A Bayesian hierarchical modelling approach to policy assessment:

Evaluating the 'no cold calling' scheme in Peterborough, England.

Robert Haining[+], Guangquan Li[*], Sylvia Richardson[*] and Nicky Best[*]

[+]University of Cambridge

[*]Imperial College, London

A BIAS II project: Funded through the ESRC's National Centre for Research Methods.

Background

- Initiated by the Cambridgeshire and Peterborough Distraction Burglary and Rogue Trader Task Force, the "No Cold Calling" (NCC) project aims to reduce the impacts of distraction burglary and rogue trading in terms of (i) the number of incidents and (ii) the public's fear of crime.
- This project was first implemented in selected areas within Peterborough (pop^{n}. ≈160,000) in 2005 and subsequently (from late 2006 onwards) in other urban areas in Cambridgeshire such as Cambridge, Huntingdon and St Ives.
- In addition to setting up signage to discourage cold calling, every resident was visited in the targeted areas and given an information pack containing literature advising how to avoid becoming a victim and the steps to take when answering the door.
- An evaluation of the NCC scheme by the Cambridgeshire Police concluded that residents in the NCC areas generally expressed increased confidence in dealing with cold callers.
- **However, there has been no assessment based on offence data.**

Definition of “cold call”

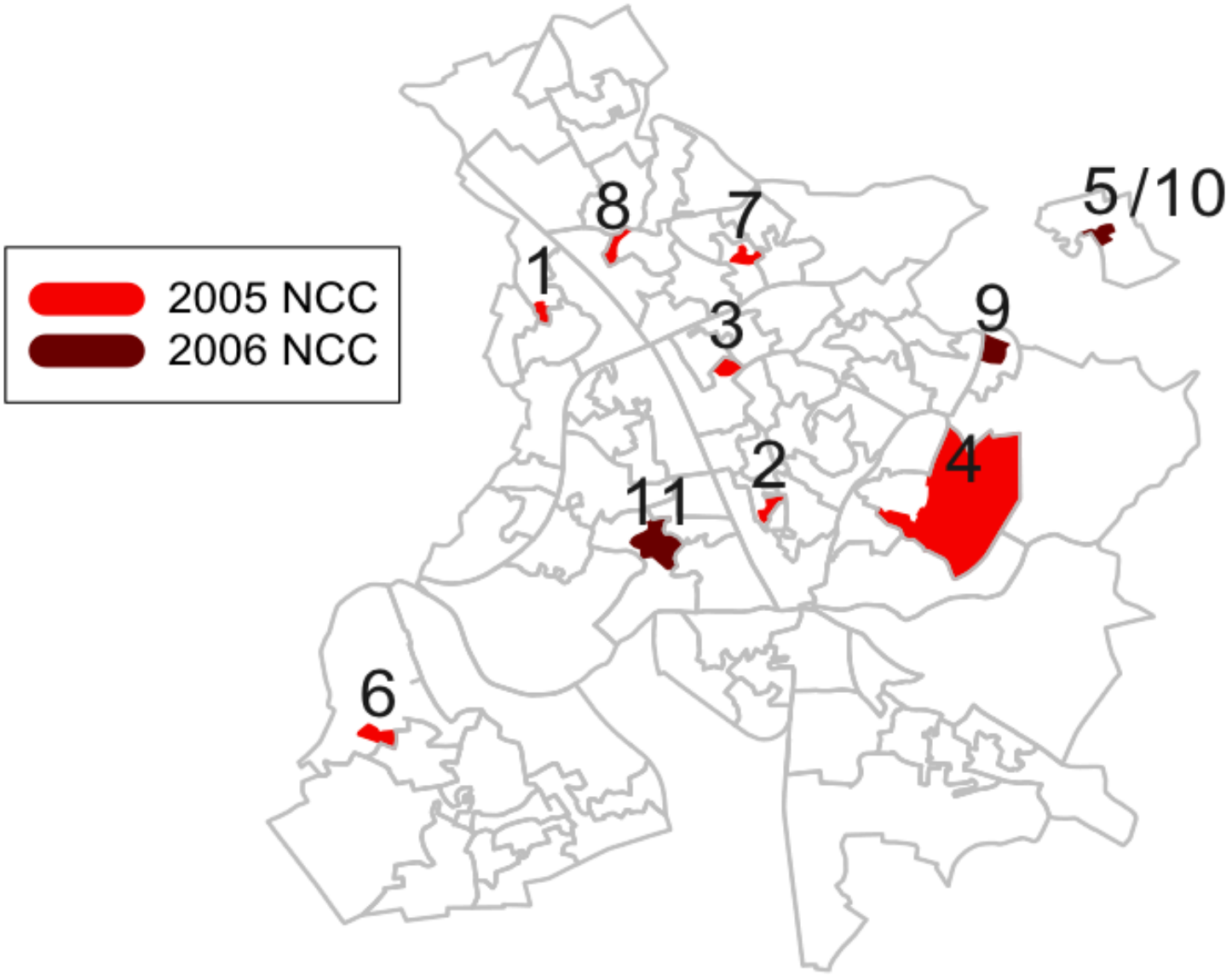
- A visit or a telephone call to a consumer by a trader, whether or not the trader supplies goods or services, which takes place without the consumers expressly requesting the contact.

Data on “No Cold Calling”

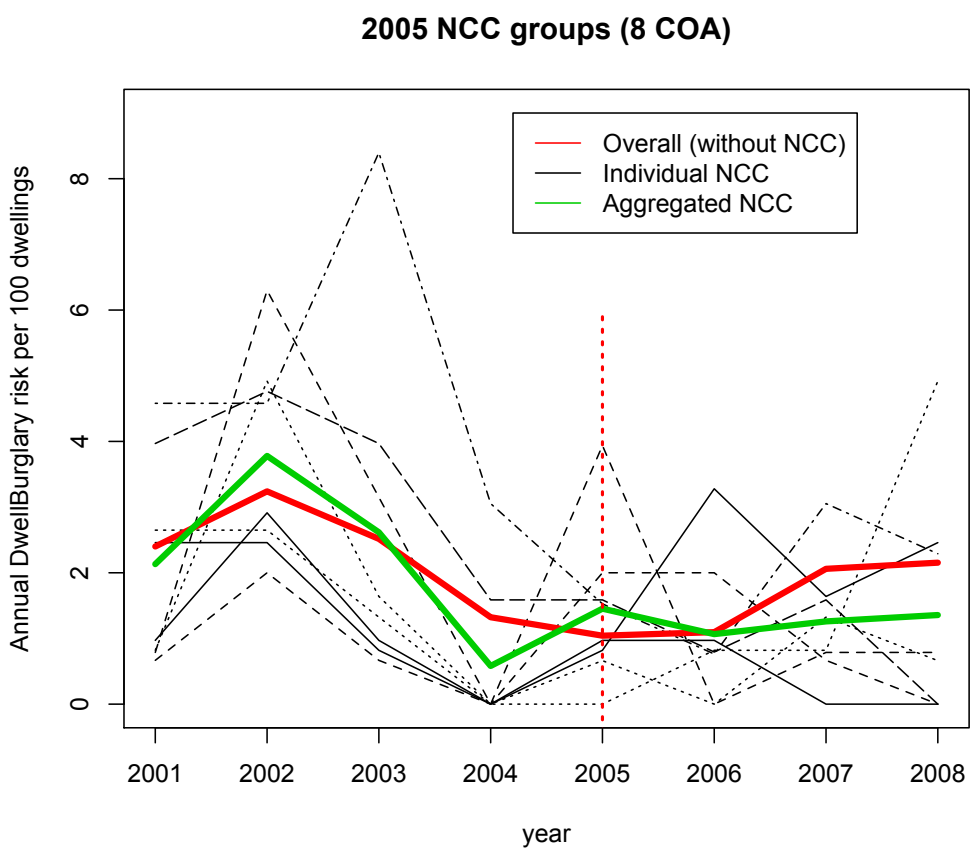
	OA_code	Postcode	Area name	Numbers	Started	Dwell	Coverage
	NCC 2005						
1	00JANC0016	PE3 8JU	Hanover Court, Bretton	42	10/03/2005	122	0.34
2	00JANE0006	PE1 2NL	Kimbolton Court, Millfield	48	28/01/2005	150	0.32
3	00JANE0010	PE1 3RR	Eaglesthorpe, New England	28	28/01/2005	151	0.19
4	00JANG0013	PE1 5JD	Mellows Close, Eastfield	12	25/01/2005	131	0.09
5	00JANH0003	PE6 7TZ	Boxgrove Close, Eye	8	03/06/2005	126	0.06
6	00JANQ0023	PE2 6XN	Napier Place, Orton Wistow	54	17/03/2005	103	0.52
7	00JANT0027	PE4 7PS	Bevishall, Paston	45	20/07/2005	127	0.35
8	00JANY0010	PE4 6QT	Dudley Avenue, Walton	10	20/12/2005	122	0.08
	NCC 2006						
9	00JANG0025	PE1 4SL	Keys Park Mobile Home Park	100	22/08/2006	168	0.60
10	00JANH0003	PE6 7XF	Woad Court	28	19/10/2006	126	0.22
11	00JAPB0010	PE3 6LA	Thorpe Avenue	36	27/09/2006	128	0.28

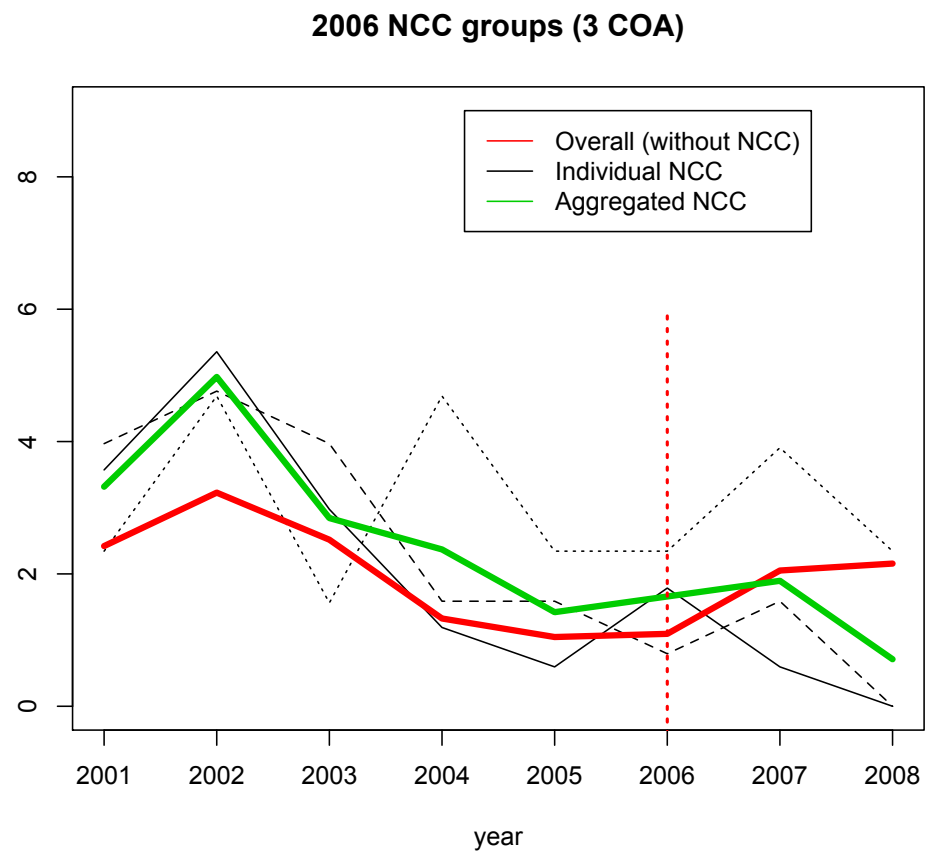
Table Summary of the NCC scheme in Peterborough started in 2005 and 2006 at the COA level

Locations of the NCC areas

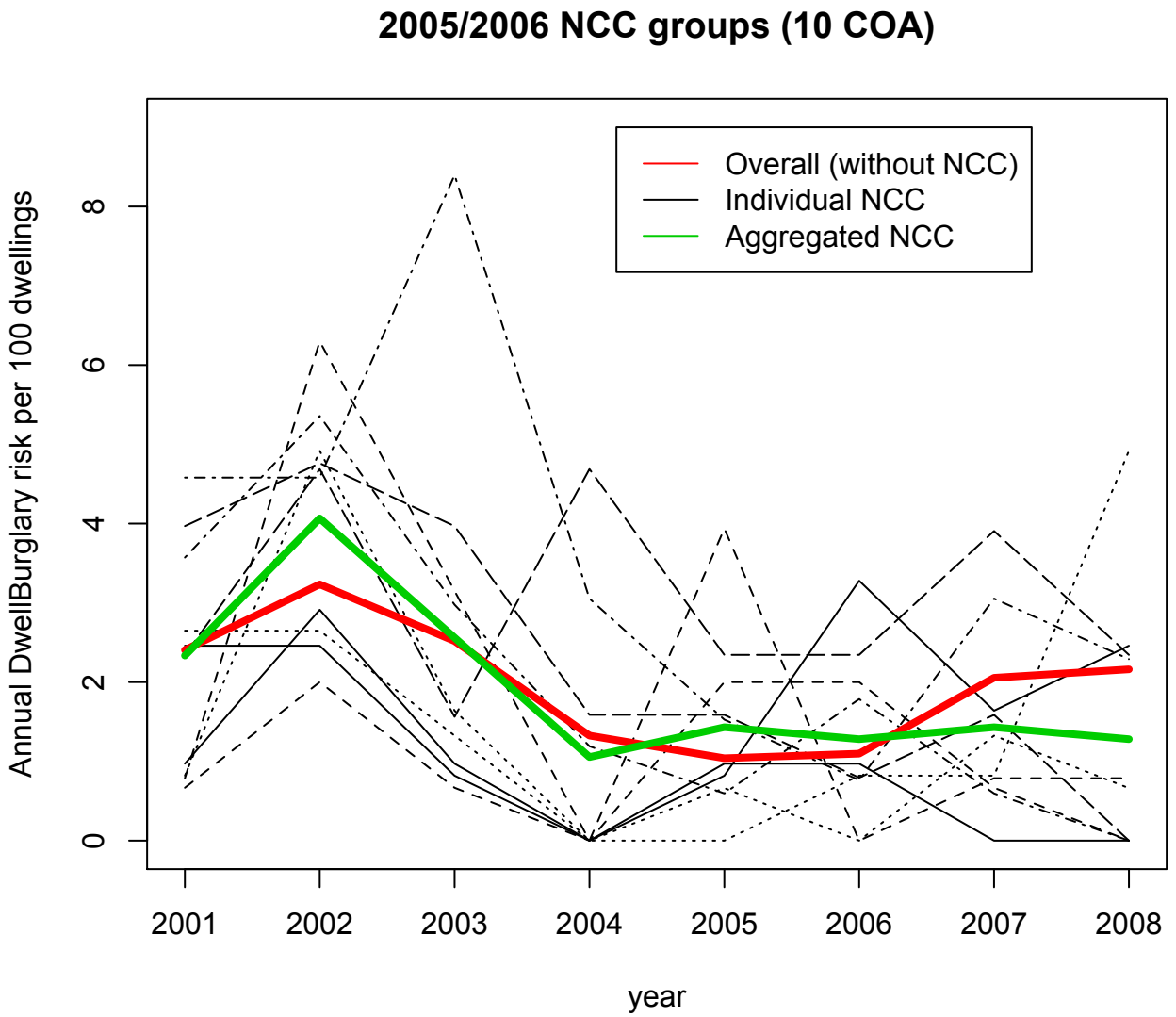


Raw data: temporal profile





Raw data: aggregated temporal profile



Positive impact of policy?

Policy evaluation

1. Comparing burglary rates before and after the implementation of the NCC scheme;

2. Comparison is done after adjusting for systematic changes in burglary rates in other (non NCC) areas;

3. Allow for sparsity of data (i.e., small number of burglary events)

Constructing the control group

- To form the control group, areas are selected on a basis of having similar local characteristics (e.g., burglary rates or deprivation scores) to those in the NCC-targeted group.
  - Lower Super Output Areas (LSOAs) are the basic units.

ID	Matching criterion	No. of LSOAs
1	All LSOAs in Peterborough	88
2	±10% burglary rate of the NCC group in 2005	9
3	±20% burglary rate of the NCC group in 2005	20
4	±30% burglary rate of the NCC group in both 2004 and 2005	8
5	LSOAs containing the NCC-targeted COAs (but excluding the NCC-targeted COAs)	9 (one LSOA is outside Peterborough)
6	LSOAs that had “similar” multiple deprivation scores (MDS) as those for the NCC LSOAs in 2004	46

Combining information

Data on individual NCC-targeted COAs are too sparse if treated independently. To strengthen the analysis, two approaches have been considered for synthesizing information.

1. All NCC-targeted COAs are grouped into one single unit
   - The number of dwellings in this resulting unit (1328 HHs) is more comparable to the size of LSOAs (min=378; max=916; mean=651)
   - The NCC policy is then assumed to be implemented in 2005.

2. A Bayesian hierarchical model (BHM) is applied so that the impact of the policy can be assessed locally for each targeted COA. COA-specific effects are modelled hierarchically, allowing for the global effect of the policy as well as local impact variability.

The first approach serves as a preliminary assessment of the impact and helps to choose the form for the impact function used in the second BHM approach, which provides a more flexible modelling framework.

Model for the control group

- To construct the reference temporal profile, the following model is applied to areas in the control group.

$$y_{it} \sim Poisson(n_i \cdot \theta_{it})$$
$$log(\theta_{it}) = u_i + \gamma_t + \epsilon_{it}$$
$$u_i \sim N(\alpha, \sigma_u^2) \quad \text{Place effect}$$
$$\gamma_t \sim RW_1(\mathbf{W}, \sigma_\gamma^2) \quad \text{Time effect}$$
$$\alpha \sim N(0, 100000) \quad \text{Overall burglary rate}$$
$$\epsilon_{it} \sim N(0, \sigma_\epsilon^2) \quad \text{Overdispersion}$$

y_{it} = the number of burglary cases in area i at time t
n_i = number of dwellings in area i
θ_{it} = burglary risk in area i at time t

A weakly informative half Normal prior N(0, 100) bounded strictly below by 0 for σ_u, σ_γ and σ_ϵ.

Model for the NCC-targeted group

- For the NCC group, the estimated time trend pattern from the control group is used to explain the observed data.
- In addition to that, an "impact function" is included to assess/ quantify the impact of the policy.

$$y_t^* \sim Poisson(n^* \cdot \theta_t^*)$$
$$log(\theta_t^*) = \alpha^* + \gamma_t + I(t - t_0) \cdot f(t, \mathbf{b}) + \epsilon_t$$
$$\alpha^* \sim N(\alpha, \sigma_u^2)$$
$$\epsilon_t \sim N(0, \sigma_\epsilon^2)$$

$$I(x) = 1 \text{ if } x \geq 0$$
$$0 \text{ otherwise}$$

$t_0 =$ the time (year) when the NCC policy was implemented

The impact function

- We consider various functional forms for the impact function.
- The impact of the policy is to be quantified through the estimation of the function parameter(s).

Name	Functional form
No change	$f(t, \mathbf{b}) = 0$
Step change	$f(t, \mathbf{b}) = b_1$
A linear function of time	$f(t, \mathbf{b}) = b_2 \cdot (t - t_0 + 1)$
A generalized function	$f(t) = b_3 \cdot f(t-1) + (\alpha^* - b_4)$ if $t \geq t_0$ $f(t) = 0$ otherwise

Remarks

- Evidence for positive impact if $b_1<0$ or $b_2<0$.

- Both the step and linear functions are special cases of the generalized function, allowing for non-linearity of change on the log scale:
  - when $b_3=0$, we have the step change;
  - when $b_3=1$, we have the linear change of time.
  - b_3 is a measure of curvature (on the log scale).

- While the generalized function provides a better description of change, it is more difficult to interpret the parameters for the purpose of policy evaluation.

Results: the NCC group

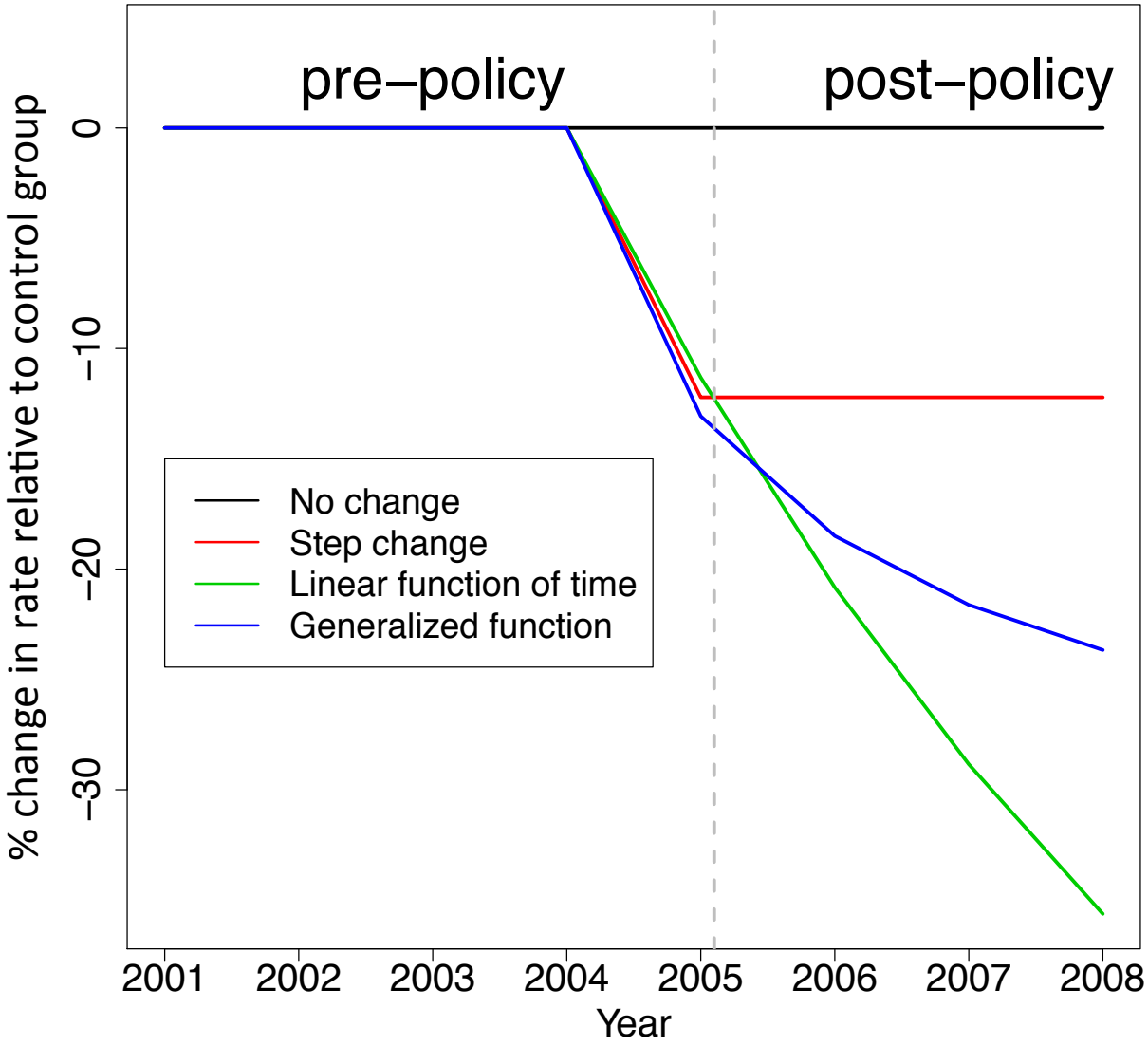
Control criteria	Step Change	Linear function	Generalized function	
	b_1 (after-before)	b_2 (slope)	b_3 (rate)	(α*-b_4)
1	-0.16 (-0.64, 0.32)	-0.12 (-0.28, 0.03)	0.50 (0.03, 0.96)	-0.15 (-0.47, 0.17)
2	-0.22 (-0.75, 0.29)	-0.14 (-0.32, 0.04)	0.48 (0.03, 0.97)	-0.21 (-0.61, 0.17)
3	-0.20 (-0.71, 0.28)	-0.12 (-0.28, 0.05)	0.48 (0.03, 0.96)	-0.17 (-0.53, 0.17)
4	-0.23 (-0.70, 0.21)	-0.10 (-0.26, 0.06)	0.44 (0.03, 0.96)	-0.16 (-0.52, 0.13)
5	-0.15 (-0.76, 0.46)	-0.14 (-0.34, 0.07)	0.49 (0.03, 0.96)	-0.17 (-0.57, 0.22)
6	-0.22 (-0.66, 0.21)	-0.14 (-0.29, 0.01)	0.50 (0.04, 0.96)	-0.19 (-0.51, 0.09)

Posterior mean (95% credible interval)

1. Evidence for "positive" impact of NCC in stabilizing the burglary rate in the targeted areas.
2. Results are robust against various definitions of the control group.

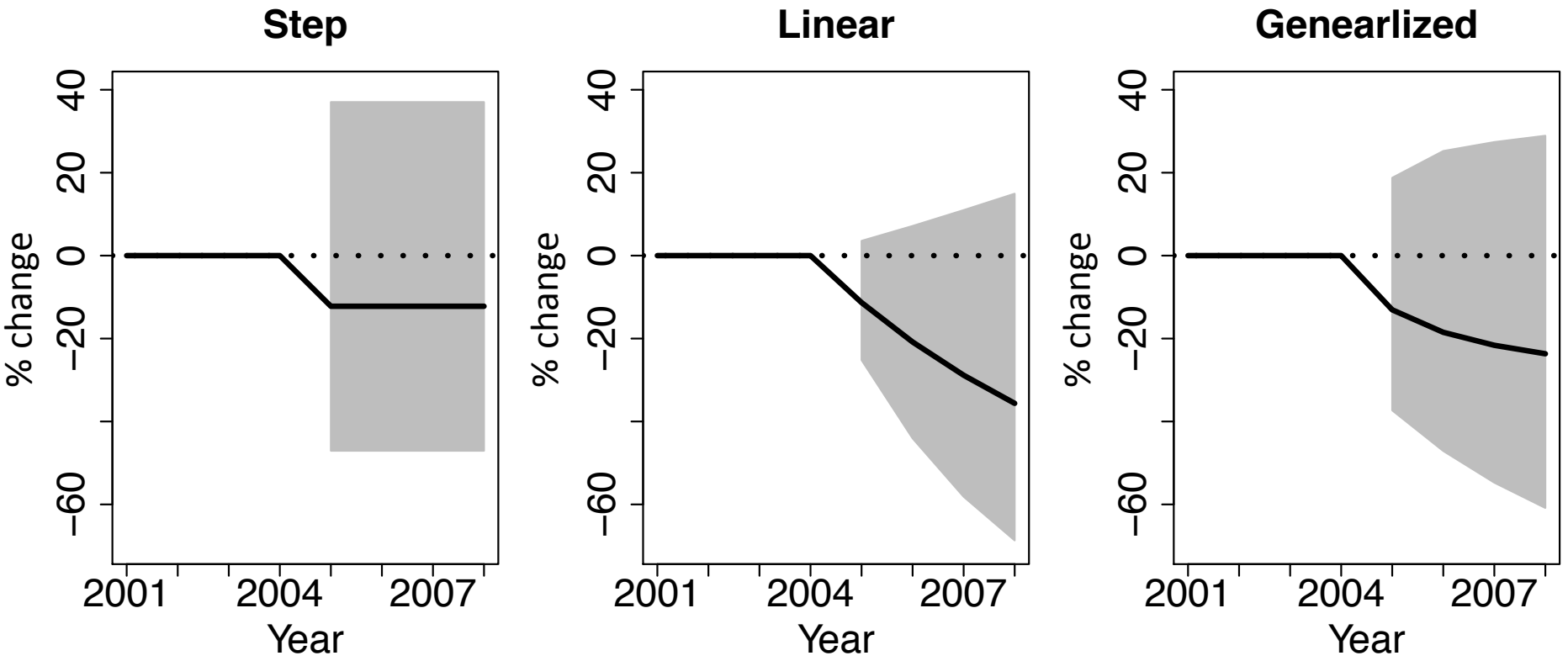
Before-After change in burglary rate

(having adjusted for the trend from Control group 1)

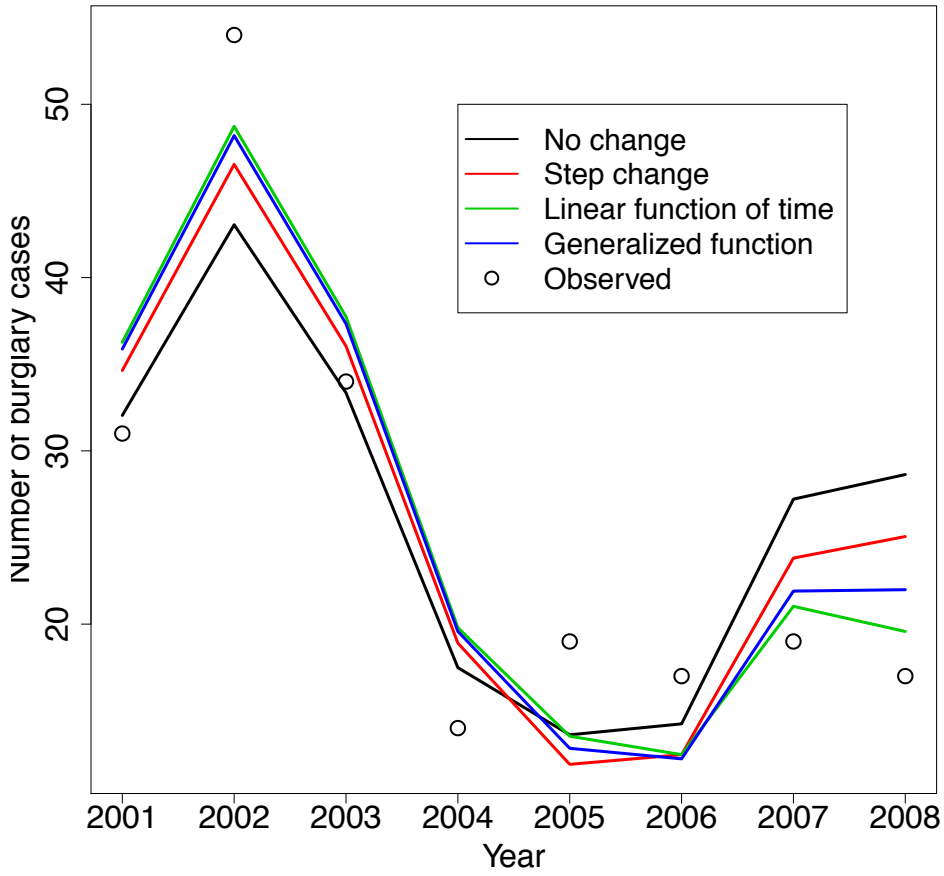


Uncertainty

(95% bounds)



Results: comparing different impact functions



	No Change	Step	Linear	Generalized function
Dbar	15.27	14.32	**9.77**	11.75
pD	1.21	2.29	**2.25**	2.57
DIC	16.49	16.61	**12.02**	14.33

With a smallest DIC value, the linear function is the most parsimonious model amongst the four.

Interpretations

- All three impact functions allowing for change consistently showed that the burglary risks of the NCC group during the post-policy period were lower than what would be predicted from the control trend.
- This suggests a positive impact of the NCC policy which had the effect of "stabilizing" the burglary risk in the targeted areas while overall burglary rates were going up.
- The linear function of time describes a gradual and persistent change. Moreover, the negative slope suggests that the trend of the NCC group moved further away from the control group over time.
- This departure may exhibit some curvature on the log scale (not perfectly linear) but little information to estimate the degree of curvature (i.e., b_3 in the generalized function).
- Since the linear impact function model produced the smallest DIC value, this model is the most parsimonious of the four models.

Modelling NCC-targeted COAs

- Instead of using one aggregated NCC unit, a Bayesian hierarchical model is used to allow for local impacts.
  - Based on results from the grouped analysis and for ease of interpretation, the linear function is used as the impact function.
- For each NCC-targeted COA, we have

$$
\begin{aligned}
y^*_{it} &\sim \text{Poisson}(n^*_i \cdot \theta^*_{it}) \\
log(\theta^*_{it}) &= \alpha^*_i + \gamma_t + I(t - t_{0,i}) \cdot b_{2,i} \cdot (t - t_{0,i} + 1) + \epsilon_{it} \\
\alpha^*_i &\sim \text{N}(\alpha, \sigma^2_u) \\
b_{2,i} &\sim \text{N}(\mu_b, \sigma^2_b) \\
\epsilon_{it} &\sim \text{N}(0, \sigma^2_\epsilon)
\end{aligned}
$$

Local and global impact assessments

- Vague priors are assigned to hyper-parameters.

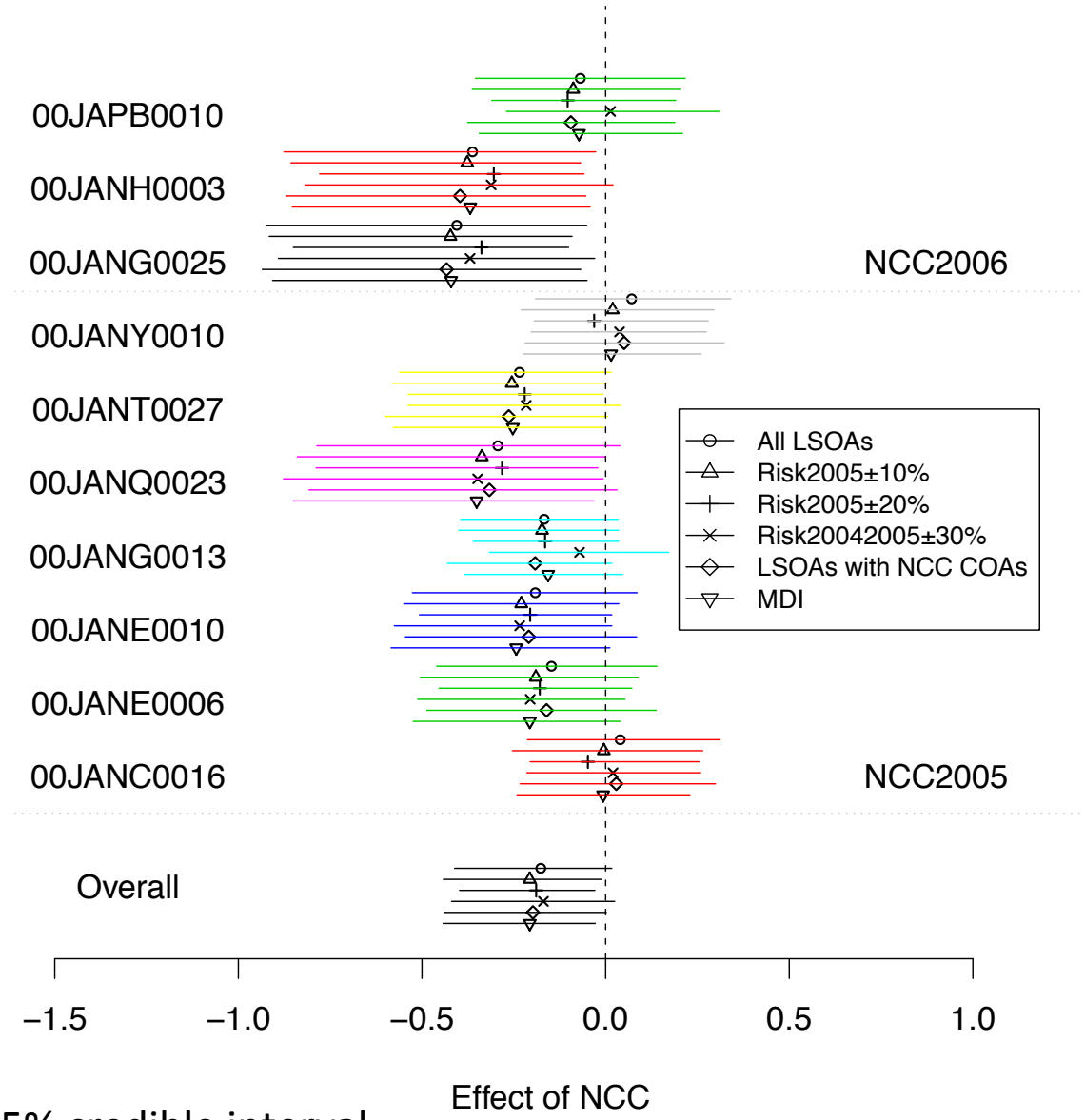
Modelling NCC-targeted COAs

- The local policy impacts can also be modelled allowing for area coverage, i.e., proportion of dwellings visited by the police in each targeted COA.
  - The coverage ranges from 9% (in 00JANG0013) to 60% (in 00JANG0025).

$$
\begin{aligned}
y_{it}^{*} &\sim \text{Poisson}(n_i^{*} \cdot \theta_{it}^{*}) \\
log(\theta_{it}^{*}) &= \alpha_i^{*} + \gamma_t + I(t - t_{0,i}) \cdot b_{2,i} \cdot (t - t_{0,i} + 1) + \epsilon_{it} \\
\alpha_i^{*} &\sim \text{N}(\alpha, \sigma_u^2) \\
b_{2,i} &\sim \text{N}(\beta_0 + \beta_1 \cdot \text{coverage}_i, \sigma_b^2) \\
\epsilon_{it} &\sim \text{N}(0, \sigma_\epsilon^2)
\end{aligned}
$$

- Vague priors are assigned to hyper-parameters.

Results: local and global impacts



Posterior mean and 95% credible interval

Results: parameter estimates

Parameters	Without coverage		With coverage	
Measure of overall impact	Overall	-0.18 (-0.41, 0.00) --> 97%**	10%	0.01 (-0.29, 0.35) -> 47%
			30%*	-0.20 (-0.43, 0.00) -> 97%
			60%	-0.51 (-1.07, -0.07) -> 99%
Effect of coverage	--		-1.05 (-2.58, 0.16)	
Variability of local impacts	0.07 (0.00, 0.28)		0.06 (0.00, 0.26)	

* The overall coverage percentage in the present study

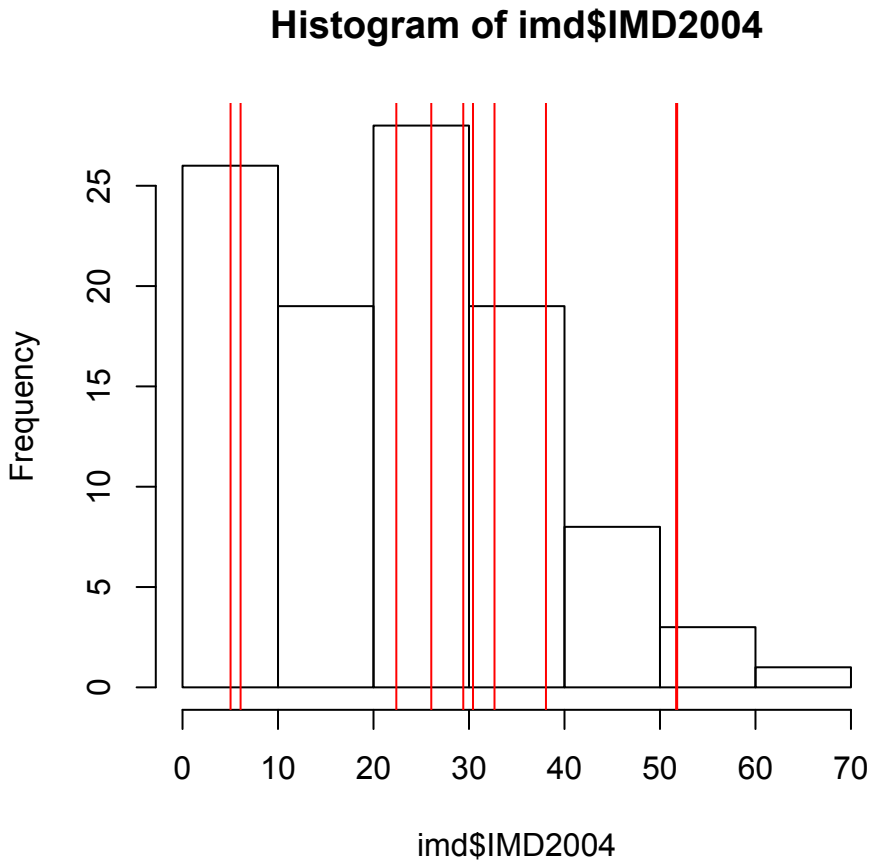
** The posterior probability that the slope parameter b_2 is less than 0, i.e., the prob. of success.

Remarks:

1. Local impacts appeared to be influenced strongly by the percentage of dwellings visited by the police;
2. Variability of local impacts was reduced slightly when the coverage percentage was included.

Additional slides

IMD 2004




```
> imd[ncc.imd.ids,]
          LSOA_name IMD2004 IMD2007 LSOA_code
39 Peterborough 009B   30.42   31.34 E01015596
65 Peterborough 014B   51.69   48.29 E01015600
43 Peterborough 010A   38.06   35.39 E01015603
63 Peterborough 013F   51.80   49.68 E01015616
60 Peterborough 013C   32.67   32.52 E01015613
20 Peterborough 005C   22.39   23.87 E01015619
88 Peterborough 018E    5.03    6.27 E01015648
29 Peterborough 007C   29.40   31.14 E01015656
22 Peterborough 006A   26.05   30.07 E01015674
72 Peterborough 015D    6.08    6.59 E01015690
```

Matching criterion based on the MDS2004: LSOAs which had MD scores between 20 and 40 in 2004.