Fisheries management when quotas are costly to change

Carl Boettiger, Michael Bode, James Sanchirico, Jacob LaRiviere, Alan Hastings, Paul Armsworth

08/12/2014

Progress in modeling ecological complexity:

Liza Gross
@lizabio

Follow

No public policy issue is ultimately about science; it's about stakeholders, values, economics, ideology. Goldston #ESA2014

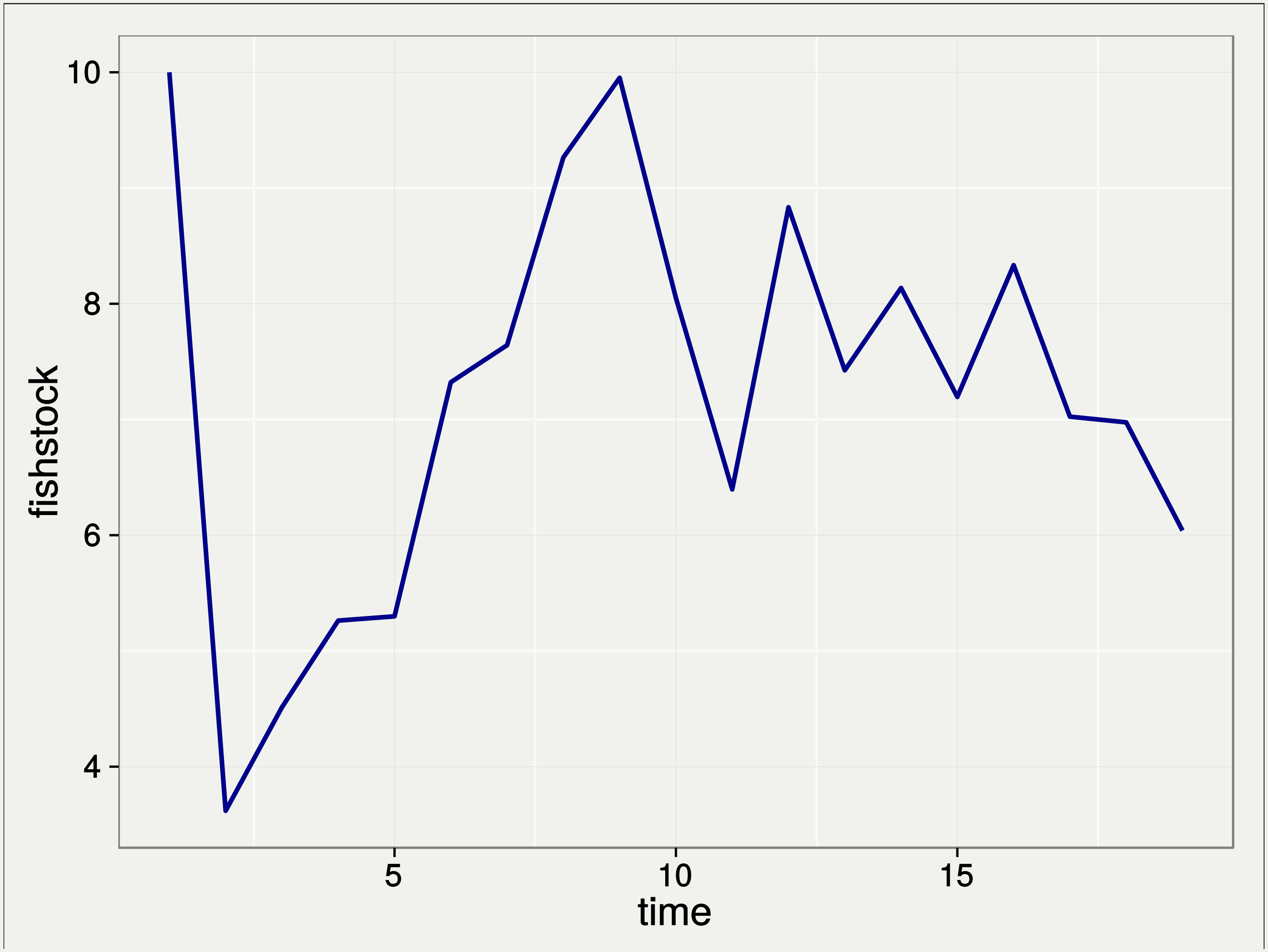
4:19 PM - 11 Aug 2014

8 RETWEETS **9** FAVORITES

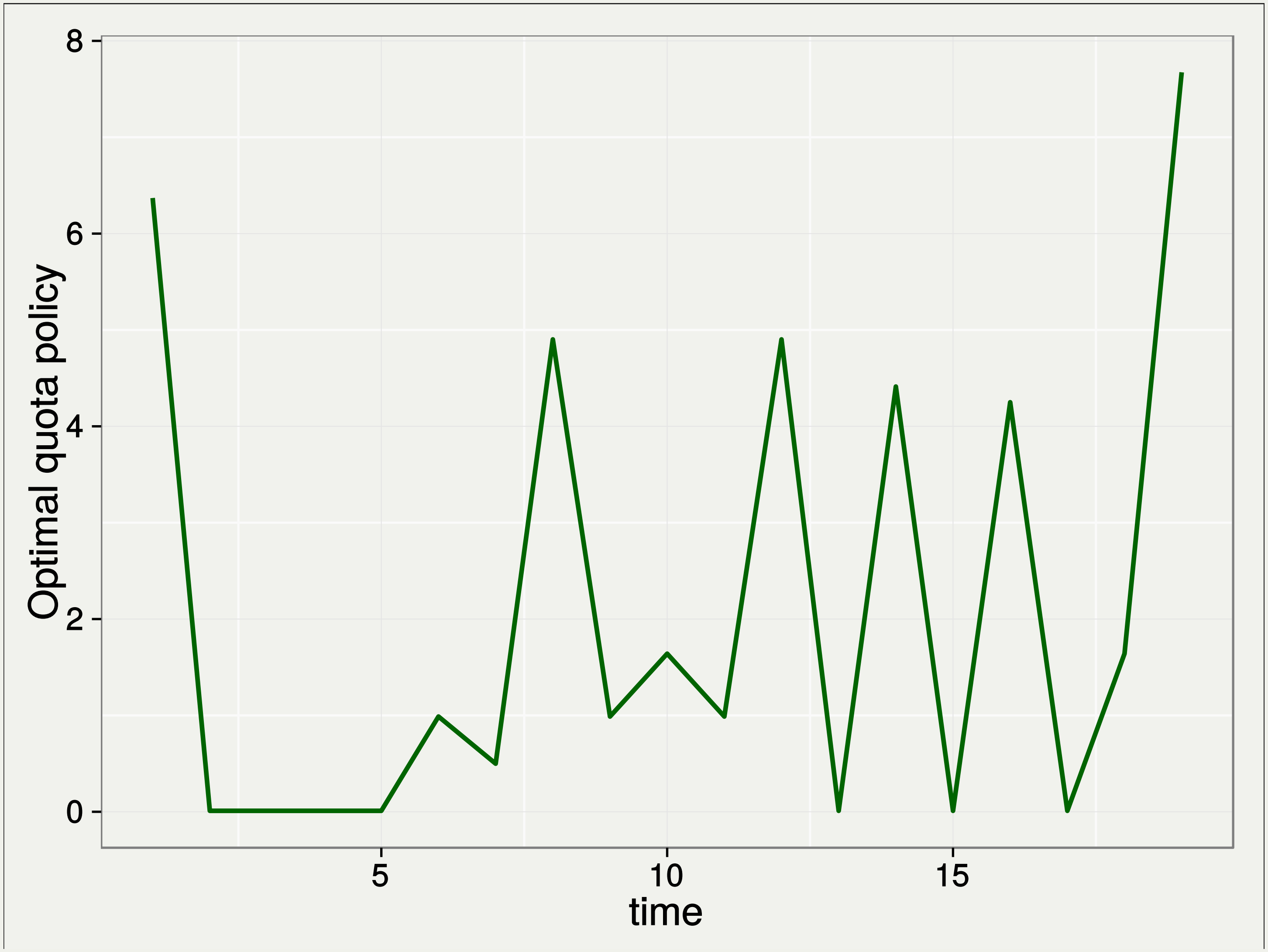
Hmm…

Can we put that in our models too?

Natural populations fluctuate…



So then, do our optimal policies



Real policies: not so much

NOAA

Bluefin Tuna Stocks vs Quota (base TAC), ICCAT 1987 - 2007

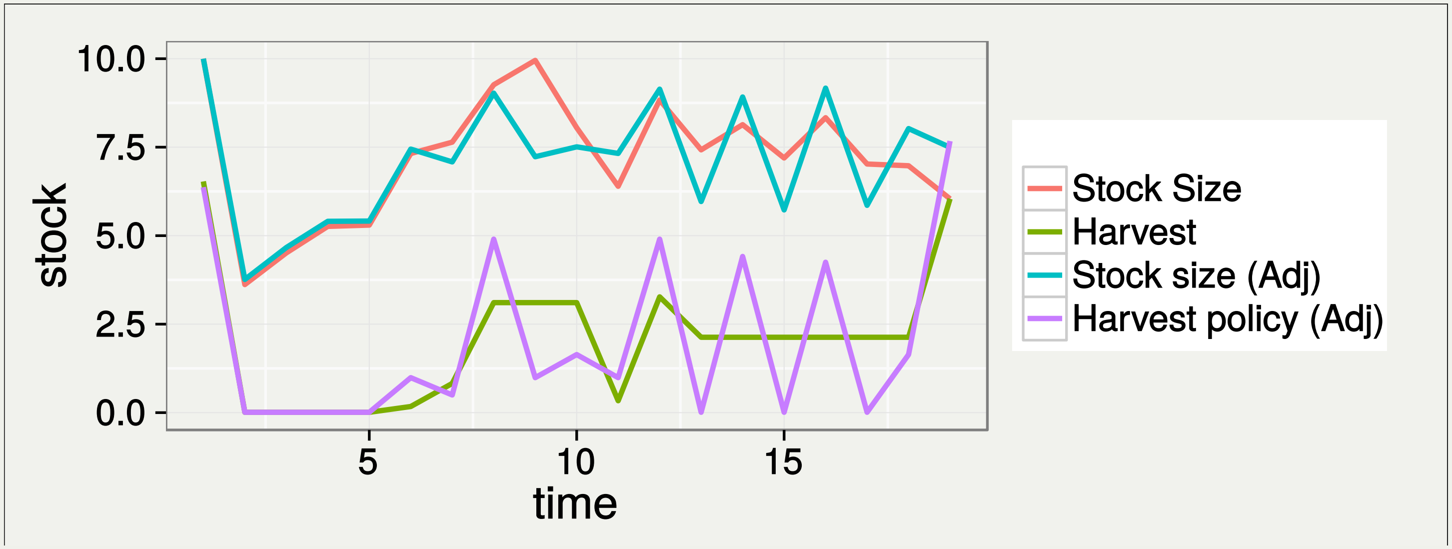
As ecologists, we've always focused on accounting for ecological dynamics

Not so good at *policy* dynamics

- We account for *ecological* dynamics but not *political* ones
- We don't know the equations of politics (does anyone?)
- Instead, we can investigate the potential impact that costly adjustments have on optimal policy

Model setup

- Focus on *stochastic* dynamics: thus a constant harvest is not optimal.
- Follow the textbook classic approach: **Reed (1979)** 10.1016/0095-0696(79)90014-7



Fish population dynamics

(state equation)

Population grows under a Beverton-Holt stock-recruitment curve,

$$N_{t+1} = Z_t \, \frac{A(N_t - h_t)}{1 + B(N_t - h_t)}$$

- subject to multiplicative log-normal growth shocks Z_t

Optimization

Select harvest policy that maximizes the Net Present Value (NPV) of the stock:

$$\max_{\mathbf{h}} \mathbf{E}(NPV_0) = \max_{\mathbf{h}} \sum_0^\infty \mathbf{E}\left(\frac{\Pi_0(N_t, h_t)}{(1+\delta)^{t+1}} \right)$$

- Profits from harvesting depend on price and costs $\Pi_0(N_t, h_t) = ph_t - c_0 E_t(N_t, h_t)$
- Harvest quota h_t in year t
- Stock size N_t , measured before harvest
- discount rate δ

Costs of policy adjustment

- We replace Π_0 in the NPV_0 equation with…

“Linear costs”

$$\Pi_1(N_t, h_t, h_{t-1}) = \Pi_0 - c_1|h_t - h_{t-1}|$$

- All previous terms, minus:
- The cost to change the harvest policy (quota): proportional to the size of the change

“Quadratic costs”

$$\Pi_2(N_t, h_t, h_{t-1}) = \Pi_0 - c_2(h_t - h_{t-1})^2$$

- Small adjustments are very cheap
- Large adjustments are very expensive
- Closest to typical assumptions of quadratic costs on harvest/effort (but here it is the *change* in harvest/effort)

“Fixed costs”

$$\Pi_3(N_t, h_t, h_{t-1}) = \Pi_0 - c_3(1 - \mathbb{I}(h_t, h_{t-1}))$$

- A fixed transaction fee for any change to policy, independent of size (or sign) of the change.

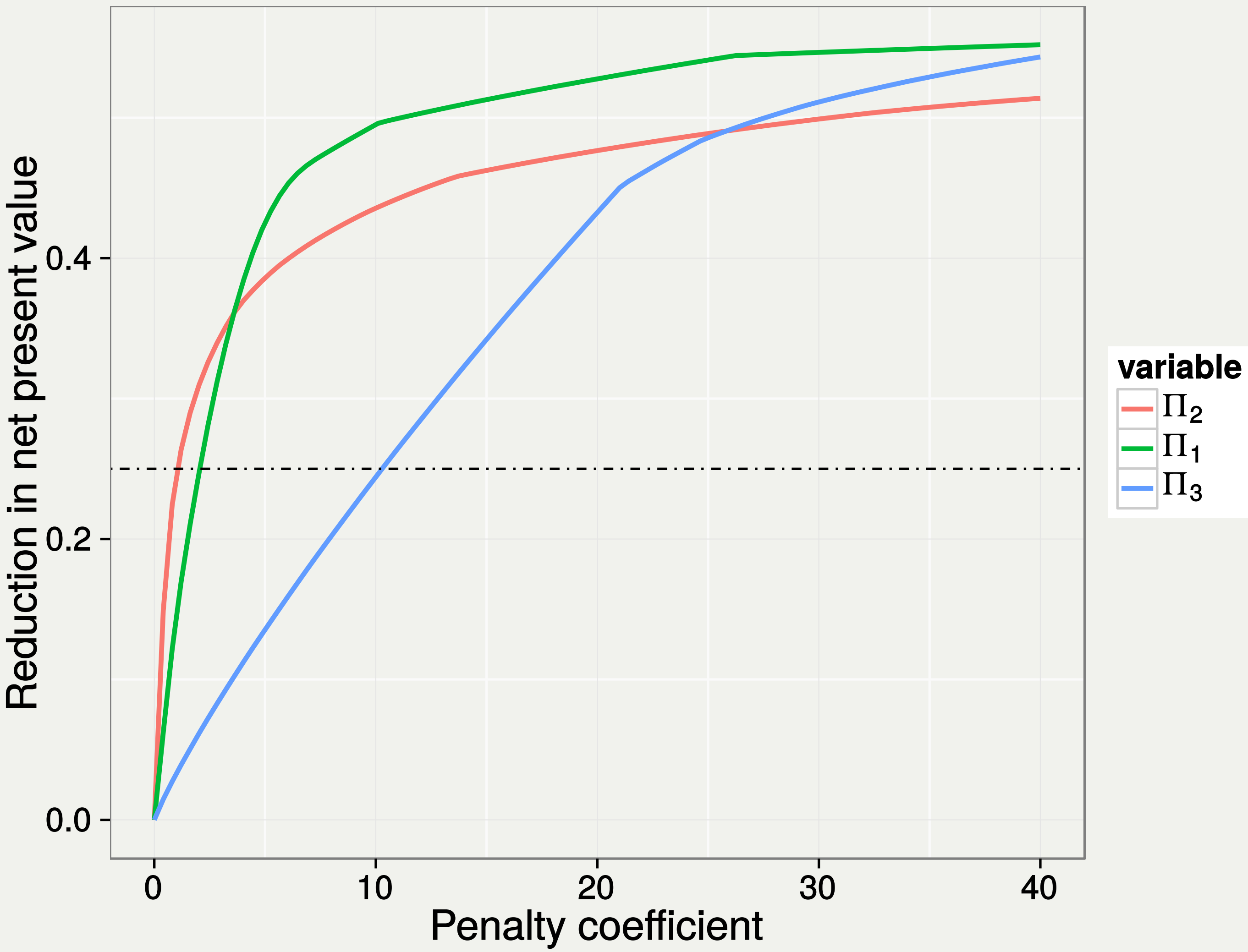
($\mathbb{I}(\mathrm{x}, \mathrm{y})$ is indicator function, equals 1 iff $x = y$, zero otherwise.)

Apples to Apples

How do we pick coefficients c_i such that only the functional form and not the overall cost differ?

- All forms will create complete resistance to change if the costs are high enough
- But how do we compare across forms that have different units and different coefficients?

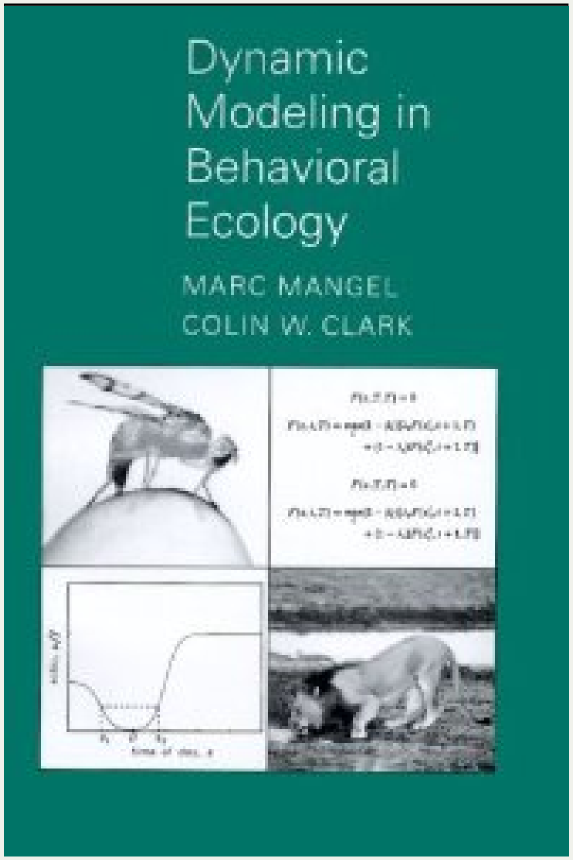
Apples to Apples



Problem defined. Time to compute solutions.

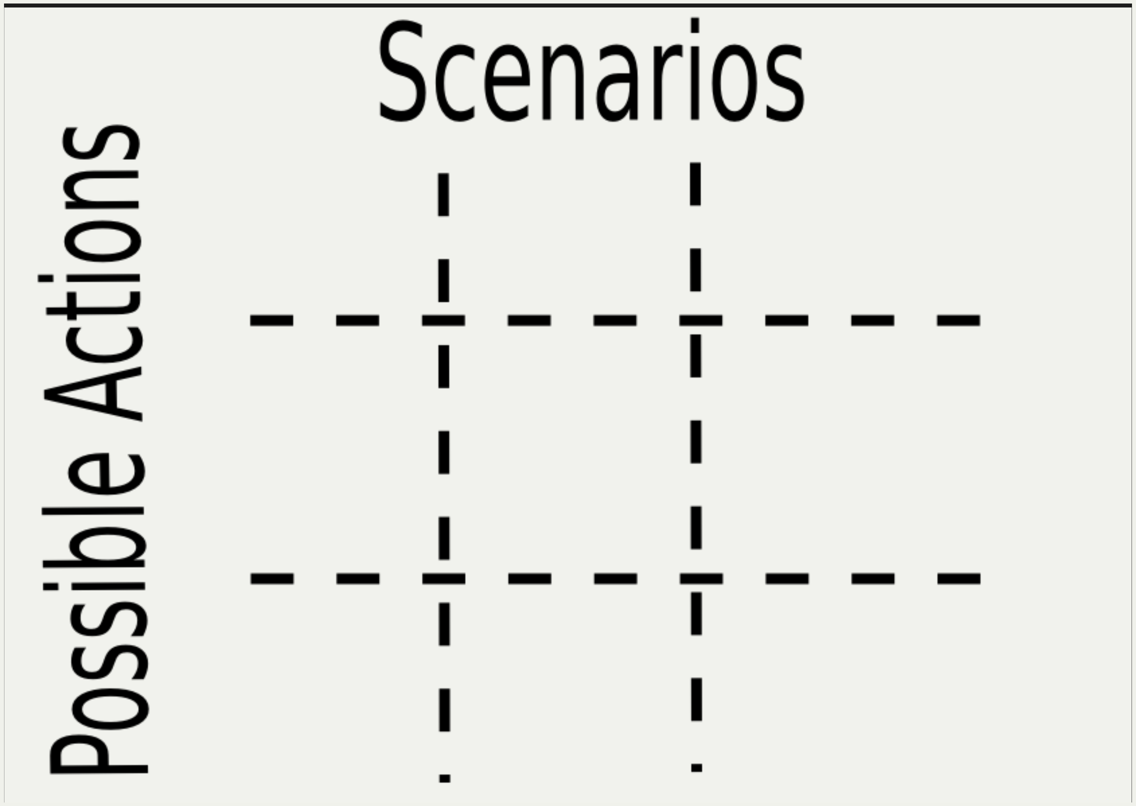
Implementation:

Stochastic Dynamic Programming



Possible Actions

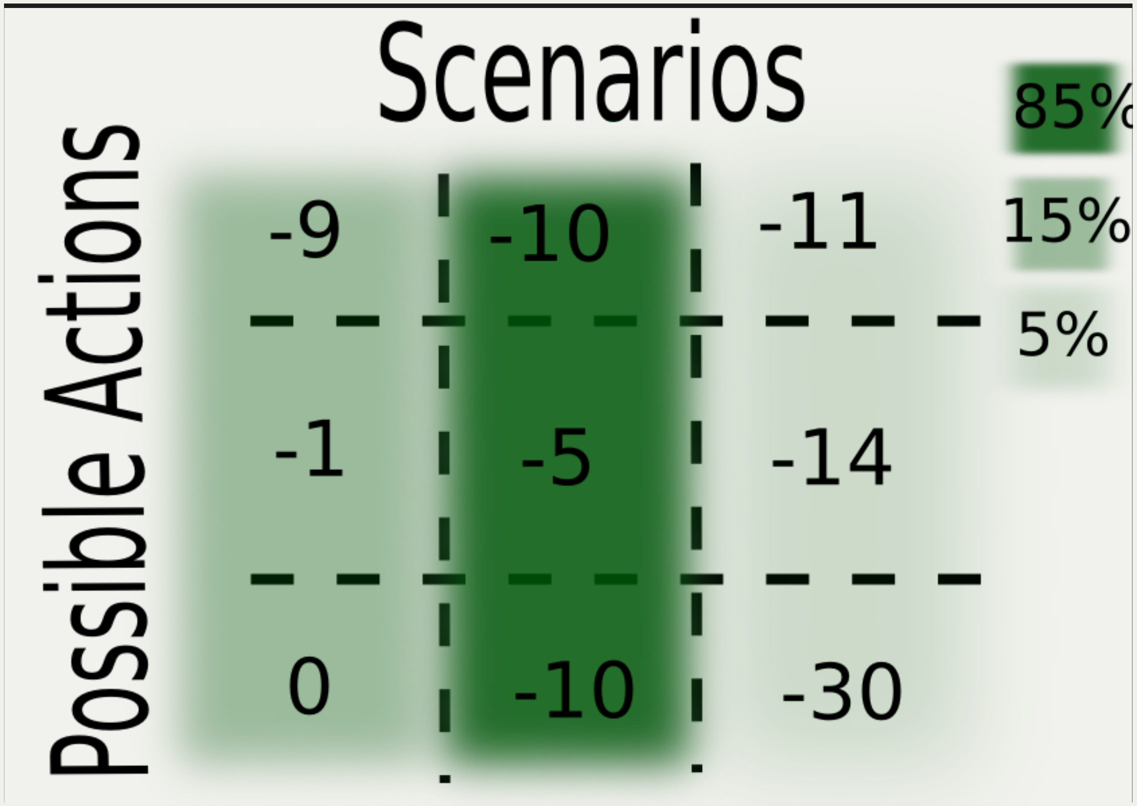
	Scenarios
Possible Actions	

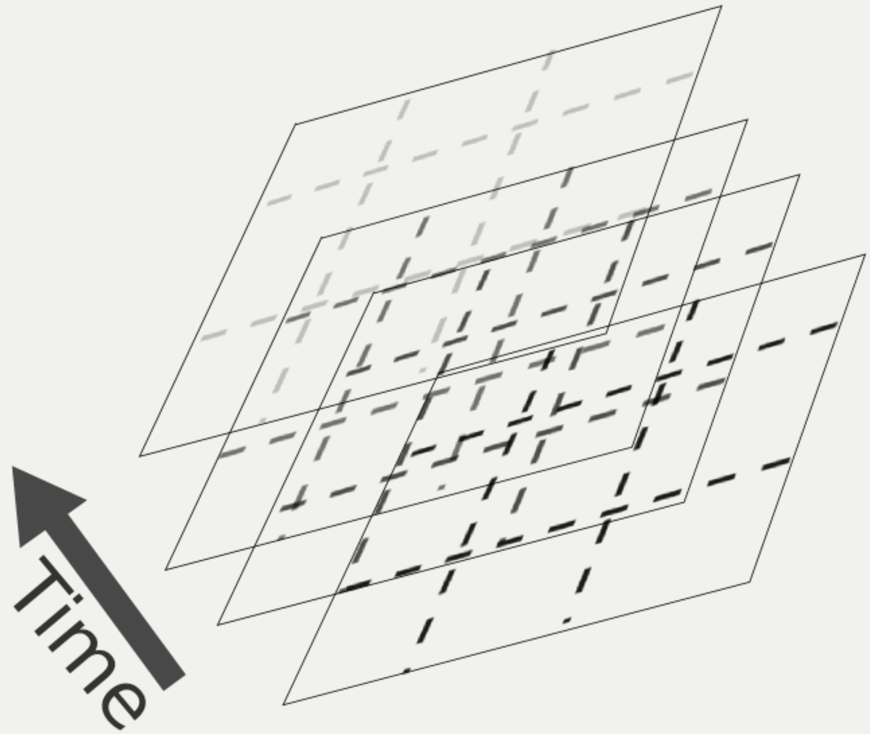

Scenarios
Possible Actions

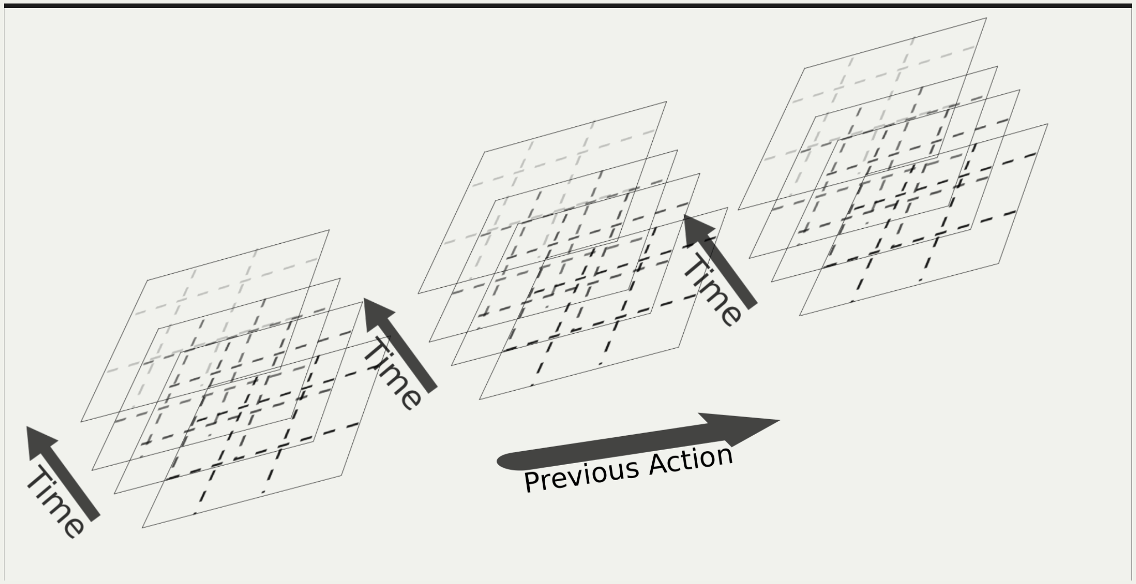
Scenarios

Possible Actions

-9	-10	-11
-1	-5	-14
0	-10	-30


Scenarios
Possible Actions
-9
-10
-11
-1
-5
-14
0
-10
-30
85%
15%
5%


Time

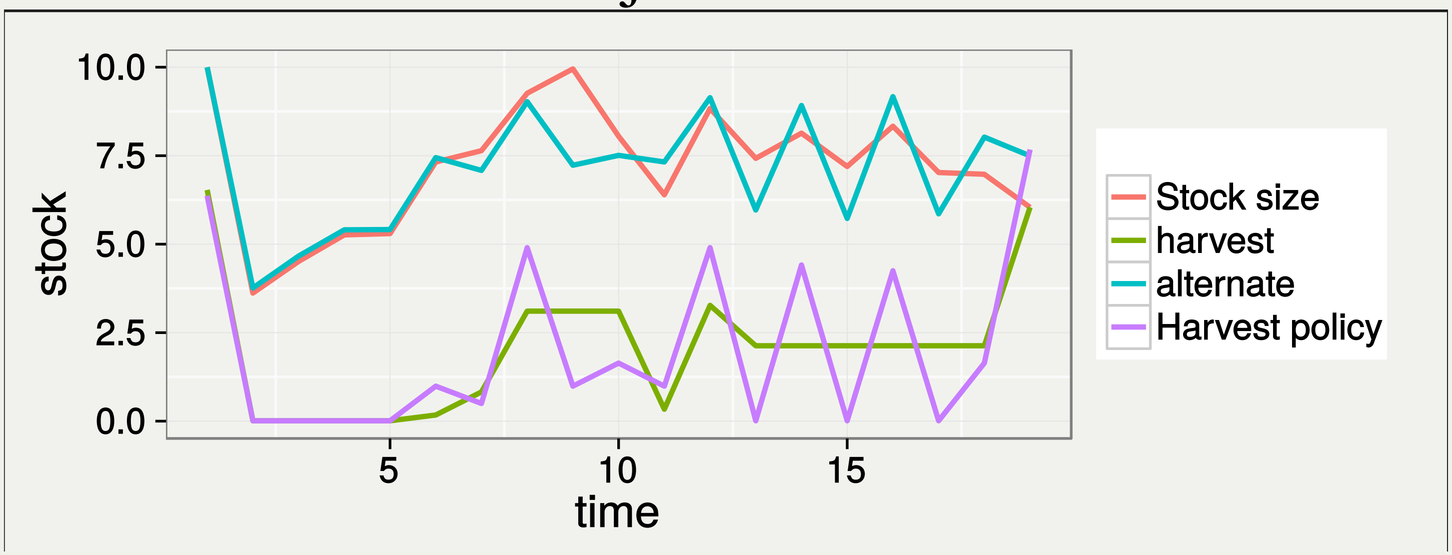


Time
Time
Time
Previous Action

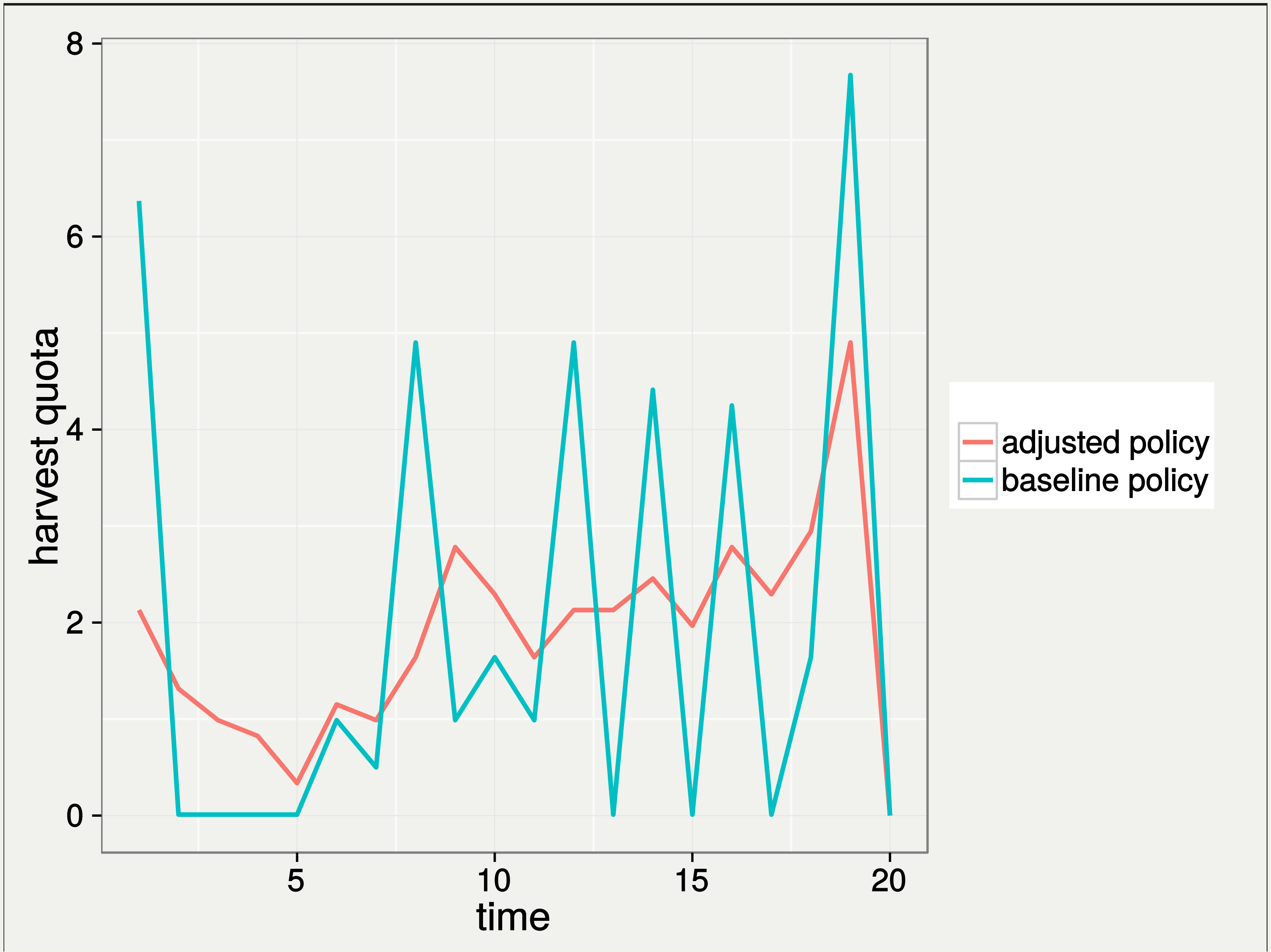
Effect of policy adjustment costs on optimal quotas and stock sizes

What would you predict for…

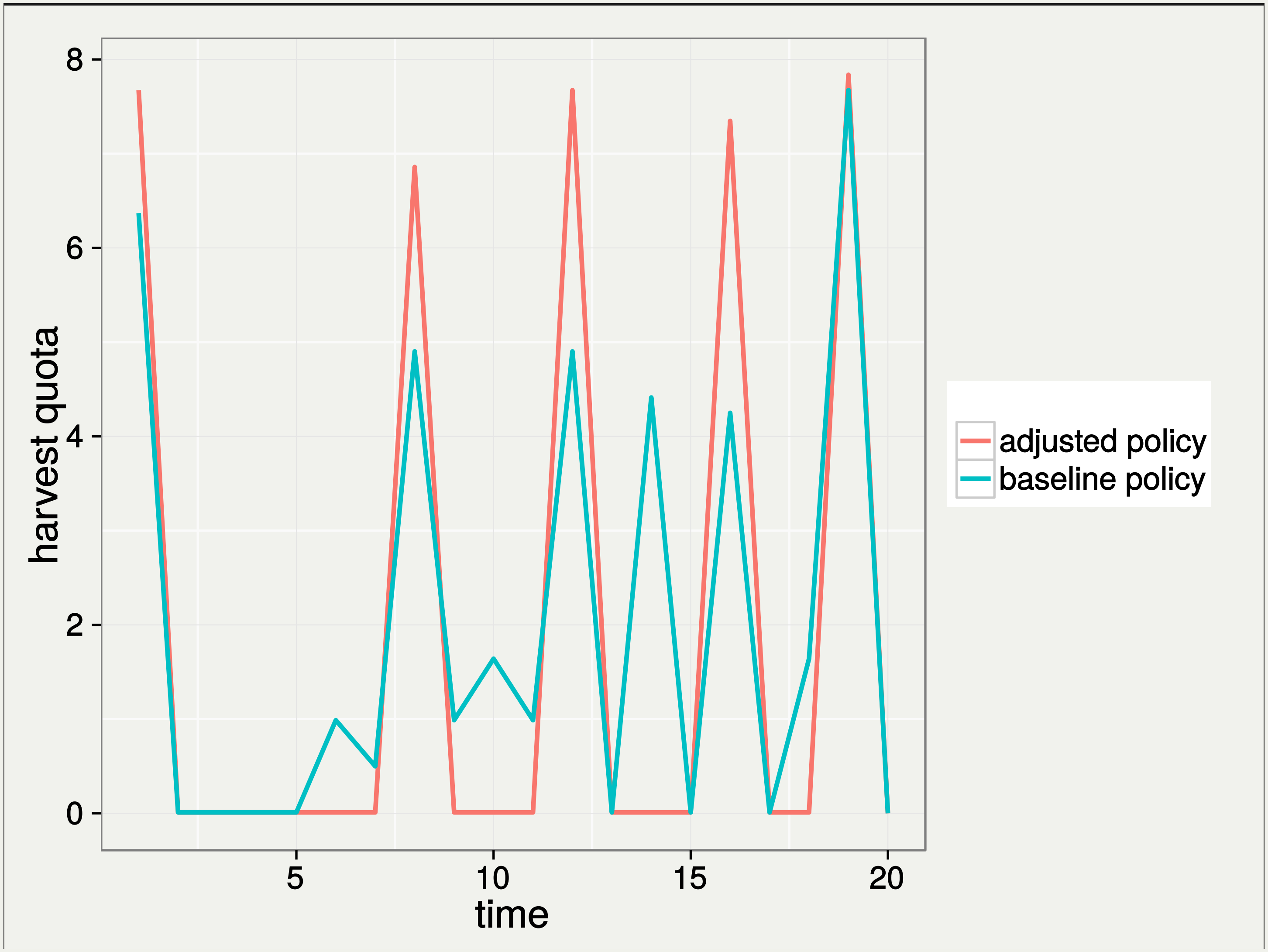
- Quadratic adjustment costs?
- Linear adjustment costs?
- Fixed adjustment costs?



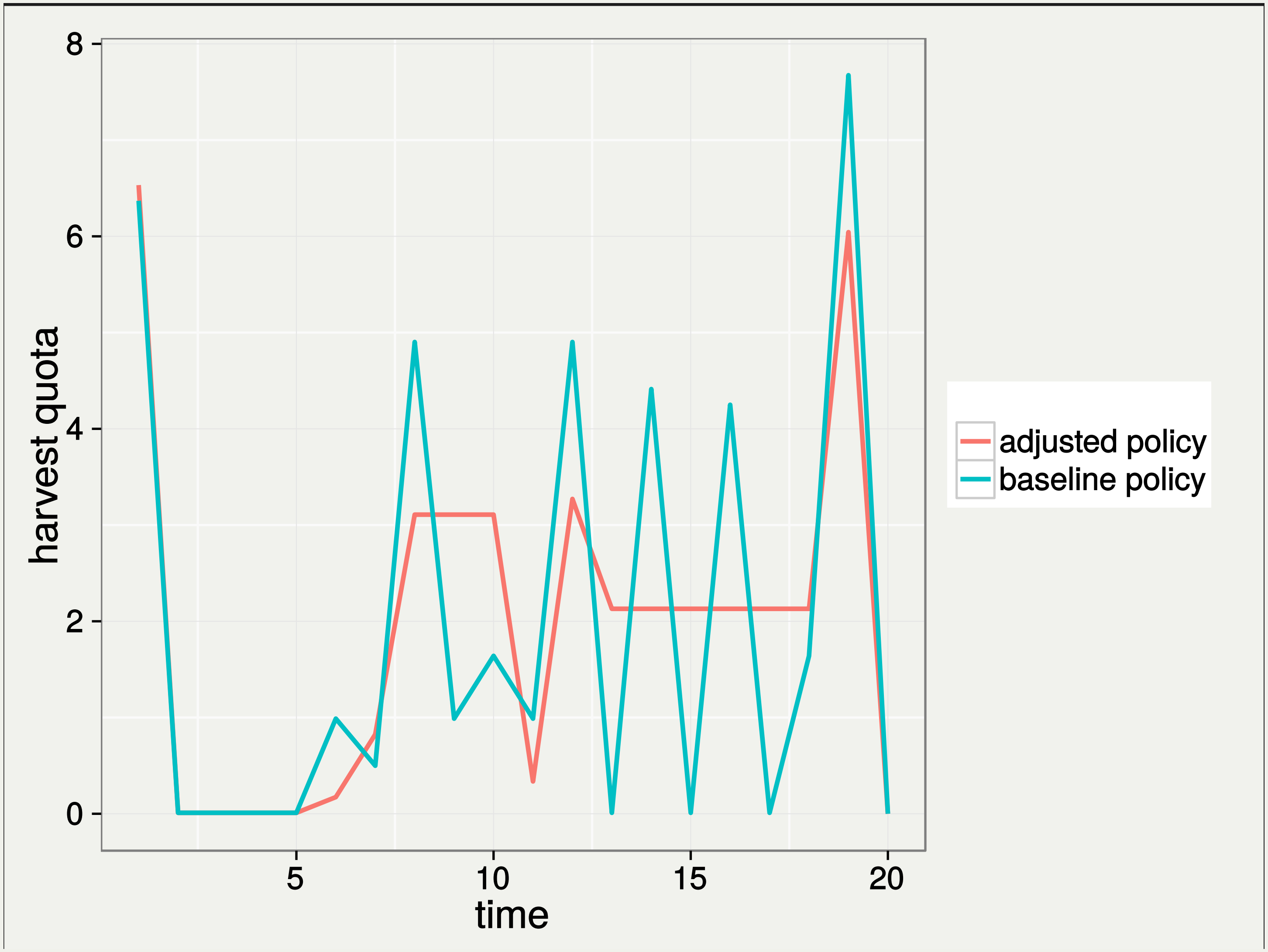
Quadratic Costs (Π_2)



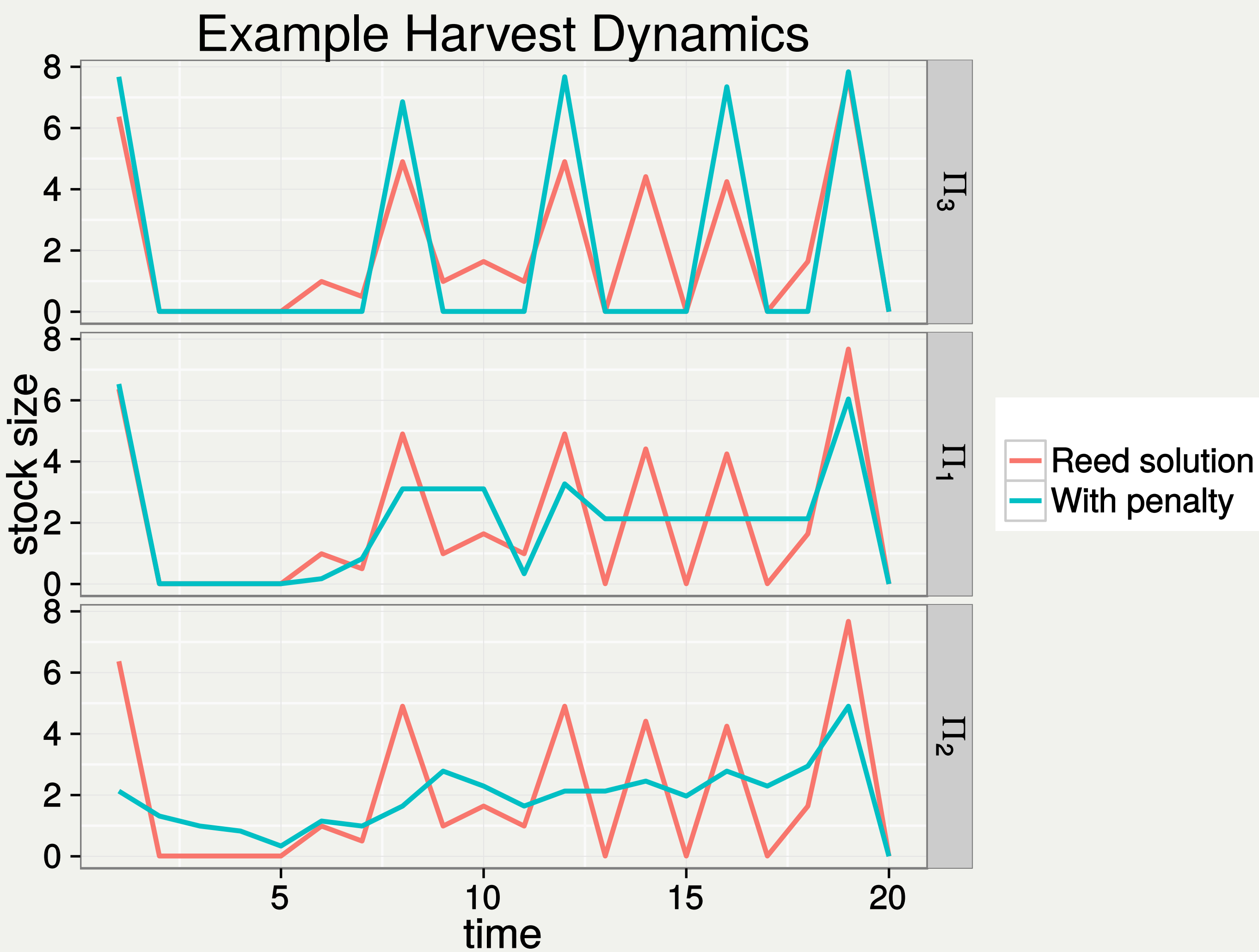
Fixed Costs (Π_3)



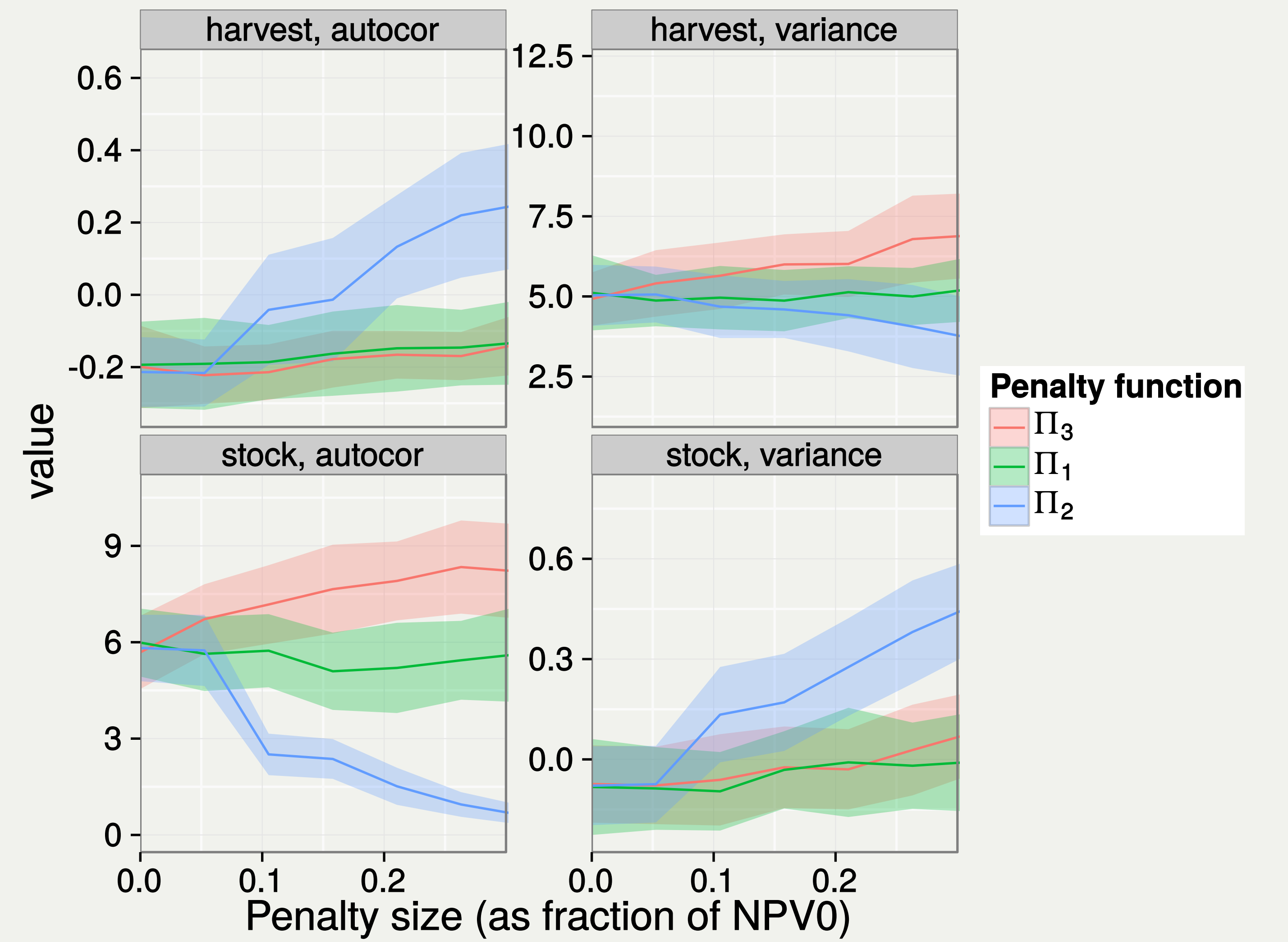
Linear Costs (Π_1)



(For comparison)



General trends



- Quadratic (Π_2) smooths, Linear (Π_1) flattens, Fixed (Π_3) jumps

Okay, so the policies "look" different. Does it matter?

Yes

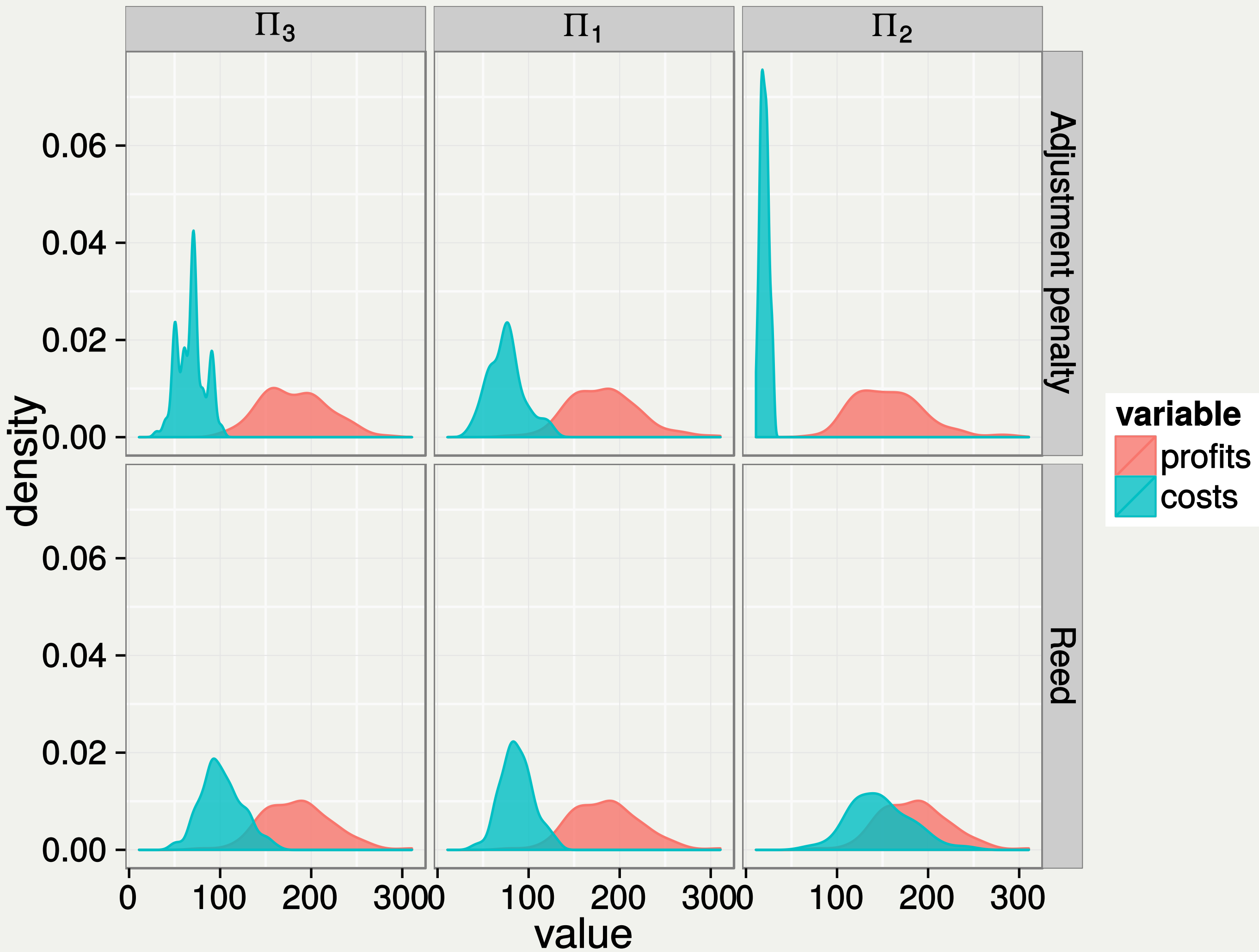
Managing under the wrong assumptions

$$NPV_i(h_1^*) = \sum_{t=0}^{\infty} (\overbrace{ph_{1,t}^* - c_0 E_{1t}^*}^{[1]} - \overbrace{c_1 |h_{1,t}^* - h_{1,t-1}^*|}^{[2]}) \frac{1}{(1+\delta)^t}$$

$$NPV_i(h_0^*) = \sum_{t=0}^{\infty} (\underbrace{ph_{0,t}^* - c_0 E_{0t}^*}_{[3]} - \underbrace{c_1 |h_{0,t}^* - h_{0,t-1}^*|}_{[4]}) \frac{1}{(1+\delta)^t}$$

1. Dockside profits when accounting for adjustment cost
2. (Anticipated) Fees paid for adjusting the policy
3. Theoretical maximum dockside profits
4. (Unanticipated) fees for those adjustments

Consequences of policy adjustment costs



Consequences of policy adjustment costs

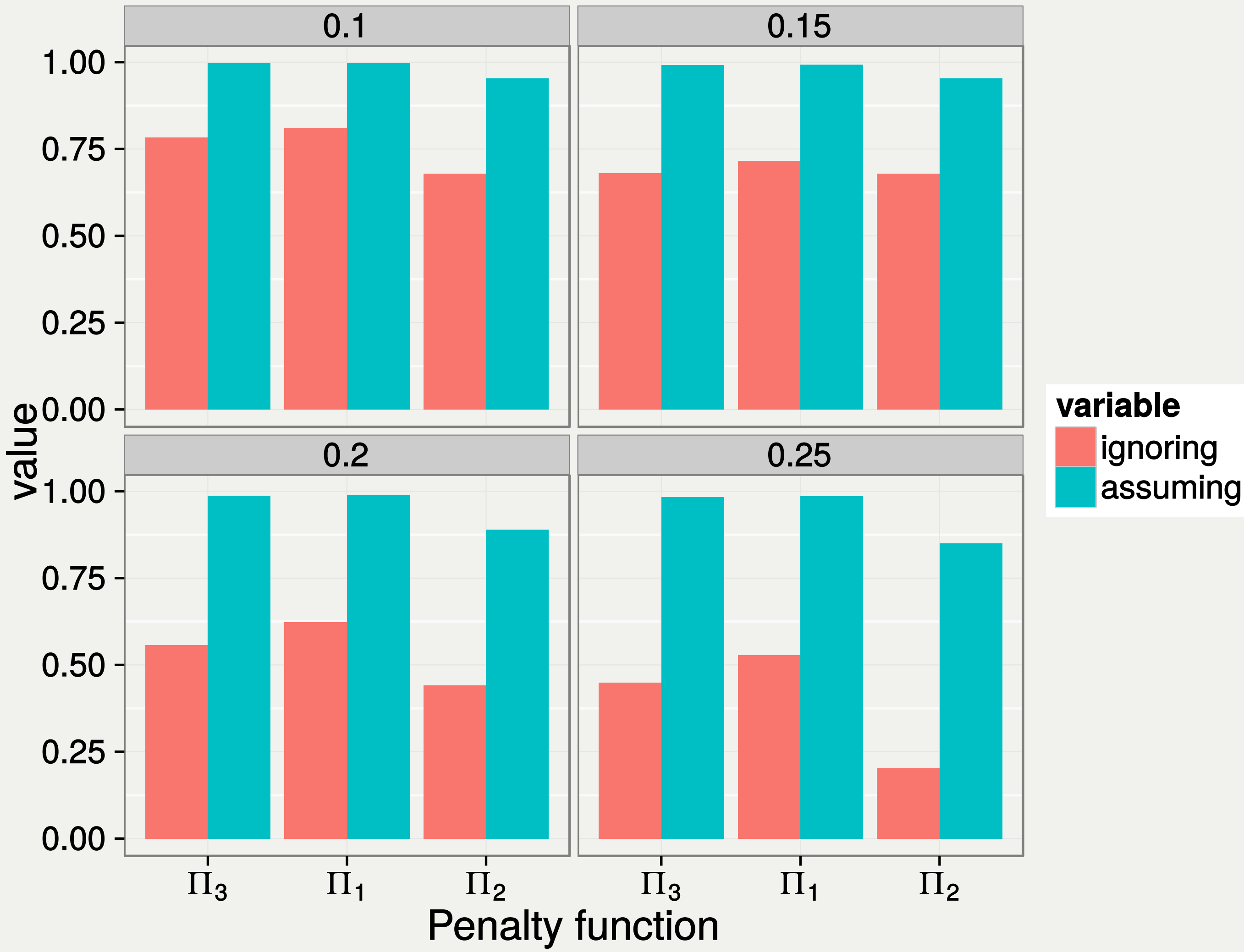
What is the impact of assuming costs are present when they are not?

- *Very little change to your bottom line* (regardless of cost structure)

What is the impact of ignoring costs when they are present?

- *Substantially higher costs* (particularly for quadratic costs).

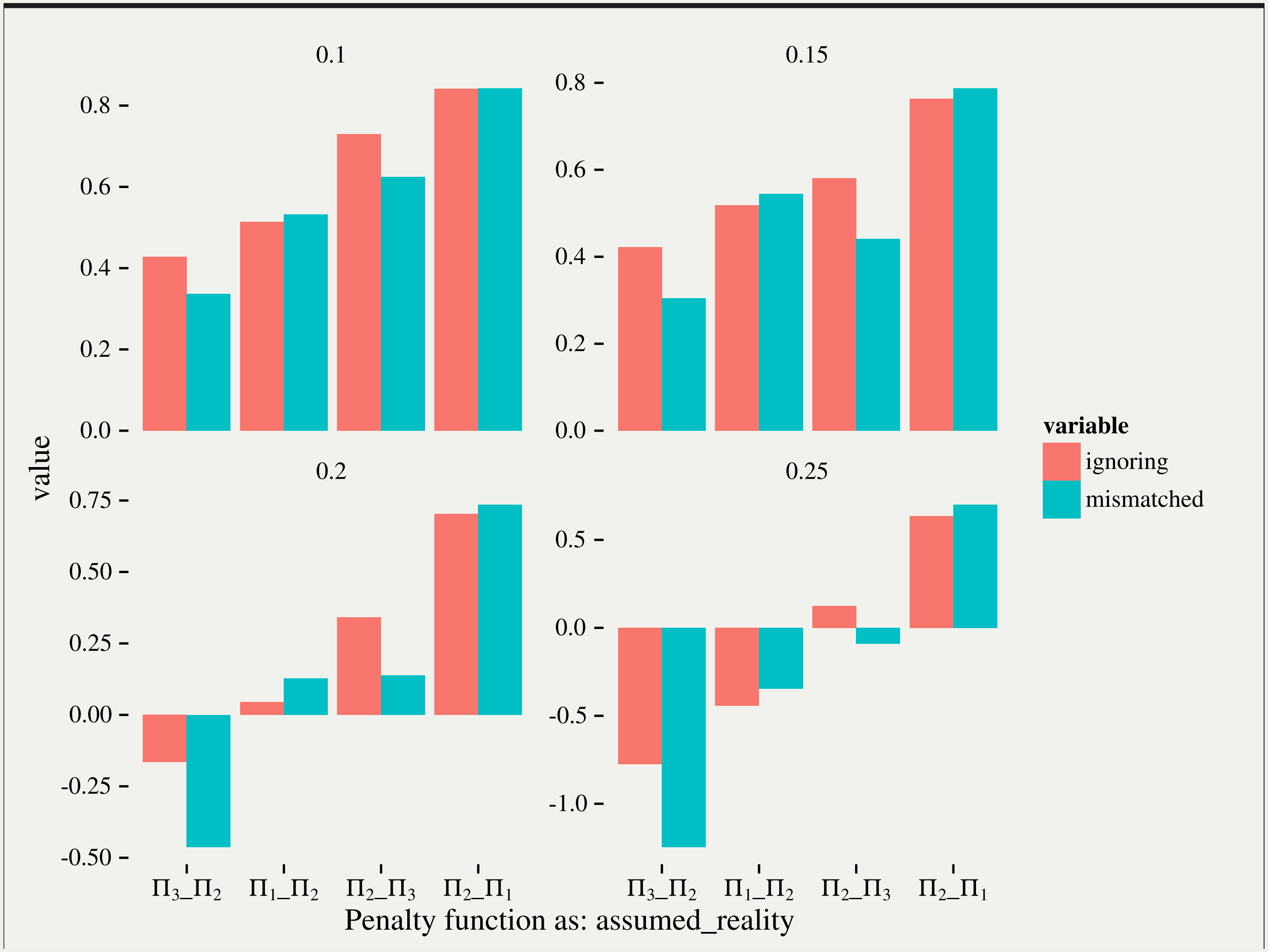
To say that another way:



What about managing when costs are present…

..but you’re using the wrong model??

Mismatches are even worse:



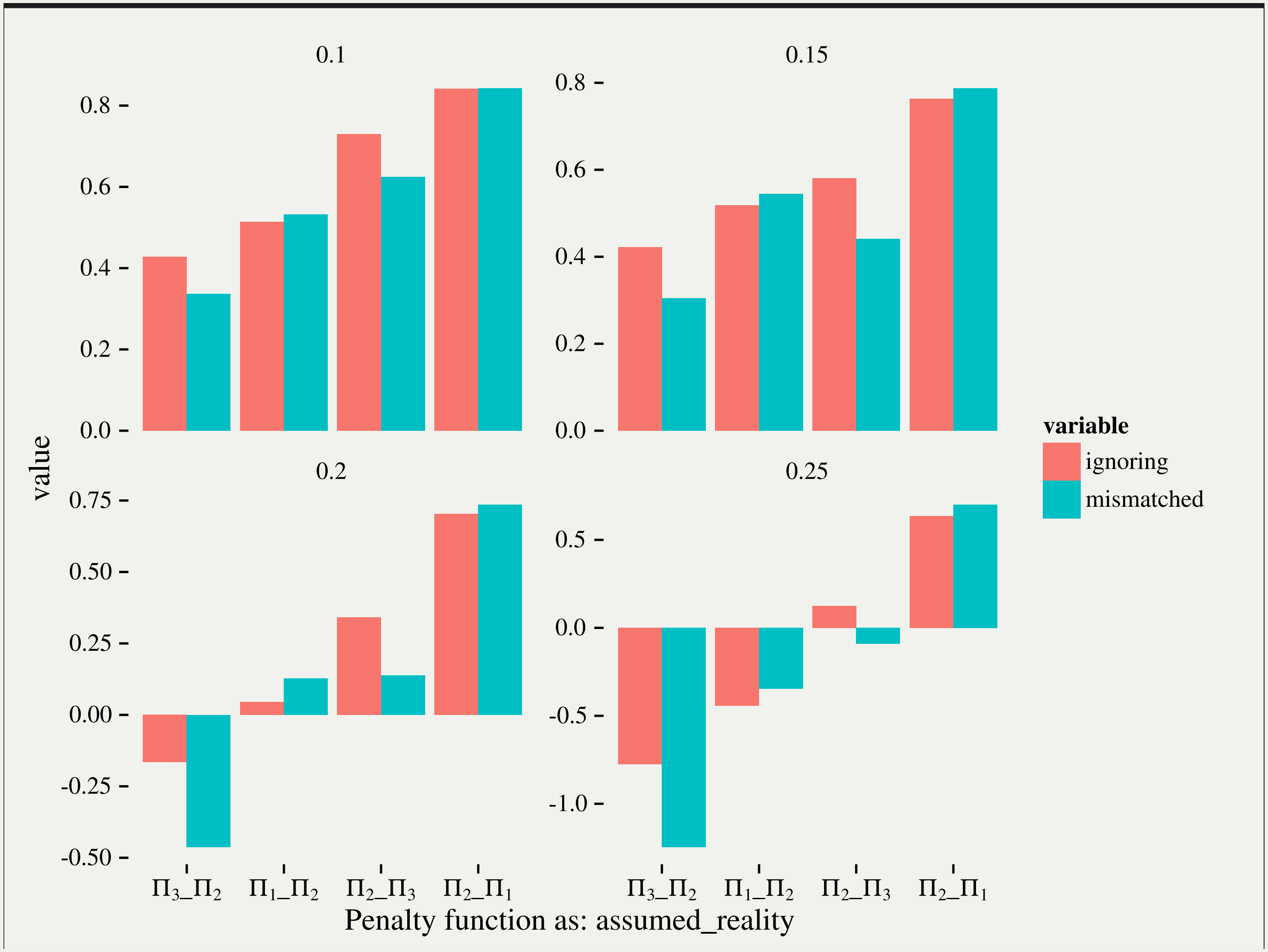
Mismatched costs are intuitive if we remember the general patterns

- Quadratic (Π_2) smooths
- Linear (Π_1) flattens
- Fixed (Π_3) jumps

Predict which is worse: assuming the wrong cost or no assuming no cost at all, when:

- Costs are assumed linear but in reality quadratic?
- True costs are assumed quadratic but in reality fixed?

Mismatched costs are intuitive



Conclusions

A 'Pretty Darn Good' Working Group

Acknowledgements

Slides, data, references, code and more at: http://io.carlboettiger.info/pdg_control