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A new approach to one-way sensitivity analysis and the tornado plot

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Background

Cost-effectiveness models are intended to inform healthcare resource allocation decisions. Expenditure on healthcare in the Euro-zone has reached 11.3% of GDP, emphasising the magnitude of resource allocation decisions. While economic models output a point estimate of cost-effectiveness, reporting of uncertainty in outputs is critical for understanding and conveying decision uncertainty.[1]

The traditional approach to one-way sensitivity analysis (OWSA) is based on setting each parameter at its upper and lower bound values, respectively, while keeping all other parameters at their means. It systematically presents a series of scenario analyses with individual parameters at their extreme values. It is often interpreted as a measure of influence of individual parameters on uncertainty.

We explored a simple inversion of the traditional OWSA, where one parameter is set at its mean while all others are varied. This approach gives an estimate of the uncertainty eliminated by fixing the parameter, from which we can infer the uncertainty created by the parameter.

Methods

This case study used a Markov cost-utility model of herpes zoster vaccination in the general population in Ireland at age 50 years.[2] Herpes zoster, also known as shingles, is caused by reactivation of the varicella zoster virus. Mainly affecting adults, it is characterised by a skin rash associated with itching and pain, typically lasting up to four weeks. The closed-cohort Markov model simulated a two-dose vaccination strategies for people turning 50 years of age. The model included a variety of parameters for epidemiology, clinical effectiveness, quality of life, and costs. The model was run for 20,000 simulations.

The outcome was expressed as net monetary benefit (NMB) at a willingness-to-pay threshold of €20,000 per QALY. We conducted one-way sensitivity analysis using two approaches:

- set one parameter at a time at its upper and then lower bounds with all others at their mean (traditional)
- set one parameter at a time at its mean and vary all others (alternative).

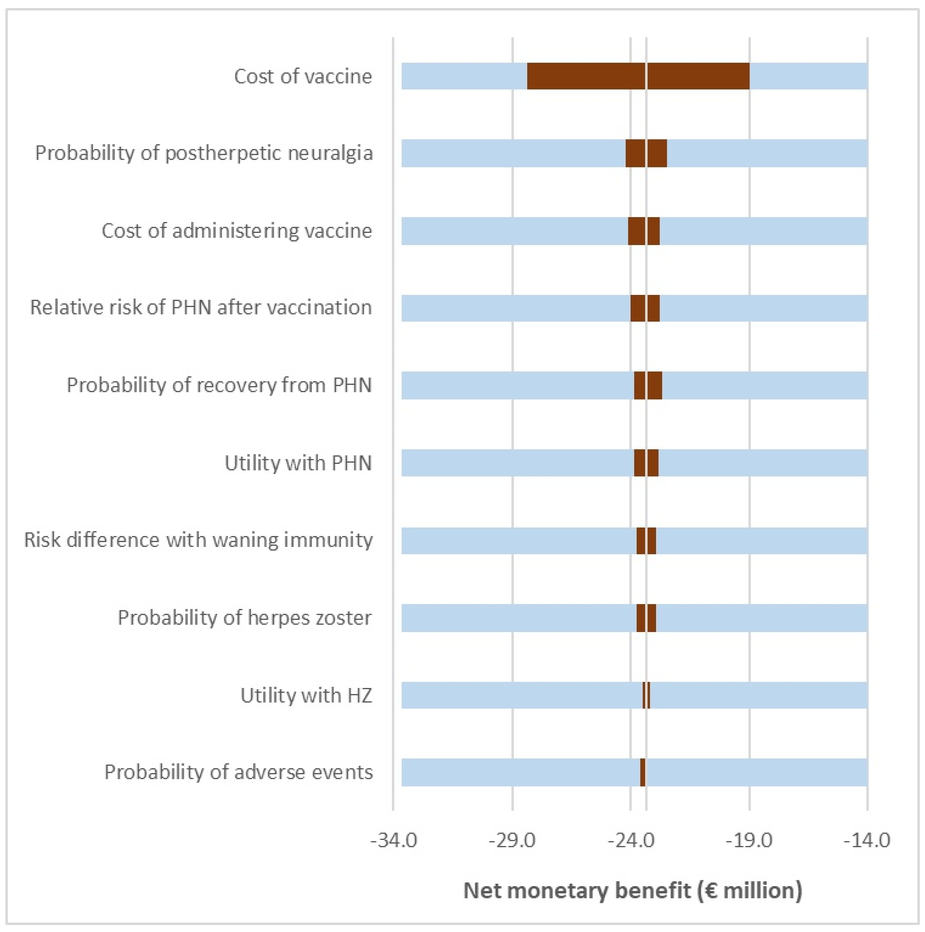
Results

Traditional tornado plot

The NMB when all parameters were allowed to vary was -€23.34 million (95% CI: -€33.7m to -€14.0m).

In a standard tornado plot, we can see the outcome (in this case the NMB) when a parameter is set at its upper and lower bounds while all others are at their mean. In this case, setting the cost of the vaccine at it's upper and lower bounds has the largest impact on the NMB. That is, 48% of total uncertainty is spanned by varying just one parameter. The next most important parameter, the probability of developing postherpectic neuralgia (PHN), spans 9% of total uncertainty.

Figure 1. Uncertainty in net monetary benefit when each parameter is set at its upper and lower bounds while all others are fixed at their mean

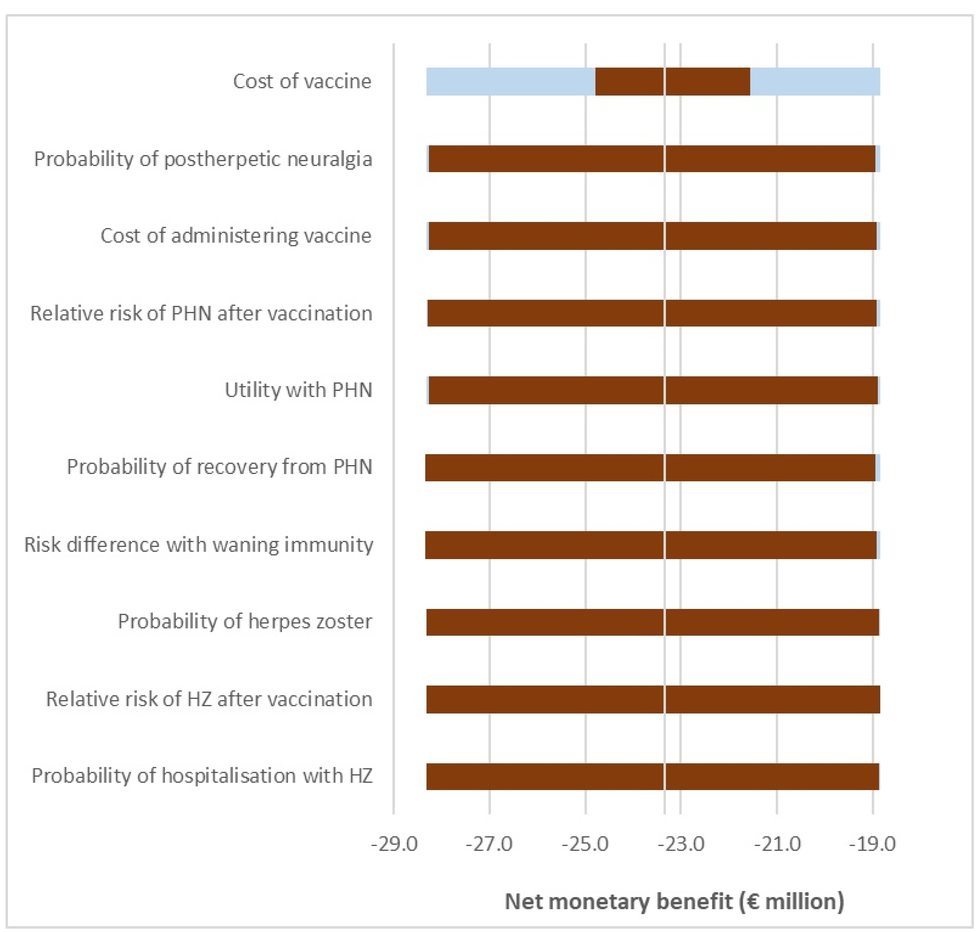


Alternative tornado plot

In the alternative tornado plot, we can see the uncertainty remaining if a single parameter is fixed at its mean while all others continue to vary. Again, the cost of the vaccine is the most influential parameter. In this case, 34% of total uncertainty remains if the parameter is fixed.

The next most influential parameter is again the probability of developing postherpectic neuralgia. In this analysis, 98% of uncertainty remains after fixing the PHN parameter. Indeed, no parameter other than vaccine cost eliminated more than 2% of uncertainty.

Figure 2. Uncertainty remaining in net monetary benefit when each parameter is fixed at its mean while all others are allowed to vary



Conclusions

The traditional approach to a tornado plot can give an inflated sense of the influence of a single parameter. By setting a parameter at it's upper and lower bounds, it focuses on extreme values. It may also ignore correlations between parameters. The alternative approach shown here is more closely aligned with the expected value of perfect information by showing how much uncertainty remains when a single parameter is fixed at its mean.

The analysis presented here is based on a single case study where most parameters had a limited influence on the outcome. Exploring whether this alternative approach is acceptable and interpretable to decision makers could be helpful in understanding how it might be used in presenting sensitivity analysis results.

Analysis of eliminating uncertainty gives a different perspective on the influence of each parameter to overall uncertainty, and forms a useful additional tool alongside the traditional tornado plot.

References

1. Briggs A. et al., Model Parameter Estimation and Uncertainty: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-6. Value in Health. 2012; 15: 835-842
2. HIQA. Health technology assessment of Herpes Zoster (shingles) vaccination. Dublin, 2024.