Risk aversion in transmission infrastructure planning

Risk aversion in transmission infrastructure planning

Harry van der Weijde
Institute for Energy Systems, School of Engineering,
University of Edinburgh
Benjamin F. Hobbs
Department of Geography & Environmental Engineering and E²SHI,
Johns Hopkins University
Francisco Muñoz
Analytics Department, Sandia National Laboratories

2014 Informs Annual Meeting, San Francisco

With thanks to funding sources: NSF, ESPRC and US DoE

THE UNIVERSITY of EDINBURGH
School of Engineering

Outline

- Uncertainty and risk aversion in electricity markets: **what can we already do, what don't we know, and what are the main challenges?**
- Example: risk-averse transmission planners: **does risk aversion matter here?**
- Transmission planning s.t. risk-averse generation investors: **do you plan transmission differently if generators are risk averse?**
- Some conclusions

THE UNIVERSITY of EDINBURGH
School of Engineering

Uncertainty in electricity markets

- Short-term variability (aleatory)
  - Outages, demand, wind
- Long-term uncertainty (epistemic)
  - Investment costs (generation and transmission), variable costs of generation, demand growth, policy
- Problem: long lead times, irreversible decisions + incomplete markets
- Risk aversion

Long lead times?

JHU

UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

We Need Electric Policy Models with Uncertainty and Risk Aversion!

Benjamin F. Hobbs

Schad Professor of Environmental Management
Whiting School of Engineering, The Johns Hopkins University

Electricity Policy Research Group, University of Cambridge

California ISO Market Surveillance Committee

bhobbs@jhu.edu

The 1st International Ruhr Energy Conference
Stochastics and Risk Modelling for Energy and Commodity Markets
5 October 2009

Thanks to: Lin Fan, Catherine Norman, Javier Inon (JHU); Ming-Che Hu (UIUC); Steve Stoft; Murty Bhavaraju (PJM); Harry van der Weijde (Cambridge); Anthony Patt, Keith Williges, Volker Krey (IIASA)

THE UNIVERSITY of EDINBURGH
School of Engineering

What can we already do?

- **Generation capacity investment**
  - Roques, Newbery & Nuttall, 2008, EE 30: Portfolios
  - Fan, Hobbs & Norman, 2010, JEEM 60: CARA utility
  - Morbee & Willems, 2010, EE 32(4): include risk trading
  - Ehrenmann & Smeers, 2011 in Bertocchi et al.: stochastic discount rates
  - Ehrenmann & Smeers, 2011, OR 59(6): CVaR maximisation
  - Ralph et al., INFORMS 2013: existence of equilibria using CVaR/other CRMs.

What can we already do?

- **Transmission planning**
  - Delgado & Claro: min total costs (gen + trans), network structure is important
  - Arroyo et al., 2010, IEEE Trans PS 25(3): min max regret + total costs: small increase in costs can mitigate a lot of risk
  - Other infrastructure/planning settings (e.g. De Palma, Picard & Andrieu, 2012, Netw Spat Econ 12)

What don’t we know (well)?

- **Risk aversion in networks**
- **Bi-level risk-averse (transmission) planning**
  - Risk-averse transmission planner/policy maker vs.
  - Risk-averse generation investors
- **Dynamic models: multi-period investment**

What are some challenges?

1. **Individual decision making**
   - Project-based: each plant is evaluated separately e.g., Ehrenmann & Smeers, 2011, OR 59(6); Fan, Hobbs & Norman, 2010, JEEM 60.
     - No physical or financial hedging opportunities
   - Portfolio-based, e.g. Roques, Newbery & Nuttall, 2008, EE 30
     - Needs heterogeneous investors to be interesting

What are some challenges?

2. What type of risk aversion?

- Economics: max CRRA/CARA utility functions
  - Empirical evidence/behavioural theory supports RRA, ARA easier to use
- Finance: VaR/CVaR/others
  - max CVaR = I only care about worst x% of cases
  - max combination of CVaR + expected profits = I put a higher weight on the worst x%
  - CVaR constraints = the worst x% can't be worse than z
- Other measures

What are some challenges?

3. **Individual to collective: how does the regulator value risk?**
   - e.g., risk-averse generators: should planner min cost or incorporate generator's objective?
4. **Dynamic models: time consistency**
5. **Financial markets: presence and completeness**

THE UNIVERSITY of EDINBURGH
School of Engineering

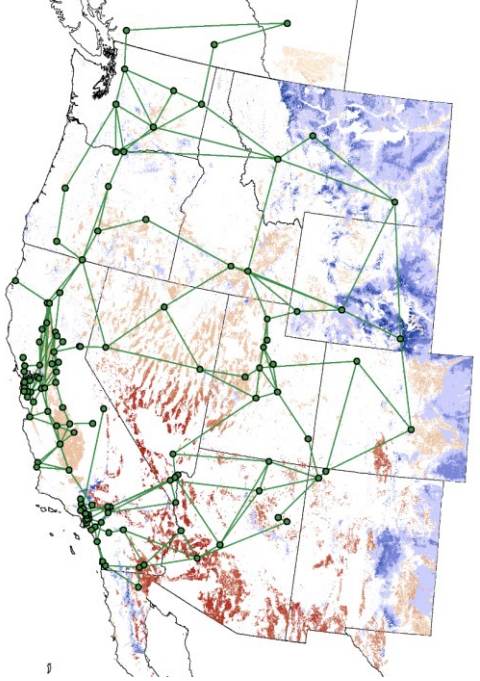
Example: risk-averse transmission planners

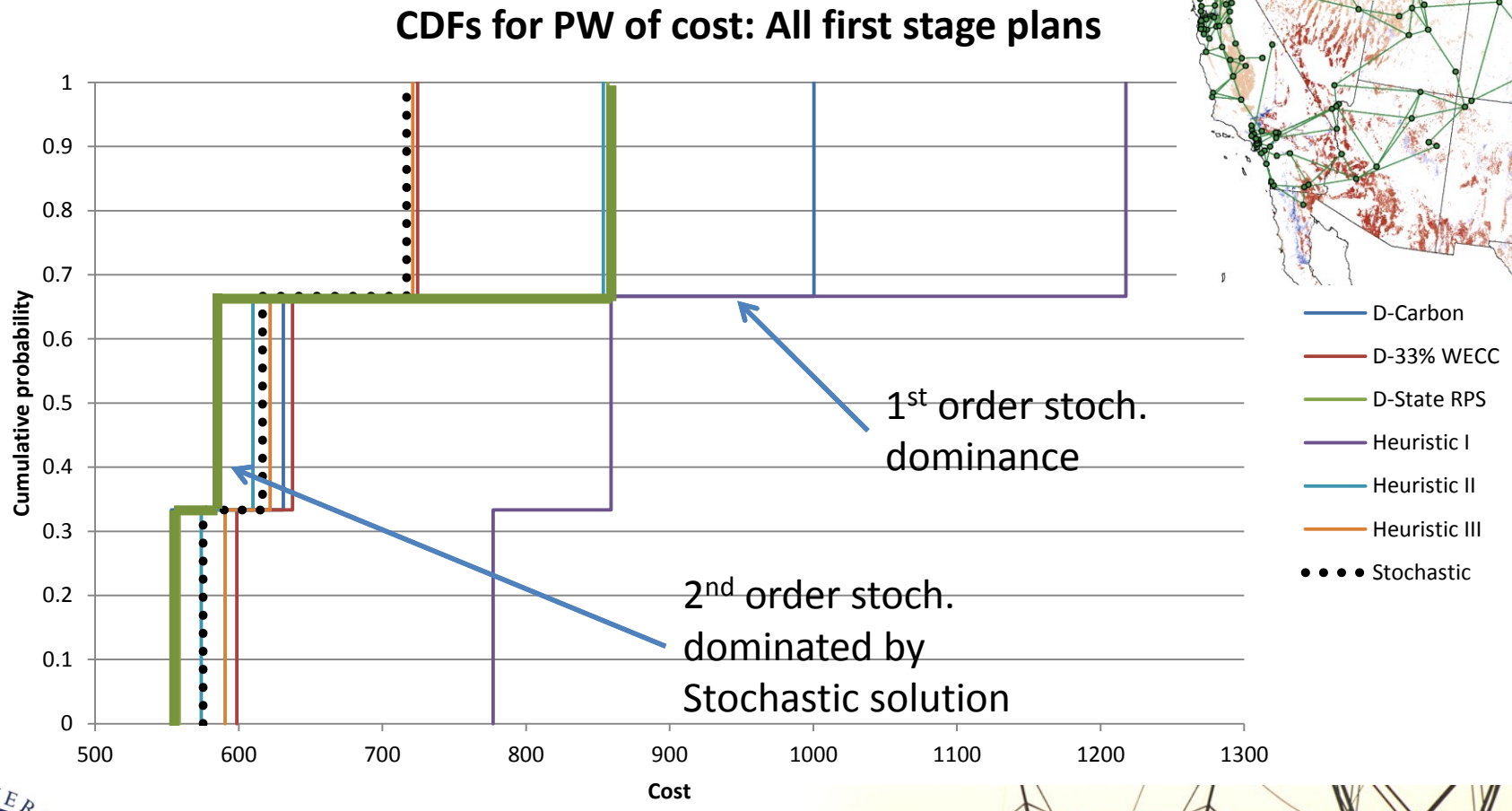
- van der Weijde & Hobbs (2012), Energy Econ 34
  - transmission planning + generation response in simplified UK network, 6 scenarios, 5 investments
- Munoz et al. (2014), IEEE TPS 29(1)
  - much larger WECC network, 3 scenarios, many investments
- Show value of stochastic planning
  - changed first-stage decisions, VSS, EVPI

Example: risk-averse transmission planners

- Find deterministic plan for each scenario (what would a naïve planner do?)
  - Are generators also naïve or not?
- Evaluate how plans perform for every outcome
  → calculate cost of ignoring uncertainty (VSS)
- Can use results to consider risk aversion, but:
  - Generators still risk neutral
  - Subset of possible plans considered: there may be others

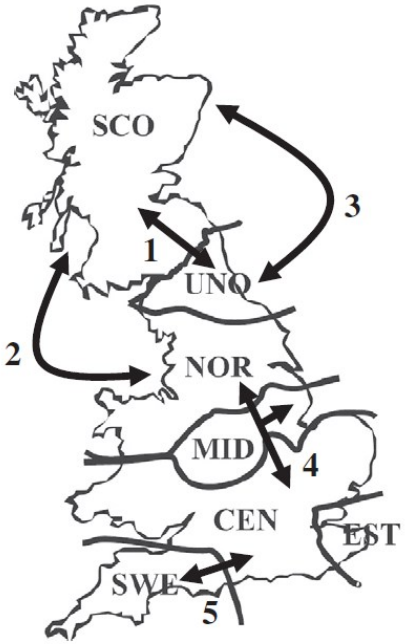
WECC 3-scenario model (trans only)

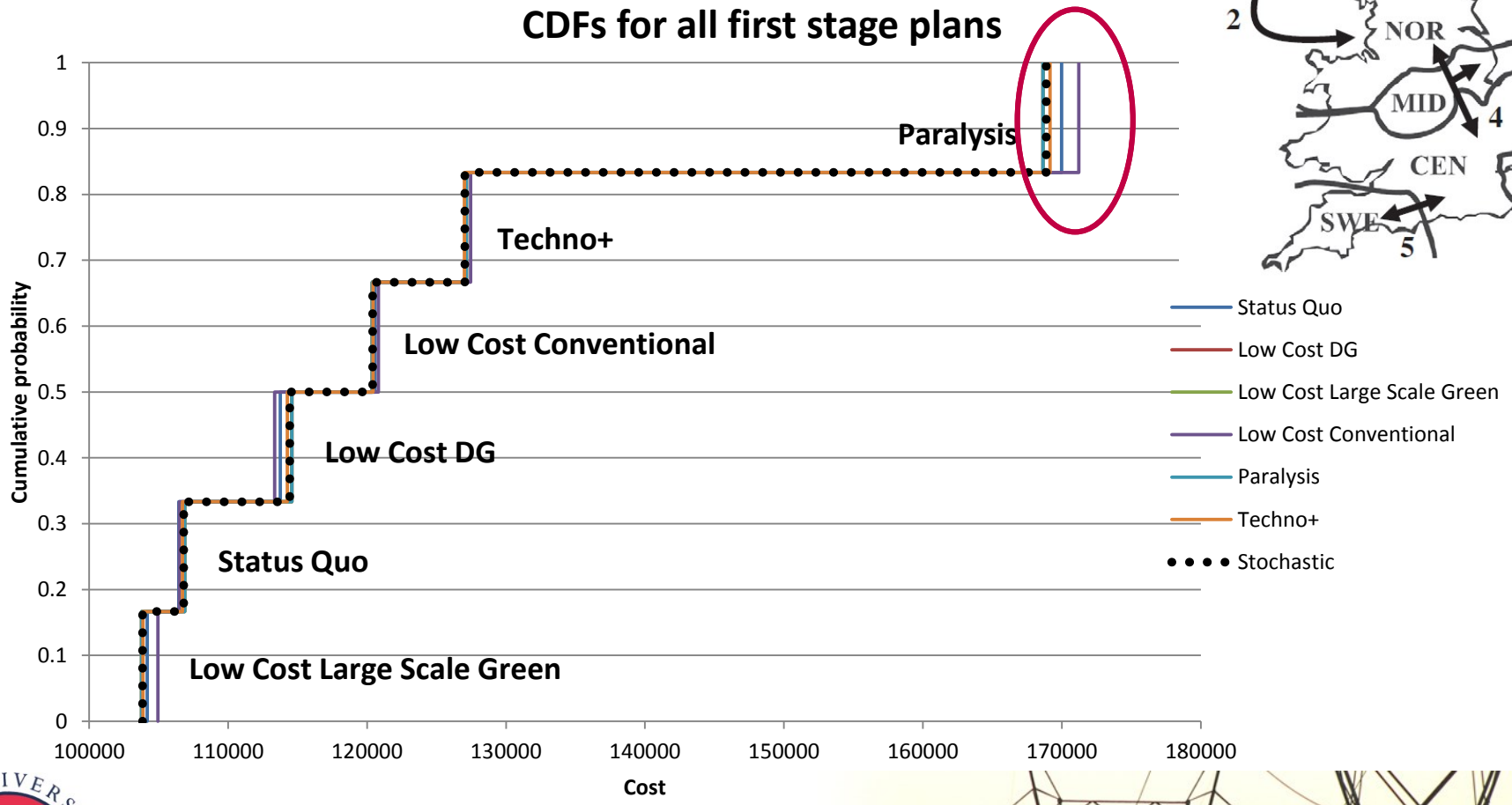




THE UNIVERSITY of EDINBURGH
School of Engineering

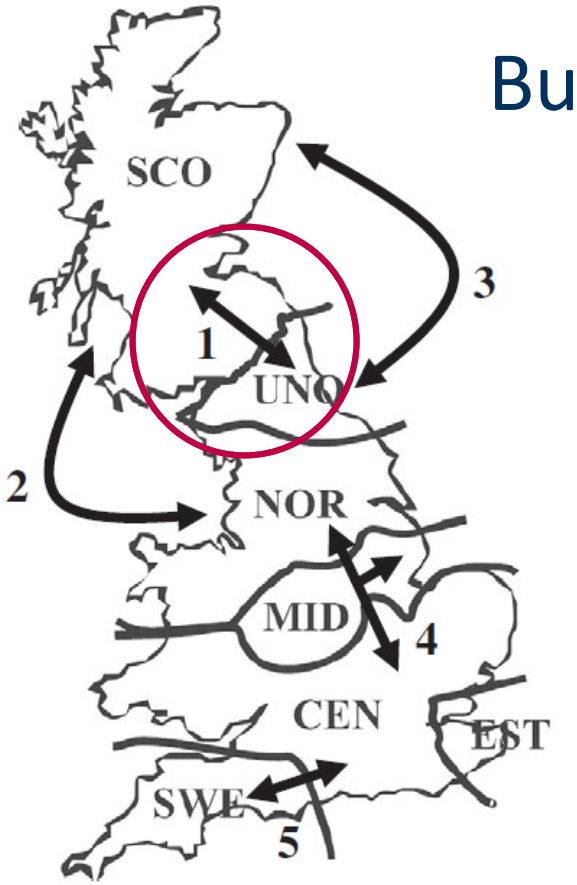
UK model (gen + trans)





THE UNIVERSITY of EDINBURGH
School of Engineering

UK model



Build (1) in addition to (2) and (3):

Expected costs: +0.004%

Worst case costs: -0.14%

THE UNIVERSITY of EDINBURGH
School of Engineering

Risk-averse generation planners

- **Need bi-level model**
- Why? Risk aversion:
  - changes amount of new generation capacity
  - changes location of new generation capacity
    - E.g. put wind in more accessible place or spread out more (spatial hedging) if local demand might not materialise
  - changes type of new generation capacity
- Influenced by transmission -> changes optimal transmission expansion

THE UNIVERSITY of EDINBURGH
School of Engineering

Risk-averse generation planners

- **Need equilibrium model**
- Why? One investor's risk aversion changes prices –> other investors' profits.
- Interactions not always straightforward: e.g., making all investors risk averse doesn't mean that each individual investor is less exposed.
- Settings with one planner do not capture this.
- Problem: nonlinearity

THE UNIVERSITY of EDINBURGH
School of Engineering

Conclusions

- Risk-averse transmission planner
  - May build more in some situations
  - Small increase in expected costs may mitigate much larger amount of risk
- Transmission planner + risk-averse generation investors: **needs more attention**