A General Approach to Value of Information using Stochastic Mathematical Programming

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Overview

- Value of information (VOI) analysis
- Traditional approach to the expected value of perfect information (EVPI)
- Stochastic mathematical programming (SMP) approach to EVPI
- Two-stage SMP formulation
- Empirical application: Traditional EVPI vs. SMP EVPI
- Conclusions

Value of Information (VOI) analysis

- Provides a framework for establishing the value of funding future research
- EVPI: difference between a decision made with perfect information and one made with current information

Traditional EVPI approach

- Measured by net benefits forgone due to an incorrect decision
- Based on an arbitrary threshold WTP, λ
- Fails to identify the opportunity costs of displacing unrelated interventions or programmes

Stochastic Mathematical Programming (SMP)

- Accommodates information on the comparison of multiple treatment options within multiple population groups and healthcare programmes simultaneously

- Maximises total health benefits subject to a set of constraints

- Avoids the use of arbitrary parameters

- Identifies the true opportunity costs of the decision

- Leads to an optimal allocation of resources

A Two-Stage SMP Formulation

Follows in 5 steps:

(1) Set up the allocation problem

(2) Distinguish between uncertain and variable parameters

(3) Determine the optimal allocation based on current information and calculate the expected health benefit

(4) Determine the optimal allocation based on perfect information and calculate the expected health benefit

(5) Calculate the EVPI

The Allocation Problem

3 treatments x 3 populations x 3 programmes = 27 decision var.

$$X = (x_{ijk}, \text{ for } i, j, k = 1, .., 3)$$

x_{ijk} proportion of population group *i* in healthcare programme *k* that is allocated treatment *j*

Total set of random parameters, *Z*, consists of the set of

Uncertain parameters, Δ

Variable parameters, Φ

Current Information

1st Stage

$$\text{Max.} \quad E_Z(B(Z,X)) \qquad \text{health benefits}$$

$$\text{s.t.} \quad E_Z(C(Z,X)) \leq \Psi \qquad \text{budget constraint}$$

$$\sum_{j=1}^{3} x_{ijk} = 1 \quad \text{for} \quad i,j,k = 1,..,3$$

Optimal solution:

$$B^*, \;\; C^*, \;\; X^* = (x_{ijk}, \; \text{for} \;\; i,j,k = 1,..,3)$$

Current Information

2nd Stage

$$
\text{for all } Z \quad \begin{cases} \text{Min.} & (B^* - B(Z,Y)) \\ \text{s.t.} & C(Z,Y) \le \Psi \\ & y_{i1k} \ge x^*_{i1k} \quad \text{for} \quad i,k = 1,..,3 \\ & \sum_{j=1}^{3} y_{ijk} = 1 \quad \text{for} \quad i,j,k = 1,..,3 \end{cases}
$$

Current Information

2nd Stage

$$\text{for all } Z \quad \begin{cases} \text{Min.} & (B^* - B(Z,Y)) \\ \text{s.t.} & C(Z,Y) \leq \Psi \\ & y_{i1k} \geq x^*_{i1k} \quad \text{for } \; i,k = 1,..,3 \\ & \sum_{j=1}^{3} y_{ijk} = 1 \quad \text{for } \; i,j,k = 1,..,3 \end{cases}$$

Expected health benefits: $E_Z(B(Z, Y^*(Z)))$

Optimal allocation: $Y^*(Z) = (y_{ijk}, \text{ for } i, j, k = 1, .., 3)$

Perfect Information

1st Stage

$$
\text{for all } \Phi \left\{ \begin{array}{rl} \text{Max.} & E_{\Delta|\Phi}(B(\Phi, \Delta, X)) \\ \text{s.t.} & E_{\Delta|\Phi}(C(\Phi, \Delta, X)) \leq \Psi \\ & \displaystyle\sum_{j=1}^{3} x_{ijk} = 1 \quad \text{for} \quad i, j, k = 1, .., 3 \end{array} \right.
$$

Optimal solution:

$$
B^{**}(\Phi), \;\; C^{**}(\Phi), \;\; X^{**}(\Phi) = (x_{ijk}, \text{ for } i, j, k = 1, .., 3)
$$

Perfect Information

2nd Stage

$$\text{for all } \Phi \left\{ \text{for all } \Delta \left\{ \begin{array}{ll} \text{Min.} & (B^{**}(\Phi) - B(\Phi, \Delta, Y)) \\ \text{s.t.} & C(\Phi, \Delta, Y) \leq \Psi \\ & y_{i1k} \geq x_{i1k}^{**} \quad \text{for} \quad i, k = 1, .., 3 \\ & \sum_{j=1}^{3} y_{ijk} = 1 \quad \text{for} \quad i, j, k = 1, .., 3 \end{array} \right. \right.$$

Expected health benefits: $E_{\Phi}(E_{\Delta|\Phi}(B(\Phi, \Delta, Y^{**}(\Delta|\Phi))))$

Optimal allocation: $Y^{**}(\Delta|\Phi) = (y_{ijk}, \text{ for } i, j, k = 1, .., 3)$

Expected Value of Perfect Information (EVPI)

- EVPI = Expected benefits$_{perfect}$ – Expected benefits$_{current}$

Converting EVPI in health gains into monetary terms:

- Decrease the budget with perfect information to generate the same benefits as current information

E.g.

Budget	Current	Perfect	EVPI (benefits)
£5,995,377	4373.6	4390.4	16.8
£6,130,377	4390.4	4404.3	13.8

-£135,000

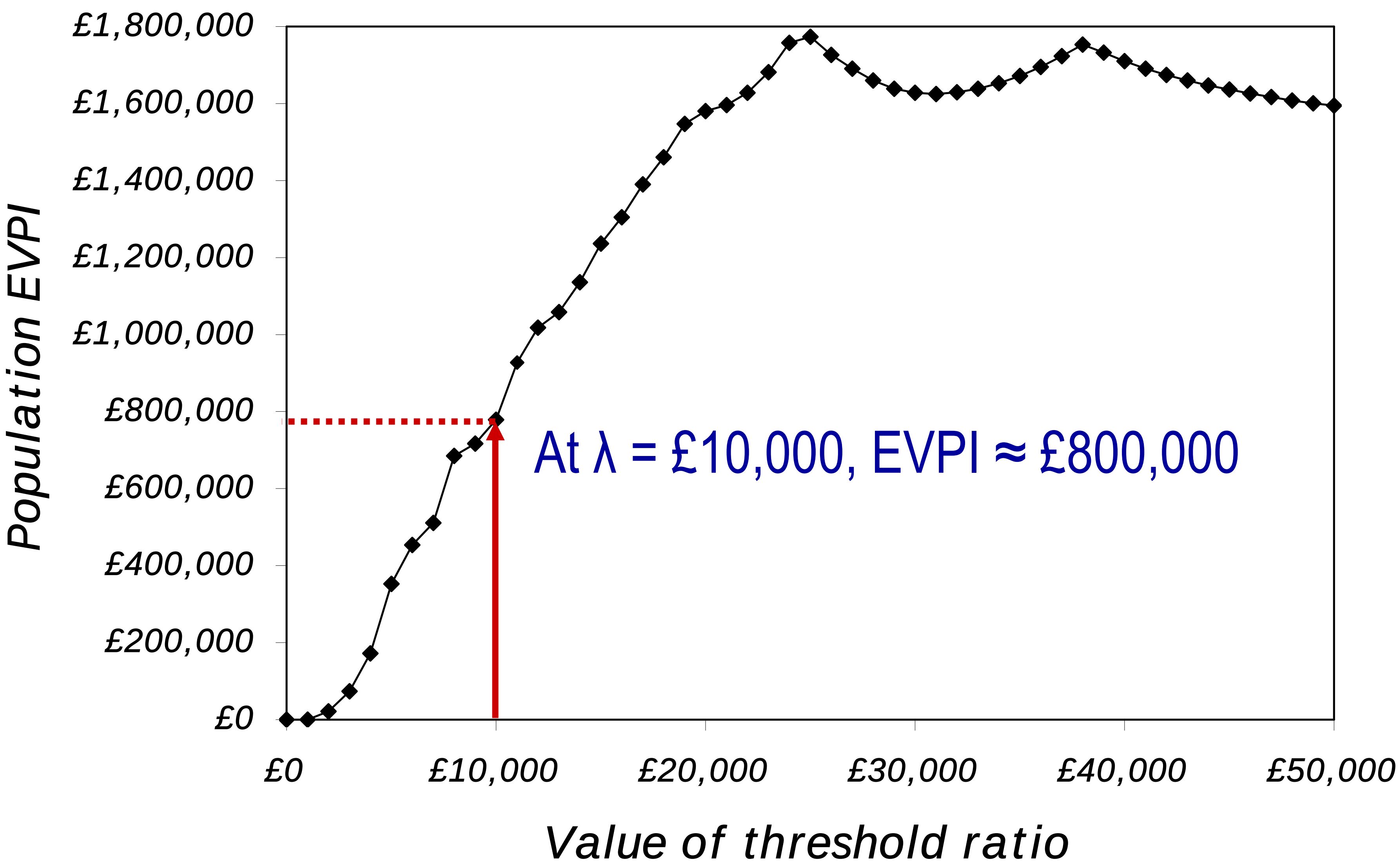
At £6,130,377, EVPI = £135,000

Traditional EVPI approach

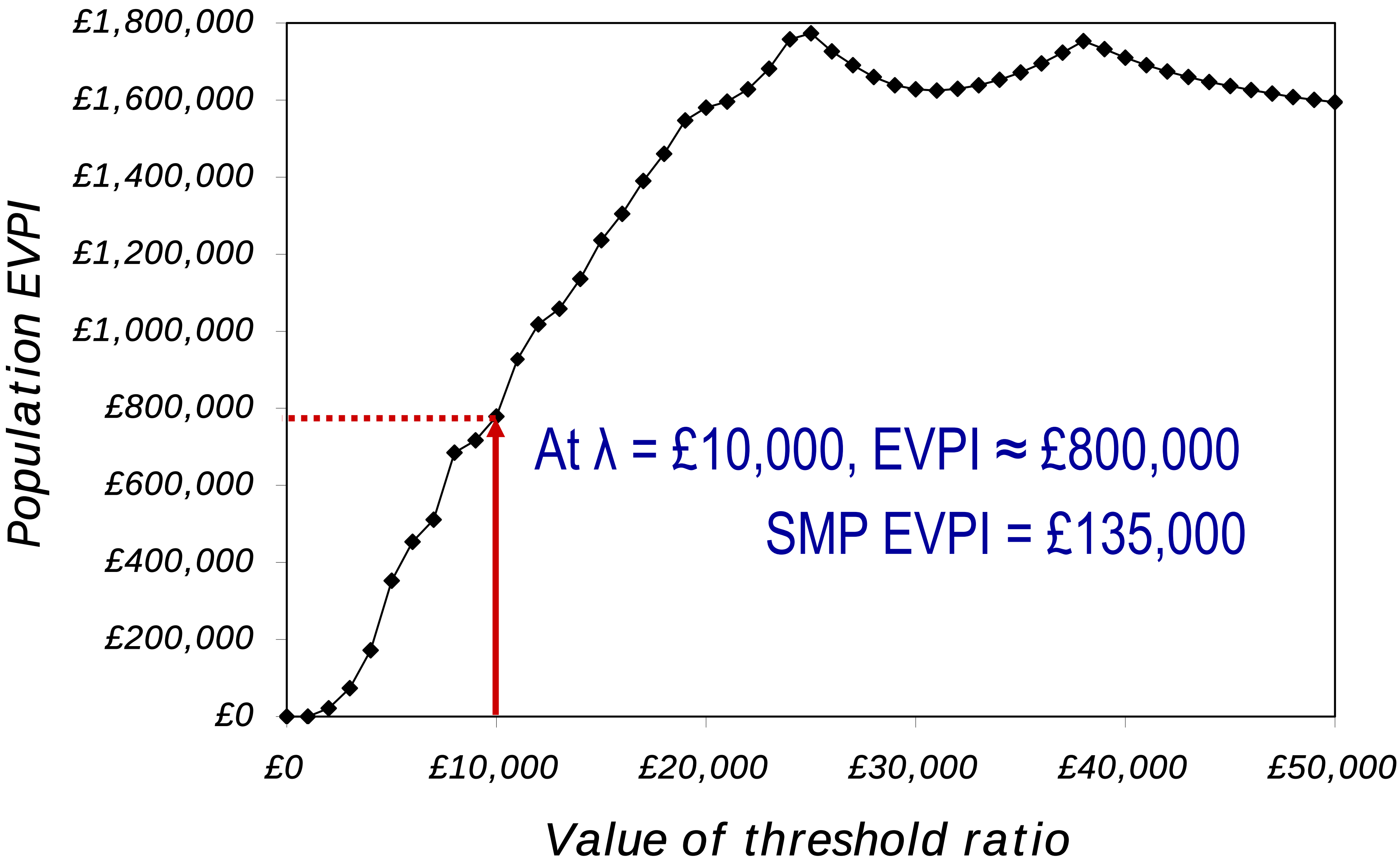
vs.

Stochastic Mathematical Programming EVPI

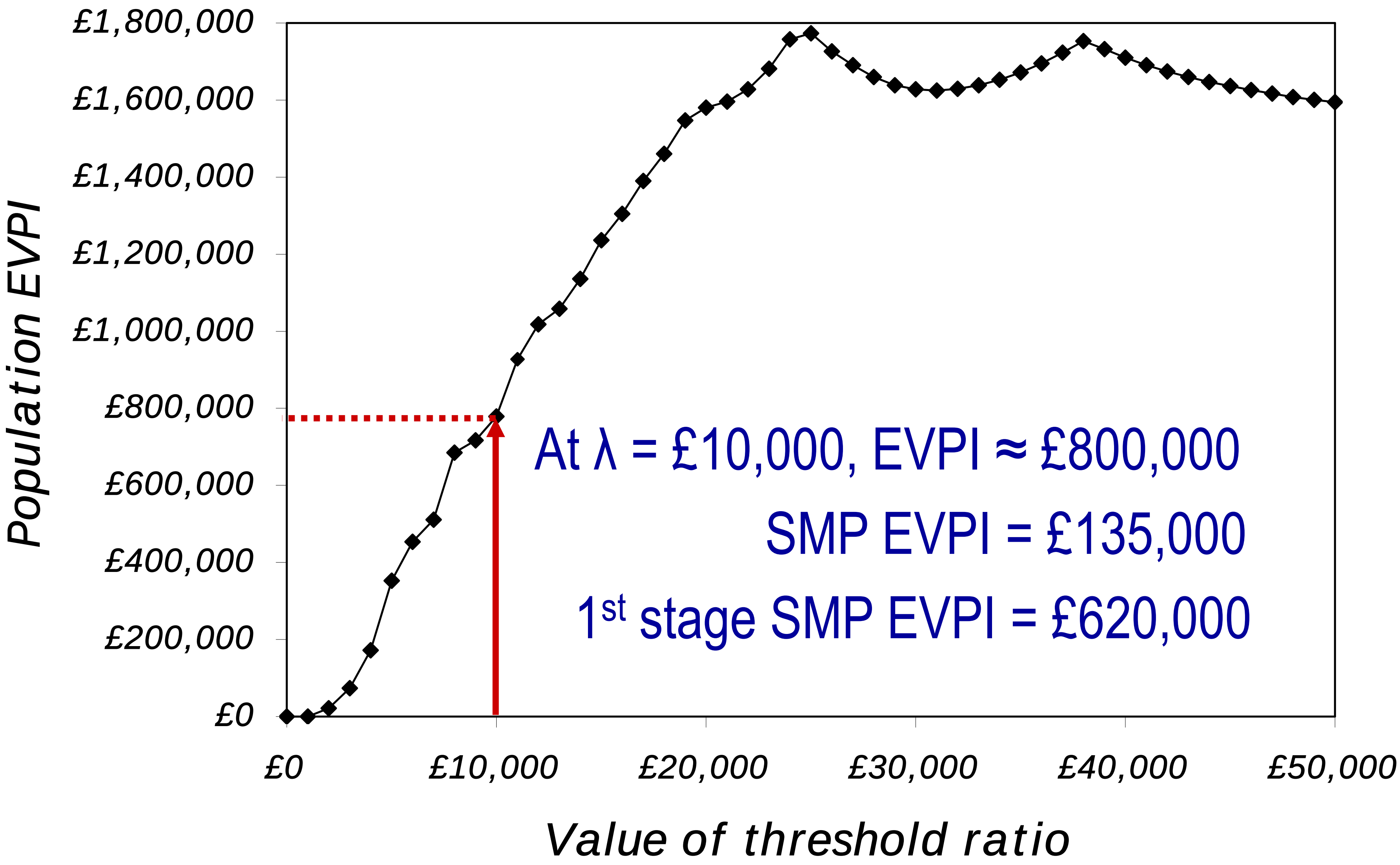
Traditional EVPI



Traditional EVPI vs. SMP EVPI



Traditional EVPI vs. SMP EVPI



Conclusions

- Traditional EVPI based on an analysis of each of the decision problems separately can overestimate the value of research

- The EVPI for the allocation problem as a whole provides the correct upper limit since it incorporates the impact of uncertainty on other unrelated treatments within other programmes

Decisions regarding allocation of resources and the value of acquiring further evidence to inform these decisions must be made in the context of the whole allocation problem