Governing the adaptation of long-lived assets: State or phat dependence?

Closing the Climate Adaptation Gap, March 24th, 2022

KLAUS EISENACK
 - RESOURCE ECONOMICS GROUP
HUMBOLDT-UNIVERSITÄT ZU BERLIN
WWW.RESOURCE-ECONOMICS.HU-BERLIN.DE
KLAUS.EISENACK@HU-BERLIN.DE

Barriers to CCA: Path dependence

- Generally well known in the adaptation literature
  (e.g. Moser & Ekstrom 2009, Biesbroek et al. 2011, Eisenack et al. 2014)
- Various interpretations of "path dependence", some equivalent, e.g.
  - "Small / random changes early on lead to large differences later"
  - "Inefficient conditions that are stable because they are self-enforcing"
  - Textbook example: QWERTY vs. Dvorak keyboards

(David 1985 American Economic Review, Arthur 1989 Economic Journal)

- Adaptation examples
  1. Institutional inertia / procrastination
  2. Poverty traps or fiscal stress from previous extreme events
  3. Adapting long-lived assets: dykes, houses, pipes, trees…
  4. Learning: water management based on historical record

Path… what?

- Consider sequences of system states $x_1, x_2, \ldots, x_t, x_{t+1}, \ldots$
- Simple state dependence: $x_{t+1} = G(x_t)$
- Path dependence: $x_{t+1} = G(x_1, x_2, \ldots, x_t)$

  For the next state x_{t+1}, the whole history $x_1, x_2, \ldots, x_t$ matters
- Phat dependence: $x_{t+1} = G(\{x_1, x_2, \ldots, x_t\})$

  Only the set of historic states $\{x_1, x_2, \ldots, x_t\}$ matters, not it's sequence

- "Equilibrium-dependent": Multiple long-run equilibria possible, depends on past states
- Under certain conditions equivalent to:
  There are states that cannot be reached from other states

(Page 2006, Quarterly Journal of Political Science)

Does this apply to CCA? Examples...

1. Institutional inertia / procrastination
   - Current set of rules blocks institutional adaptation; history of rule emergence does not matter
2. Poverty traps or fiscal stress from previous extreme events
   - Current wealth/poverty matters, not how it was reached
3. Adapting long-lived assets: dykes, houses, pipes, trees...
   - Current climate matters, but possibly also age of the assets; yet not sequence of events during past operation
4. Learning: water management based on historical record
   - Aggregate statics of past runoff matters; not sequence of e.g. flood events

	State	Phat	Path	Equ. Dep.
(1)	✓	×	×	✓
(2)	✓	×	×	✓
(3)	×	✓	×	?
(4)	×	✓	×	✓

- So far, I spotted no CCA example of path dependence in the strict sense

Path dependence always a problem?

- Path / equilibrium dependence might stabilize adaptation gaps or maladaptation over time
- But we might also be inclined to stabilize adaptation options over time
- Options might be designed to create appropriate equilibrium dependence
- For instance:

1. Avoiding a roll-back of local adaptation plans: Institutional inertia
2. Protecting rainy-day funds for extreme events from confiscation
3. Safeguarding long-term maintenance of protective infrastructure

- Path dependence more an analytical concept, not a normative

Governing path dependence

- How to chose actions or governance arrangements which enforce or dissolve path/equilibrium dependence?
- Some abstract strategies…

1. History
   – Learning / unlearning
2. Tipping points: states, where paths branch to multiple equilibria
   – Minor action effective
3. Self-enforcing mechanisms
   – Weaken / strengthen
4. Purposefully control flexibility / inertia

… let’s see an example

Adapting long-lived investments under climate change uncertainty

(Eisenack & Paschen 2022, under review)

If climate change continuously worsens weather conditions:

➢ Designing more “bunker houses”…

… or more “paper houses”?

- Increase robustness of investments (and expand expected life-time)?
  – Obtain benefits for a longer time, even under unfavorable climate
- Decrease robustness of investments (and shorten expected life-time)?
  – Remain more flexible in light of uncertain trends
- General considerations on how to adapt long-lived assets to uncertain climate change (Fisher & Rubio 1997, Callaway 2004, Hallegatte 2009, de Bruin & Ansink 2011, van der Pol et al. 2014)
  – E.g. if climate follows ongoing trend, long-lived assets need to adapt to broader range of conditions
  – Risk of making bad adaptation decisions due to uncertainty

Analysis as a stopping problem of stochastic dynamic control

Model structure with two adaptation decisions:

- Reactive: Abandoning the mal-adapted investment
- Anticipatory: Changing the investment's robustness up-front

Timing:

1. Irreversibly decide on robustness (by anticipating stage 2)

   … project starts, uncertain climate and stream of benefits enfolds

2. Irreversibly decide to stop the investment at some time T^*

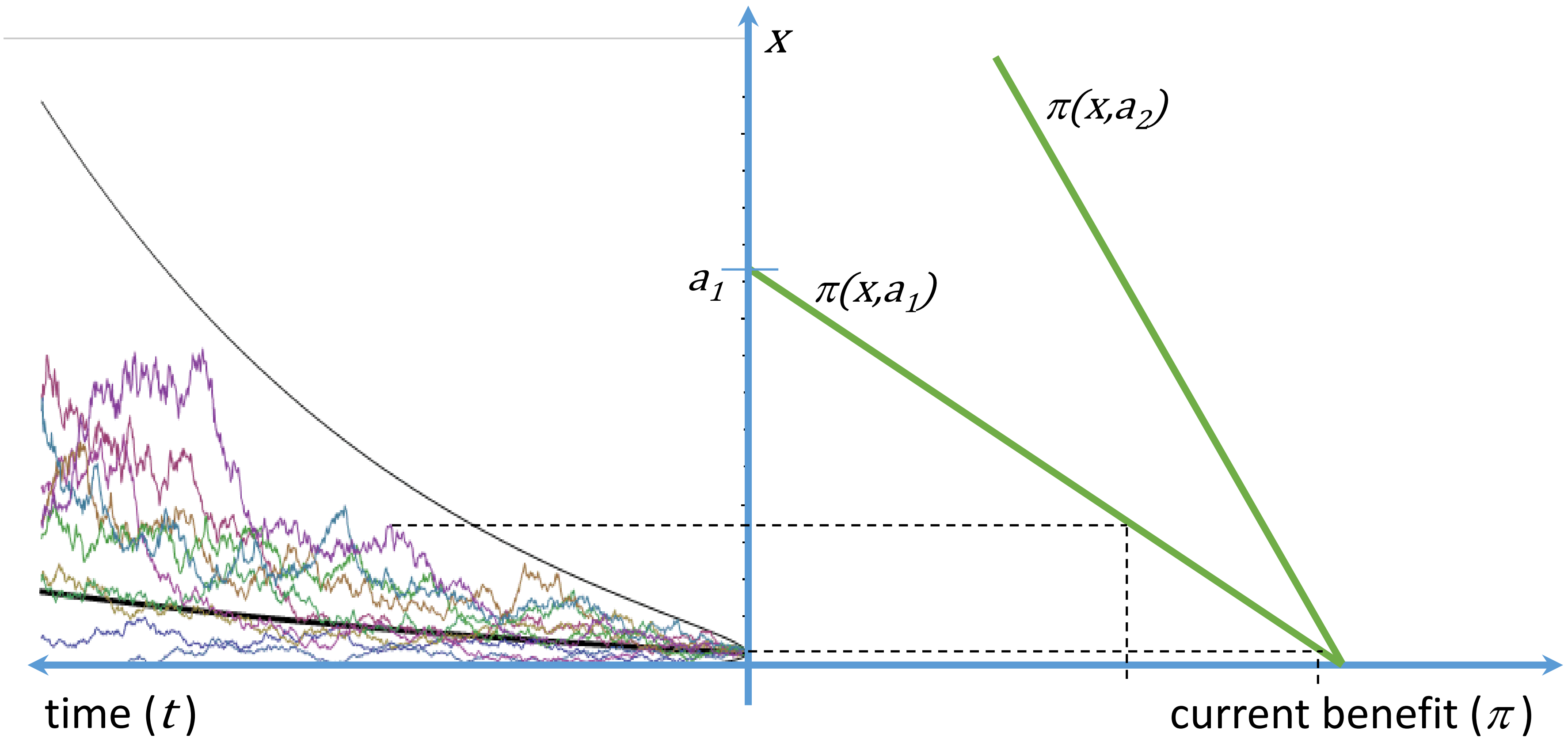
Maximize with respect to robustness *a* and stopping time T^*

$$J(x_0, a, \mu, \sigma) = E[\int_0^{T^\star} \pi(x,a)e^{-rt}dt] - C(a)$$

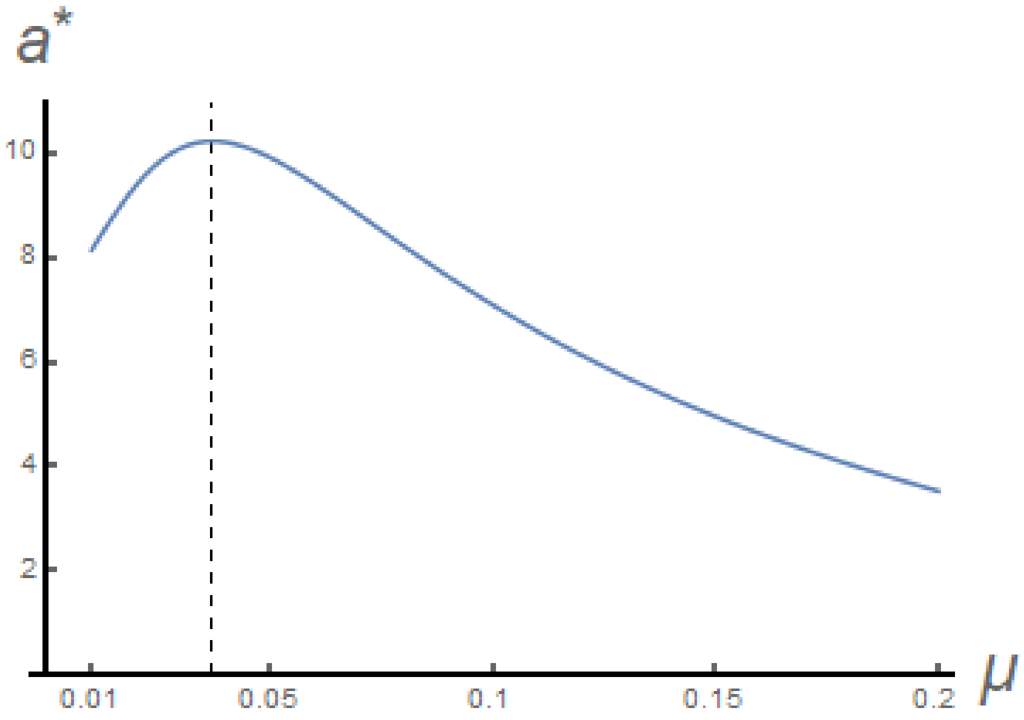
subject to the geometric Brownian motion $dx = \mu x \, dt + \sigma x \, dz$

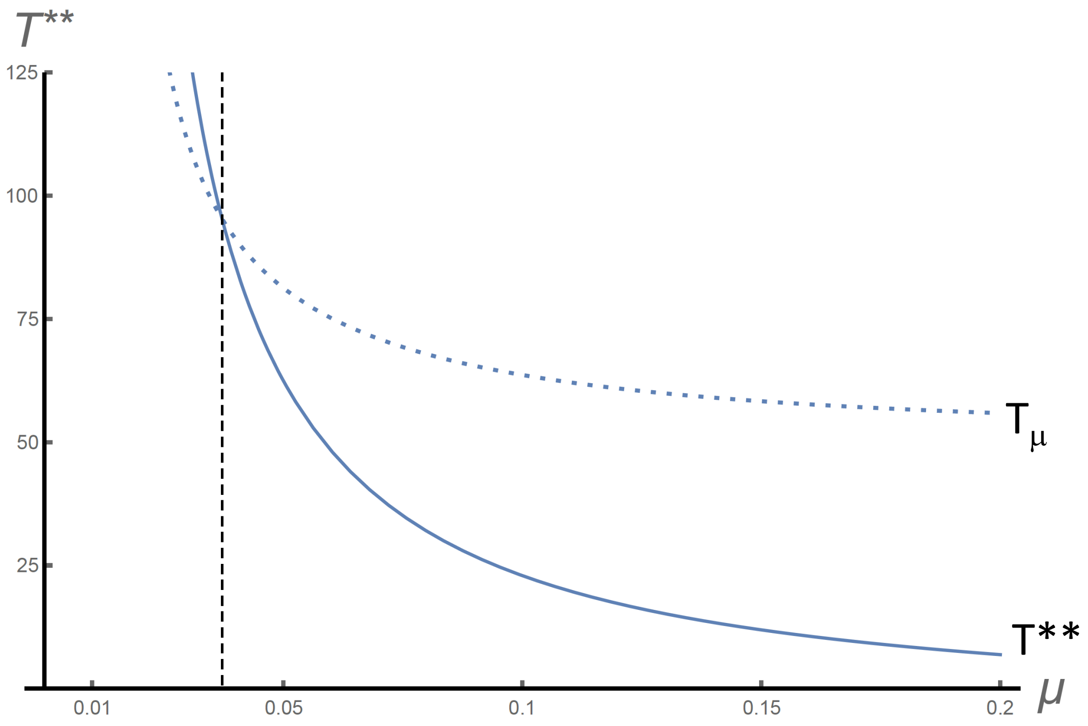
x	climate parameter
π	current benefit
a	robustness
μ	trend
σ	uncertainty
r	discount rate
C	robustness costs

Insightful case with linear current benefit and robustness



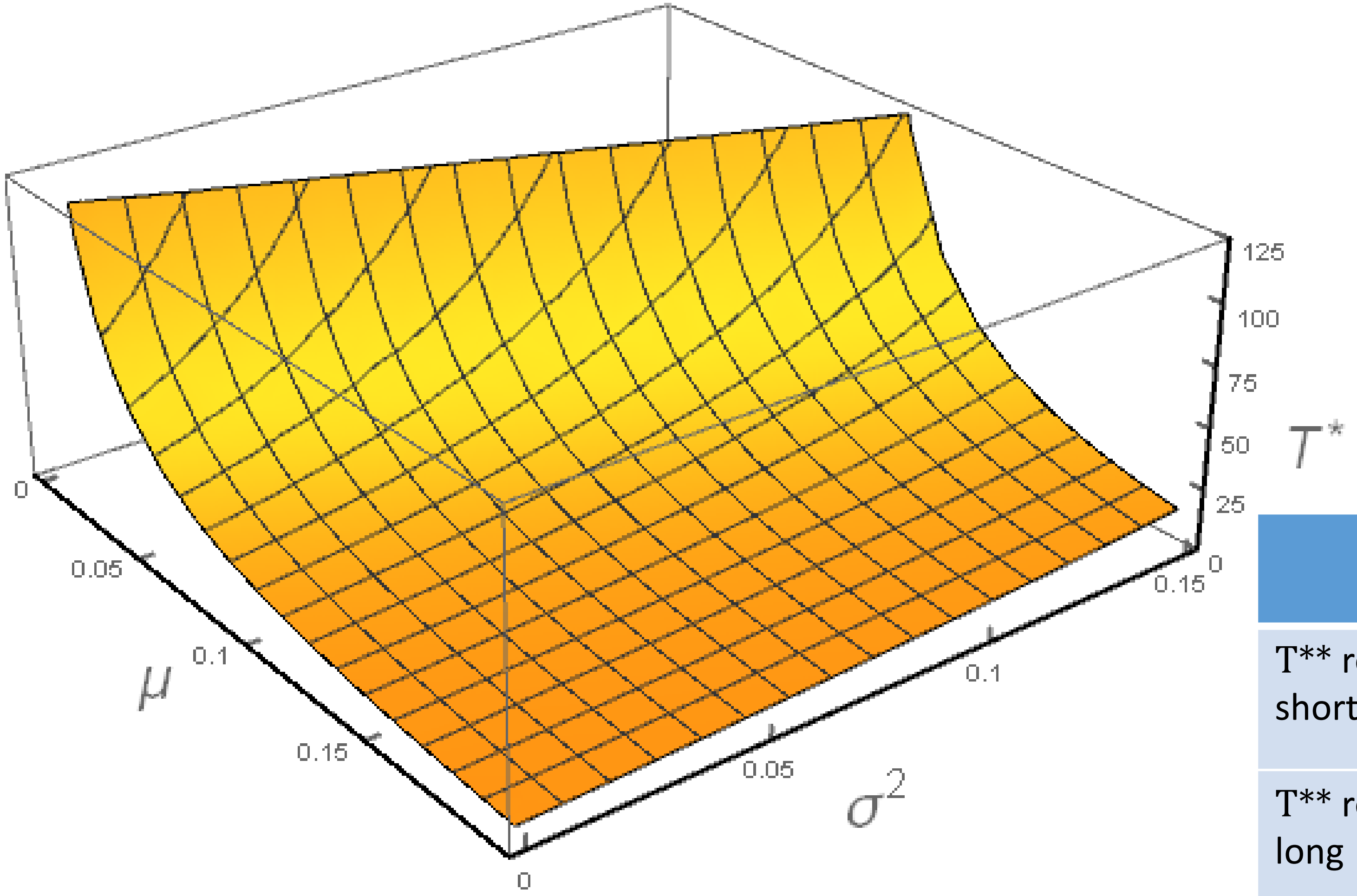
Numerical experiments for different trends





		Robustness (a*)	Expected life-time (T**)
T** relatively short	Uncertainty (σ)	(+)	(+)
	Trend (μ)	(-)	(-)
T** relatively long	Uncertainty (σ)	(-)	(?)
	Trend (μ)	(+)	(?)

Numerical experiments, for different trends and uncertainty



		Robustness (a*)	Expected life-time (T**)
T** relatively short	Uncertainty (σ)	(+)	(+)
	Trend (μ)	(-)	(-)
T** relatively long	Uncertainty (σ)	(-)	(?)
	Trend (μ)	(+)	(?)

General results

Current infrastructure	Change parameters	Optimal result	
Optimal expected life-time (T**)		Robustness (a*)	Expected life-time (T**)
Relatively short (T** below some T_σ or T_μ)	uncertainty (σ)	(+)	(+)
	trend (μ)	(–)	(–)
Relatively long (T** above some T_σ or T_μ)	uncertainty (σ)	(–)	(?)
	trend (μ)	(+)	(?)

First-order effects dominate

(also mixed cases possible with $T_\sigma < T_\mu$ or $T_\sigma > T_\mu$)

Conclusions

- Not everything is path dependence
- Path dependence in climate change adaptation needs to be governed
- One governance channel is to increase/decrease the flexibility of options' consequences
- Thus, climate change might require to design investments in a less robust way
- Expectations about the future…
  - Missing component in standard conceptualizations of path dependence
  - Matter a lot for adaptation decision making, in particular in the presence of long lead-times or long-lived adaptations
  - To make things more complicated: past experience can shape expectations
  - Conceptualizations of "Adaptation lock-in" might take this into account

Thank you very much for your attention

KLAUS.EISENACK@HU-BERLIN.DE

WWW.RESOURCE-ECONOMICS.HU-BERLIN.DE