Managing a Spatial Externality of RES Development: Uniform vs. Differentiated Regulation

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Overview

1) Motivation

2) Model setup

3) Results

4) Discussion and conclusion

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- Albeit their positive impact on climate, **RES exhibit negative effects on the environment themselves** (cf. Zerrahn (2017); Meyerhoff et al. (2010); Drewitt and Langston (2006))

  - audio-visual impact on people
  - collision, disturbance or displacement effect on birds and bats

Special features of negative RES externalities

Spatial heterogeneity

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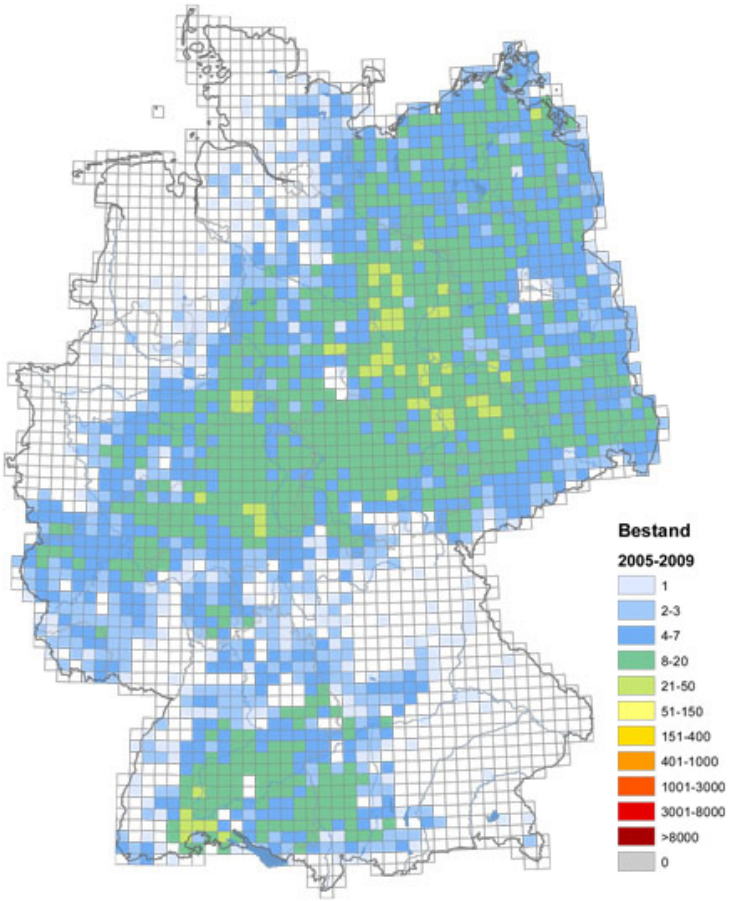

Figure: Prevalence of the red kite in Germany (Source: Gedeon et al. (2014))

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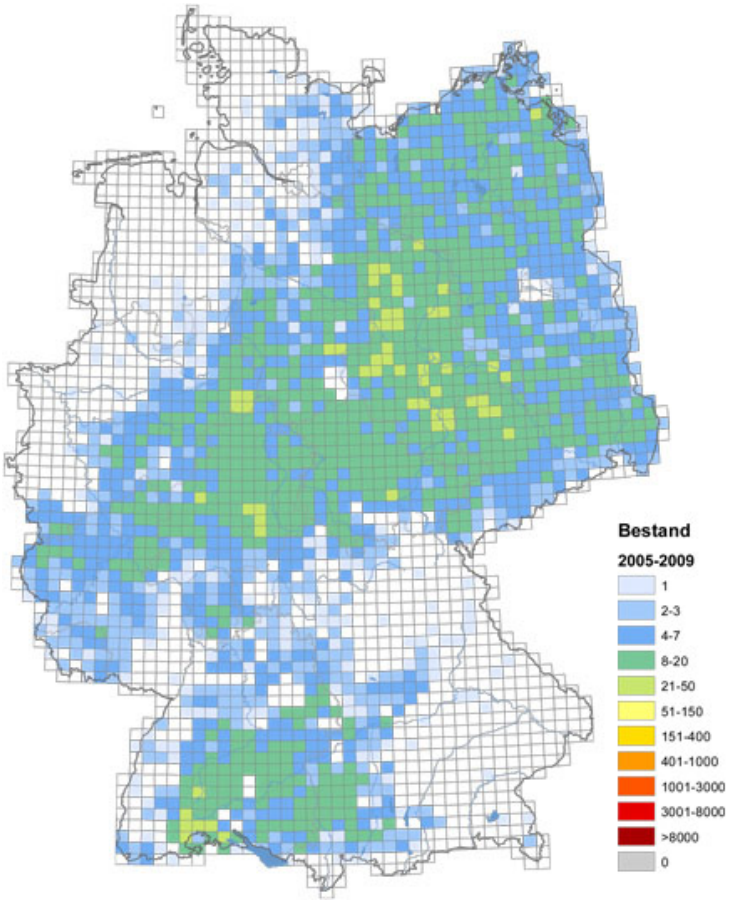

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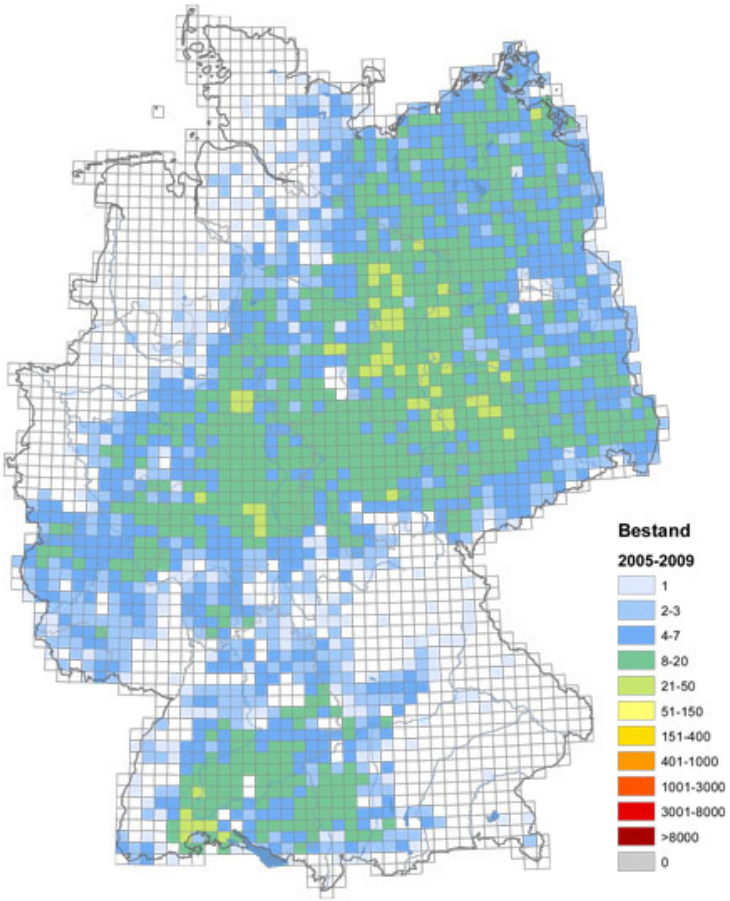

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Cumulative environmental effect

- Impact on birds and bats (cf. Schaub (2012); Kirol et al. (2015); May et al. (2019)):
  - Supply of alternate habitat
  - Turn source- into sink-habitats (meta-population effects)

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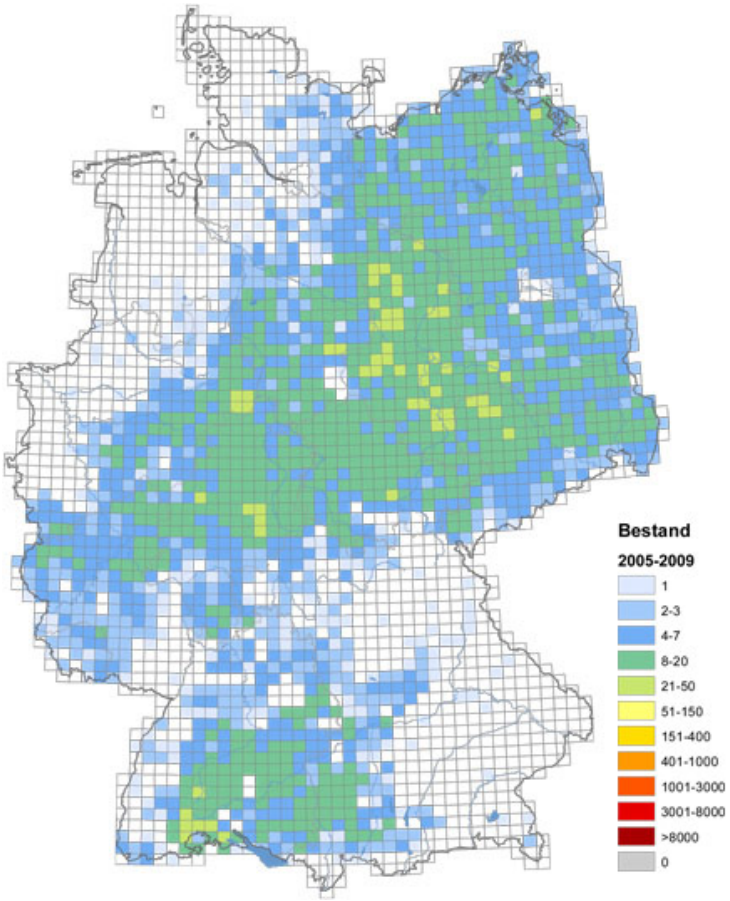

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⇒ **Knowledge** on spatial heterogeneity and cumulative environmental impacts is **incomplete**

Research Question

How to regulate **spatially-heterogeneous** RES externalities that display **cumulative environmental effects** in **a second-best setting** based on imperfect information?

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- First-best setting with perfect information: Spatially-differentiated instrument design
- Second-best setting with imperfect information:
  - Insights on environmental effects of renewables are insecure and incomplete
  - Spatially-differentiated or spatially-uniform instrument design?

Literature and Contribution

Literature

- Spatially-differentiated regulation always dominates spatially-uniform regulation in terms of welfare in a first-best setting (cf. Tietenberg (1978); Kolstad (1987); Waetzold and Drechsler (2005))
- In a second-best setting, spatially-differentiated instruments need not always welfare dominate spatially-uniform designs (Fowlie and Muller, 2019)

Contribution

- Cumulative environmental impacts of RES electricity production
- External RES power production target

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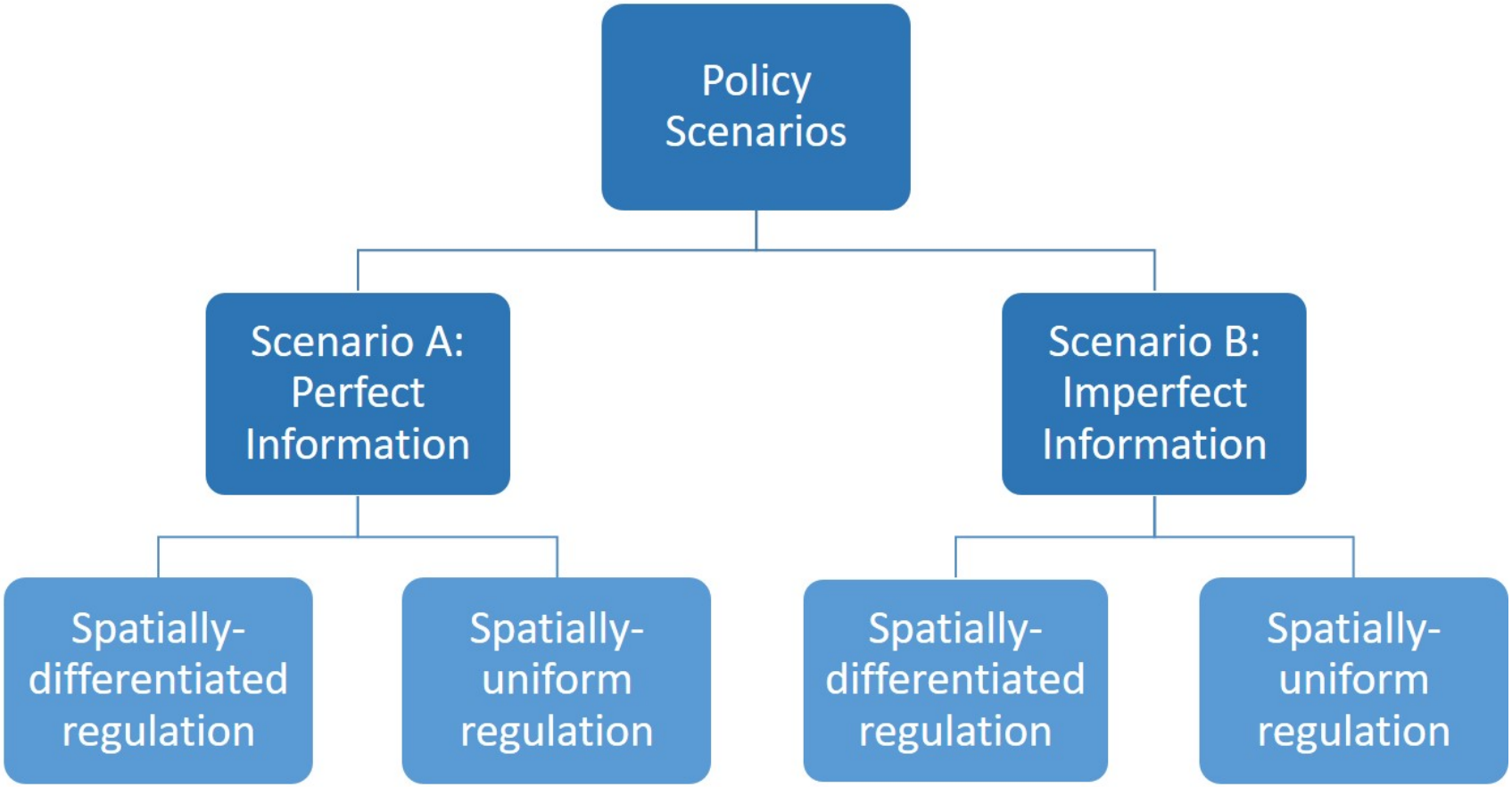
- Regional damages: $D_i(x_i) = \frac{d_i}{2} x_i^2$, with $i = 1, 2$ and $\boldsymbol{d_1 \neq d_2}$
- Aggregate damages: $D(x_1, x_2) = \sum_{i=1}^{2} \frac{d_i}{2} x_i^2 + \boldsymbol{k} x_1 x_2$, with $k \neq 0$

Regulating RES externalities

- Regulator seeks to reach the power production target $\bar{\boldsymbol{X}}$ across both regions
- Private investor decides on regional RES capacity development
- To incentivise RES electricity generation, the private investor is remunerated with the per-unit subsidy $\boldsymbol{s}$ for each power unit x produced
- Regulator may choose a **spatially-differentiated** – s_i or a **uniform** subsidy – s^U

Regulating RES externalities - Policy scenarios



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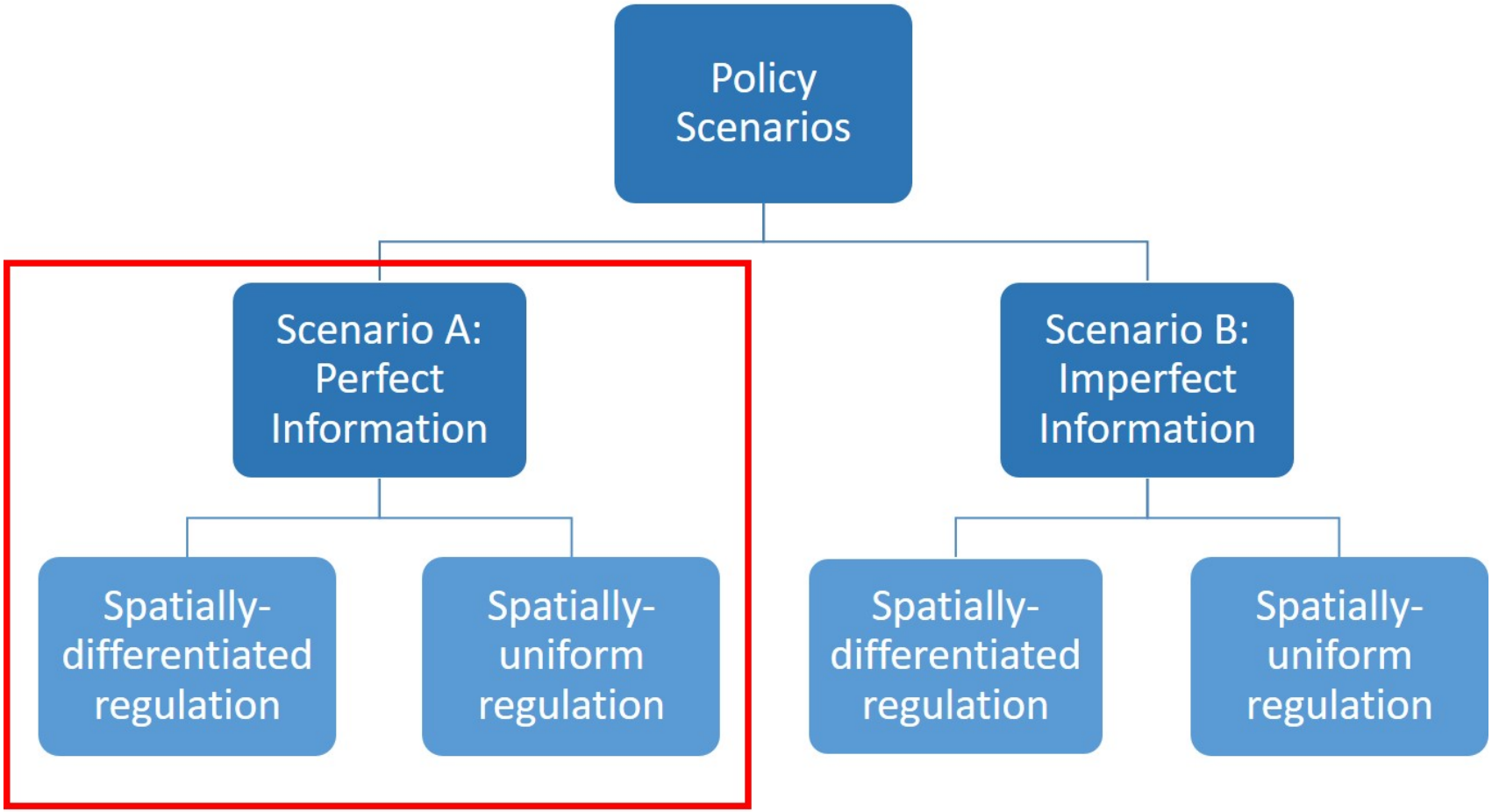

Policy Scenario A: Perfect Information - First-best spatially-differentiated subsidy

- The regulator aims at achieving $\bar{X}$ at minimal social cost of electricity generation:

$$\underset{x_1,x_2}{min} SC = \sum_{i=1}^{2} C_i(x_i) + \sum_{i=1}^{2} D_i(x_i) + kx_1x_2 \qquad \text{s.t. } \sum_{i=1}^{2} x_i = \bar{X}$$

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$$\max_{x_1,x_2} \pi = \sum_{i=1}^{2} s_i x_i - \sum_{i=1}^{2} c_i(x_i), \qquad \text{s.t.} \qquad s_i > 0$$

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$\Rightarrow$ First-best RES capacities are implemented by a **regionally differentiated subsidy** $\qquad s_i^* = \frac{c_i(c_j+d_j-k)\bar{X}}{c_i+d_i+c_j+d_j-2k}$

Policy Scenario A: Spatially-uniform subsidy

- The regulator chooses s^U to reach $\bar{X}$: $\quad s^U = \frac{c_1 c_2 \bar{X}}{c_1 + c_2}$

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$\Rightarrow$ **Result I**: Under perfect information, a **spatially-differentiated subsidy is always at least as effcient as a spatially-uniform subsidy**. A uniform subsidy implements the first-best allocation only in the case $k = \frac{c_1 d_2 - c_2 d_1}{c_1 - c_2}$.

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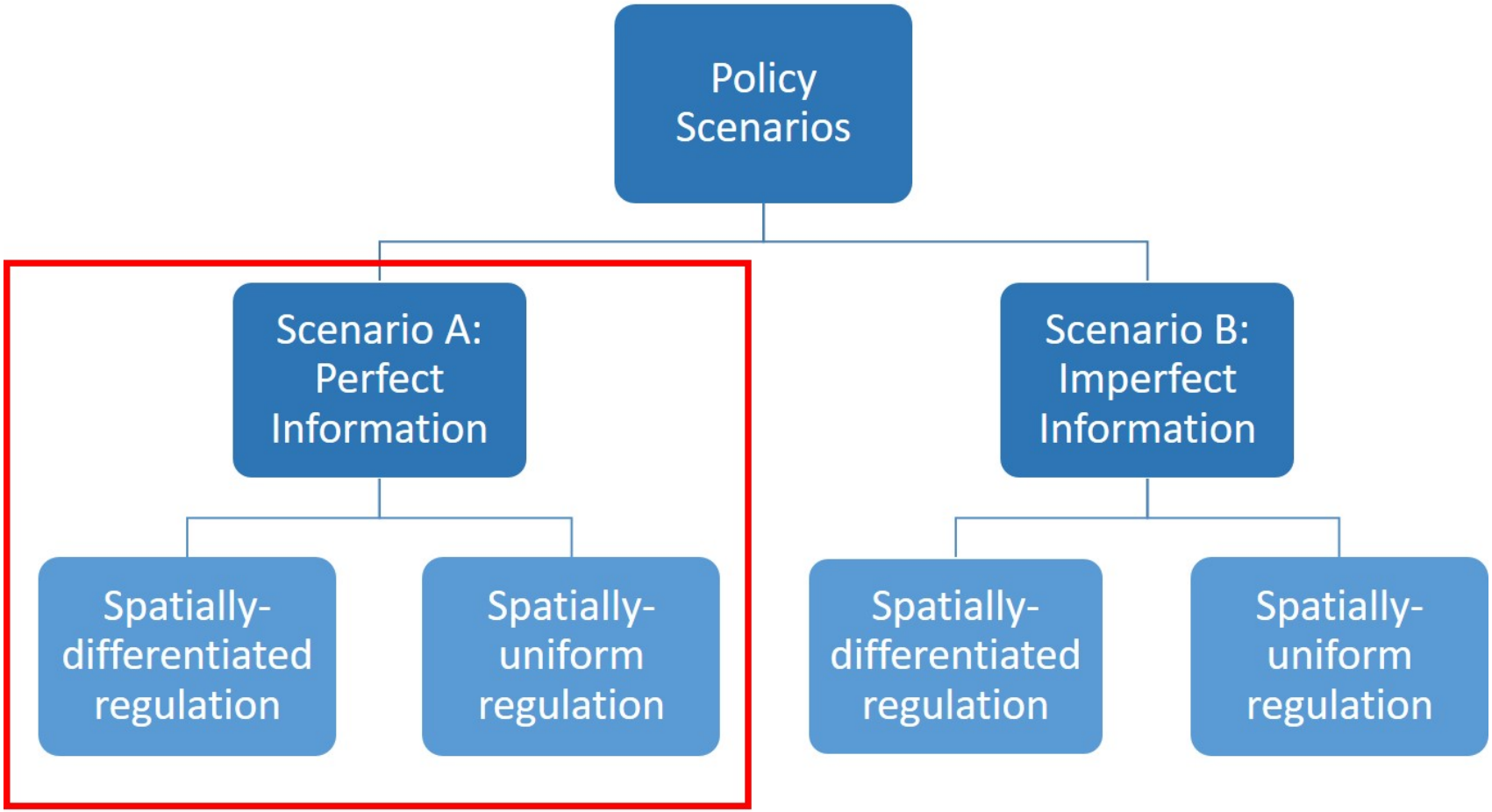

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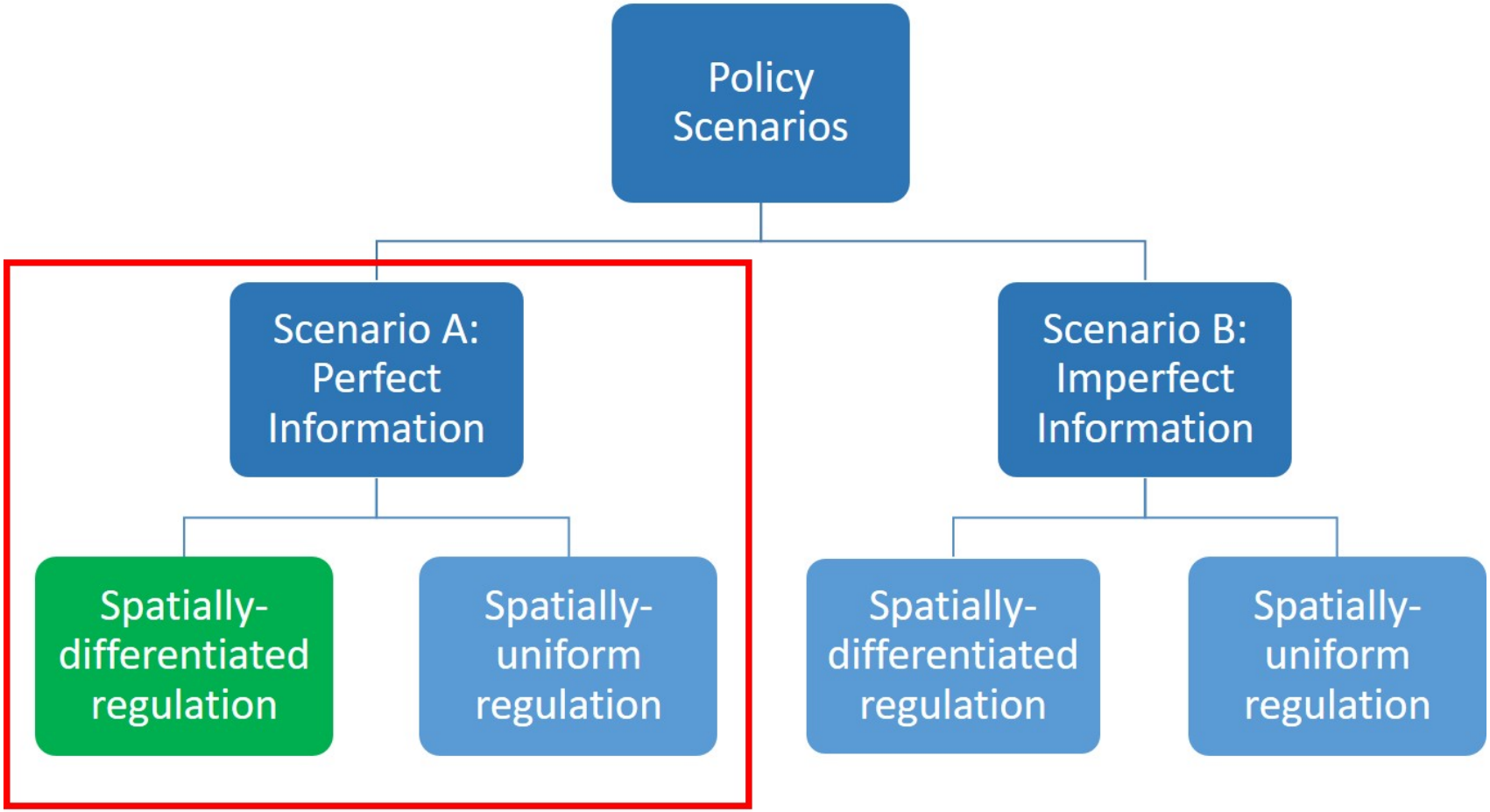

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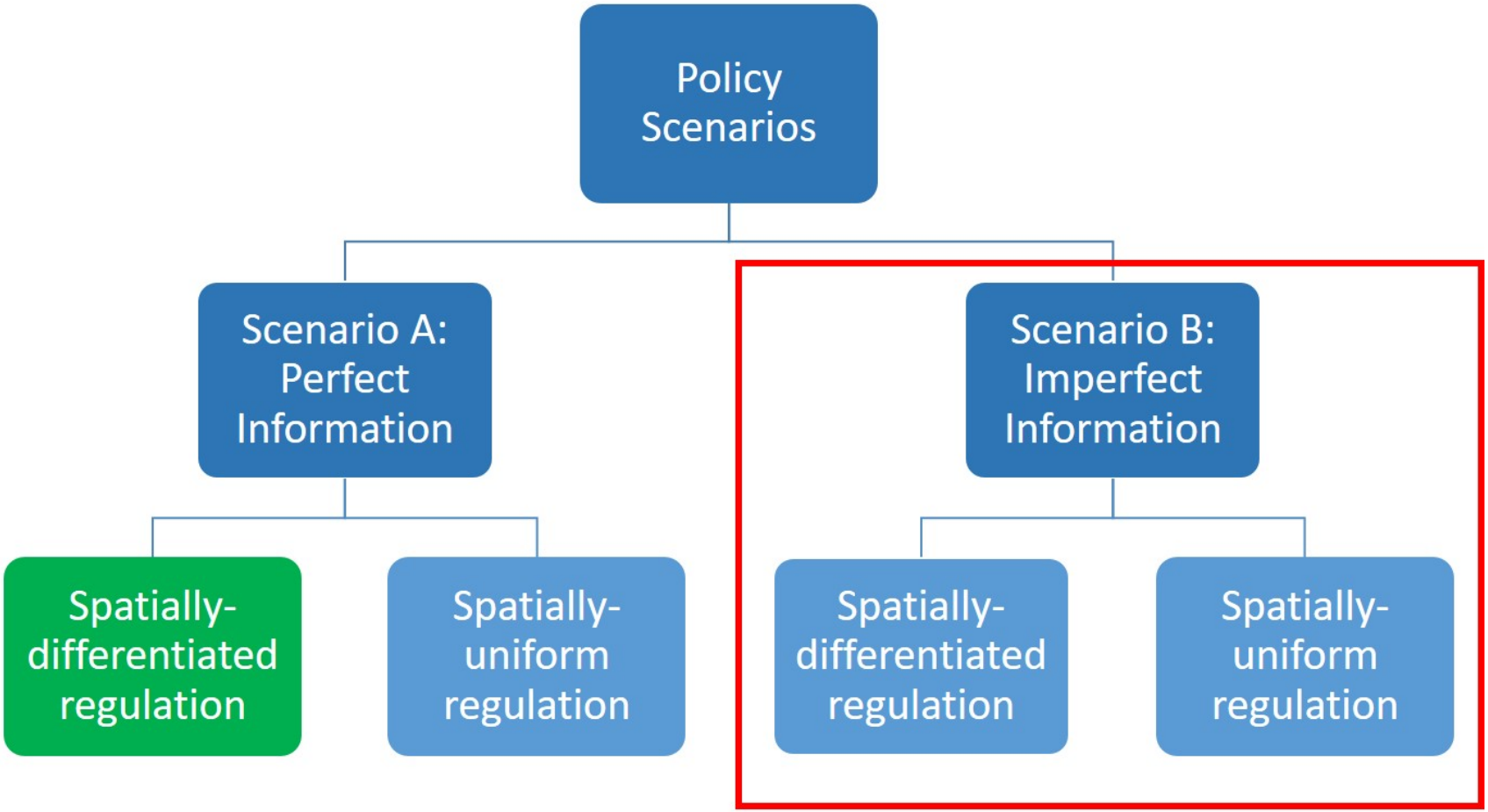

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$$\min_{s_i, s_j} SC = \sum_{i=1}^{2} C_i(s_i) + \sum_{i=1}^{2} D_i(s_i) + \beta \boldsymbol{k} \left(\frac{s_i}{c_i}\right)\left(\frac{s_j}{c_j}\right)$$

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- Second-best spatially-differentiated subsidy $\boldsymbol{s_i'} = \frac{c_i \bar{X}(c_j + d_j - \beta k)}{(c_i + d_i + c_j + d_j - 2\beta k)}$

Results I: Uniform vs. second-best spatially-differentiated subsidy

- Comparing outcomes of s^U and s_i': In a **second-best setting** based on imperfect information on k, the decision between implementing a spatially-uniform or -differentiated subsidy is **not clear**

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  - This is also true if the regulator is not informed about the cumulative environmental impact of RES at all ($\beta = 0$)

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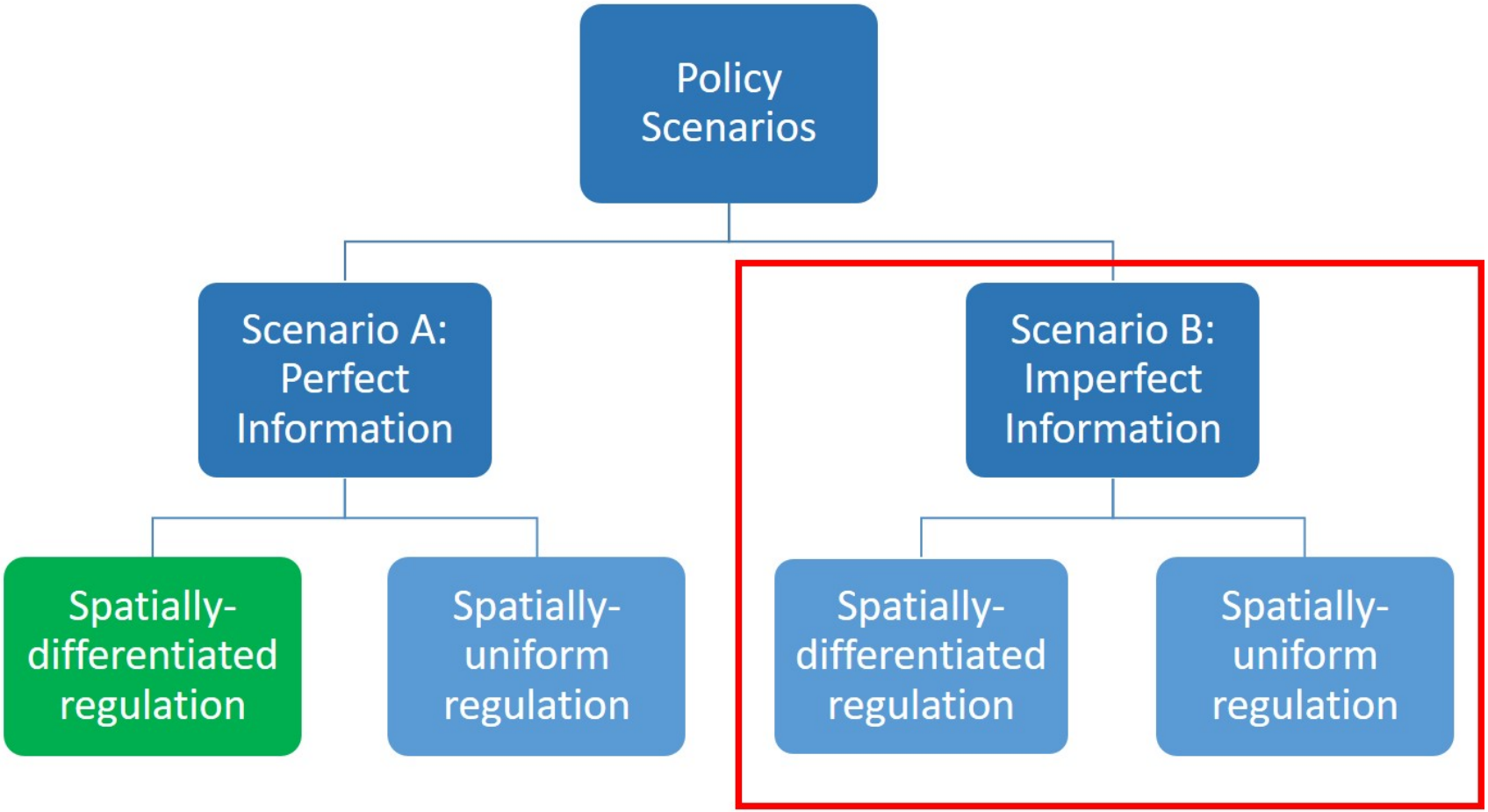

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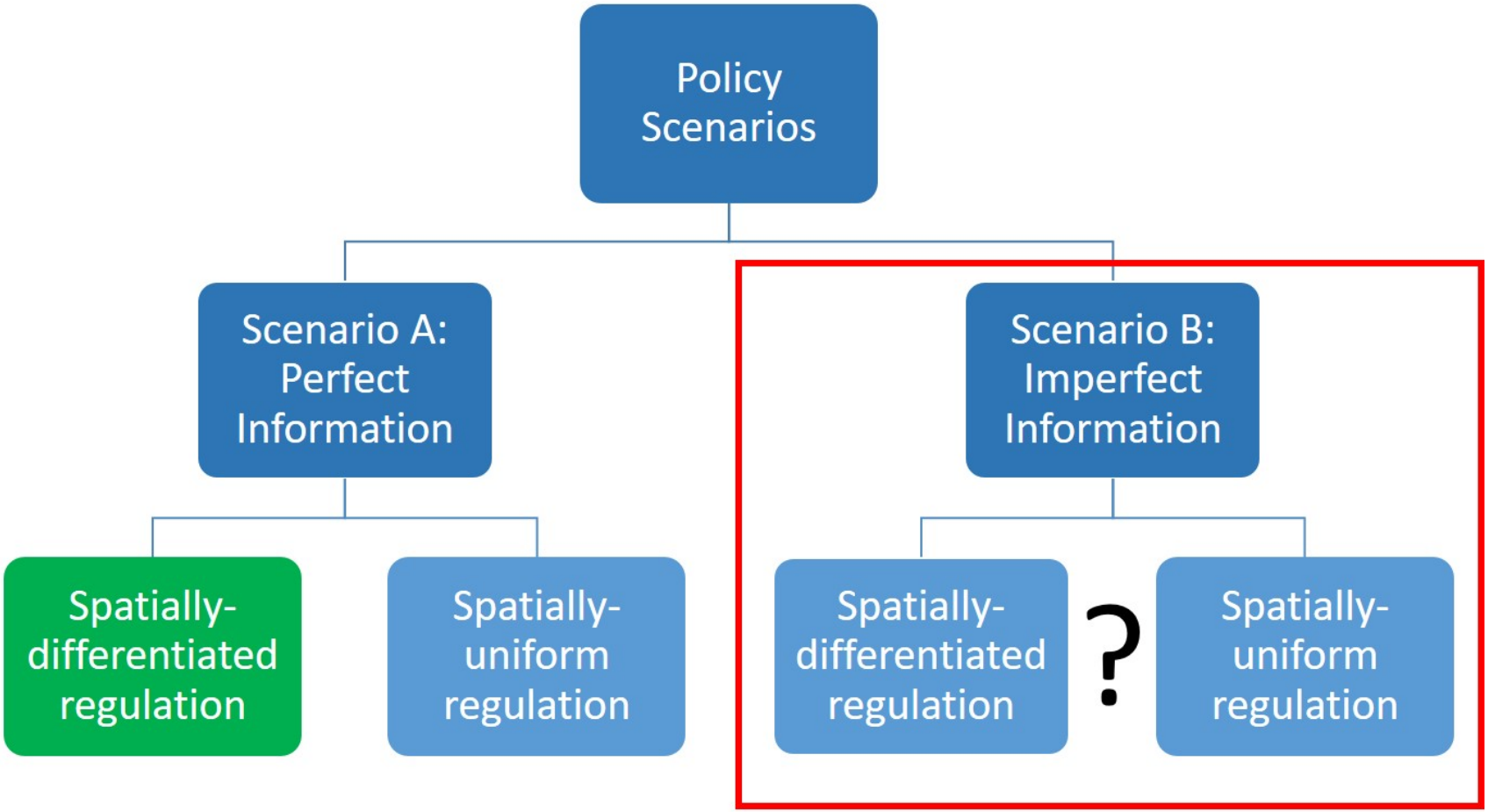

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  - results in the private-cost efficient distribution of production capacities across regions under a uniform subsidy
  - increases the gains from differentiation in the perfect and imperfect information scenarios:

$$SC(x_1*, x_2^*) - SC(x_1^U, x_2^U) = -\frac{\bar{X}^2}{2} \frac{(c_1 d_2 - c_2 d_1 + k(c_2 - c_1))^2}{(c_1+c_2)^2(c_1+c_2+d_1+d_2-2k)} < 0$$

$$SC(x_1^*, x_2^*) - SC(x_1', x_2') = -\frac{k^2\bar{X}^2}{2} \frac{(c_1+d_1-c_2-d_2)^2(1-\beta)^2}{(c_1+d_1+c_2+d_2-2k)(c_1+d_1+c_2+d_2-2\beta k)^2} < 0$$

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- Especially for environmental damages, evidence on the sign of marginal effects is inconclusive
- Uncertainty on the spatial heterogeneity of environmental damages is likely

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- **Size and level of cumulative effects** and the **regulator's degree of information** are determinants for the decision between a spatially-uniform or a spatially-differentiated instrument.
- However, identifying these determinants requires a considerable level of information

Thank you for your attention!

Questions and comments are very welcome.

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