Online supplementary material

Explaining spatial variation in human papillomavirus vaccination uptake in Switzerland: A multi-level spatial analysis of a national vaccination coverage survey

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1. Variables: definitions and sources

A summary of all variables (covariates and outcome) is given in Table S2.

Nationality: Nationality was available in two levels, namely Swiss and non-Swiss, which we coded as 0 and 1 respectively. Nationality was missing for all participants residing in the canton of Jura (N=755) (not asked in the questionnaire), some participants from canton Aargau (missing/total): 177/457, Neuchâtel (115/352) and Basel Landschaft (4/603). For these 1051 individuals in total, this variable was set to the proportion of people with non-Swiss nationality in their municipalities of residence. The variable can thus be interpreted as a probability of not being a Swiss national.

Urbanisation levels: We categorized the level of urbanization into three groups: rural, semi-urban and urban, according to a subdivision suggested by the Federal Statistical Office (FSO) [1] (figure S1). Urban represents urban centres areas, semi-urban means areas under influence of urban centres and rural represent municipalities outside the influence of urban centres. We retrieved urbanisation level in Switzerland in 2016 from the FSO [1].

Swiss-SEP: Swiss-SEP is a neighbourhood-based measure of socio-economic position (SEP), developed by the Swiss National Cohort study group [2,3]. It was calculated for each residential building using median rent per square metre, proportion households headed by a person with primary education or less, proportion households headed by a person in manual or unskilled occupation, and the mean number of persons per room among the 50 households nearest to the building based on a street network [4]. For this study, we used mean Swiss-SEP for each municipality categorized into quartiles (figure S2). We then compared the combined 2nd and 3rd quartiles (baseline) with the lowest and highest quartiles (1st and 4th respectively). We used data from the national census held in 2000 [5].

Political opinion: The Swiss political system is based on parliaments as well as popular initiatives and referendums that shape legislation and constitutional changes (semi-direct democracy). We used the mean acceptance (% in favour of the law revision) per municipality of a public referendum against the revision of the federal law about epidemics. In September 2012, the Swiss Parliament proposed a revision of the federal law about epidemics aimed at better detection, prevention and interventions for communicable diseases, replacing the previous law dating back to 1970 [6]. The revision would give more power to the federal government in the management of epidemic threats [6,7]. The revised law stipulates that vaccination can be mandatory for specific population groups at high risk of infection in particular situations: if the regular authorities are unable to prevent and control the outbreak and spread of a communicable disease with high risk for the population and if there is, either i. an increased threat of transmission and spread of disease, or ii. a specific threat to public health, or iii. a serious impact on the economy or other areas of daily life, or if the World Health Organization (WHO) declares a health emergency of international concern threatening public health in Switzerland [8]. A referendum committee, comprising groups opposed to mandatory vaccination and/or vaccination collected the 50,000 signatures required to table a referendum against the revision of this law revision in January 2013 [7]. This referendum was not supported by any major political party. The debate was heavily focused on scepticism towards vaccination in general. According to the referendum committee, the revised law would "introduce mandatory vaccination although vaccines are dangerous" and "induce early sexualisation of children at school", among other issues [7,9–11]. On 22 September 2013, 60% of the voters voted to accept the revision of the law (participation of 46.76%) [12]. Given the vaccination-focused background to this referendum, we assumed that strong opposition to the revision of the law at municipality level would be closely related to vaccine scepticism amongst individual in a municipality. We categorized the percentage of yes (in favour of the law revision) in each municipality into quartiles and compared the baseline (2^cd^ and 3^rd^ quartiles) with the lowest and highest acceptance (1^st^ and 4^th^ quartiles), in order the capture the impact of extremes (figure S3).

Religious denomination: The main religious denomination per municipality was considered Protestant or Catholic if the absolute majority of the inhabitants (≥ 50%) were integrated in one of these two religious denomination. If there was no absolute majority of Protestants or Catholics, the municipality was classified as "no major religious denomination" (figure S4). We used data from the national census held in 2000 [5].

Language region: Switzerland has four national and three official languages (German 63% of the population, French, 23% and Italian: 8% in 2015) [13]. Romansh is the fourth national language, spoken by only 0.5% of the population (essentially in canton Graubünden, which is officially trilingual: German, Italian and Romansh). Four cantons are French-speaking, three are bilingual French and German, one canton is Italian-speaking (Ticino) and the 17 remaining cantons are German speaking (figure S5). Language region is defined at municipality level, two cities (Biel/Bienne and Fribourg/Freiburg) are officially bilingual (French/German) cities (10). We retrieved municipality-based language in 2016 from the FSO [1].

School-based vaccination: Following recommendations by the Swiss Federal Office of Public Health (FOPH), all cantons implemented their HPV vaccination programmes by the end of 2008. The cantonal programmes include the base vaccination for 11-14 years old girls, and catch-up and complementary vaccination for girls until 26 years and boys from 11 to 26 years. The cantonal HPV vaccination programmes differ in many ways such as the way (school-medical services, private physicians, mandated vaccination service, hospitals, etc.), where (at school, apart from school, both) and when the vaccinations are provided. We used a variable indicating whether or not the cantons offer the possibility to deliver vaccination by the school-medical services according to an evaluation of the cantonal HPV vaccination program led in 2009 (figure S6) [14]. The questionnaire asked whether cantons allowed vaccination to be offered in schools, by private physicians, at hospitals, or a combination. For three cantons (BE, GE and TI, acronyms are explained in Table B), the evaluation contained no information. We thus completed the information based on personal oral communication from the Chief Medical Officer in Bern and on information available on the official websites of cantonal administrations of Geneva and Ticino [15,16]. For canton Aargau, the information on the report was imprecise (personal communication with S. Dehler from the Cantonal Medical Office of Aargau) and we classified canton Aargau as school-based vaccination delivery.

Survey Period: Survey period is a categorical variable, each category representing one of the three periods: 2008-2010, 2011-2013 and 2014-2016. Adding survey period as a covariate is essential for adjusting for the increasing time trend in the HPV vaccination uptake.

2. Statistical analysis

2.1 Model description

We specified the following logistic regression model:

$$logit(Y_k) = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{X}_k$$

where Y_k is the vaccination status of an individual (0 non-vaccinated, 1 vaccinated), β_0 is an intercept, $\boldsymbol{\beta}$ a vector of coefficients, and $\boldsymbol{X}_k$ the vector containing the values of the selected covariates for the k^{th} individual.

When there is spatial autocorrelation due to unmeasured confounding, the above model (model 7) might lead to inflated type I errors and sometimes even yield biased regression coefficients [17,18]. To correct for this, we extended model 7 to account for spatial correlation at the municipal level by adding random effects with conditional autoregressive (CAR) prior distributions[19,20]. Accounting for spatial autocorrelation also facilitates mapping spatial variation in uptake prevalence. When uptake is assessed by survey, a map of crude uptake prevalence at municipal level will be affected by high sampling variability associated with small sample sizes or entirely missing samples (in the case of cluster sampling) in certain municipalities. By including spatial autocorrelation, information from adjacent areas is borrowed, allowing to obtain more reliable uptake prevalence [21].

There are several CAR model used in the literature [22–24]. We selected the Besag, York and Mollié (BYM) model which is the most commonly used CAR model in epidemiology [19,20]. Simulation studies suggest that the BYM model performs comparably well [25].The model includes a spatially structured (independent between area units) and an unstructured random effect component (correlated between adjacent spatial units). Let $\boldsymbol{\phi}$ be the vector of the spatial structured random effects and let $\boldsymbol{u}$ be the vector of the spatially unstructured effects (these vectors have *n* elements, where *n* is the number of municipalities). Let $\boldsymbol{W}$ be a matrix of weights with elements:

$$w_{ij} = \begin{cases} 1, & if\ j\ belongs\ to\ the\ 1st\ order\ neighbors\ of\ i \\ 0, & otherwise \end{cases}$$

Then the full BYM model is specified as follows:

$$logit(Y_{ki}) = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{X}_{ki} + \phi_i + u_i$$

$$\phi_i | \boldsymbol{\phi}_{-i} \sim N\left(\frac{\sum_{j=1}^{n} w_{ij}\phi_j}{\sum_{j=1}^{n} w_{ij}}, \frac{\sigma_1^2}{\sum_{j=1}^{n} w_{ij}}\right)$$

$$u_i \sim N(0, \sigma_2^2)$$

Where σ_1^2 and σ_2^2 are unknown variances and i denotes the municipality of residence of the individual and $-i$ all other municipalities. Bayesian inference and prior distributions for all model parameters are reported in the following sections.

2.2 Model selection

We compared the following models:

Model 1: $logit(Y_{ki}) = \beta_0 + \phi_i + u_i$

Model 2: $logit(Y_{kih}) = \beta_0 + \phi_i + u_i + v_h$, where v_h is a random intercept at the cantonal level: $v_h \sim N(0, \sigma_3^2)$, $h = 1, \ldots, 21$ for the 21 cantons available in our study and σ_3^2 and unknown variance.

Model 3: $logit(Y_{kih}) = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{X}_{kih} + \phi_i + u_i + v_h$

Model 4: $logit(Y_{ki}) = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{X}_{ki} + \phi_i + u_i$

Model 5: $logit(Y_{kh}) = \beta_0 + v_h$

Model 6: $logit(Y_{kh}) = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{X}_{kh} + v_h$

Model 7: $logit(Y_k) = \beta_0 + \boldsymbol{\beta}^T \boldsymbol{X}_k$

Model 8: $logit(Y_k) = \beta_0 + \beta_p x_{kp}$, where $p = 1, \ldots, P$, where P corresponds to the p^{th} covariate for the k^{th} individual.

For model selection, we used the deviance information criterion (DIC) [26]. This is a commonly used criterion in the context of Bayesian hierarchical models. It favours good model fit while at the same time penalising the complexity of the model (number of effective parameters).

2.3 Inference

Inference for hierarchical models as the CAR class described above is often conducted in the Bayesian setting:

$$p(\boldsymbol{\theta},\boldsymbol{\xi}|\boldsymbol{Y}) \propto p(\boldsymbol{Y}|\boldsymbol{\theta},\boldsymbol{\xi})p(\boldsymbol{\theta},\boldsymbol{\xi})$$

where $\boldsymbol{\xi}$ is a vector of hyper-parameters (in the BYM model, for example, is a vector of σ_1^2 and σ_2^2), $\boldsymbol{\theta}$ is a vector of the parameters of interest (in the BYM model, for example, is the $\boldsymbol{\theta} = [\boldsymbol{\phi}, \boldsymbol{u}]$), and $p(\boldsymbol{\theta},\boldsymbol{\xi})$ is the selected prior distribution of the parameters. The goal is to calculate the marginal posteriors of the parameters of interest given the observed data: $p(\theta_l|\boldsymbol{Y}) = \int p(\theta_l|\boldsymbol{\xi},\boldsymbol{Y})p(\boldsymbol{\xi}|\boldsymbol{Y})d\boldsymbol{\xi}$. A commonly used approach relies on Markov chain Monte Carlo (MCMC) simulations. However this procedure is greatly hampered by computational time. Instead we used integrated nested Laplace approximation (INLA) which greatly reduces computation time [27]. All calculation were computed in the R software environment for statistical computing [28], using the R-INLA package [29].

2.4 Priors

For the prior specification, we selected the default (vague) priors that are implemented in the R-INLA package [29]. That is loggamma(1, 0.0005) for $\log(\frac{1}{\sigma_1^2})$, $\log(\frac{1}{\sigma_2^2})$ and $\log(\frac{1}{\sigma_3^2})$ and $\beta_0 \sim N(0,0)$ and $\beta_p \sim N(0, 0.001)$ $(p = 1, \dots, P)$ (read N(mean, precision) for the two latter priors).

3. Sensitivity analysis

We conducted three sensitivity analyses in order to test the robustness of our results to possible sources of bias.

First, we examined whether the non-respondents differ from respondents with respect to the covariates. The SNVCS provides information about municipality and nationality of non-respondents. We used the best-fit model (model 3) and changed the outcome to being respondent (yes/no). This analysis showed that non-Swiss nationality and last survey period were associated with poorer response (OR: 0.5, 95% CI: 0.46-0.56 and OR: 0.63, 95% CI: 0.56-0.72, respectively) (Table S4). We also observed differences in response rates (also see figure S7) at the cantonal but not the municipal level: cantonal random effect (median 0.61, 95% credible intervals of the standard deviation: 0.53-0.67), BYM structured (median: 0.03, 95% CI: 0.02-0.04) and BYM unstructured (median: 0.03, 95% CI: 0.02-0.05). This observation highlights the need to include a random effect at the cantonal level. Cantonal differences in the response rate might be driven by different sampling procedures and different contextual factors, as discussed in the main text. To further examine the robustness of our results, we assessed odd ratios with regard to different assumptions about the response rate and after adjusting for the sampling method (Table S5). Results for the other covariates did not reveal any major systematic differences between respondents and non-respondents in the survey (Table S4).

Second, to account for possible respondent bias, we ran the full model (model 3) including all survey non-respondents under two extreme assumptions: 1) all non-respondents received vaccination, and 2) all non-respondent did not receive vaccination. Accounting for extreme assumptions about non-respondent resulted in similar odds ratios (OR) compared to the full model (model 3) for most covariates, except for nationality and survey period (Table S5). That comes in line with the first sensitivity analysis, where we observed systematic differences in response among these covariates (Table S4).

Third, to account for sampling methods, we included a categorical variable (as shown in Table S1) in model 3. Accounting for different sampling methods resulted in similar OR estimates compared to the full model (Table S5).

Supplemental Tables

Table S1. Swiss cantons with information about population size [30], HPV vaccination uptake in 2014-16 [31], school-based vaccination [14] and sampling method. Sampling method is either cluster or simple random sampling (SRS) except for cantons JU, BS and VD where the information was collected by school nurses. Cantons highlighted in grey did not participate in this study.

Cantons	Acronym	Population size (2013)	HPV vacc. uptake (1 dose, 3rd period), mean (95% CI)	School-based vacc.	Sampling method (3rd period)	Responders /sampled (%)
Zürich	ZH	1,425,631	51 (41.7-59.7)	yes	cluster	405/636 (64%)
Bern	BE	1,001,281	51 (42.1-59.2)	yes	SRS	265/310 (85%)
Vaud	VD	749,373	68 (61.3-74.6)	yes	school nurses	476/532 (89%)
Aargau	AG	636,362	80 (71.3-87.8)	yes	SRS	277/445 (62%)
St. Gallen	SG	491,699	63 (54.7-71.7)	yes	SRS	551/746 (74%)
Genève	GE	469,433	59 (47.1-71.4)	yes	SRS	138/346 (40%)
Luzern	LU	390,349	44 (35.1-52.4)	yes	SRS	-
Ticino	TI	346,539	52 (42.9-61.2)	no	SRS	587/712 (82%)
Valais	VS	327,011	79 (72.4-86.3)	yes	SRS	519/692 (75%)
Fribourg	FR	297,622	71 (63.5-77.9)	yes	SRS	517/651 (79%)
Basel-Landschaft	BL	278,656	69 (60.5-76.6)	yes	SRS	365/444 (82%)
Solothurn	SO	261,437	58 (51.0-65.0)	no	cluster	361/596 (61%)
Thurgau	TG	260,278	43 (33.9-51.2)	no	cluster	965/1294 (75%)
Graubünden	GR	194,959	53 (44.7-61.8)	no	SRS	-
Basel-Stadt	BS	189,335	69 (64.6-73.5)	yes	school nurses	1319/1891 (70%)
Neuchâtel	NE	176,402	70 (61.6-78.4)	yes	SRS	233/292 (80 %)
Schwyz	SZ	151,396	38 (29.4-47.0)	no	SRS	229/289 (79%)
Zug	ZG	118,118	46 (33.2-59.4)	no	SRS	255/372 (69%)
Schaffhausen	SH	78,783	72 (63.8-80.9)	yes	SRS	209/265 (79%)
Jura	JU	71,738	62 (55.8-69.1)	yes	school nurses	755/820 (92%)
Appenzell Aus.	AR	53,691	38 (26.4-49.0)	yes	SRS	-
Nidwalden	NW	41,888	59 (47.3-71.0)	yes	SRS	-
Glarus	GL	39,593	65 (52.1-77.8)	no	SRS	-
Obwalden	OW	36,507	31 (19.9-42.5)	no	SRS	243/329 (74%)
Uri	UR	35,865	43 (30.6-54.4)	no	SRS	234/292 (80%)
Appenzell In.	AI	15,778	40 (27.9-53.0)	no	SRS	277/445 (62%)

Table S2. Individual, municipal and cantonal variables (covariates and outcome) of the model.

Variable	Type of data	Analysis level	Source (year)	Number of missing Values
HPV vaccination status	≥ 1 doses HPV vaccination received, yes or no). Outcome variable	Individual	SNVCS (2008-2016)	-
Nationality	Swiss, non-Swiss	Individual	SNVCS (2008-2016)	1,051
Urbanization level	Rural, semi-urban, urban	Municipality	BFS (2012)	-
Swiss-SEP	Baseline (2nd and 3rd quartile) compared to 1st quartile and 4th quartile	Municipality	BFS (2000)	-
Political opinion	Baseline (2nd and 3rd quartile) compared to 1st quartile and 4th quartile of proportion of yes)	Municipality	BFS (2013)	8
Religious denomination	No major religious denomination (baseline), ≥50% Protestant, ≥50% Catholic)	Municipality	BFS (2000)	-
Language region	German (baseline), French, Italian	Municipality	BFS (2012)	-
School-based HPV-vaccination programme	School-based vaccination delivery in ≥ 1 school, yes or no	Canton	PLANES (2009)	-
Survey period	2008-2010 (baseline), 2011-2013 and 2014-2016)	Canton	SNVCS (2008-2016)	-

Abbreviations: HPV human papillomavirus, SNVCS Swiss National Vaccination Coverage Survey, SEP socio-economic position, BFS Bundesamt für Statistik (Federal Statistical Office)

Table S3. Odds ratio (OR) and 95% credible intervals (CI) for receipt of ≥ 1 HPV vaccine dose in the three Bayesian hierarchical logistic regression models.

Covariates		Univariable model [a] OR (95% CI)	Adjusted model[b] OR (95% CI)	Full model[c] OR (95% CI)
Nationality	Swiss	1	1	1
	Non-Swiss	1.41 (1.27-1.58)	1.25 (1.11-1.4)	1.23 (1.09-1.39)
Urbanization level	rural	1	1	1
	urban	1.35 (1.21-1.51)	0.97 (0.84-1.13)	0.96 (0.8-1.15)
	semi-urban	1.16 (1.01-1.33)	0.96 (0.82-1.13)	0.88 (0.73-1.06)
SEP quartile	lowest SEP	1.27 (1.15-1.4)	1.25 (1.11-1.42)	1.18 (1-1.38)
	baseline SEP	1	1	1
	highest SEP	0.95 (0.85-1.05)	0.87 (0.77-0.98)	0.93 (0.78-1.1)
Political opinion	lowest acceptance	0.42 (0.38-0.47)	0.58 (0.51-0.66)	0.61 (0.50-0.73)
	baseline acceptance	1	1	1
	highest acceptance	1.28 (1.14-1.45)	1.16 (1-1.34)	1.22 (0.99-1.5)
Religious denomination	No relig. denomination	1	1	1
	≥ 50% Protestant	0.62 (0.54-0.71)	0.88 (0.74-1.05)	1.02 (0.82-1.28)
	≥ 50% Catholic	0.91 (0.83-0.99)	1.11 (0.99-1.26)	1.12 (0.9-1.4)
Language region	German Speaking	1	1	1
	French Speaking	2.19 (1.98-2.42)	0.99 (0.85-1.15)	1.06 (0.8-1.41)
	Italian Speaking	1.02 (0.86-1.21)	1.32 (1.05-1.65)	1.3 (0.66-2.61)
School-based vaccination	other	1	1	1
	school medical services	2.9 (2.65-3.18)	2.58 (2.29-2.91)	2.51 (1.77-3.56)
Survey period	2009-2010	1	1	1
	2011-2013	1.38 (1.24-1.53)	1.27 (1.13-1.42)	1.22 (1.07-1.38)
	2014-2016	1.85 (1.66-2.07)	1.67 (1.48-1.88)	1.58 (1.39-1.81)

Abbreviations: OR odds ratio, CI credible intervals, SEP socio-economic position
[a] Referred as model 8 in the main text
[b] Referred as model 7 in the main text
[c] Referred as model 3 in the main text

Table S4. Sensitivity analysis using identical covariates and random effects as the full model (model 3) and the response to the survey as the outcome.

	Covariates	OR (95% CI)
Nationality	Swiss	1
	Non-Swiss	0.50 (0.46-0.56)
Urbanization level	rural	1
	urban	1.03 (0.86-1.22)
	semi-urban	0.85 (0.73-1.00)
SEP quartile	lowest SEP	0.97 (0.84-1.12)
	baseline SEP	1
	highest SEP	1.04 (0.90-1.21)
Political opinion	lowest vote acceptance	0.92 (0.79-1.07)
	baseline acceptance	1
	highest vote acceptance	0.99 (0.83-1.18)
Religious denomination	No religious denomination	1
	≥ 50% Protestant	1.00 (0.82-1.22)
	≥ 50% Catholic	1.08 (0.88-1.34)
Language region	German Speaking	1
	French Speaking	1.12 (0.82-1.50)
	Italian Speaking	1.37 (0.36- 5.17)
School-based vaccination	no	1
	yes	1.12 (0.61-2.06)
Survey period	2009-2010	1
	2011-2013	0.98 (0.86-1.10)
	2014-2016	0.63 (0.56-0.72)

Abbreviations: OR odds ratio, CI credible intervals, SEP socio-economic position
[a]median and credible intervals of the standard deviation.

Table S5. Sensitivity analysis imputing the outcome in non-respondents (1 and 2) and accounting for different sampling methods (3). Sensitivity 1 (2) stands for a model assuming that all non-respondents to the survey were vaccinated (non-vaccinated). Sensitivity 3 includes the sampling method as a covariate.

Covariates		Sensitivity 1 OR (95% CI)	Sensitivity 2 OR (95% CI)	Sensitivity 3[a] OR (95% CI)
Nationality	Swiss	1	1	1
	Non-Swiss	1.61 (1.45-1.79)	0.82 (0.75-0.91)	1.23 (1.09-1.39)
Urbanization level	rural	1	1	1
	urban	1.00 (0.85-1.17)	0.91 (0.78-1.07)	0.96 (0.80-1.15)
	semi-urban	0.89 (0.75-1.04)	0.90 (0.77-1.06)	0.87 (0.73-1.05)
SEP quartile	lowest SEP	1.18 (1.03-1.37)	1.10 (0.96-1.26)	1.20 (1.03-1.41)
	baseline SEP	1	1	1
	highest SEP	0.95 (0.81-1.10)	0.96 (0.83-1.11)	0.94 (0.79-1.12)
Political opinion	lowest accept.	0.71 (0.61-0.83)	0.67 (0.57-0.79)	0.60 (0.50-0.72)
	baseline accept.	1	1	1
	highest accept.	1.21 (1.00-1.47)	1.19 (1.00-1.41)	1.23 (1.00-1.52)
Religious denomination	No rel. denomination	1	1	1
	≥ 50% Protestant	1.00 (0.82-1.23)	1.02 (0.84-1.24)	1.03 (0.82-1.29)
	≥ 50% Catholic	1.02 (0.83-1.26)	1.14 (0.93-1.39)	1.10 (0.88-1.39)
Language region	German	1	1	1
	French	1.07 (0.82-1.41)	1.13 (0.84-1.50)	1.06 (0.78-1.42)
	Italian	1.06 (0.50-2.28)	1.75 (0.71-4.36)	1.19 (0.52-2.67)
School-based vaccination	no	1	1	1
	yes	1.94 (1.34-2.83)	2.02 (1.47-2.81)	2.59 (1.72-3.93)
Survey period	2009-2010	1	1	1
	2011-2013	1.21 (1.08-1.35)	1.17 (1.04-1.30)	1.18 (1.04-1.34)
	2014-2016	1.76 (1.57-1.98)	1.17 (1.05-1.31)	1.45 (1.25-1.69)
Sampling method	SRS	-	-	1
	Cluster	-	-	0.79 (0.64-0.96)
	schoolnurses	-	-	0.87 (0.50-1.47)

Abbreviations: OR odds ratio, CI credible intervals, SEP socio-economic position, SRS simple random sampling

[a] Sampling methods (SRS, cluster or school nurses) was included as covariate.

Supplemental figures

Figure S1. Levels of urbanisation in Switzerland at the municipal level.

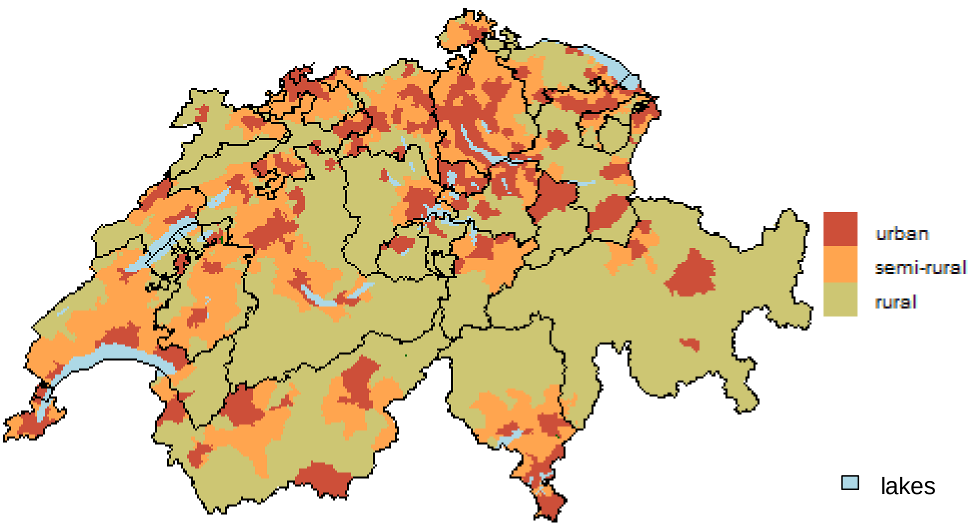


Figure S2. Socio-economic index (Swiss-SEP) in quartiles (2nd and 3rd quartile combined as baseline category compared to lowest and highest quartile) in Switzerland at the municipal level in 2000.

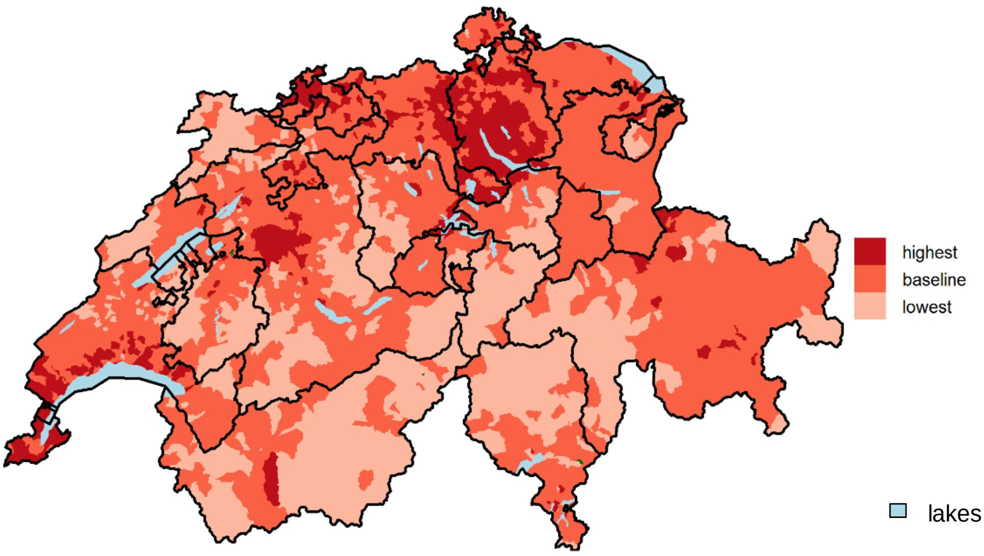


Figure S3. Political opinion for a public vote linked with vaccination in quartiles (2nd and 3rd quartile combined as baseline category) in Switzerland at the municipal level.

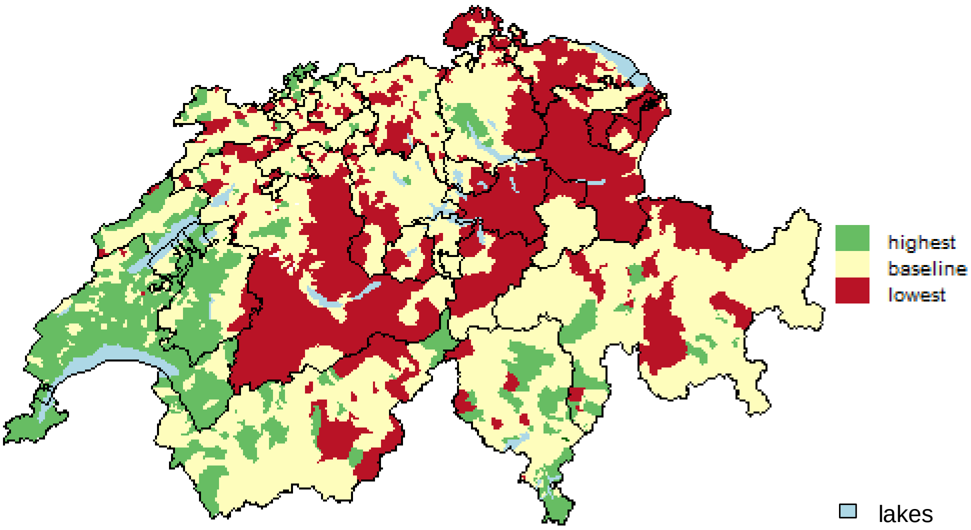


Figure S4. Major religious denomination (no major religion (baseline), ≥50% Protestant, ≥50% Catholic) per municipality in Switzerland in 2000.

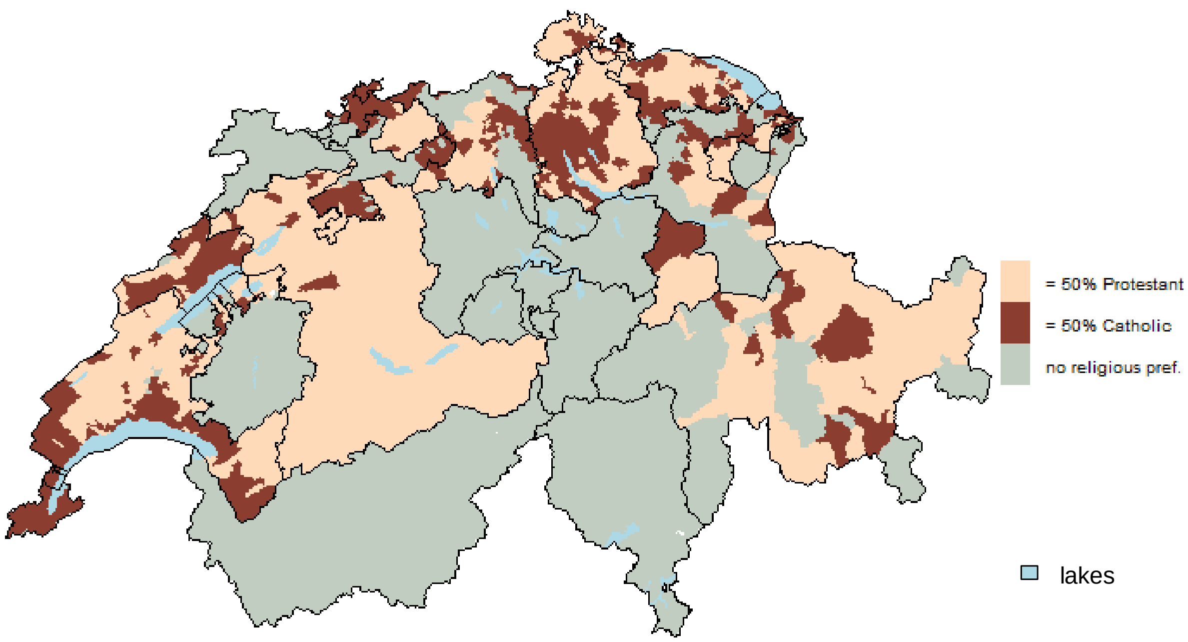


Figure S5. The four different language regions in Switzerland at the municipal level.

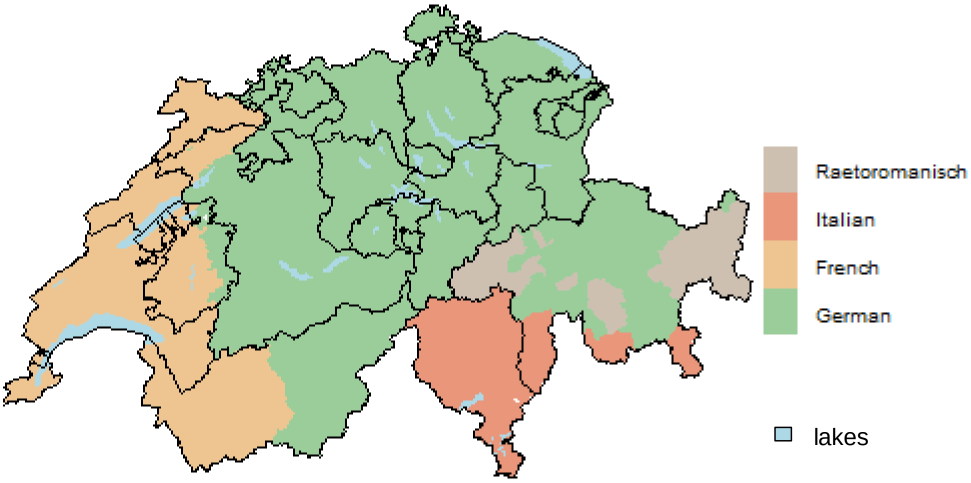


Figure S6. Vaccination provided by school medical services at the cantonal level in 2009.

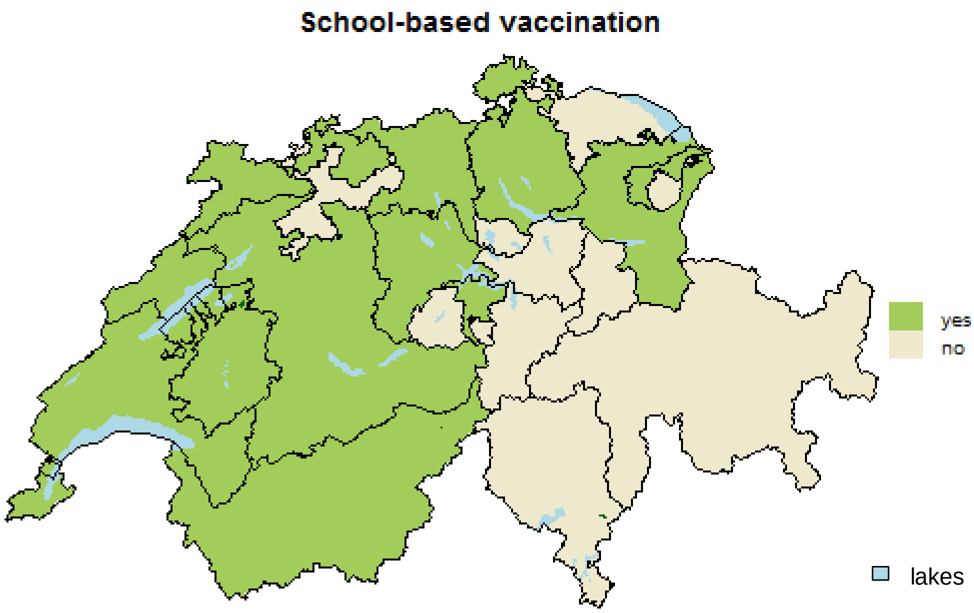


Figure S7. Response rate (number of respondents/ number of sampled) by municipality (top panel) and by canton (bottom panel). The cantons that did not participate in this study are shown in white.

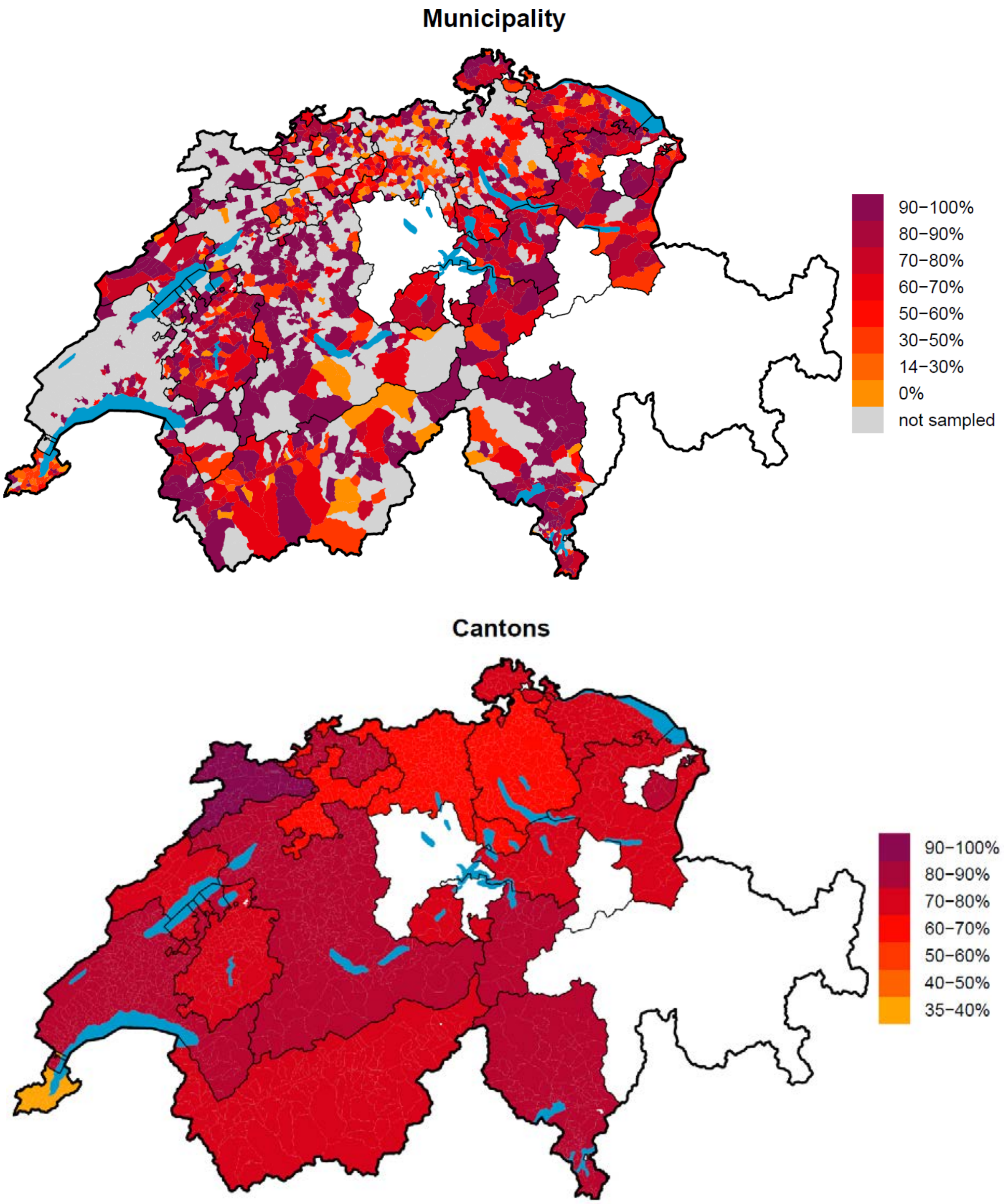
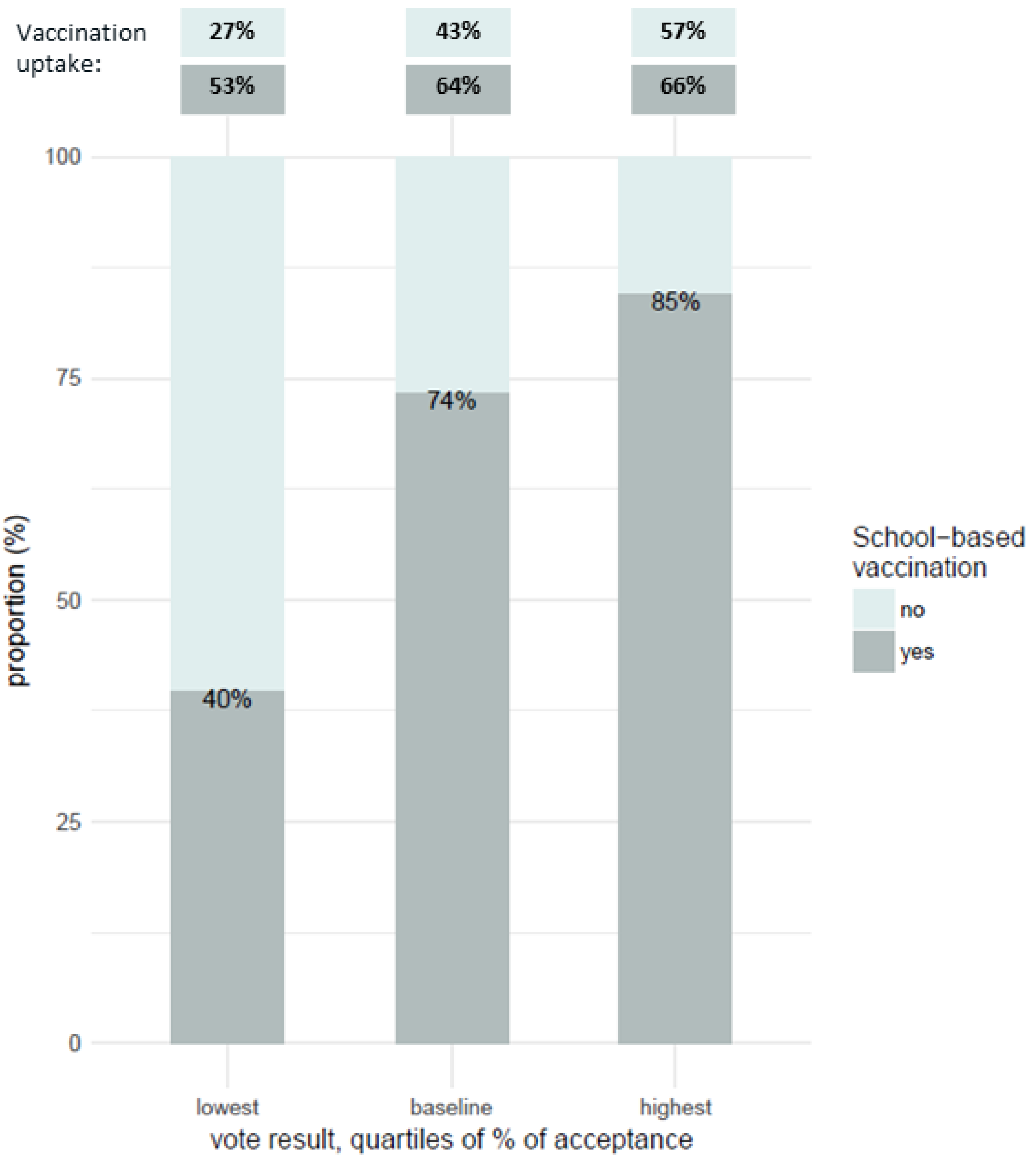


Figure S8. Relation between the covariates school-based vaccination and political opinion and vaccination uptake rates within the subgroups.



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