Causes of ethnic segregation in a nineteenth century city

The case of Vyborg

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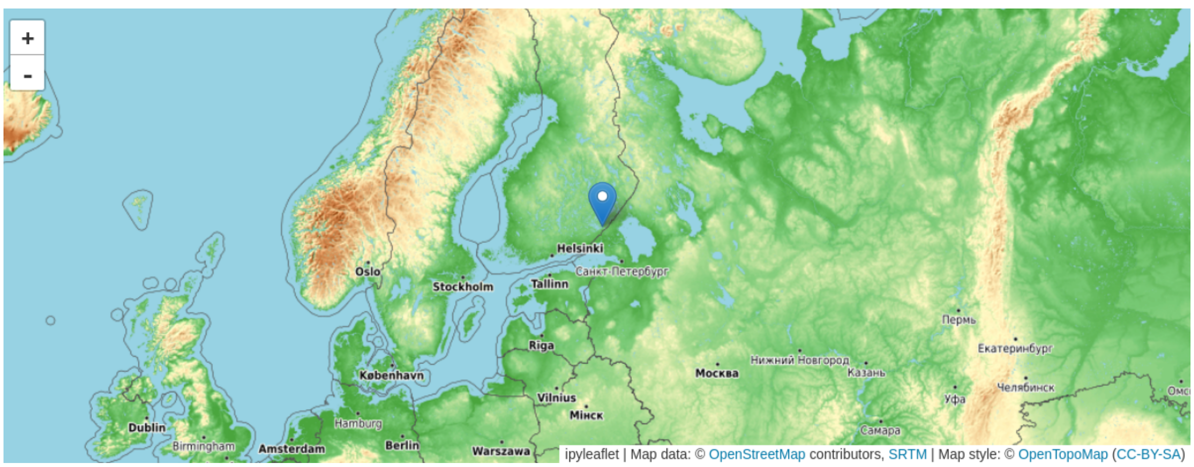
Introduction

Vyborg, a Karelian city



Vyborg, a Karelian city

- castle founded in the late 13th century
- town privileges 1403

Sources

Estimating the size of Russian population

- over 90% of Orthodox in Vyborg Russian

Poll tax records

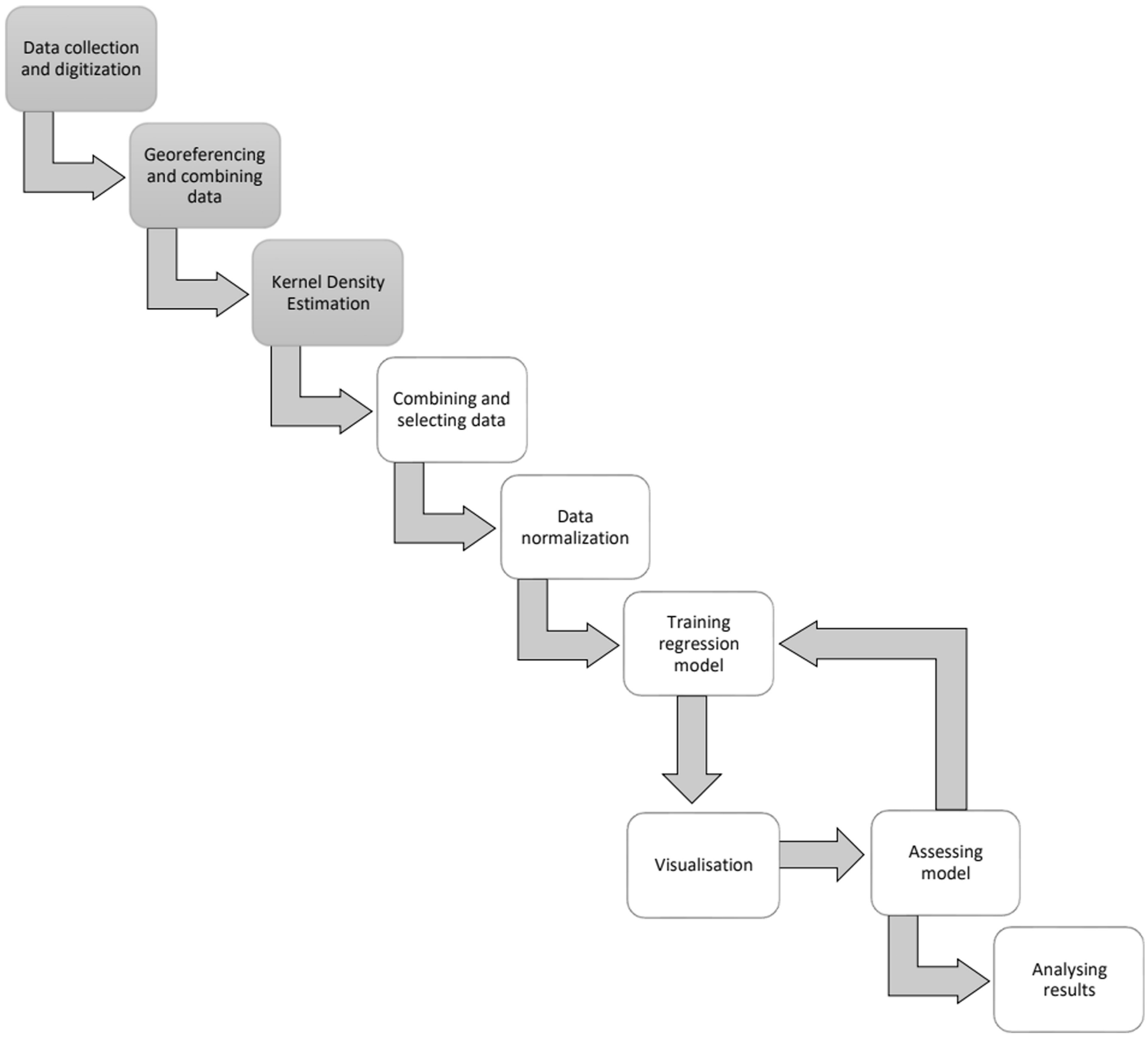
Table 1: poll tax record columns in 1894

column	description
plot_number	Plot number
taxpayer_men	Men paying poll tax
taxpayer_women	Women paying poll tax
no_tax_men	Men exempt from poll tax
no_tax_women	Women exempt from poll tax
in_russia_men	Men legally residing in Russia proper
in_russia_women	Women legally residing in Russia proper
total_men	Total men
total_women	Total women
independent	Civil servants, entrepreneurs, and financially independent
white_collar	White collar workers
worker_industry	Workers in industry
worker_other	Other workers
servants	Servants
other	Other employment status
non_resident	Resident elsewhere
orthodox	Orthodox
other_christian	Non-Lutheran and non-Orthodox Christian
other_religion	Other religions
draftable	21-year-old males eligible for draft

Estimating the size of Lutheran population

$$P_{Lutheran} = (P_{total\_men} + P_{total\_women}) - (P_{Orthodox} + P_{other\_Christian} + P_{other\_religion})$$

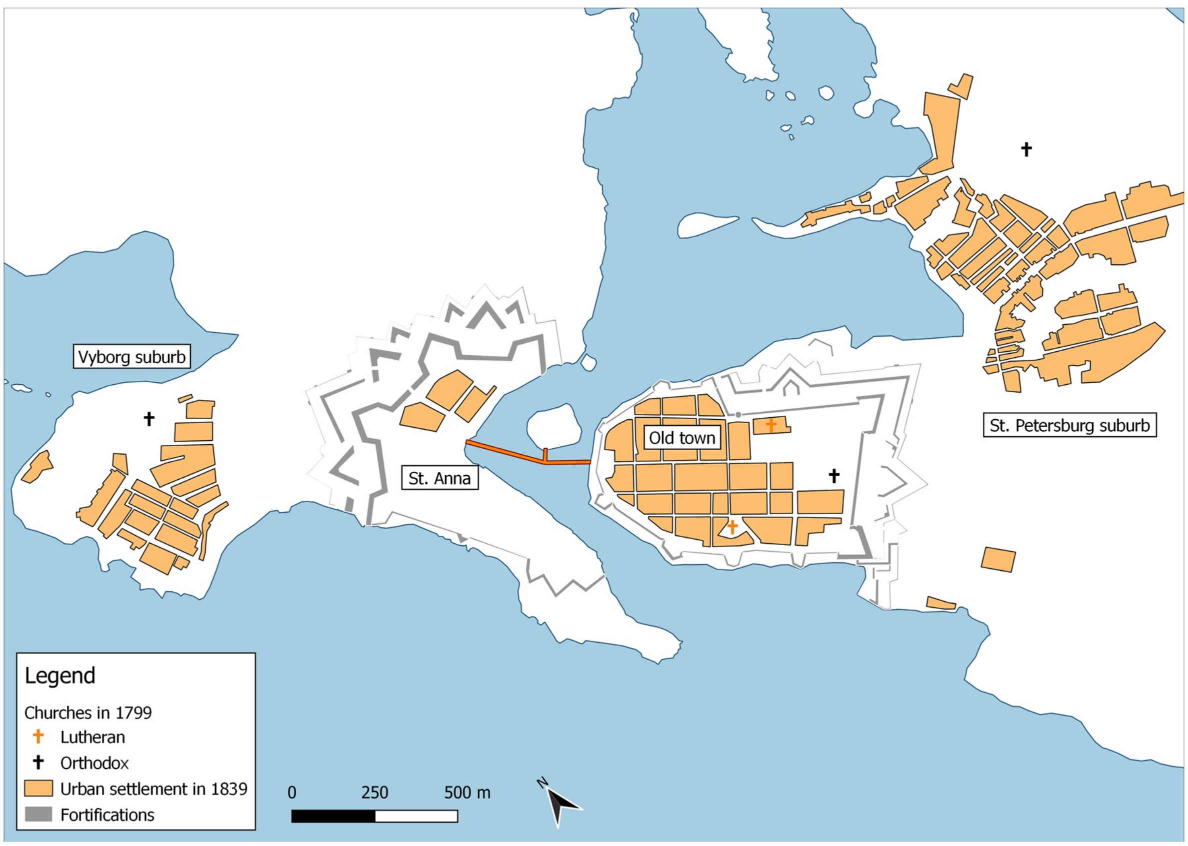
Work flow



Sources

Table 2: Sources from the National archives of Finland

Signum	Original year	Digitization process
Town plan of Vyborg. Vyborg military engineer detachment's archive of plans for fortifications and buildings, 7, 11.	1878	Georeferenced using ground control points, vectorized manually into shapefile
Vyborg province poll tax registers	1880	Digitized manually into CSV
Financial office of the city of Vyborg, Municipal tax levies and payment registers	1880	Digitized manually into CSV



Population growth

Table 3: Population growth in key areas

District	1822	1880
Centre	1192	2506
St. Anna	244	117
Vyborg suburb	642	756
St Petersburg suburb	1512	2685

Population surface model

Population surface model

Based on Martin, Tate, and Langford (2000).

$$P_i = \sum_{j=1}^{N} P_j w_{ij}$$

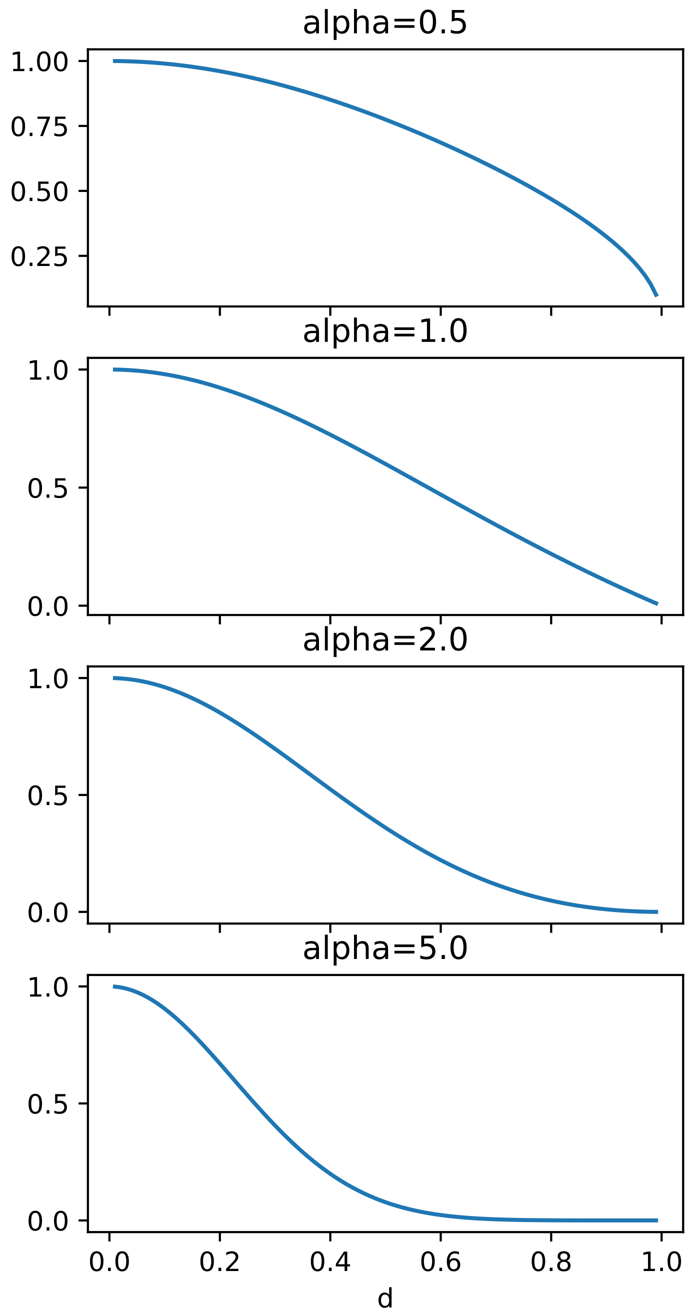
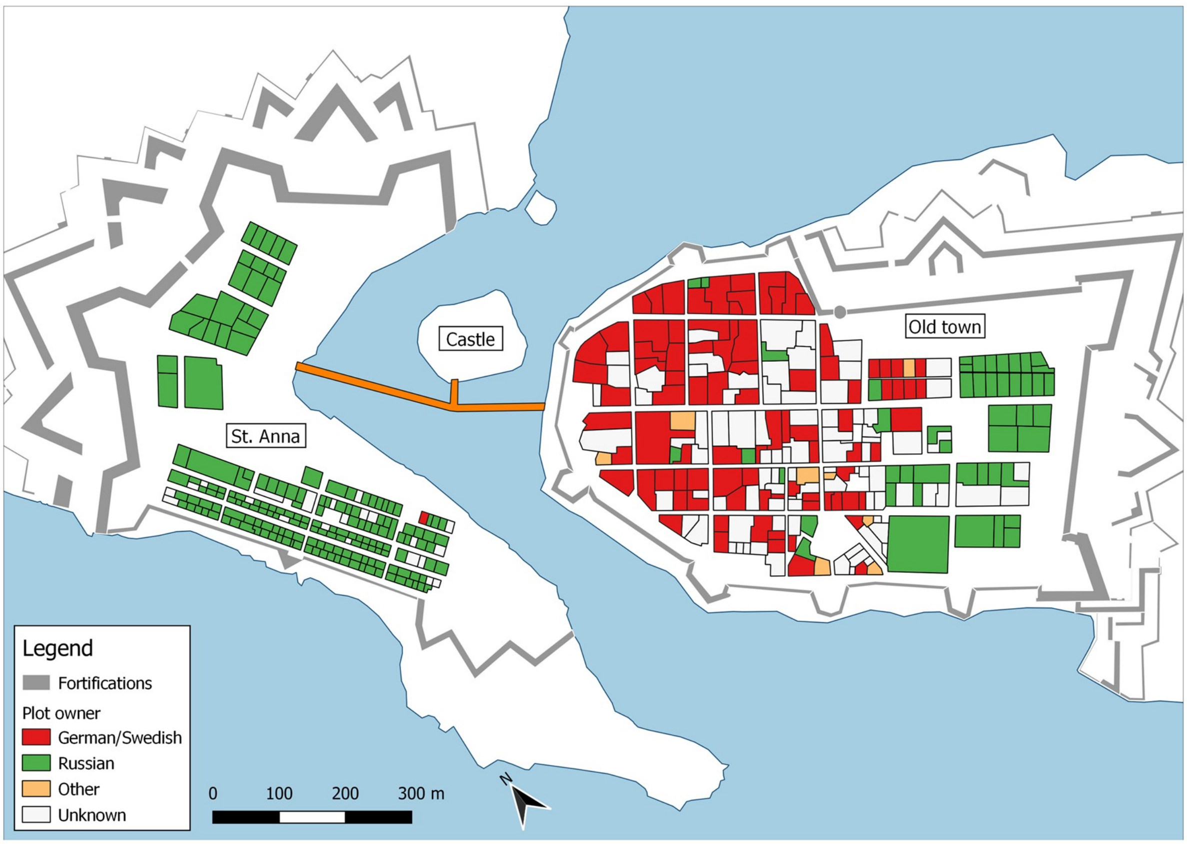


Figure 1: Kernel function

Biweight kernel

Segregation

1700s




Vyborg suburb
St. Anna
Old town
Drivers' sloboda
Soldiers' sloboda
St. Petersburg suburb
Orthodox churches (1799)
Highways
Fortifications (1839)
Orthodox, % (1880)
> 35
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
< 5
0
250
500 m
N

Explaining segregation

Regression model (1)

$$O_i \sim MvNormal(\mu, \mathbf{K})$$

$$\mu_i = \beta_{0,k[i]} + \beta_{1,k[i]} ln(W) + \beta_{2,k[i]} C_i$$

$$k \in 1,2,3,4 \qquad i,j \in 1,2,3,\ldots 539$$

$$\beta_k \sim MvNormal\left(\theta, \begin{bmatrix} 0.1 & 0 & 0 \\ 0 & 0.1 & 0 \\ 0 & 0 & 0.1 \end{bmatrix}\right)$$

$$\theta \sim MvNormal\left(\begin{bmatrix}0\\0\\0\end{bmatrix}, \begin{bmatrix}0.1 & 0 & 0\\0 & 0.1 & 0\\0 & 0 & 0.1\end{bmatrix}\right)$$

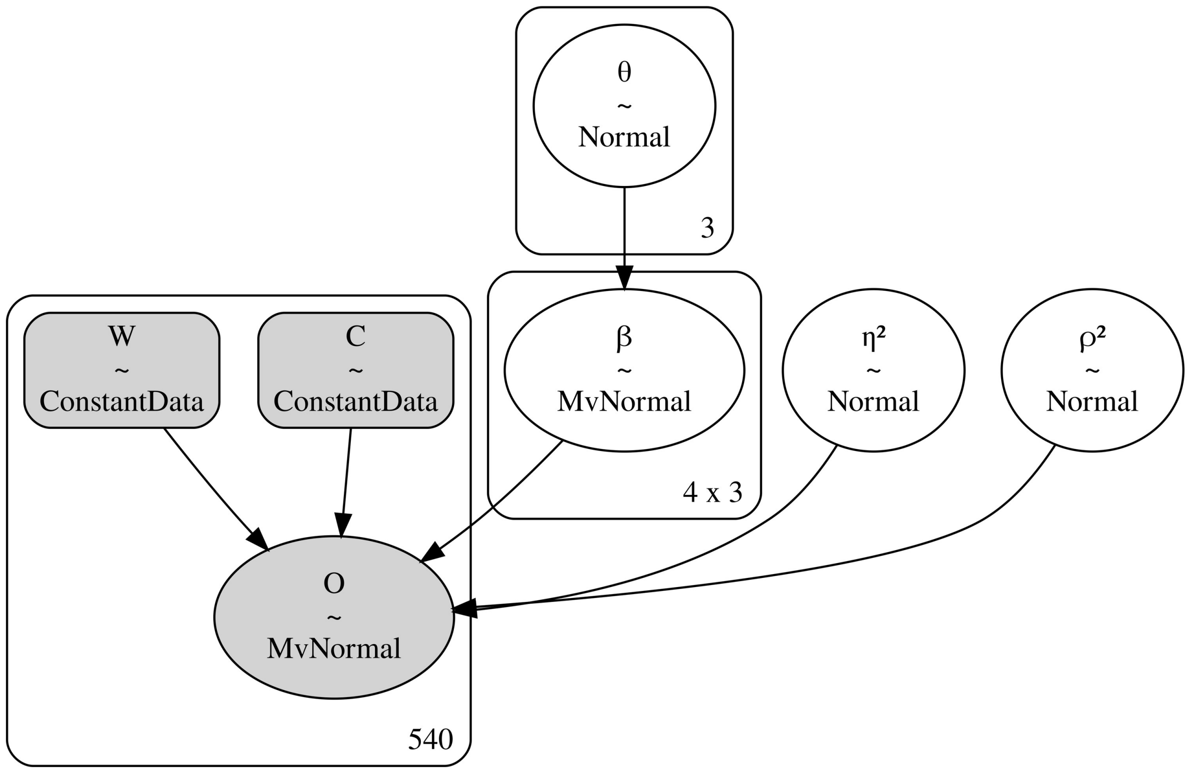
Regression model (2)

$$\mathbf{K}_{ij} = \eta^2 exp(-75\rho^2 d_{ij}^2) + 0.01 \times I_{540}$$

$$\eta^2 \sim Normal(1, 0.2)$$
$$\rho^2 \sim Normal(1, 0.2)$$

Multilevel Bayesian regression

Variable	Shape	Description
O	540	Normalized proportion of Russian Orthodox of the local population
W	540	Smoothed total income in a location in öre
C	540	Distance to nearest Orthodox church in 1799 in kilometres
d	540 x 540	Distance matrix holding pairwise distances between plots
	3	Hyperparameter for
	4 x 3	Linear regression coefficients for each district
2	1	Parameter for the covariance function
2	1	Parameter for the covariance function



Results

Variable	Mean	SD	HDI, 95%	
0	−0.027	0.096	−0.227	0.15
1	0.027	0.085	−0.142	0.193
2	−0.135	0.096	−0.309	0.067
0,0	−0.609	0.299	−1.162	−0.013
0,1	0.104	0.056	−0.009	0.209
0,2	−1.076	0.314	−1.702	−0.487
1,0	0.097	0.3	−0.46	0.743
1,1	0.142	0.14	−0.117	0.433
1,2	−0.037	0.316	−0.625	0.626
2,0	0.118	0.299	−0.509	0.677
2,1	0.119	0.074	−0.024	0.261
2,2	−0.287	0.312	−0.905	0.306
3,0	0.016	0.272	−0.54	0.515
3,1	0	0.069	−0.141	0.135

Variable	Mean	SD	HDI, 95%	
3,2	−0.496	0.248	−0.991	−0.024
scaled 2	0.93	0.04	0.852	1.006
2	1.0	0.099	0.812	1.194

Spline model (1)

$$S_i \sim Normal(\mu_i, \sigma)$$

$$\mu_i = \alpha + \sum_{k=1}^{K} w_k B_{k,i}$$

$$\alpha \sim Normal(0.45, 0.01)$$
$$\sigma \sim HalfNormal(0.05)$$

Spline model (2)

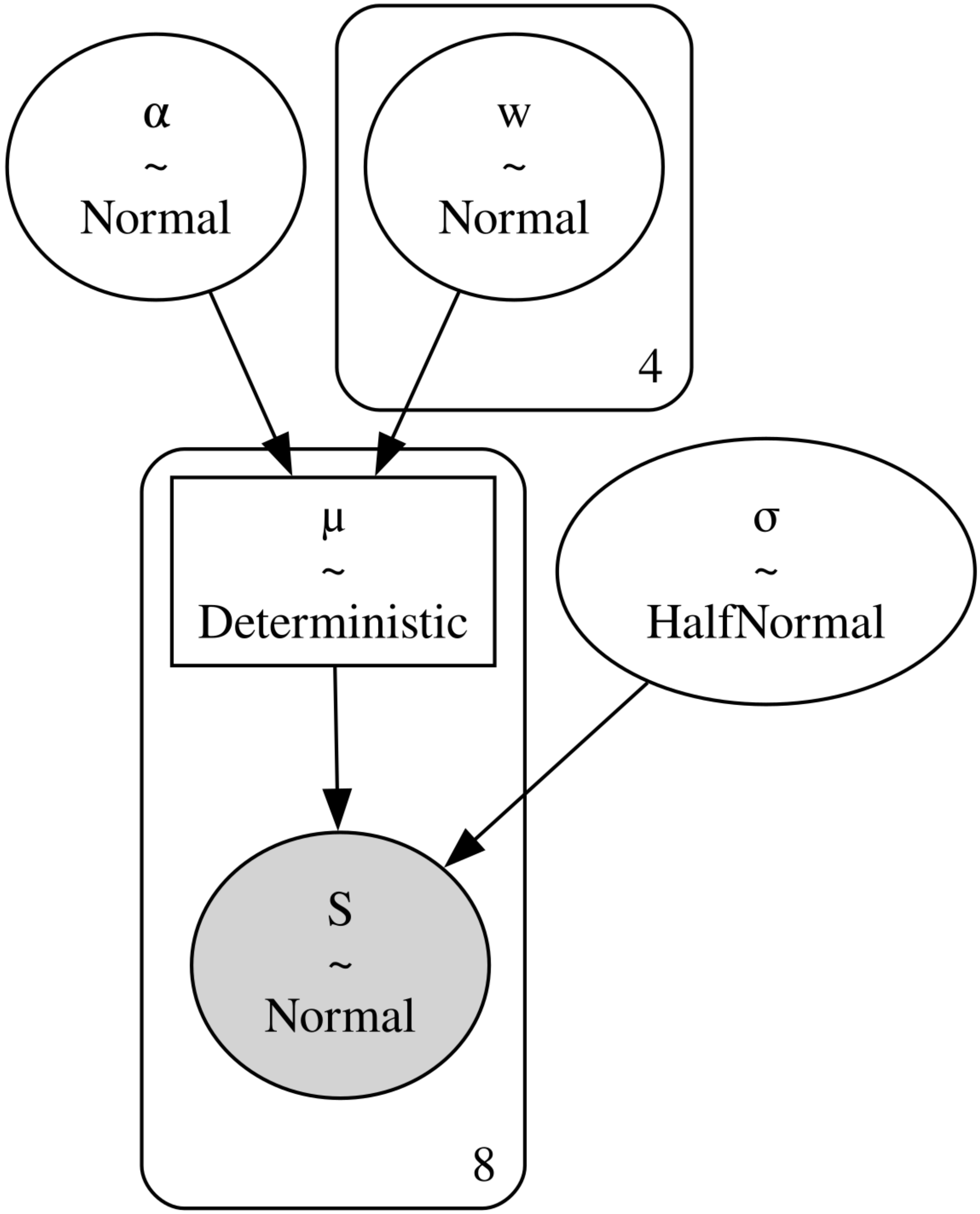
$$B = \begin{bmatrix} 1 & 0.687 & 0.295 & 0.02 & 0 & 0 & 0 & 0 \\ 0 & 0.299 & 0.601 & 0.612 & 0.367 & 0.276 & 0.007 & 0 \\ 0 & 0.015 & 0.104 & 0.367 & 0.612 & 0.658 & 0.209 & 0 \\ 0 & 0 & 0 & 0 & 0.02 & 0.066 & 0.784 & 1 \end{bmatrix}$$

$$w_k \sim Normal(0, 0.1)$$

Spline model code

```
import pymc as pm

with pm.Model() as model:
    a = pm.Normal(" ",  _a,  _a)
    w = pm.Normal("w", mu= _w, sigma= _w, shape=B.shape[1])
      = pm.Deterministic(
       " ", a + pm.math.dot(np.asarray(B, order="F"), w.T
    ))
      = pm.HalfNormal(' ',  _ )
    S = pm.Normal("S",  ,  , observed=regression_data['200'])
    idata = pm.sample(1000, tune=1000, chains=2)
```


α
~
Normal
w
~
Normal
4
μ
~
Deterministic
σ
~
HalfNormal
S
~
Normal
8

References

Martin, David, Nicholas J. Tate, and Mitchel Langford. 2000. "Refining Population Surface Models: Experiments with Northern Ireland Census Data." *Transactions in GIS* 4 (4): 343–60. https://doi.org/https://doi.org/10.1111/1467-9671.00060.