The Effect of Legal Gap and Economic Attractiveness on Sex–Trafficking Victim Rates across Europe

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Abstract

We study how cross–border legal differences and economic attractiveness jointly structure spatial dependence in registered sex–trafficking victim rates across Europe. A geographically embedded graph is constructed using land–border adjacency. Vertex attributes encode the statutory age of consent and edge operators encode legal gaps and economic gradients. Using official 2023 registered–victim data for sexual exploitation and GDP per capita, we estimate undirected and directed spatial operators. We show that (i) undirected legal–gradient structure explains strong spatial clustering, (ii) purely legal direction does not generate directional dependence, and (iii) when legal direction is interacted with economic pull, the resulting dependence is negative in sign, consistent with diversion rather than diffusion. In a single–year cross–section, however, directional effects are not statistically significant.

The paper ends with "The End"

1 Introduction

This paper develops a graph–operator framework for analysing how institutional differences and economic attractiveness shape spatial patterns in sex–trafficking victim rates across European countries. The objective is not causal identification, but to test whether particular cross–border network operators induce statistically detectable dependence structures in registered victim rates.

2 Data

The dependent variable is the number of registered victims of trafficking for sexual exploitation per million inhabitants in 2023. Population and trafficking counts are taken from official European statistical releases. Economic attractiveness is proxied by GDP per capita in 2023. The geographical network is defined by land–border adjacency.

3 Graph construction

Let $G = (V, E)$ be an undirected graph whose vertices correspond to countries and whose edges represent land borders. Each vertex i is assigned a legal attribute v_i equal to the statutory age of consent.

3.1 Undirected legal–gradient operator

For neighbouring countries i and j we define

$$w_{ij} = |v_i - v_j| \tag{1}$$

Let $A^{(w)}$ be the weighted adjacency matrix and

$$L^{(w)} = D^{(w)} - A^{(w)} \tag{2}$$

be the associated weighted Laplacian.

3.2 Directed legal–gap operator

To represent legal direction we define

$$w_{ij}^{L} = \max(v_j - v_i, 0) \tag{3}$$

This induces a directed network.

3.3 Directed legal–economic operators

Let g_i denote GDP per capita. We construct two directed kernels

$$w^{LE,,\text{bin}} * ij = \max(v_j - v_i, 0)\mathbf{1}g_j > g_i, \tag{4}$$

$$w^{LE,,\text{cont}} * ij = \max(v_j - v_i, 0)\max(g_j - g_i, 0) \tag{5}$$

After row normalisation these define a directed weight matrix W.

4 Models

4.1 Undirected latent–field model

We estimate

$$y = X\beta + \theta + \varepsilon, \tag{6}$$

with

$$\varepsilon \sim \mathcal{N}(0, \sigma^2 I), \qquad \theta \sim \mathcal{N}!\left(0, (\tau L^{(w)} + \tau_0 I)^{-1}\right) \tag{7}$$

The scalar τ controls the strength of legal–gradient smoothing.

4.2 Directed spatial autoregressive model

For directed operators we use

$$(I - \rho W)u = \eta, \qquad \eta \sim \mathcal{N}(0, \sigma^2 I) \tag{8}$$

with

$$y = X\beta + u. \tag{9}$$

The parameter ρ captures directional dependence along the specified kernel.

5 Estimation

All models are estimated on the induced subgraph of countries for which trafficking and GDP data are available. The design matrix X contains an intercept only. Undirected models are estimated by empirical Bayes using the Gaussian marginal likelihood. Directed models are estimated by Gaussian maximum likelihood.

6 Results

Undirected legal–gradient model. The estimated smoothing parameter is large ($\hat{\tau} \approx 33.3$), indicating strong spatial clustering aligned with legal similarity across borders.

Directed legal–gap model. Using w_{ij}^{L} yields a weak negative estimate of directional dependence.

Directed legal–economic interaction (binary). Using $w_{ij}^{LE,,\text{bin}}$ yields a negative estimate of directional dependence.

Directed legal–economic interaction (continuous). Using $w_{ij}^{LE,,\text{cont}}$ yields a negative estimate of directional dependence of smaller magnitude.

7 Interpretation

Undirected legal similarity explains common regional structure in sex–trafficking victim rates. Legal differences alone do not generate directional spillovers. When legal direction is combined with economic attractiveness, the resulting dependence is negative in sign, suggesting substitution or diversion across borders rather than diffusion from legally weaker and poorer countries toward legally stricter and richer neighbours. In a single–year cross–section, however, these directional effects are not statistically distinguishable from zero.

8 Schematic illustration

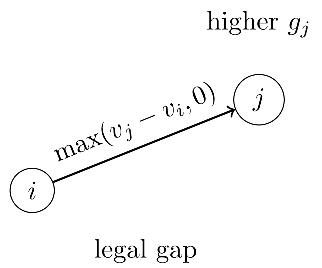

Figure 1: Directed legal–economic pull: an edge from i to j exists when $v_j > v_i$ and $g_j > g_i$.

9 Estimated coefficients

Model	Parameter	Estimate	Std. error	p–value
Undirected legal–gradient (CAR)	τ	33.3	–	–
Directed legal gap (SAR)	ρ	−0.302	0.539	0.576
Directed legal–economic (binary pull)	ρ	−0.211	0.467	0.653
Directed legal–economic (continuous pull)	ρ	−0.111	0.239	0.641

Table 1: Point estimates and asymptotic inference for the spatial dependence parameters. Standard errors and p–values for the SAR parameters are based on the observed information matrix and a delta method for the transformation $\rho = \tanh(\alpha)$. Inference for the CAR smoothing parameter τ is not reported.

10 Limitations

The analysis is cross–sectional, relies on registered victim counts, and does not identify causal mechanisms. The framework should be extended with economic, migration and law–enforcement co-variates and with panel data.

11 Conclusion

Graph operators provide a transparent way to test how institutional and economic gradients shape spatial dependence. In European sex–trafficking victim data, legal similarity produces strong undirected clustering, while legal direction becomes informative only when interacted with economic attractiveness, and in a manner consistent with diversion rather than diffusion.

A Mathematical appendix

A.1 Undirected CAR model

Let

$$Q = \tau L^{(w)} + \tau_0 I, \qquad \tau_0 > 0 \tag{10}$$

The latent field prior is

$$\theta \sim \mathcal{N}(0, Q^{-1}) \tag{11}$$

Given

$$y = X\beta + \theta + \varepsilon, \qquad \varepsilon \sim \mathcal{N}(0, \sigma^2 I), \tag{12}$$

the marginal distribution is

$$y \sim \mathcal{N}(X\beta, , \sigma^2 I + Q^{-1}) \tag{13}$$

The empirical Bayes estimator of (τ, σ^2) maximises the corresponding Gaussian marginal likelihood.

A.2 Directed SAR model

Let W be a row–normalised directed weight matrix. The SAR specification

$$(I - \rho W)u = \eta, \qquad \eta \sim \mathcal{N}(0, \sigma^2 I) \tag{14}$$

implies

$$u = (I - \rho W)^{-1}\eta, \qquad \mathrm{Var}(u) = \sigma^2 (I - \rho W)^{-1}(I - \rho W)^{-\top} \tag{15}$$

With

$$y = X\beta + u, \tag{16}$$

the log–likelihood is

$$\ell(\beta, \rho, \sigma^2) = -\frac{n}{2}\log(2\pi\sigma^2) + \log|I - \rho W| - \frac{1}{2\sigma^2}(Br)^\top (Br), \tag{17}$$

where $B = I - \rho W$ and $r = y - X\beta$.

A.3 Identification and stability

CAR model. The weighted Laplacian $L^{(w)}$ is positive semidefinite and singular when the graph has at least one connected component. The ridge parameter $\tau_0 > 0$ ensures that $Q = \tau L^{(w)} + \tau_0 I$ is positive definite and therefore defines a proper Gaussian prior.

SAR model. Let $\lambda_k(W)$ denote the eigenvalues of the row–normalised matrix W and let $\rho(W) = \max_k |\lambda_k(W)|$ be its spectral radius. A sufficient condition for invertibility of $I - \rho W$ is

$$|\rho| < \frac{1}{\rho(W)}. \tag{18}$$

Since row normalisation implies $\rho(W) \leq 1$, restricting $\rho \in (-1, 1)$ guarantees stability. Under this condition the Neumann expansion $(I - \rho W)^{-1} = \sum_{m=0}^{\infty} (\rho W)^m$ exists.

Interpretational identification. Because the design matrix contains only an intercept, the spatial parameters capture cross–border dependence rather than level effects. In richer specifications, identification of ρ requires that the spatial component is not collinear with the regressors.

References

[1] European statistical office. Trafficking in human beings and national accounts datasets, 2023 releases.

[2] L. Anselin. *Spatial Econometrics: Methods and Models.* Kluwer Academic Publishers, 1988.

[3] H. Rue and L. Held. *Gaussian Markov Random Fields: Theory and Applications.* Chapman and Hall/CRC, 2005.

Glossary

Legal gradient Difference in statutory age of consent across neighbouring countries.

Weighted Laplacian Matrix operator $L^{(w)} = D^{(w)} - A^{(w)}$ encoding undirected border penalties.

CAR prior Conditional autoregressive Gaussian prior defined through a precision matrix.

SAR model Spatial autoregressive model of the form $(I - \rho W)u = \eta$.

Economic pull Directional condition based on higher GDP per capita in the neighbouring country.

Directional kernel Non–symmetric weight matrix encoding oriented cross–border interactions.

Registered victim rate Number of officially recorded victims per million inhabitants.

The End