The Impact of Healthcare Access on COVID-19 Burden in Poland: An Investigation of Causal Relationships to Uncover the 'Dark Figure' of Infections

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Problem

Biases in the measurement of COVID-19 burden and uncertainty in estimation of the corresponding epidemiological indexes are known and common phenomena in infectious diseases. Seeking causal relations between vaccination or infection-gained immunity level and infection dynamics could be misleading without understanding the socio-epidemiological context such as the moderating and mediating role of healthcare access HCA (sensu lato). The discrepancy between reported and predicted epidemiological features in selected models may be explain by this factor (Jarynowski, 2021). We investigated to what extent HCA-related supply/demand interfered with the registered data on COVID-19 in Poland.

Healthcare Access (HCA)

Supply/demand HCA are assumed to be mediating/moderating variables that affect the relationship between the independent variables – vaccine or post-infection immunity at the end of the 3rd wave – and dependent variables being outcomes of the 4th wave outbreak. Demand HCA is a complicated conglomerate of attitudes towards healthcare (i.e. level of trust in the effectiveness of offered treatment by public healthcare), perception of accessibility (i.e. how easily one can reach healthcare facilities), burden of disease (i.e. elderly and inferior health populations seek healthcare more often).

Data for counties

Independent variables:

- **cases**: Cumulative number of cases per capita till the so-called 3rd wave of epidemic (04.03.2020 - 15.06.2021) for poviat (county) divided by its population size

- **vacc**: Fraction of vaccinated: Percentage of vaccinated with at least one dose for poviat (at the end of the 3rd wave as of 15.06.2021)

Moderating/Mediating variables:

- **HCA supply**: Healthcare Access – Supply. The number of physicians working in health care (public and private) per 10,000 inhabitants in 2019

- **HCA demand**: Healthcare Access – Demand. The number of consultations in primary care per population size provided in 2019.
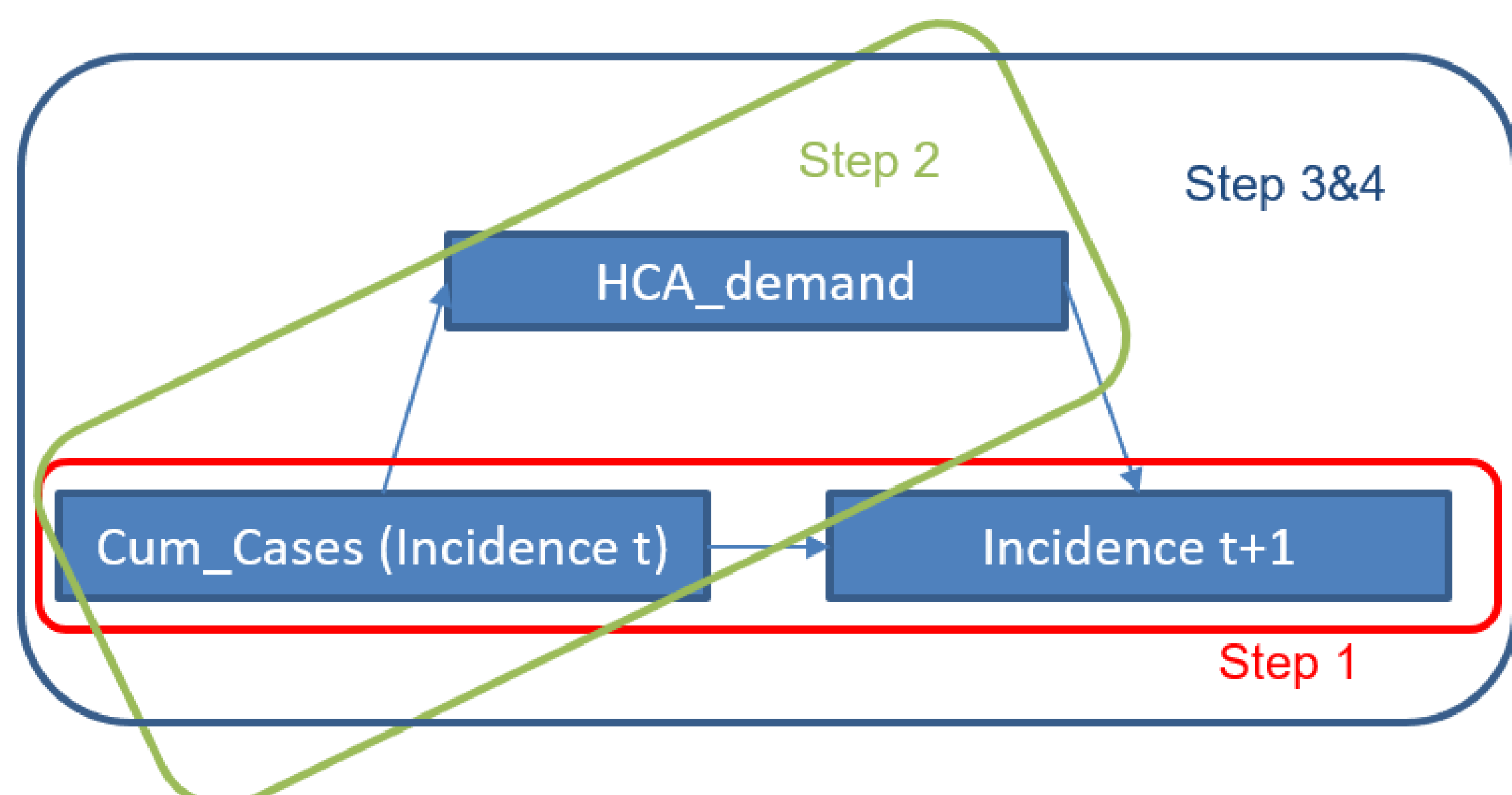
Dependent variables:

- **incidence:** 2-week incidence (per capita) of COVID-19 notifications (21.09–04.10.2021) during the beginning of the so-called 4th epidemic wave

- **death**: Normalized deaths Sep/Nov'21. Crude mortality rate (15.09–21.11.2021) during the so-called 4th epidemic

Using a linear multiple regression model with interactions to explain the geographic variation we found a strong signal of mediation/moderation (Jarynowski, Belik, 2022)
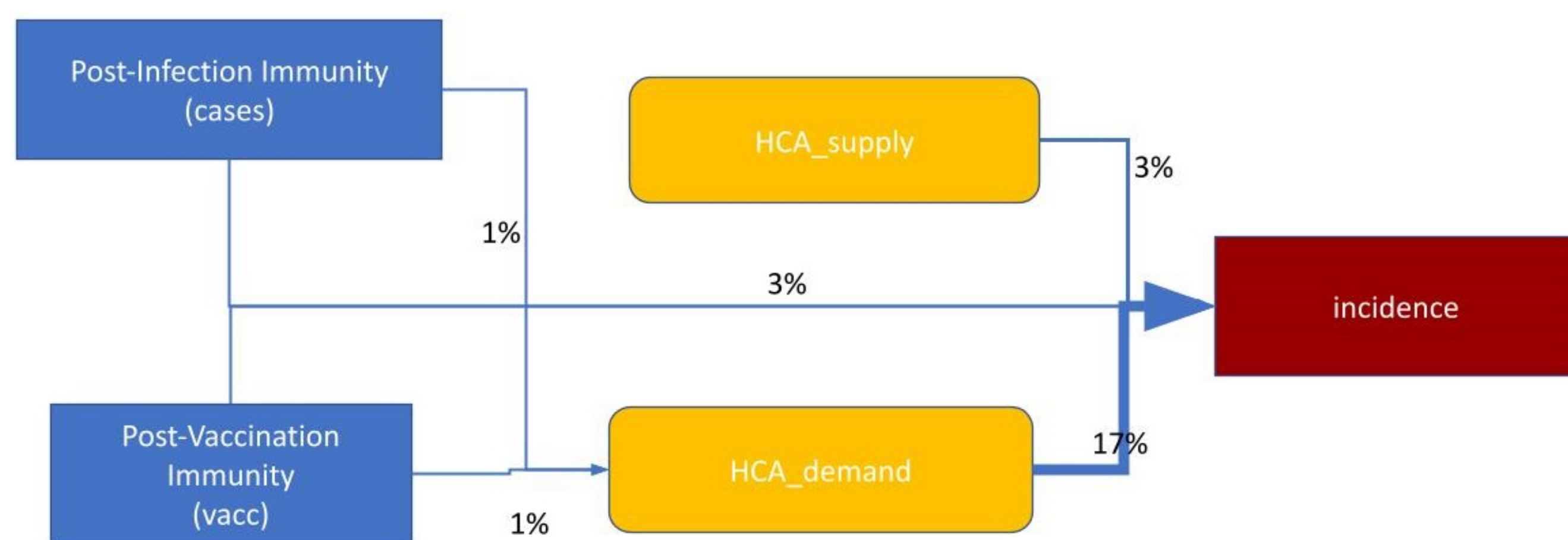

Additionally we used casual models with Bayesian optimization criteria to explain the geographic variation of incidence/mortality in beginning of the 4th wave of COVID-19 (so-called "Delta" wave in Autumn 2021) on county – old NUTS-4 level. Moreover, we verify that HCA_demand acts as a mediator of the effect of (Cum) cases (the incidence at t) on the current incidence ($t + 1$) for each county (Renard, 2019).

References

Renard, M. (2019). Doing and reporting your first mediation analysis in R. https://tinyurl.com/yc5j47ms Jarynowski, A. (2021). Reflection on contextual factors associated with burden of infectious diseases in multi-country modelling approach on the example of Eastern Europe. E-methodology, 8(8), 99-105. https://doi.org/10.15503/emet.2021.99.105 Jarynowski, A., Belik, V. (2022). Access to healthcare as an important moderating variable for understanding geography of immunity levels for COVID-19-preliminary insights from Poland. European Journal of Translational and Clinical Medicine. https://doi.org/10.31373/ejtcm/147842 Scutari, M., & Ness, R. (2012). bnlearn: Bayesian network structure learning, parameter learning and inference. R package

Mediation Model

We have determined the most important and stable causal paths. Assumption: For incidence and deaths outgoing links are forbidden (i.e. link incidence → death is blocked by default).
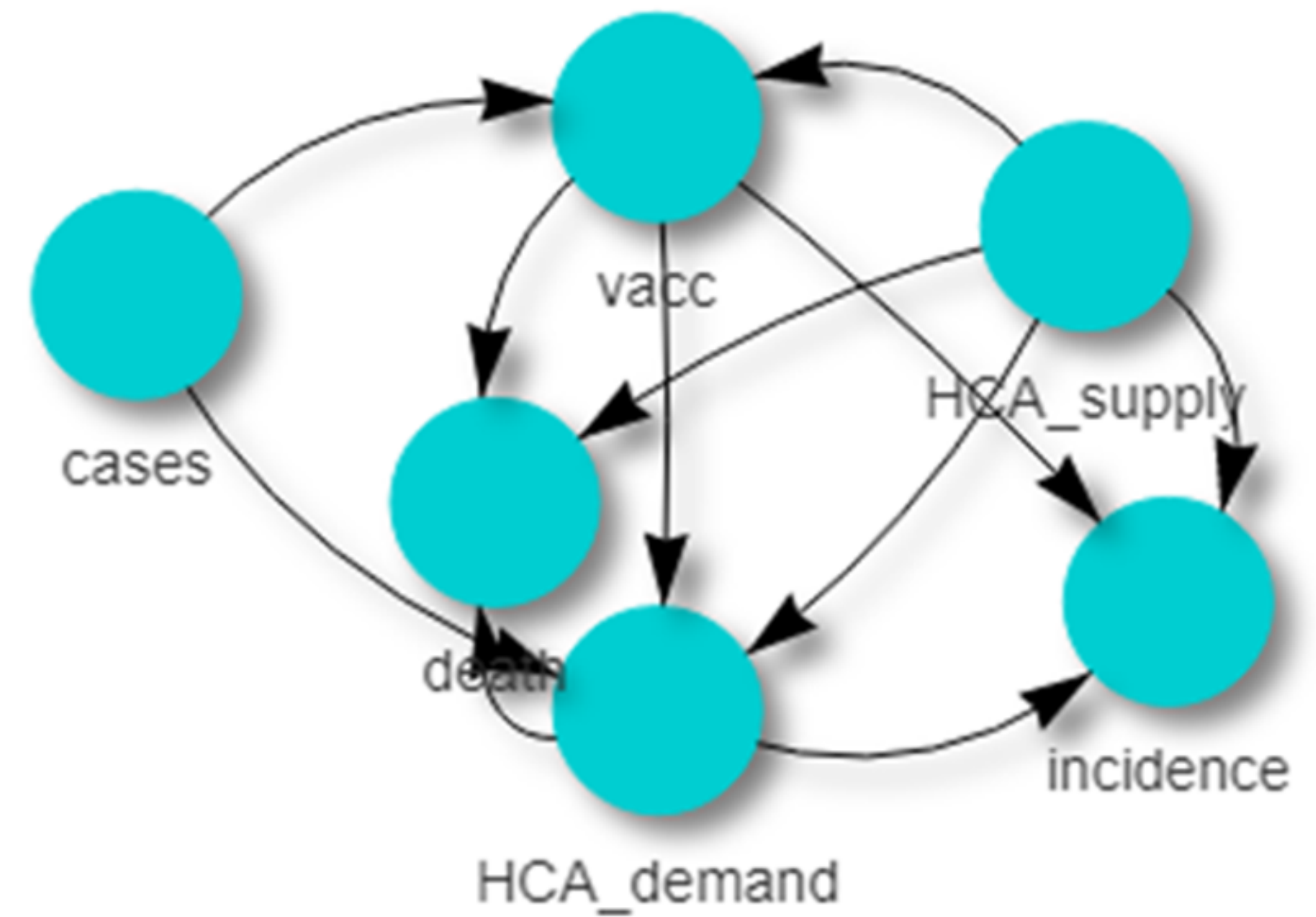

link	strength	Op* hc	Op* tabu
cases → HCA_demand	164.7	94%	69%
HCA_demand → incidence	25	79%	80%
vacc → death	23	100%	100%
HCA_demand → death	17	100%	80%

*Occurrence probability of the link according to the given algorithm (Scutari, Ness, 2012)

We see that paths going from cases through HCA_demand to incidence have the highest strength and are stable.
We proved that hypothesis of mediation triangle between cumulative and current incidence by demand HCA has > 99% probability of being actually mediation triangle according to the used algorithm (Renard, 2019). It is also very strong (at least an order of magnitude higher that any other causal path) and stable (94% of occurrence by the hill-climbing criterion). We observed a much smaller effect on deaths. This suggests that the mediating effect of HCA_Demand is strictly linked with a 'dark figure' of infections. We have observed not so strong, but extremely stable protective effect of vaccination on deaths due to COVID-19.

Moderation model
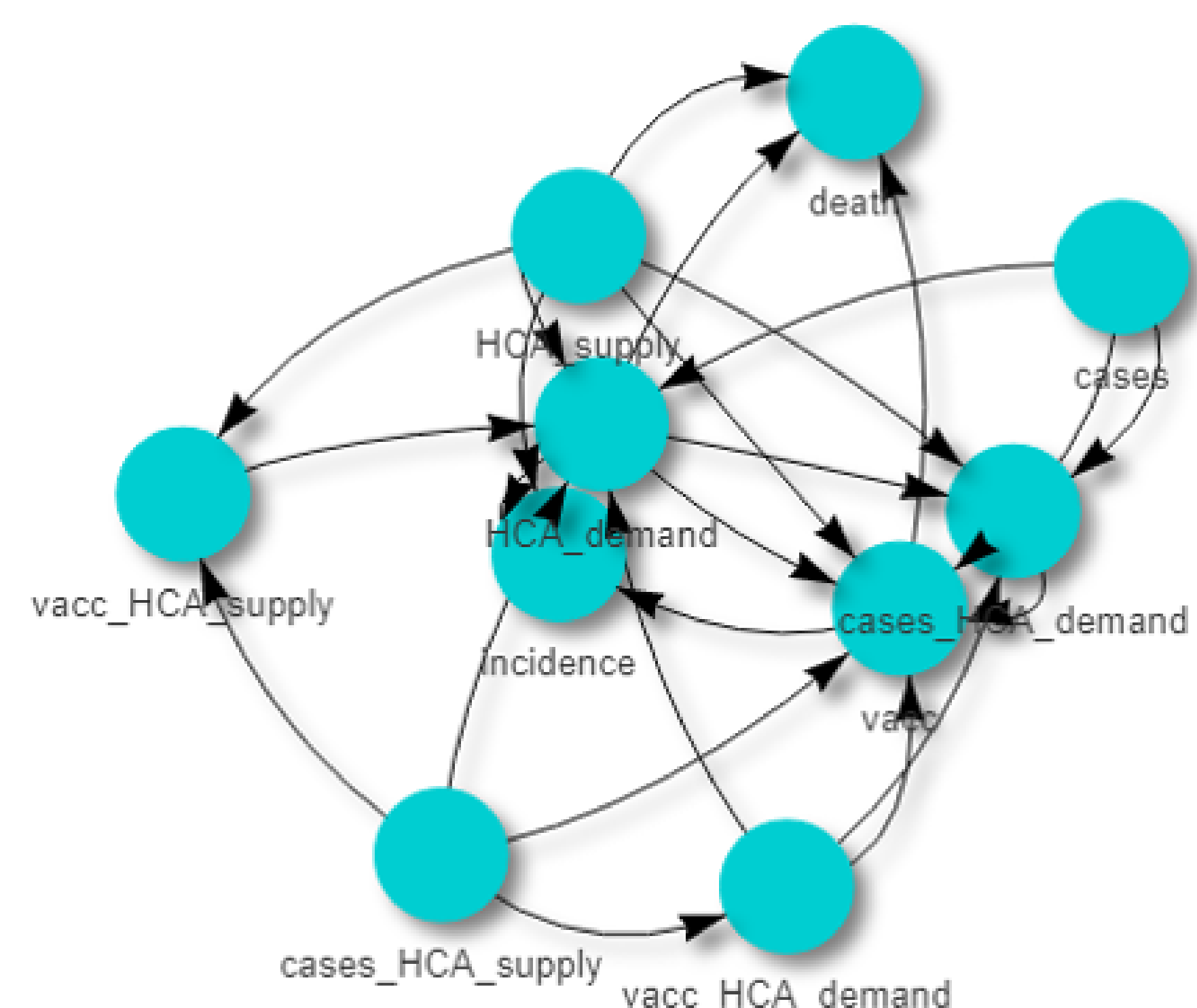
There is also not as strong, but also significant (95% of occurrence by the hill-climbing criterion) moderating phenomenon of supply HCA on vaccination having protective effects deaths due to COVID-19. We can conclude that HCA_demand has been rejected as a moderator of (cumulative) cases and incidence.

Conclusion and Acknowledgement

We demonstrated that HCA (mainly demand) directly or through paths (mainly mediation triangle from cumulative cases) has the highest causal effect on the incidence. Moreover, death rates and the vaccination rates by regions have been significantly confounded by supply HCA, which is linked to the healthcare system capacities. We postulate, that spatial distribution of case notifications is mainly driven by the way people decide to use the healthcare system rather than epidemic processes. We suggest that future epidemiological models must adopt demand HCA as a factor of so-called 'dark figure' of infections. Otherwise, spatial models may be more likely to biased by people's decisions on testing rather than to the actual burden of disease. Thus, link between the reported case numbers and the true state of the epidemic should be spatiotemporally adjusted.