The Innovation Dilemma

∼ Uncertainty and Optimization ∼

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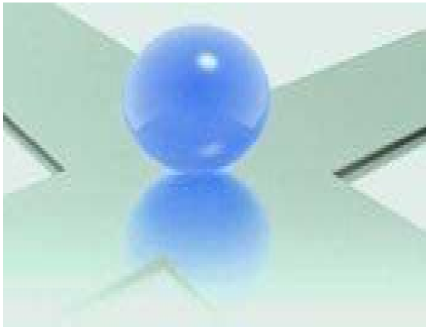

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1 *Highlights*

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§ Innovation dilemma:

- **Innovations are often:**
  - **Improvements.**

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§ **What is info-gap robust-satisficing?**

(And when is it better than optimizing the outcome?)

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(And when is it better than optimizing the outcome?)

§ **Example: Search and destroy. (Hauser and McCarthy)**

2 *Info-Gap Uncertainty: Examples*

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Lewis Carroll's

∼∼*Transcendental Probability*∼∼

Figure 1: **Dodgson, 1832–1898.**

Figure 2: **Alice**

"A bag contains 2 counters, as to which nothing is known except that each is either black or white. Ascertain their colours without taking them out of the bag."

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Figure 3: **Dodgson, 1832–1898.**

Figure 4: **Alice**

"A bag contains 2 counters, as to which nothing is known except that each is either black or white. Ascertain their colours without taking them out of the bag."

Answer: "One is black, and the other white."

∼∼*Interest rate after 9/11*∼∼

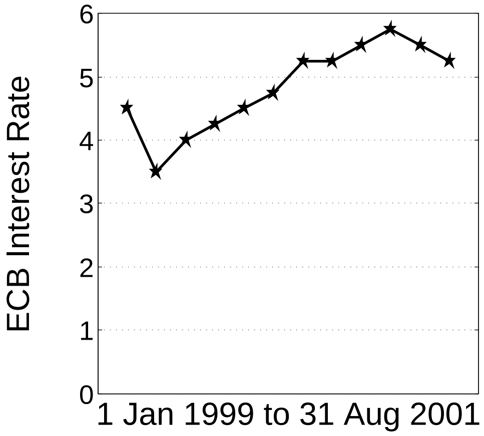

Figure 5: **ECB Interest Rates**

- **Rate fairly constant through Aug 2001**

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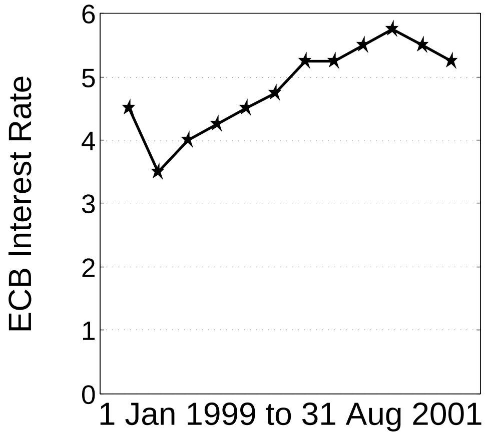

Figure 6: **ECB Interest Rates**

Figure 7: **11 Sept 2001.**

- **Rate fairly constant through Aug 2001**
- **After 9/11 ECB will reduce the rate.**
- **Info-gap:**
  - **Reduce by how much?**
  - **What is ECB decision model?**

∼∼*Climate Change*∼∼

§ The issue:

Sustained rise in green house gases

results in temperature rise

which results in adverse economic impact.

§ Models:

- **Temperature change:** $\Delta CO_2 \Longrightarrow \Delta T$.
- **Economic impact:** $\Delta T \Longrightarrow \Delta$GDP.

§ The problems:

- **Models highly uncertain.**
- **Data controversial.**

§ E.g., IPCC model for

Uncertainty in Equil'm Clim. Sensi'ty, S.

- **Likely range: 1.5°C to 4.5°C.**
- **Extreme values highly uncertain.**
- **95th quantile of S in 10 studies:**

Mean: 7.1°C. St. Dev: 2.8°C.

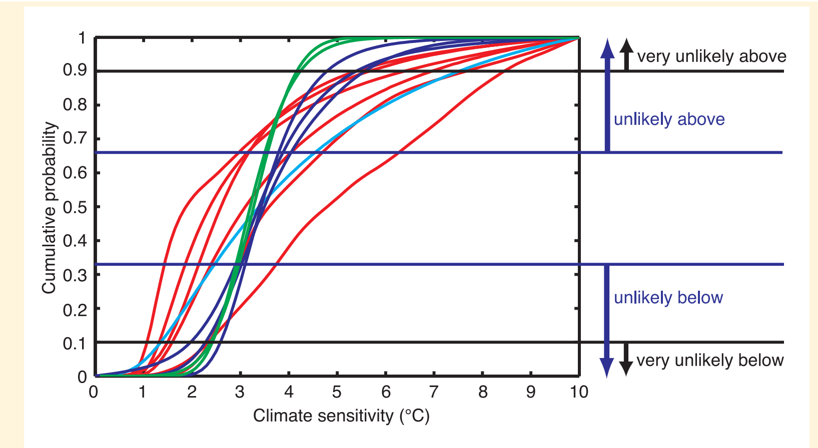

Figure 8: IPCC ch.10, p.799.

∼∼*Summary*∼∼

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§ **Severe Knightian uncertainties:** Gaps in **knowledge, understanding** and **goals.**

§ **Info-Gap models of uncertainty:**

- Disparity between what is known and what needs to be known for responsible decision.
- Unbounded family of sets of events (points, functions or sets).
- No known worst case.
- No funcs. of probability, plausibility, likelihood, etc.
- Hybrid: info-gap model of probabilities.

3 What is an Info-Gap?

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§ **Let's examine info-gap uncertainty.**

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- **Equal probabilities of 1 , . . . , 6.**
- **Known event space; known likelihoods.**

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- Excluded middle: proposit'n can't be both T and F.

§ Probability applies excluded middle to uncertainty:

Proposition can't be 'very likely' and 'very unlikely'.

§ In ecology we can't always exclude the middle.

Example: Light Brown Apple Moth in CA.

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Example: Light Brown Apple Moth in CA.

- **LBAM is an invasive species? Very likely.**

  Only recently discovered. Hence new introduction.

- **LBAM is an invasive species? Very unlikely.**

  Wide distribution. Hence old introduction.

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    — **Non-probabilistic.**
    — **Due to innovation, initiative, discovery, deceit.**
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  - Tomorrow's behavior indeterminate today.

4 *What is Info-Gap Robust-Satisficing?*

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- Seek **reliable good-enough outcomes.**
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- Don't try to optimize the outcome.
- **Optimize robustness** against surprise.
  Satisfice the outcome.

§ **Evaluate proposed policy with the robustness question:**
How much error and surprise can we tolerate and still meet our goals?

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§ **Policy neutrality:**

- **Analyst knows policymaker's goals and options.**
- **Analyst assists policymaker to prioritize options.**
- **Analysis contingent on policymaker's preferences.**

5 *Invasive Species Management: Info-Gap Approach*

§ **Allocate resources to seek and destroy an agent:**
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invasive species management, *Ecology Letters.*

§ **Related publications:**

• Moffitt, Stranlund and Field, 2005, Inspections to avert terrorism, *J Homeland Security Emer Mgt.*

• Moffitt, Stranlund and Osteen, 2008, Robust detection . . . of invasive species, *J Envir Mgt.*

• Davidovitch and Ben-Haim, 2011, Is your profiling strategy robust? *Law, Probability and Risk.*

• Sisso, Shima, and Ben-Haim, 2010, Info-gap approach to multi agent search, *IEEE Transactions on Robotics.*

§ Notation for site i (from Hauser and McCarthy):

p_i = **probability that the agent is present.**

x_i = **surveillance effort, in units of cost. Must choose.**

λ_i = **surveillance efficiency.**

$\mathrm{e}^{-\lambda_i x_i}$ = **probability of not detecting agent if it is present.**

C_i^{D} = **expected cost of incursion mgt if agent is detected.**

C_i^{U} = **expected cost if agent is present but undetected.**

Assume: $C_i^{\mathrm{U}} > C_i^{\mathrm{D}}$.

$T_i(x_i)$ = **expected combined surveillance and incursion management cost:**

$$T_i(x_i) = x_i + \underbrace{\left[\left(1 - \mathrm{e}^{-\lambda_i x_i}\right) C_i^{\mathrm{D}} + \mathrm{e}^{-\lambda_i x_i} C_i^{\mathrm{U}}\right]}_{\gamma_i(x_i)} p_i \qquad (1)$$

B = **total budget.**

n = **number of sites.**

§ We will choose effort x_i for single site.

$$T_i(x_i) = x_i + \underbrace{\left[\left(1 - \mathrm{e}^{-\lambda_i x_i}\right) C_i^{\mathrm{D}} + \mathrm{e}^{-\lambda_i x_i} C_i^{\mathrm{U}}\right]}_{\gamma_i(x_i)} \; p_i \tag{2}$$

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§ Info-gaps:

- **Costs:** C_i^{D}, C_i^{U}.
- **Functional relation between:**
  effort (λ_i) **and prob not detecting** ($\mathrm{e}^{-\lambda_i x_i}$).
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- **Costs:** C_i^{D}, C_i^{U}.
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- **Probability of presence: p_i.**

§ **Questions:**

- **Should we use best model to seek best predicted outcome? (putative optimization)**
- **Relation between putative optimization and robust-satisficing?**
- **Is there an innovation dilemma?**

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- $\widetilde{p}_i$ = **known** estimated probability of presence.
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- **No known worst case.**
- **Unknown fractional error info-gap model:**

$$\mathcal{U}(h) = \left\{ p : \ 0 \le p_i \le 1, \ \left| \frac{p_i - \widetilde{p}_i}{s_i} \right| \le h, \ i = 1, \ldots, n \right\}, \quad h \ge 0 \quad (9)$$

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- **Satisficing: Keep total cost acceptable:** $T_i(x_i) \le T_c$.
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$$\widehat{h}(T_c, x_i) = \max \left\{ h : \ \left(\max_{p \in \mathcal{U}(h)} T_i(x_i) \right) \le T_c \right\} \tag{10}$$

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§ Robust-satisficing:

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§ Numerical example:

- **Costs if detected or not:** $C_i^{\rm D} = 40$, $C_i^{\rm U} = 400$.
- **Probability of presence:** $\widetilde{p}_i = 0.03$ **and** $s_i = 0.03$.
- **Effort and efficiency vary:** x_i **and** λ_i.

§ Results.

- **Evaluate 3 options:** $x_i =$ **0.9, 1, or 1.1.**
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- **Evaluate 3 options:** x_i = **0.9, 1, or 1.1.**
- **Efficiency:** λ_i = **1.9.**
- $e^{-\lambda_i x_i}$ = **probability of not detecting agent if present.**
- $T_i(\widetilde{p}_i)$ = **putative expected surveillance and incursion management cost. . . .**

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x_i	$e^{-\lambda_i x_i}$	$T(\widetilde{p}_i)$
0.9	0.1809	4.05
1.0	0.1496	3.82
1.1	0.1237	**3.64**

Table 1: Data for robustness curves. $\lambda_i = 1.9$.

- **Putative optimum:** x_i = **1.1 (among these options).**
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§ Results.

- **Evaluate 3 options:** x_i = **0.9, 1, or 1.1.**
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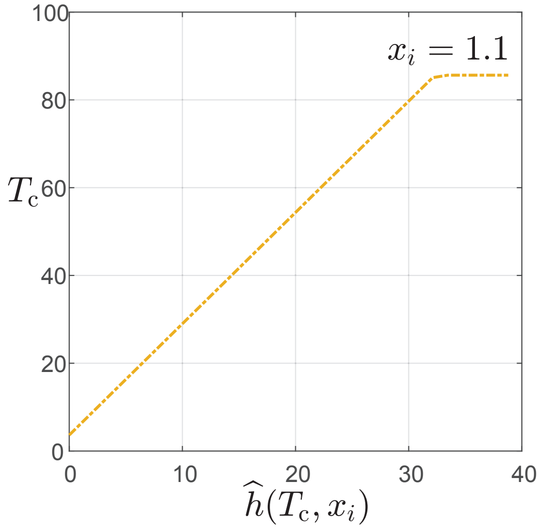
Table 2: Data for robustness curves. $\lambda_i = 1.9$.

- **Putative optimum:** x_i = **1.1 (among these options).**
- **Is** x_i = **1.1 a good choice? How robust to info-gaps?**



§ **Robustness curve.** $x_i = \mathbf{1.1}$, $\lambda_i = \mathbf{1.9}$:

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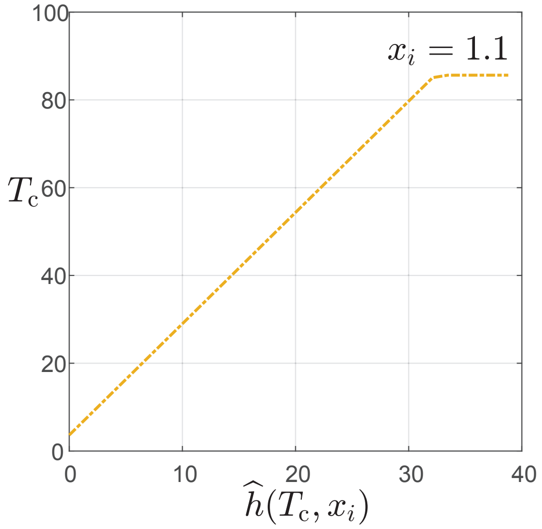
-



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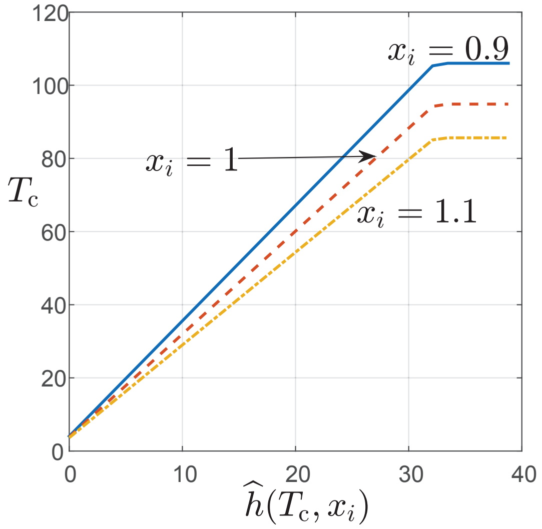
  Choosing $x_i = 1.1$ because $T_i(\widetilde{p}_i)$ minimal is **unreliable.**



§ **Robustness curves.** $x_i =$ **0.9, 1, 1.1.** $\lambda_i =$ **1.9:**

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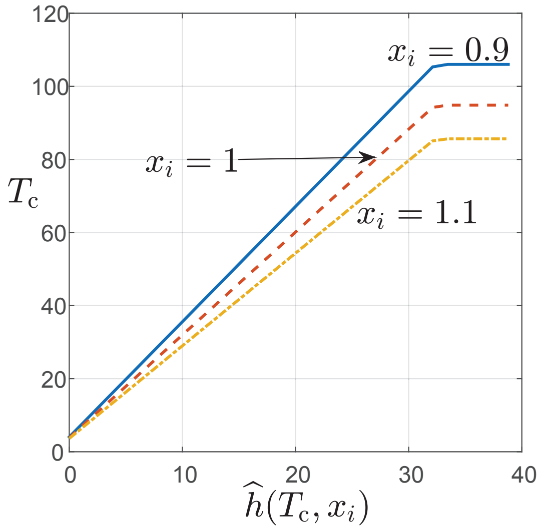
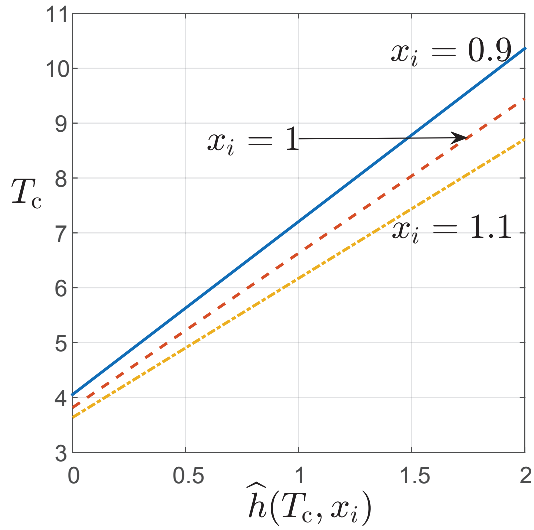
- $x_i =$ **1.1 seems robust dominant. . . .**





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- $x_i = 1.1$ seems **robust dominant. Yup!**
- Choose $x_i = 1.1$ because most robust at OK T_c:
  Robust-satisficing not putative optimization.

§ More Results.

- **Evaluate 3 options:** $x_i =$ **3, 4, or 5.**
-

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4	0.2187	**7.56**
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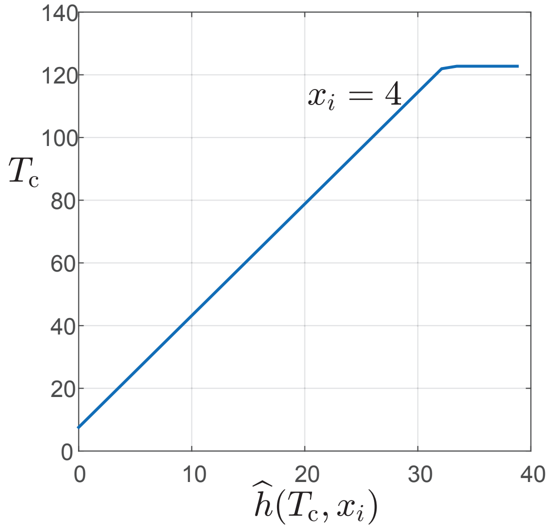

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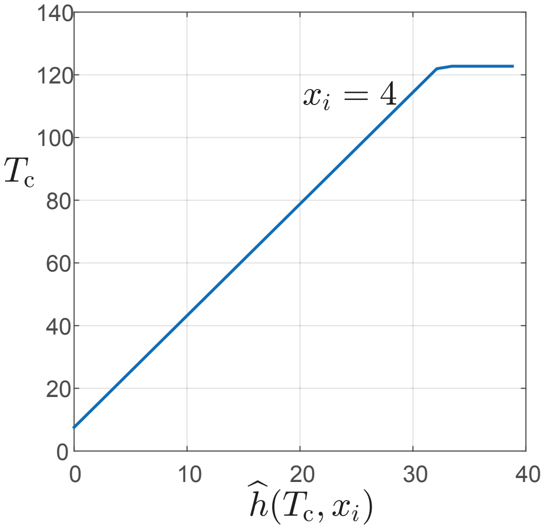

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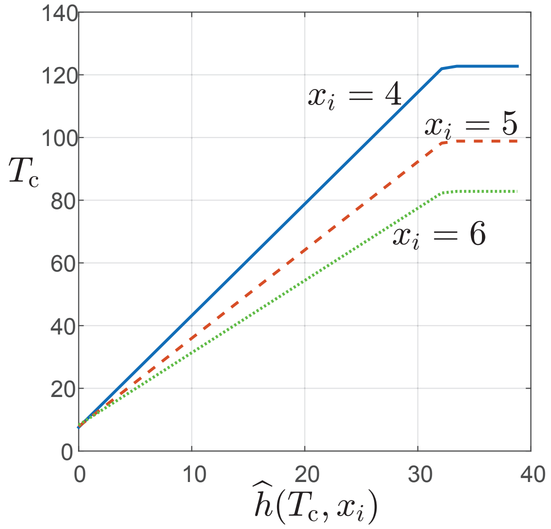

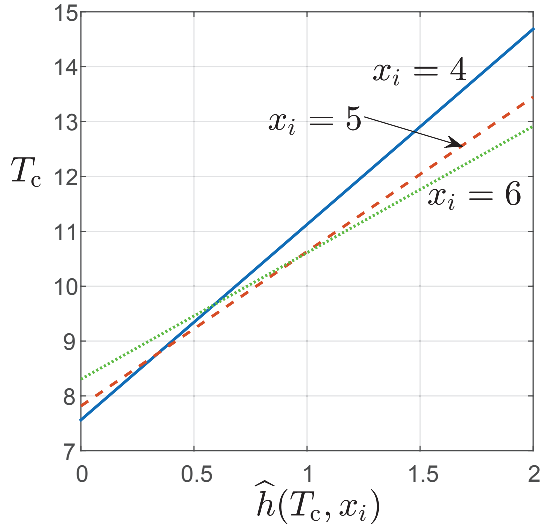

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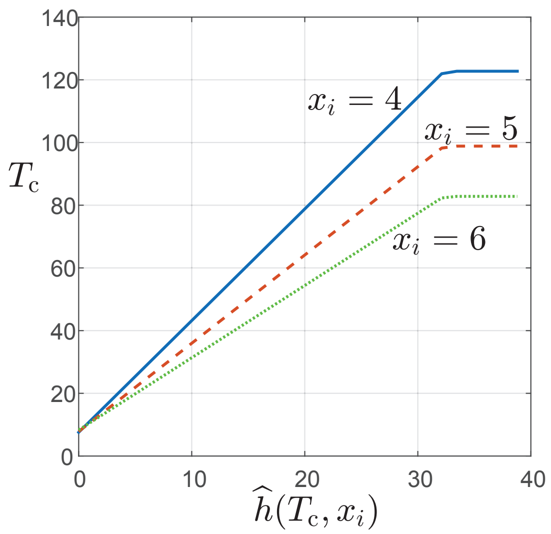
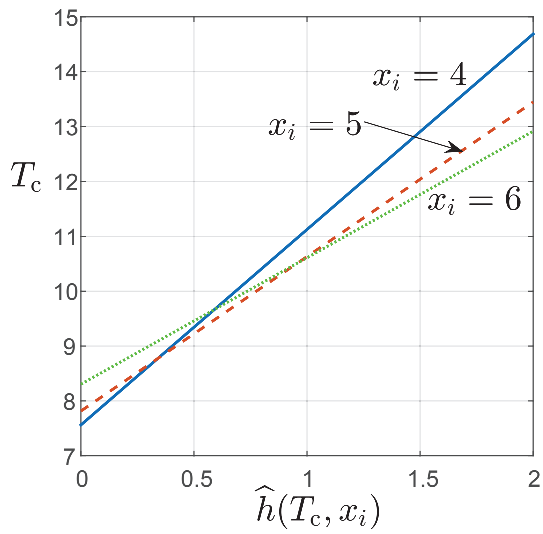
- $x_i = 4$ **not robust dominant.**
-





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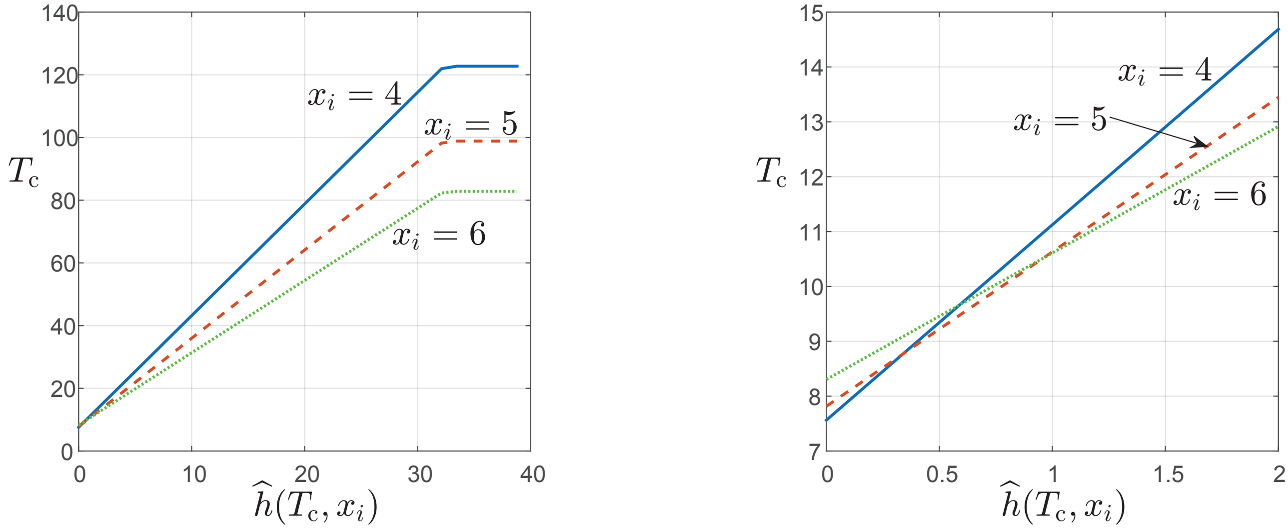
  -



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  - $x_i =$ 6: poor (hi) putative T; good (lo) cost of rbs.

6 *Conclusion*

In Conclusion

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innovation, discovery, ignorance, surprise.

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§ **Responsible decision making:**

- **Specify your goals.**
- **Maximize your robustness to uncertainty.**
- **Study the trade offs.**
- **Exploit windfall opportunities.**