An Open-Architecture Platform for Seasonal Influenza Transmission Modelling and Health Economic Evaluation

MSR210

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Why did we perform this research?

Seasonal influenza causes substantial morbidity, mortality, and economic burden[1,2]

Quantitative models are essential for evaluating vaccination programmes and resource allocation; however, many are developed for specific epidemiological and healthcare settings, limiting transferability across jurisdictions[3,4]

Objectives

To develop a transparent, comprehensive and user-friendly platform integrating epidemiological and economic analyses via an interactive web application

Summary

A web-based platform was developed, integrating influenza transmission and economic models

The platform enabled rapid vaccination scenario analyses across countries, age groups, and strategies

This framework enables transparent, adaptable evidence generation for vaccination policy decisions

Key takeaway

This modular, user-friendly framework integrates transmission modelling and health economic evaluation to support evidence-based influenza vaccination policy and is readily adaptable to new settings, influenza strains, and policy questions.

How did we perform this research?

The framework combines a dynamic transmission model (DTM) and decision tree health economic model (HEM) within an interactive Shiny application to evaluate vaccination coverage scenarios (Figure 1)

- The *de novo* deterministic DTM simultaneously estimates transmission of three influenza strains (A/H1N1, A/H3N2, B) and vaccination effects across one or more influenza seasons (Figure 2)
- The susceptible–exposed–infectious–recovered (SEIR) framework provides a biologically plausible, mathematically tractable representation of transmission dynamics, with flexibility to incorporate age structure, multiple strains, vaccination, and immunity propagation
- The HEM translates epidemiological outputs into clinical outcomes, costs, quality-adjusted life years (QALYs), cost-effectiveness, and budget impact (Figure 3)
- The platform follows best-practice modelling standards[4,5] including face validity, internal verification, and external validation, and was implemented as an R package with documentation, automated testing, and validation checks

The model was parameterised for Austria, Catalonia, Czechia, Romania, and Sweden (population range: 8.1M–19.1M); Key inputs are shown in Figure 4

- Baseline vaccination coverage was based on local uptake data, while vaccine effectiveness was informed by a meta-analysis of observational studies
- Transmission dynamics were simulated using a system of ordinary differential equations, informed by country-specific demographics and POLYMOD contact matrices[6]
- Simulated infections were translated into clinical outcomes using a static decision tree, with transition probabilities derived from the published literature
- Country-specific costs included vaccine acquisition, administration and adverse event management, healthcare resource use and productivity losses due to morbidity, mortality and paediatric caregiving
- QALY losses from influenza morbidity were estimated using health-state-specific utility decrements, while mortality-related QALY losses were based on remaining life expectancy at death

Figure 1. Model schematic

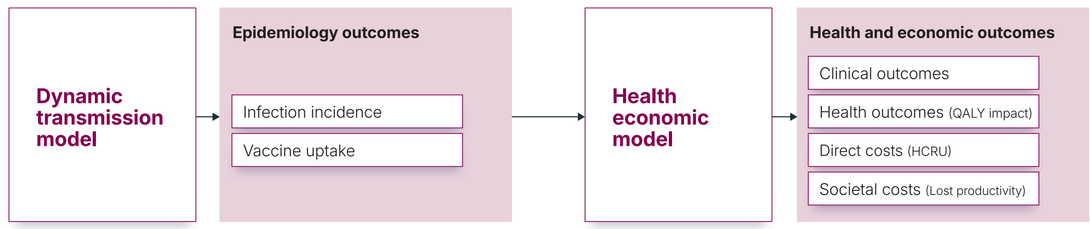


Figure 2. Dynamic transmission model

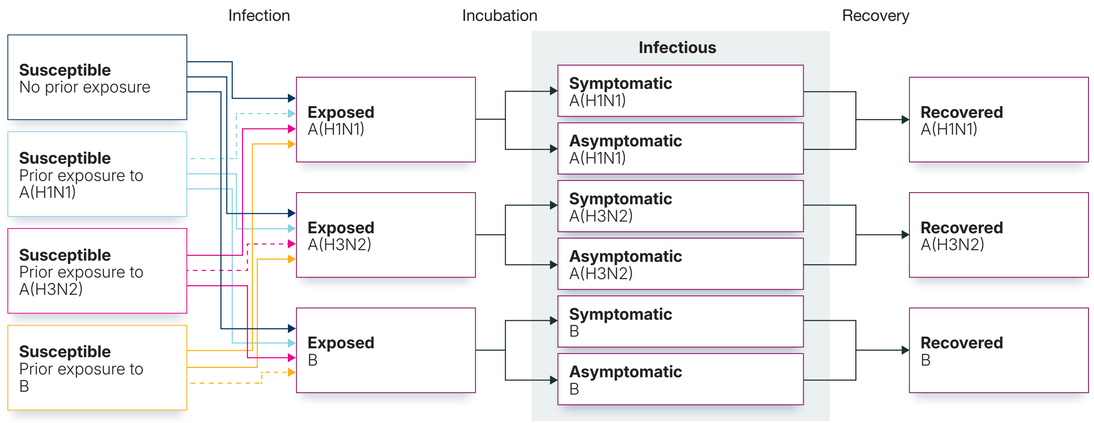


Figure 3. Health economic model

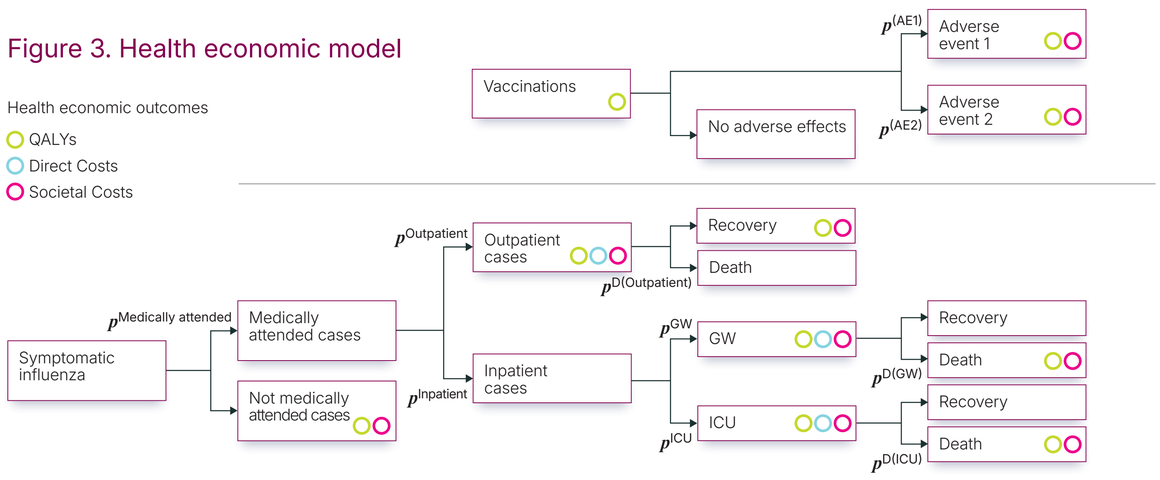


Figure 4. Key model inputs and outputs

	Key inputs	Key outputs
Clinical	• Infection rates • Vaccine effectiveness • Target coverage rates • Contact rates	• Influenza infections, N • GP visits, N • Hospitalisations (general ward and ICU), N • Influenza-related deaths, N
Costs	• Vaccine costs • Administration costs • HCRU costs • Productivity costs	• Vaccination acquisition and administration costs • Adverse event management costs • Healthcare costs (GP visits, hospitalisations) • Productivity loss due to death • Productivity loss (workdays lost) due to healthcare visits and childcare

What did we find?

Table 1. Simulated outcomes for a typical influenza season according to the reference case

	Austria	Catalonia, Spain	Czechia	Romania	Sweden
Population size	9.2M	8.1M	10.9M	19.1M	10.5M
Vaccine uptake	928,242	1,255,915	781,447	1,155,922	1,429,666
Coverage of national populations	10.1%	15.5%	7.2%	6.1%	13.6%
Influenza infections	918,252	804,106	1,086,284	1,900,830	1,047,682
Symptomatic	614,311	537,947	726,724	1,271,655	700,899
Symptomatic, seeking medical attention	61,431	215,359	72,672	127,166	69,984
Outpatient cases	48,712	212,709	57,434	100,415	65,902
GW cases	11,741	2,396	14,067	24,693	3,673
ICU cases	978	254	1,172	2,057	408
Deaths (per million)	128 (14.0)	94 (11.6)	158 (14.5)	277 (14.5)	211 (20.0)
Total QALYs lost (per million)	4,817 (525)	4,839 (596)	5,689 (521)	10,545 (553)	2,897 (275)
Total costs, societal perspective	$300.1M	$232.8M	$138.5M	$190.6M	$141.7M
Total costs, direct perspective	$141.5M	$109.4M	$70.1M	$75.3M	$80.6M

Burden of influenza

Vaccination coverage was low and variable across settings
Coverage ranged from 6.1% (Romania) to 15.5% (Catalonia); uptake 0.78–1.43 million doses

Substantial residual influenza burden persists under the reference case
An estimated 0.80–1.90 million infections per season

Severe outcomes remain considerable
Influenza leads to 275–596 QALYs lost and 11.6–20.0 deaths per million per season

Economic burden is substantial to payers and society
Total seasonal costs (2025 US$) were estimated at $70.1M–$141.5M and $138.5M–$300.1M, respectively

Findings indicate meaningful scope for improvement
Low vaccination coverage leaves substantial avoidable clinical and economic burden

What are the implications for payers?

Provides payers with an **adaptable tool to assess the impact** of alternative vaccination strategies

Enables **rapid evaluation** of coverage, target population, and vaccine selection scenarios to **inform decisions**

Supports **evidence-based resource allocation** through integrated estimates of health outcomes, costs, and cost-effectiveness

Limitations

- The model assumes that individuals cannot be infected with more than one strain, either simultaneously or within the same season
- The model captures vaccine effectiveness only through exposure and infection rates, excluding its impact on influenza-related complications, hospitalisations, and deaths

Abbreviations: GP, general practitioner; GW, general ward; HCRU, healthcare resource use; ICU, intensive care unit; N, number; QALY, quality-adjusted life year

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References: 1. World Health Organization. Influenza (Seasonal). 2025. www.who.int [accessed September 2026]; **2.** Peasah et al. Vaccine. 2013;31:5339–5348; **3.** Den Boon et al. BMC Health Serv; 2023; 12:1284; **4.** Mauskopf et al. Value Health. 2018;21(10):1133–1149; **5.** Pitman et al. Value Health. 2012 Sep 18;15(6):828–834; **6.** Prem et al. PLoS Comput Biol. 2024;20(9):e1012454.

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