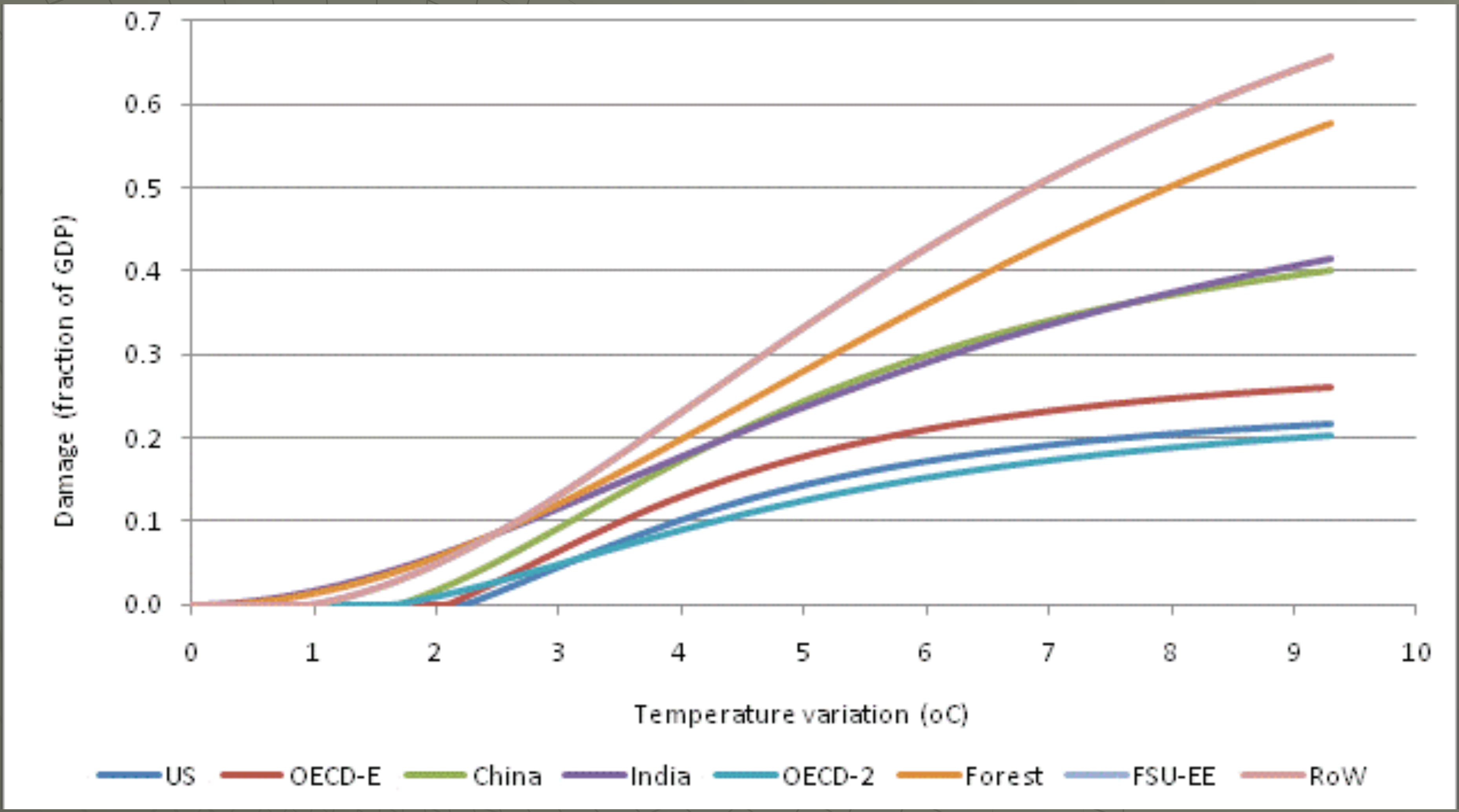
DICER Model

Description

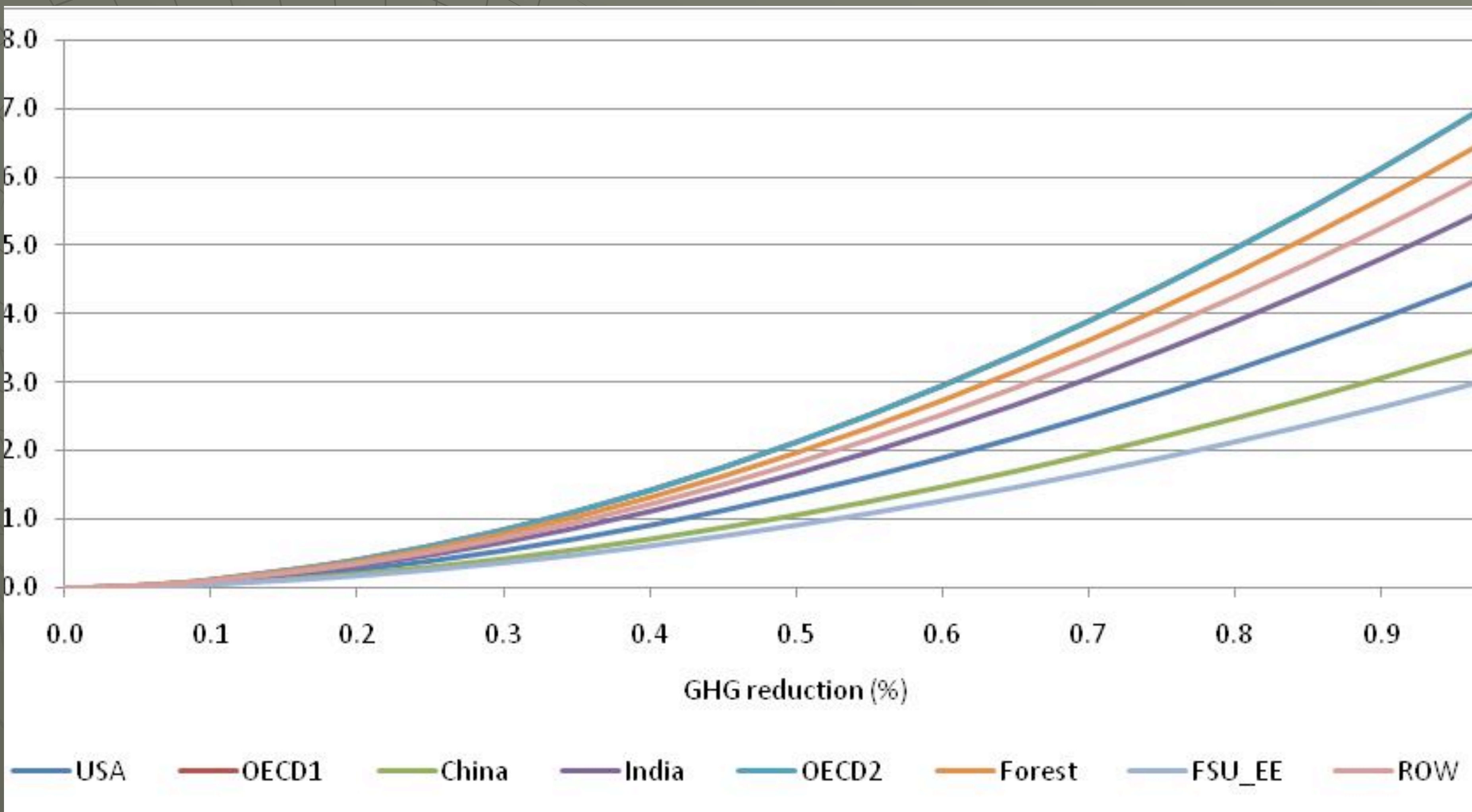
Option Value

Results

Cap on damage



Lower MAC and higher AAC



Concept of a Climate Asset

- Output (Y) is a function of:
  - capital (K)
  - GHG concentration (C)
  - $Y=r(1-\theta)F(K,C)$
- Output (Y) subject to productivity shocks
  - r – i.i.d.
  - θ – permanent irreversible shock;
- Mitigation cost
  - subject to permanent shocks (sunk cost)

Climate Asset & Economic Growth

Simple Model

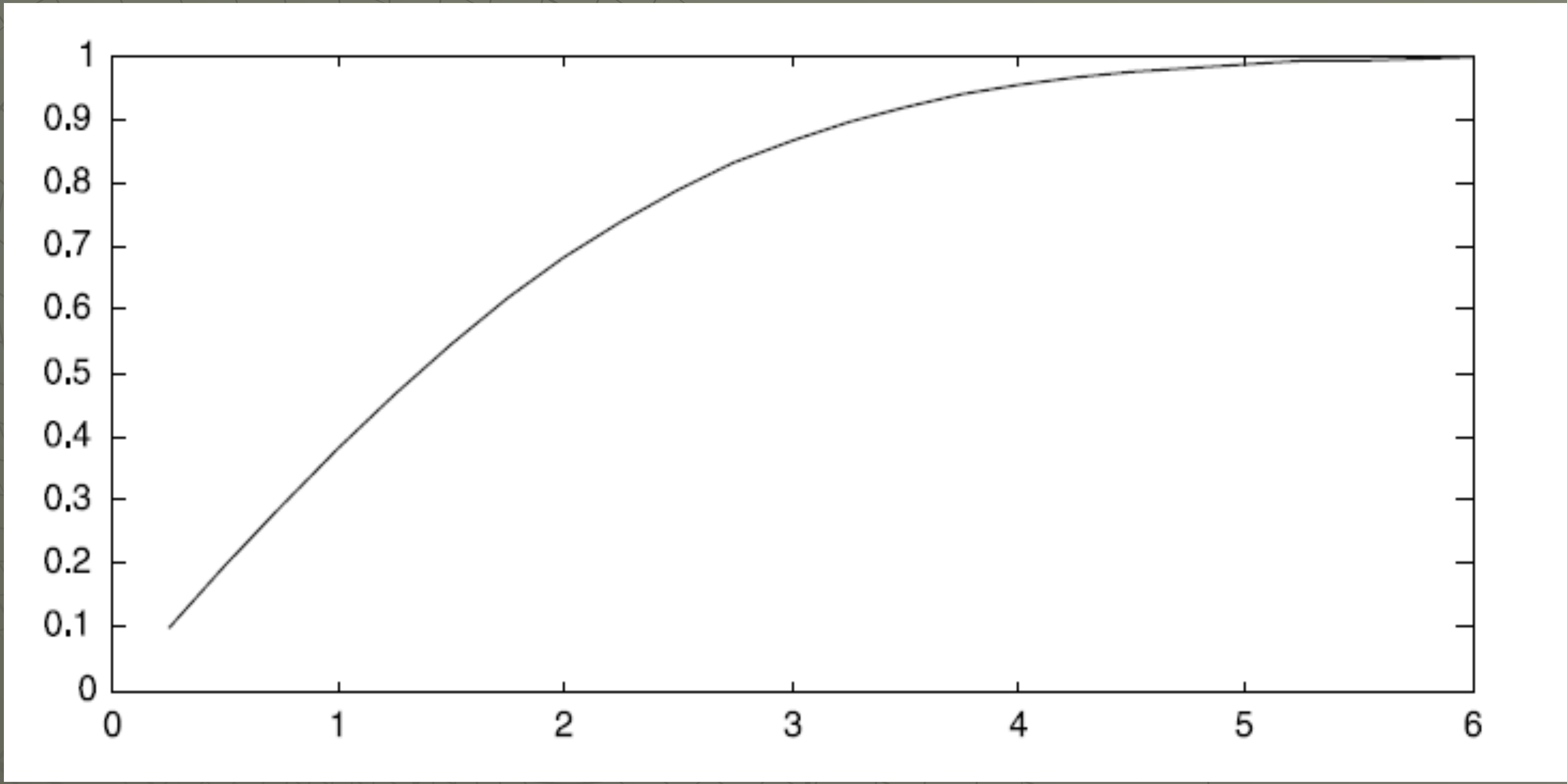
- Long–term stabilization target C_0 determines environment and long term economic productivity:

$$Y_t = Y_0 \exp(r_{C0} - \theta_{C0})t$$

- Fraction of output allocated to abatement permanently reduces productivity (r):

$$Y_t = Y_0 \exp(r - \mu_{C0} - \theta_{C0})t$$

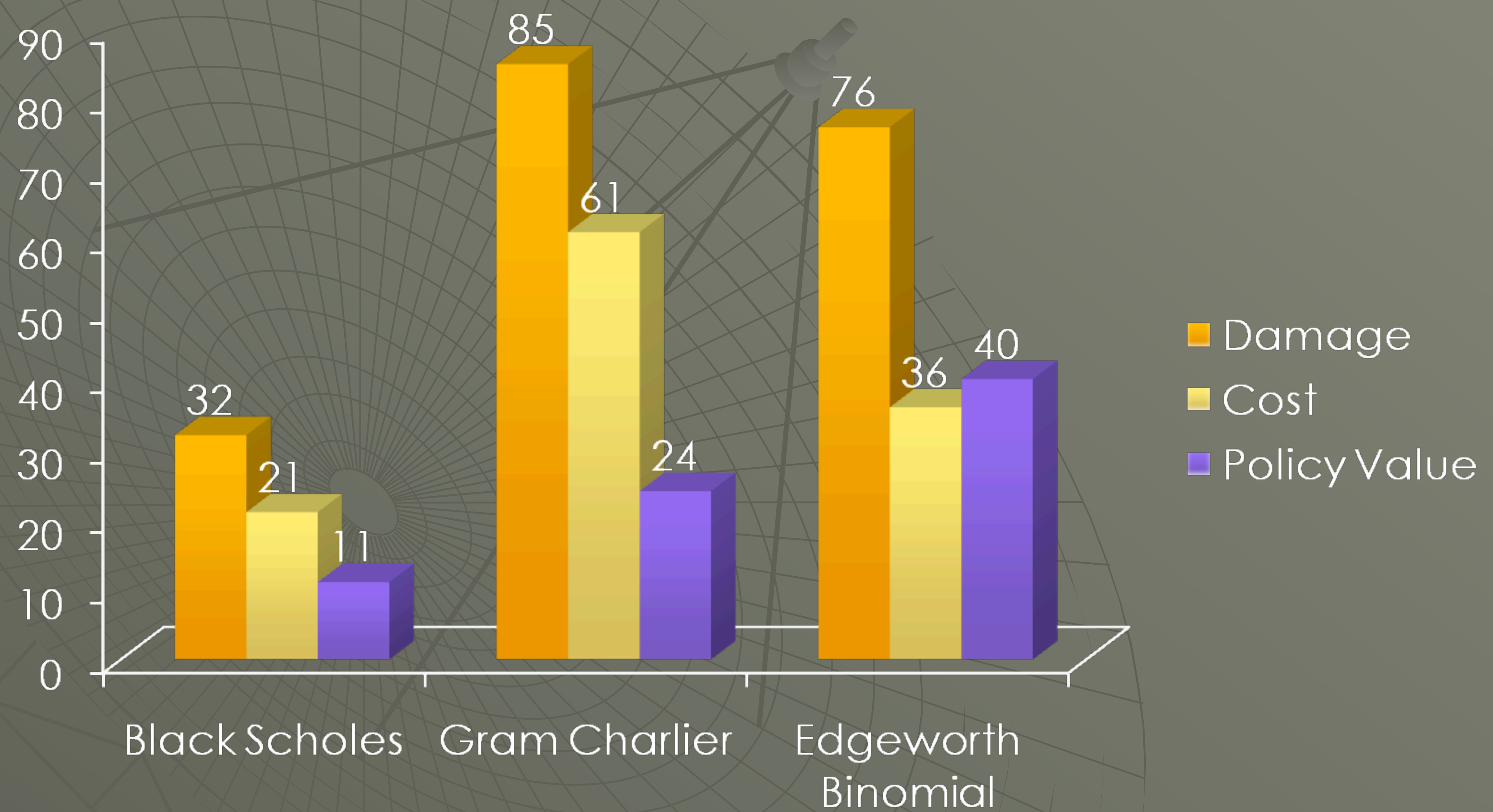
Option Value is a Function of:
Greater uncertainty in damages than in costs



Other moments are important too

ROV discounted to 2010 in $ trillion

note: Graham Charlier reflects variance and skew, but not kurtosis



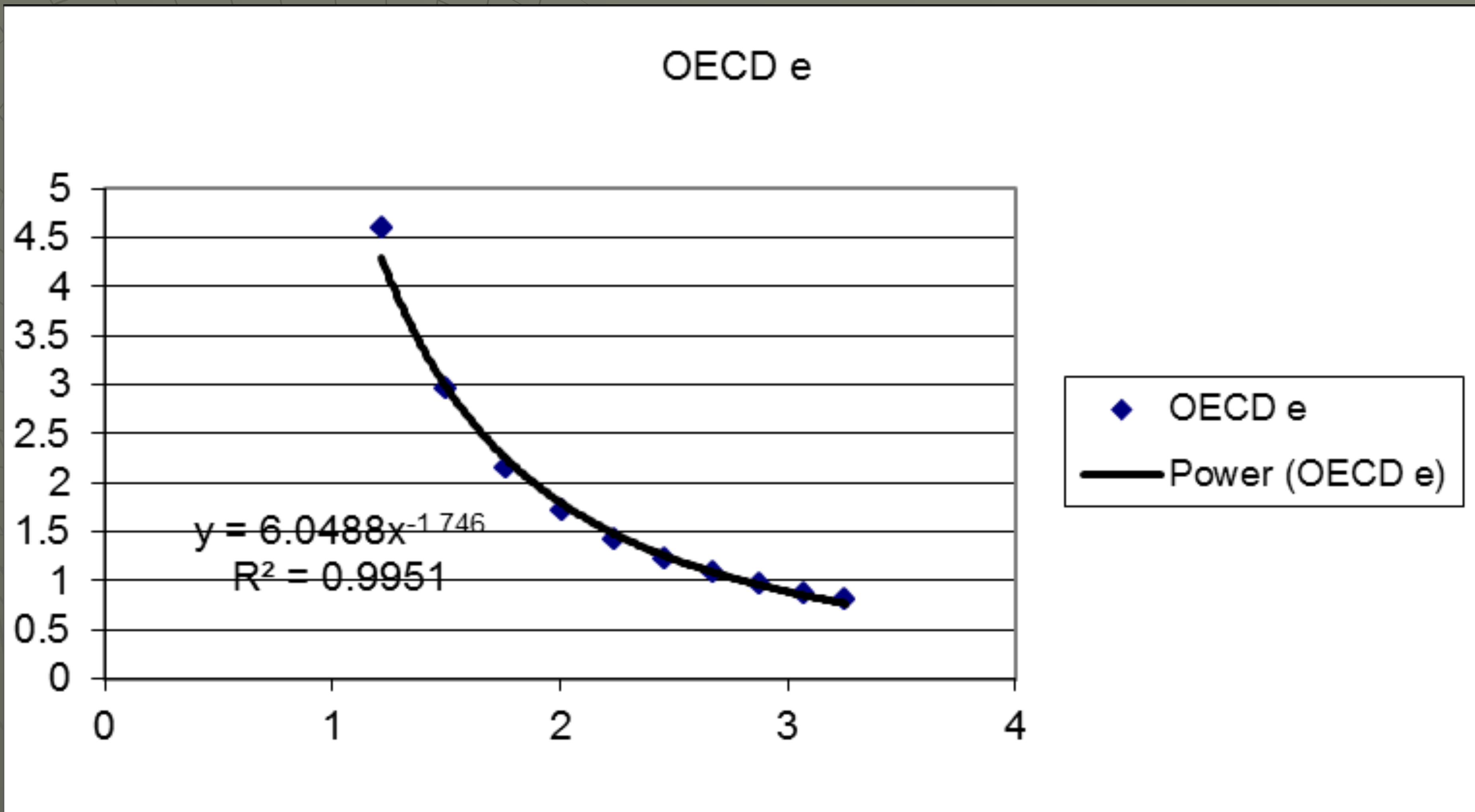
Risk adjusted cost of climate policy

- For calculation of risk adjusted costs regulator should build a risk-free portfolio;
- All future risks priced and internalized in cost of this portfolio;
- Risks attributed to climate change are the reflection of permanent shocks on economy;
- If response of climatic system to anthropogenic impact would appeared higher than it was expected, then actual adaptation cost D will be consistently higher than expected level .
- Regulator buys an at-the-money call option on adaptation. Value of this option is value of risk associated to selected policy.
- Risk adjusted damage:

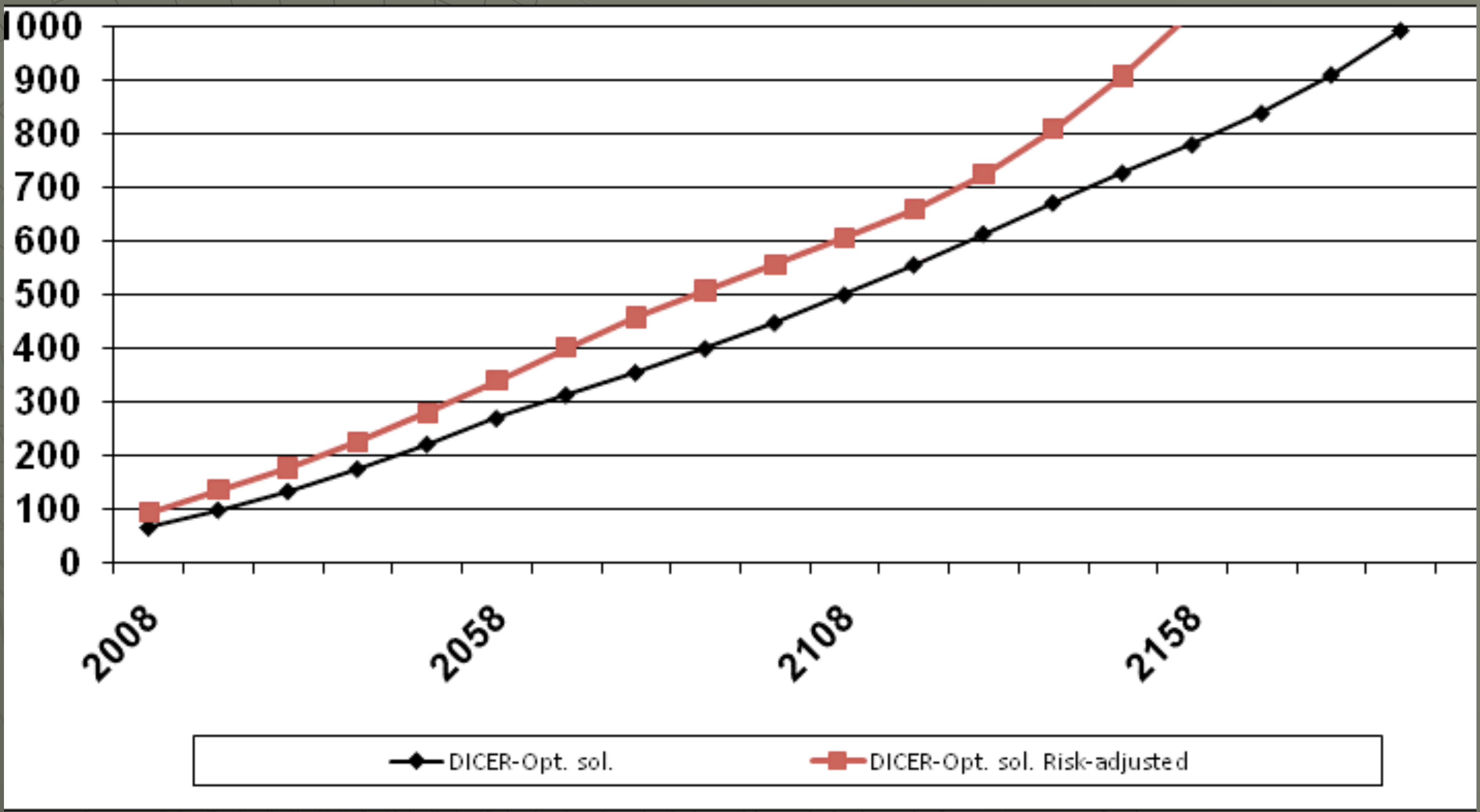
$$\widetilde{D} = \overline{D}\left(1 + v_D\right)$$

Where: v_x denotes volatility of the underlying parameter

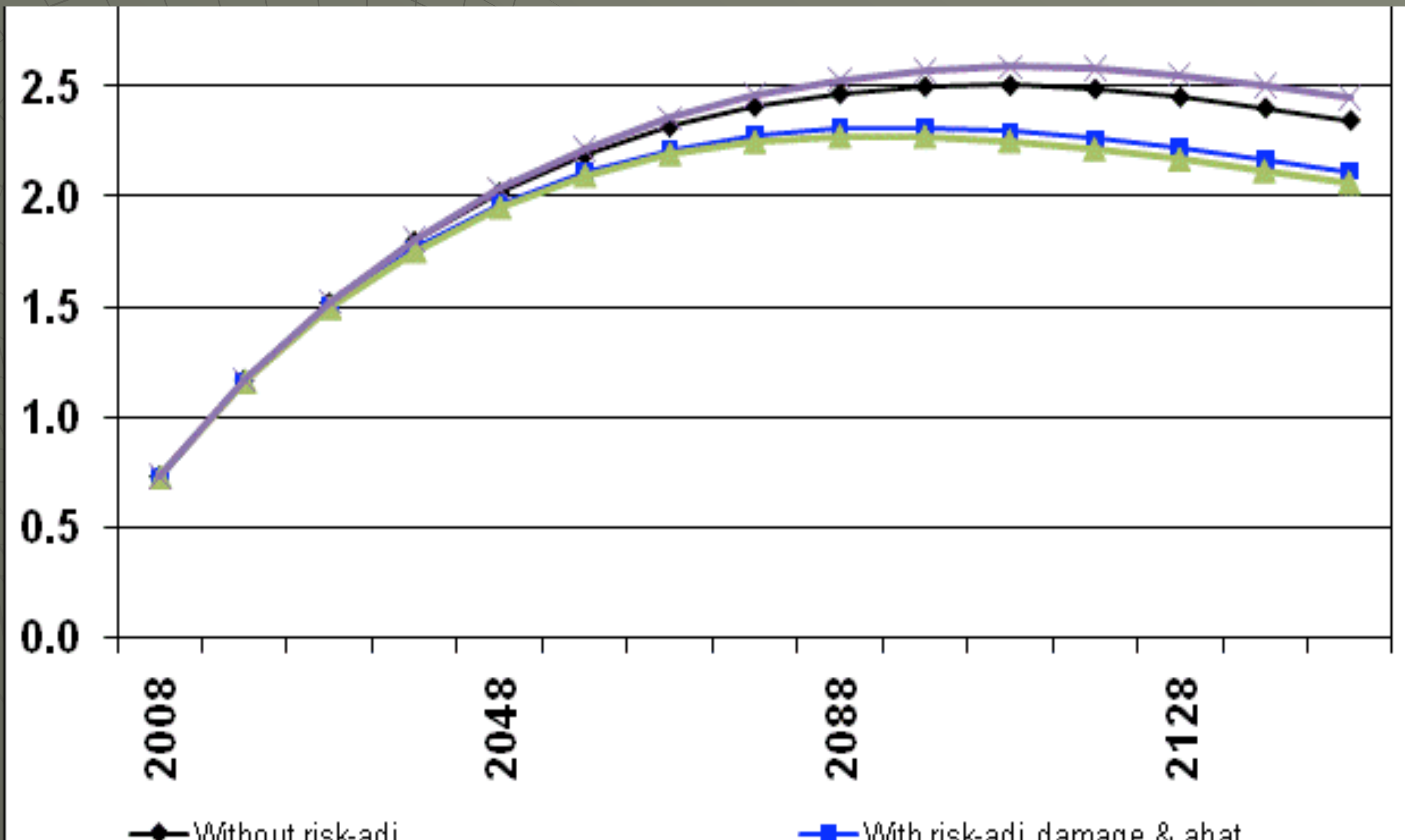
Volatility calibration



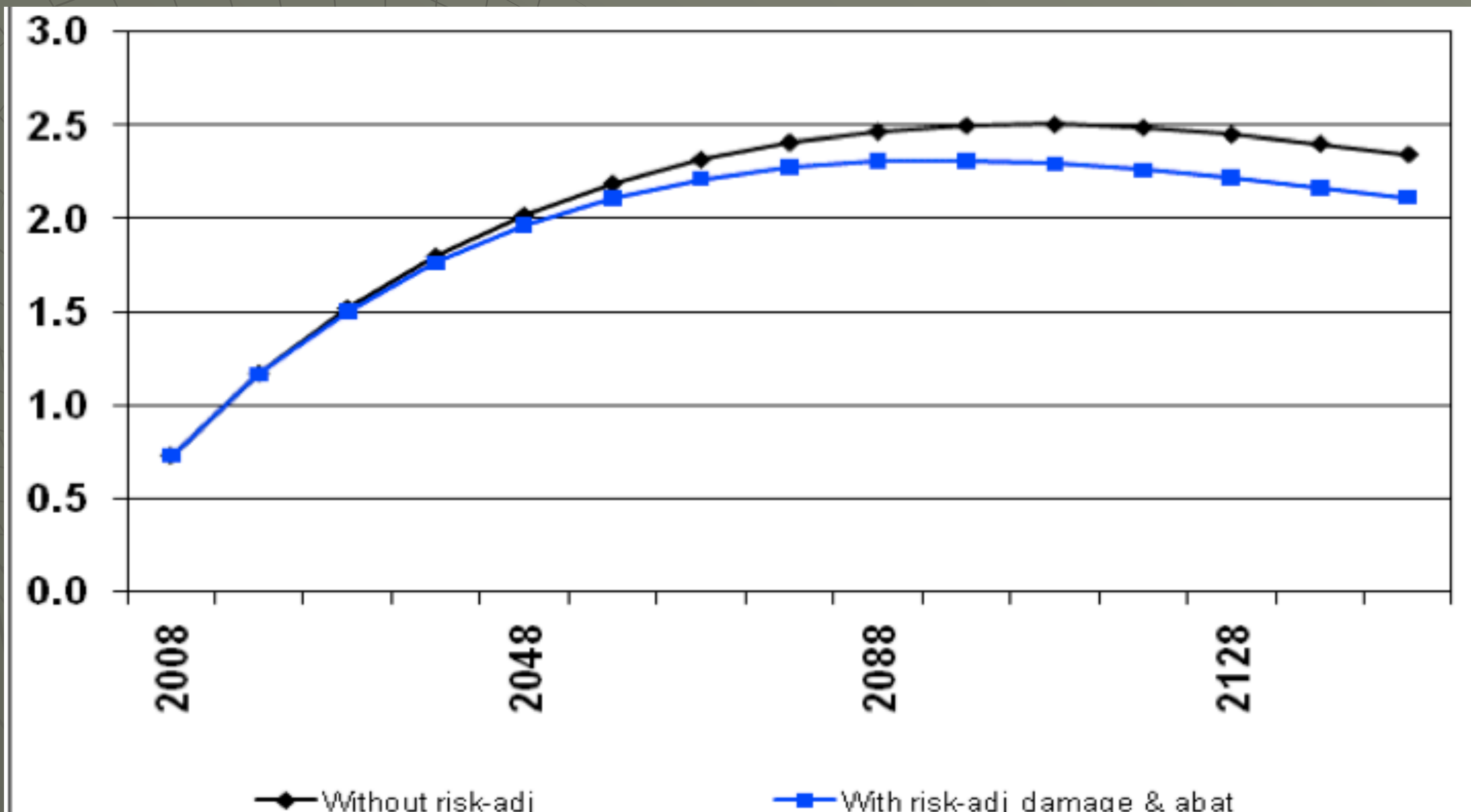
Optimal carbon price



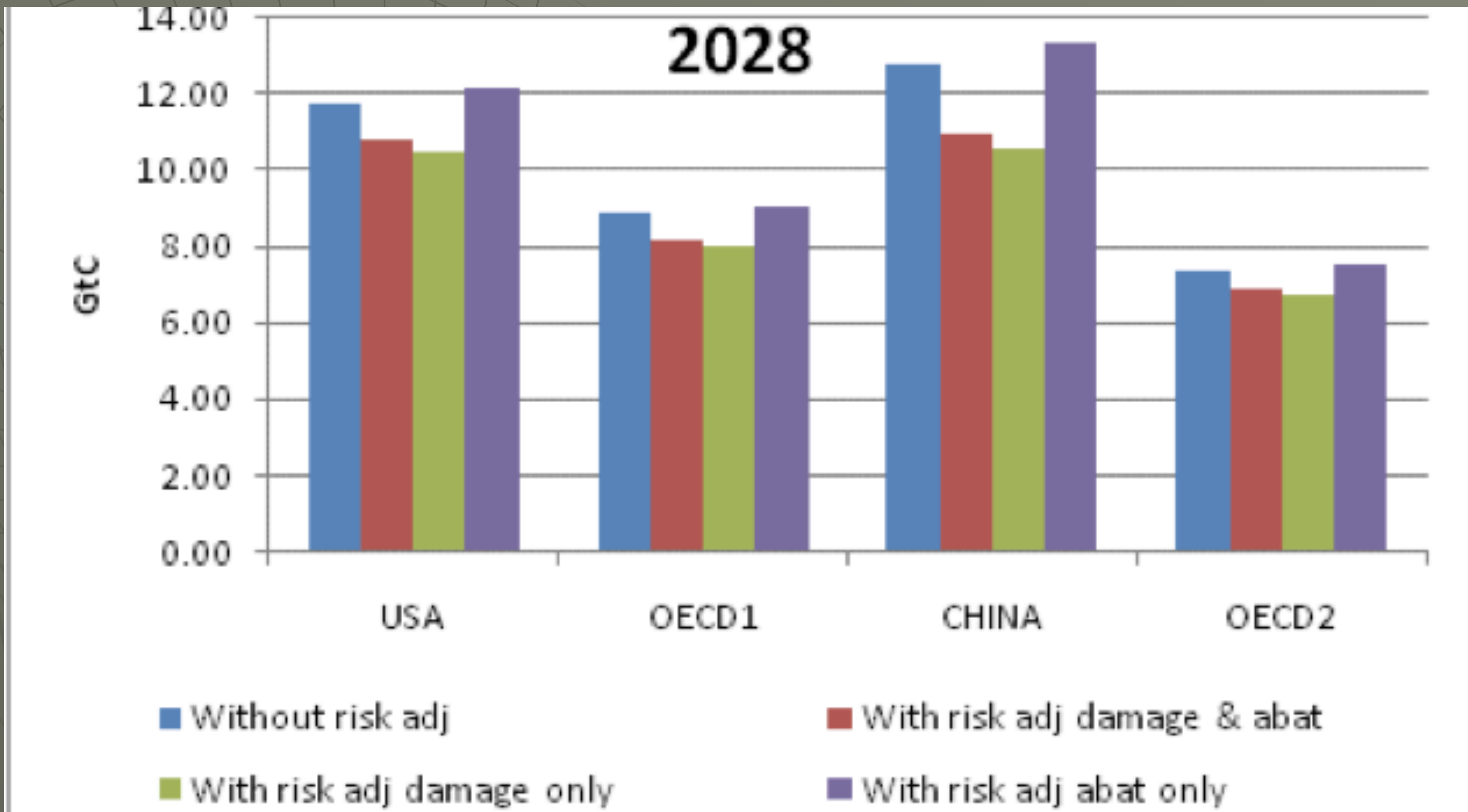
Optimal temperature increase



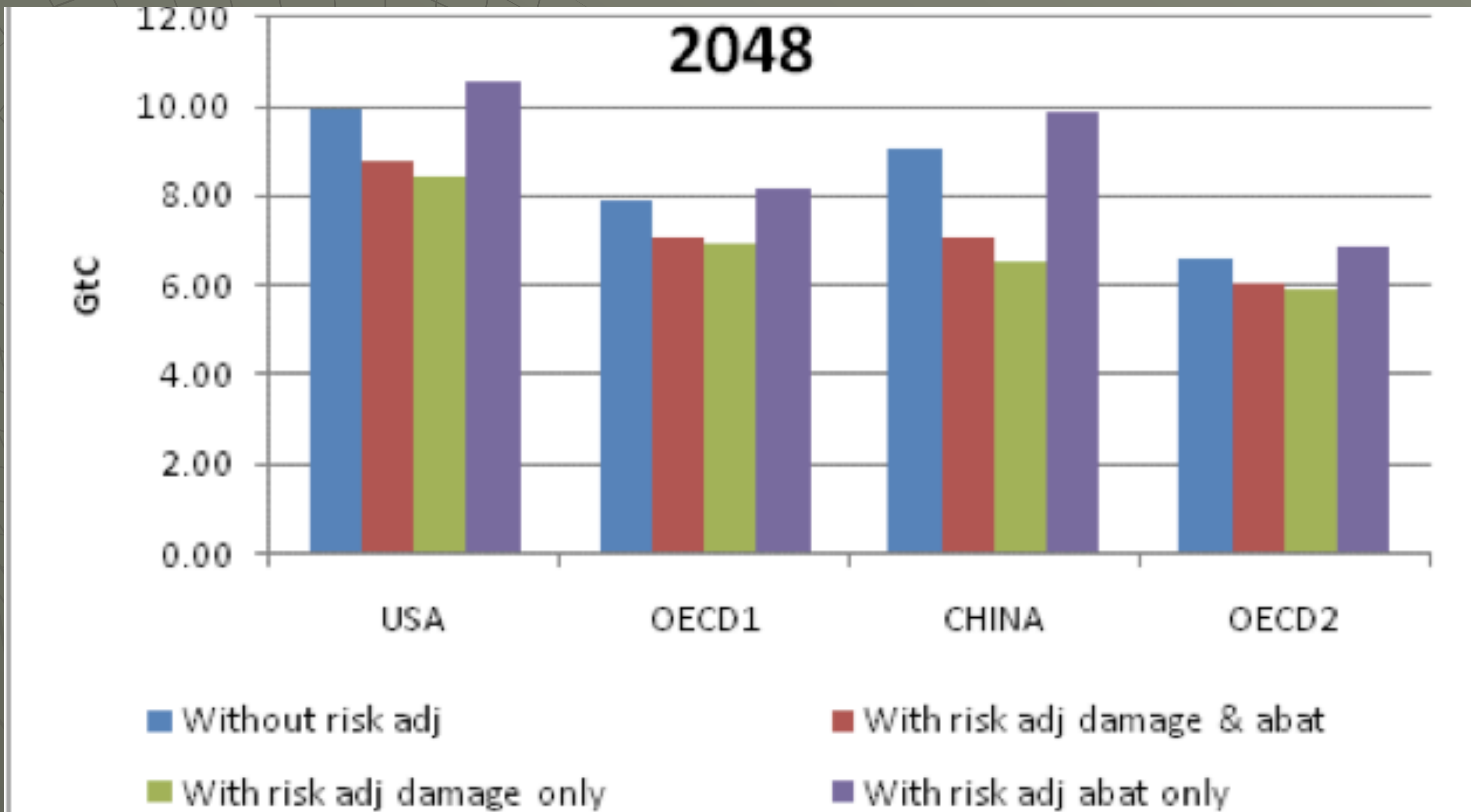
Temperature increase



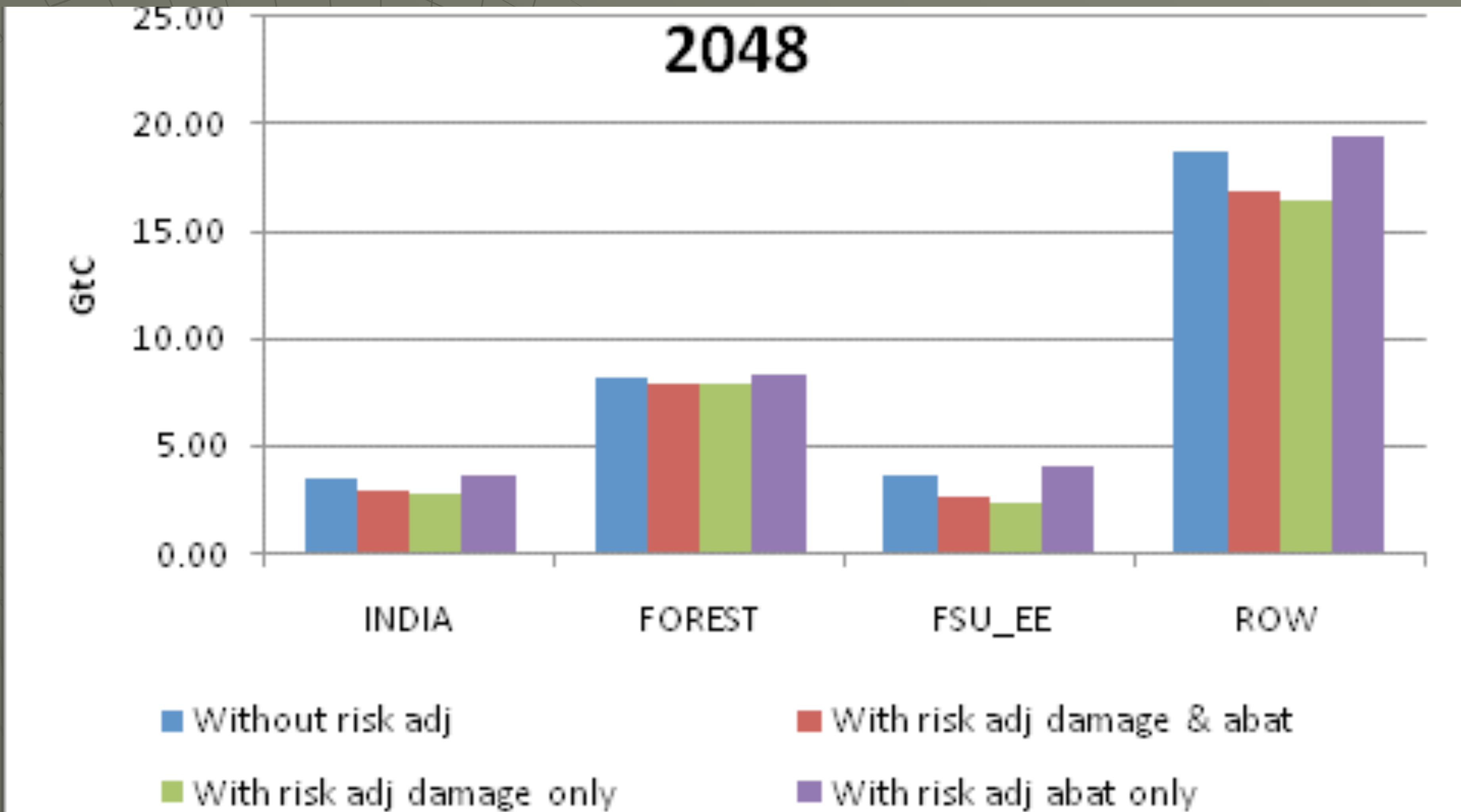
Optimal emission

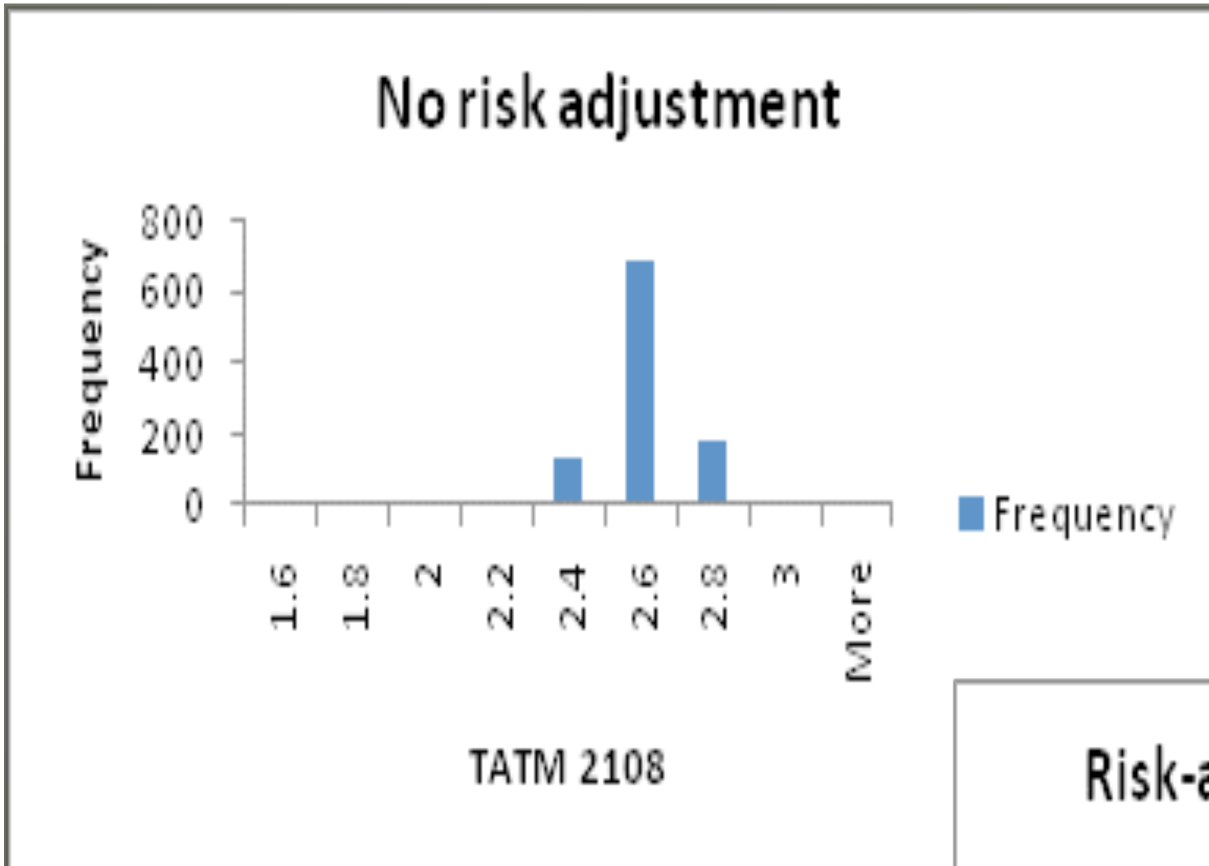


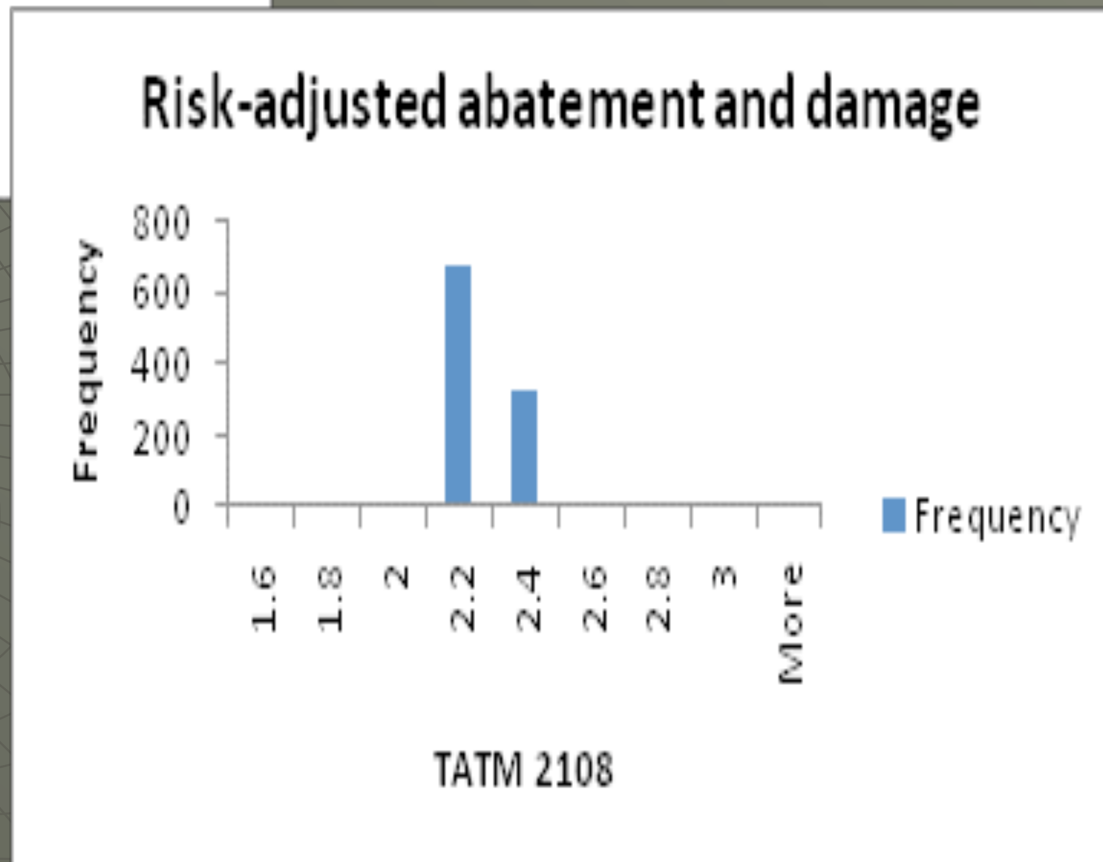
Optimal emission

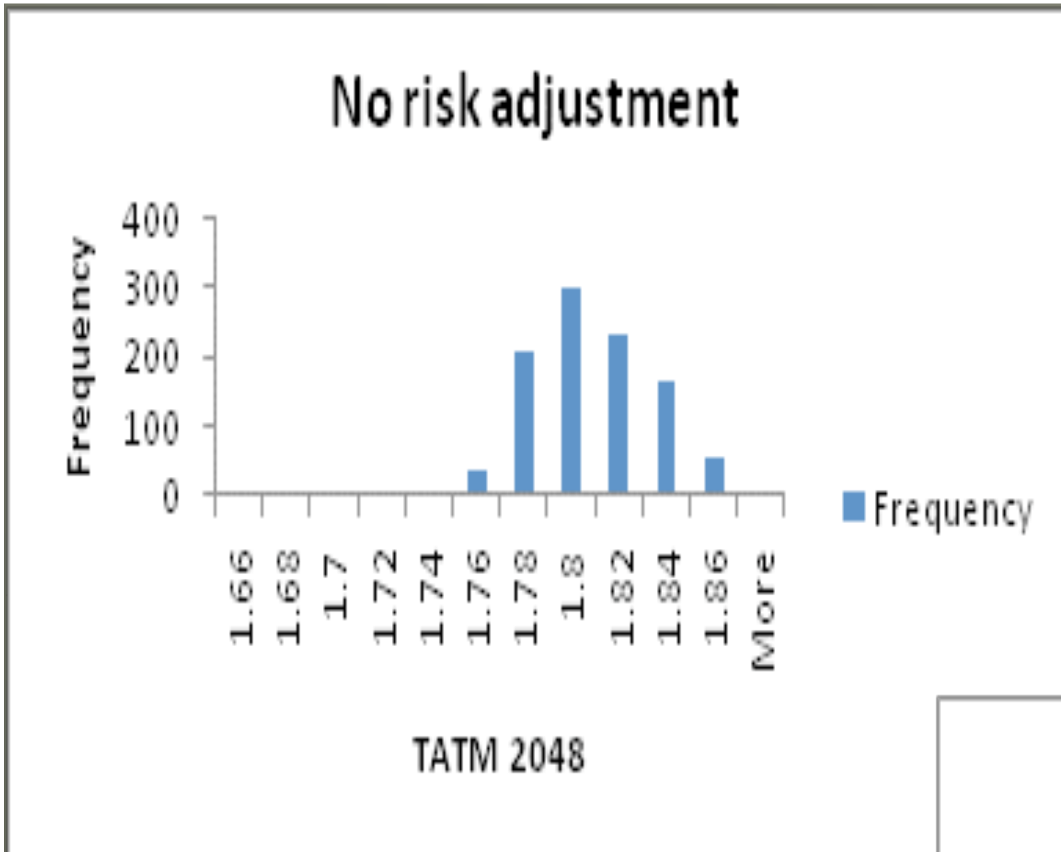


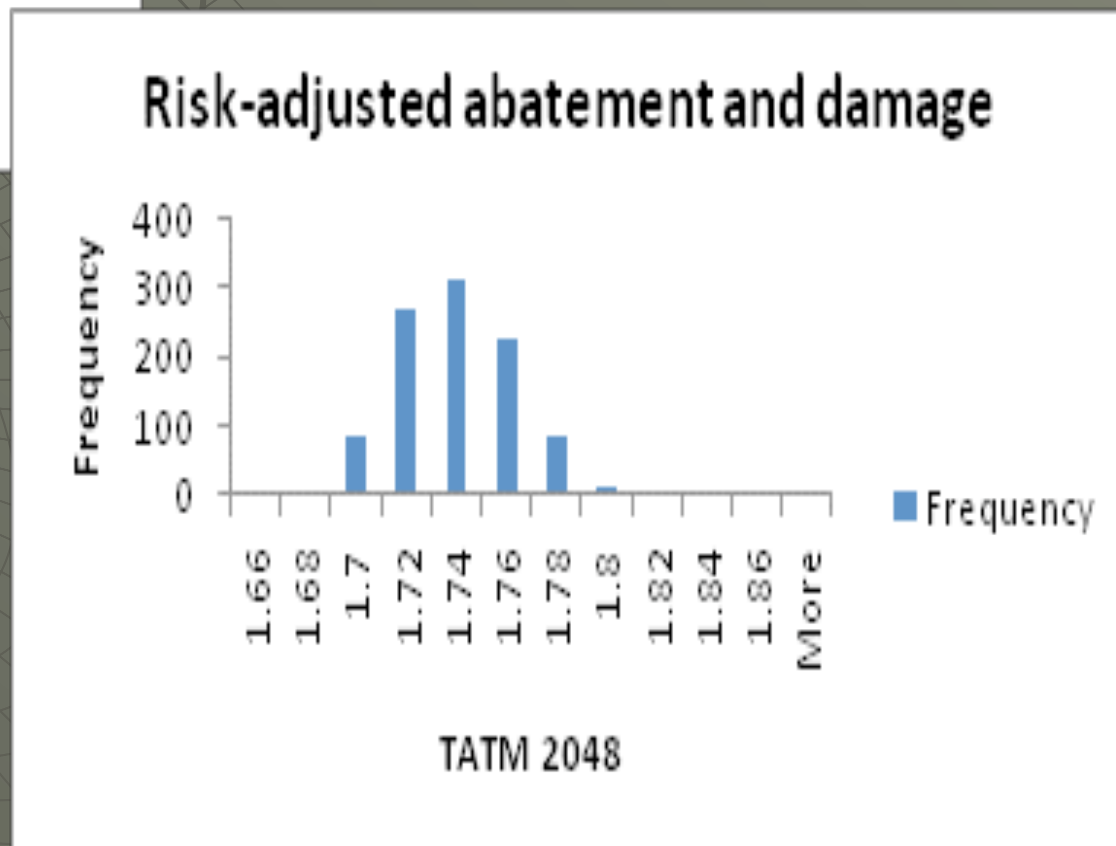
Optimal emission




No risk adjustment
Frequency
800
600
400
200
0
1.6
1.8
2
2.2
2.4
2.6
2.8
3
More
Frequency
TATM 2108


Risk-adjusted abatement and damage
Frequency
800
600
400
200
0
1.6
1.8
2
2.2
2.4
2.6
2.8
3
More
Frequency
TATM 2108


No risk adjustment
Frequency
400
300
200
100
0
1.66
1.68
1.7
1.72
1.74
1.76
1.78
1.8
1.82
1.84
1.86
More
Frequency
TATM 2048


Risk-adjusted abatement and damage
Frequency
400
300
200
100
0
1.66
1.68
1.7
1.72
1.74
1.76
1.78
1.8
1.82
1.84
1.86
More
Frequency
TATM 2048

Key Results

Policy Implications

Key results

- Global climatic system is a common good;
- Cost effective solution assumes no exemptions: all countries should cut emission;
- Risk adjusted cost and benefits = more aggressive GHG reduction;
- Decarbonization within next 100 years,

Climate Policy as a Real Option
Conceptual Rationale

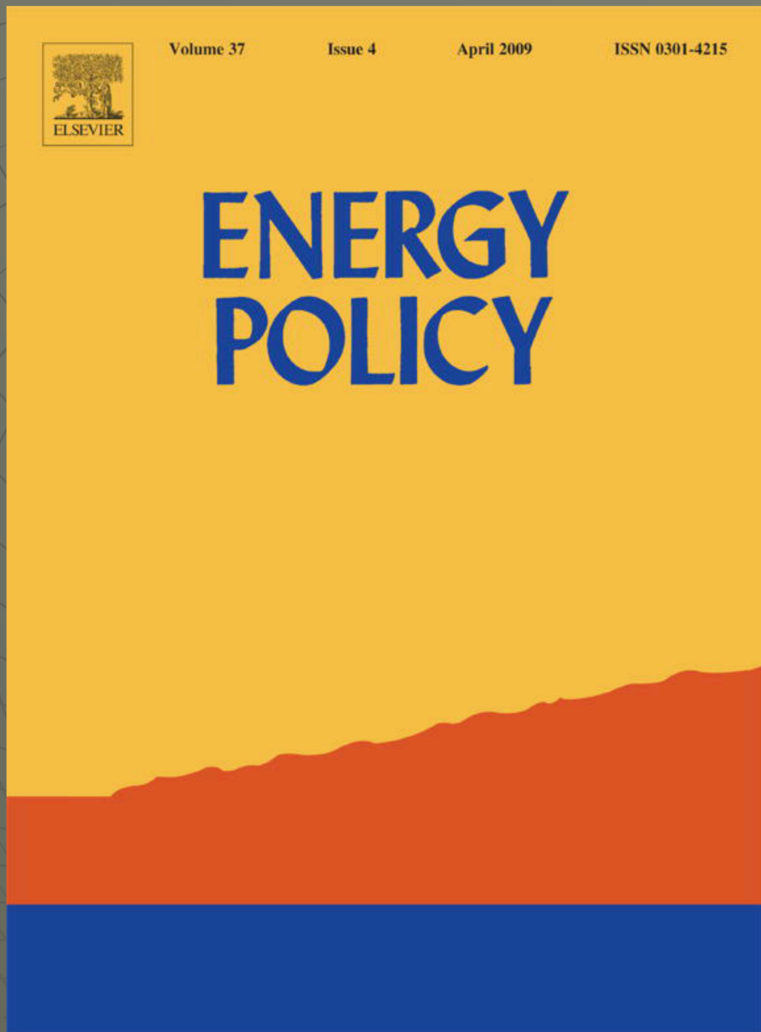
- Stabilization target is equivalent to being “long” a climate asset
- Asset carrying cost = GHG mitigation cost at target concentration
  - EV < Carrying Cost (i.e. out of money option)
- Upside is avoiding fat tail PDF of damages
  - Tail skimming = buying an out-of-money option on adaptation
  - Analogous to insuring Society’s climate asset
- Dynamic hedging
  - Target could be relaxed or tightened
  - Even if expensive, option makes new concentration targets POSSIBLE
  - NPV approach can lead to making certain concentrations IMPOSSIBLE

Summary of ROV Attributes

- Future corrections of climate policy are inevitable given the magnitude of uncertainties
- Policy formulation must recognize uncertainty and account for learning over time
- ROA provides:
  - Valuation metric for policy cost-benefit capturing all 4 first moments of both distributions
  - Algorithms for dynamic climate hedging in response to new knowledge of costs and benefits
  - Helps bridge uncertainties in target concentrations and mitigation costs
  - Access to existing IAMs to avoid complicated stochastic dynamic optimization

Conclusion

- IAM damage - insignificant GDP loss:
  - Cost now without payback but does not pay back
  - Leads to a “do something but not much” policy approach
- Catastrophic damage adds infinite variance
  - So drastic and immediate reduction is insufficient
  - Geo-engineering becomes the only feasible backstop
- Different metrics lead to more flexible policy
  - Hedging a valuable climate asset is relatively cheap
  - Geo-engineering is a position in a hedging portfolio
- You get what you measure
  - Feedbacks, uncertainty and tail risk drive climate science
  - Economics inevitably turns to metrics aligned with climate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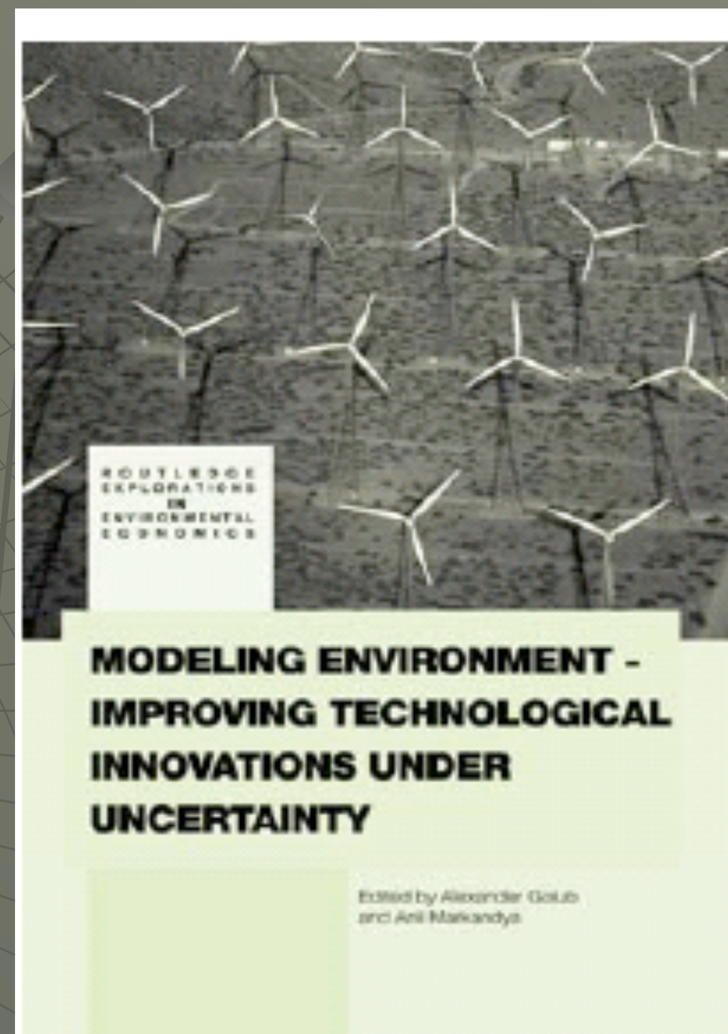
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