Explaining variations in health authority performance: a multivariate hierarchical modelling approach

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Outline

1. Context
2. Multilevel modelling
3. Data (14 performance indicators)
4. Partitioning variance (piecemeal modelling, health authority effects)
5. Linking indicators (simultaneous modelling)
6. Explaining health authority effects (determinants of performance)
7. Conclusions

1. The context

- Increased efforts to compare and learn from comparative health system performance
- Countless indicators of performance
- Analysis has been rudimentary, with weak theoretical foundations
- Potential to extract much more information from available data

The problem

- Many of the efforts to date have relied on aggregate measures of success, which may omit important information about variations within administrative entities.
- Numerous influences on aggregate performance measures, of which managerial competence is only one.
- Disaggregate data can be used to develop more secure statistical models of performance.
- It may also be possible to take advantage of systematic correlation between performance on different indicators to enhance models further.
- Can use such models to test hypotheses relating to determinants of performance.

One solution?

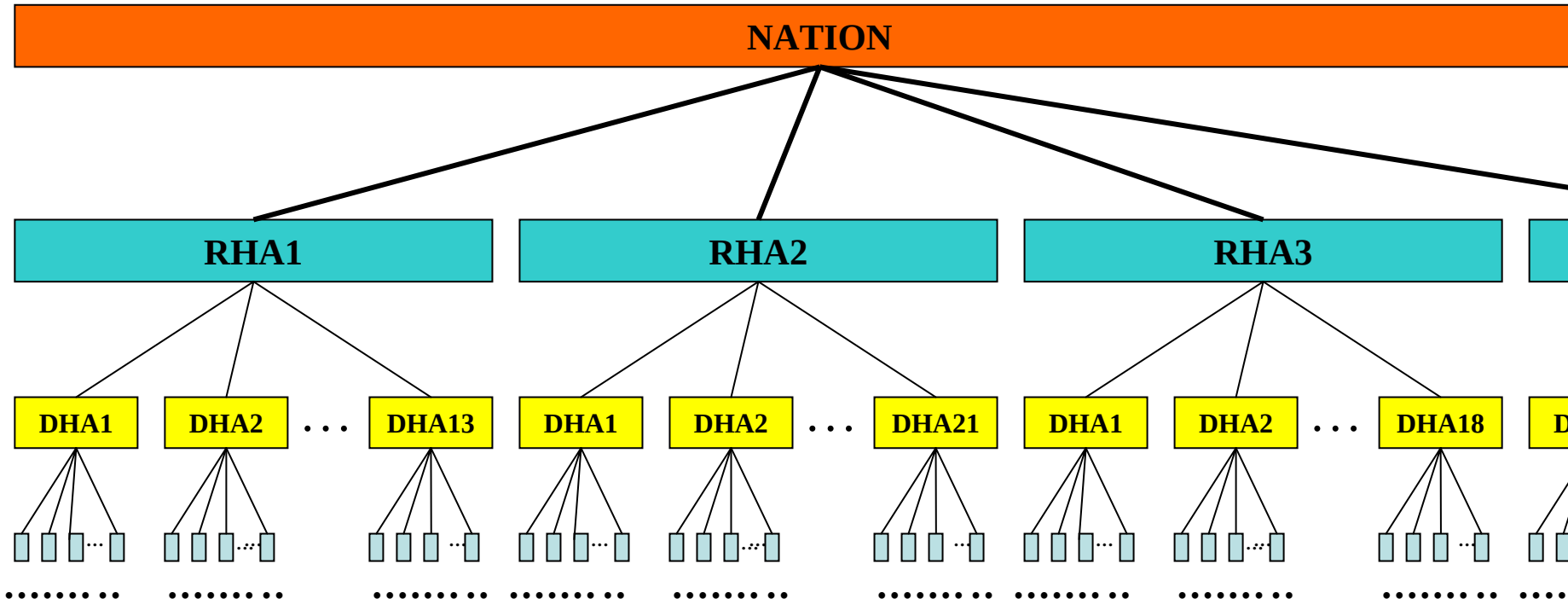
- Multilevel (hierarchical) statistical models have been developed to model such phenomena.
- Widespread use in education (pupils within classes within schools within education authorities).
- As a by-product, the methods offer estimates of the variation in performance attributable to each level in the hierarchy.
- Multiple measures of performance can be modelled simultaneously.
- The models offer the potential to test hypotheses about determinants of performance.

This paper

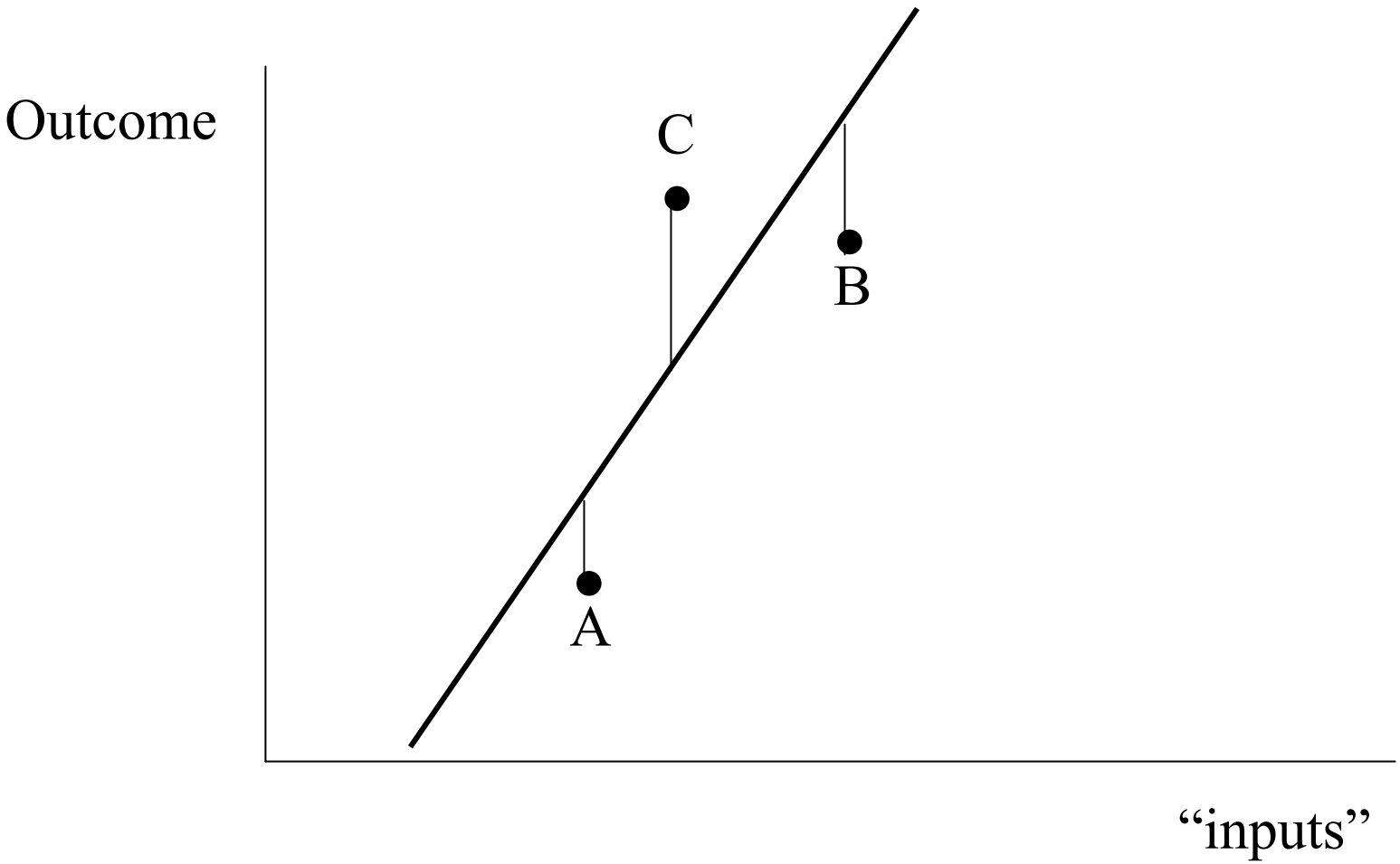
- Discusses hierarchical nature of health care delivery.
- Describes errors of interpretation about performance that may arise if aggregate data are used.
- Develops multilevel models with some data from the UK.
- Discusses the implications for future performance assessment methodology.

2. Multilevel modelling

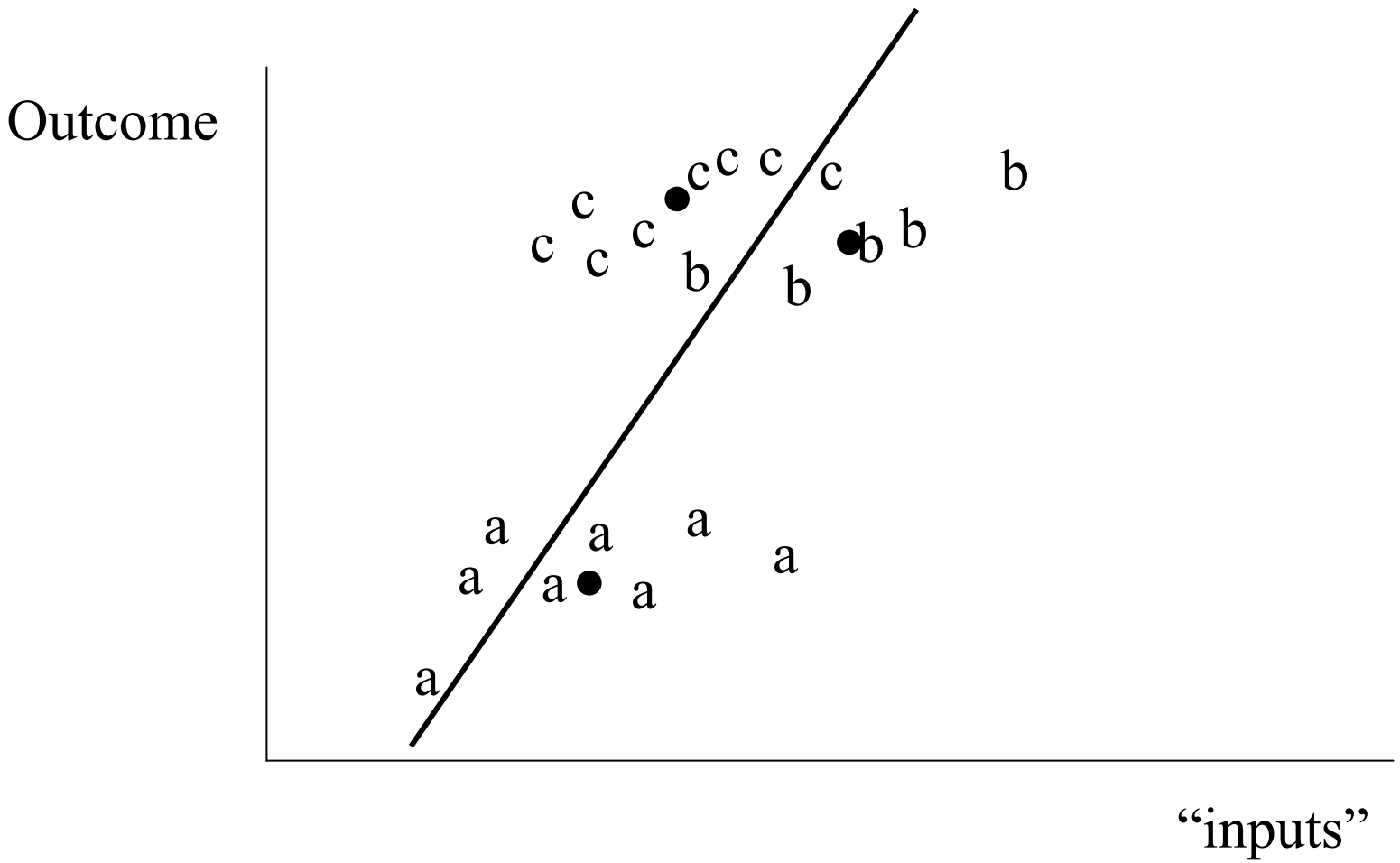
The hierarchical organization of health care in the UK



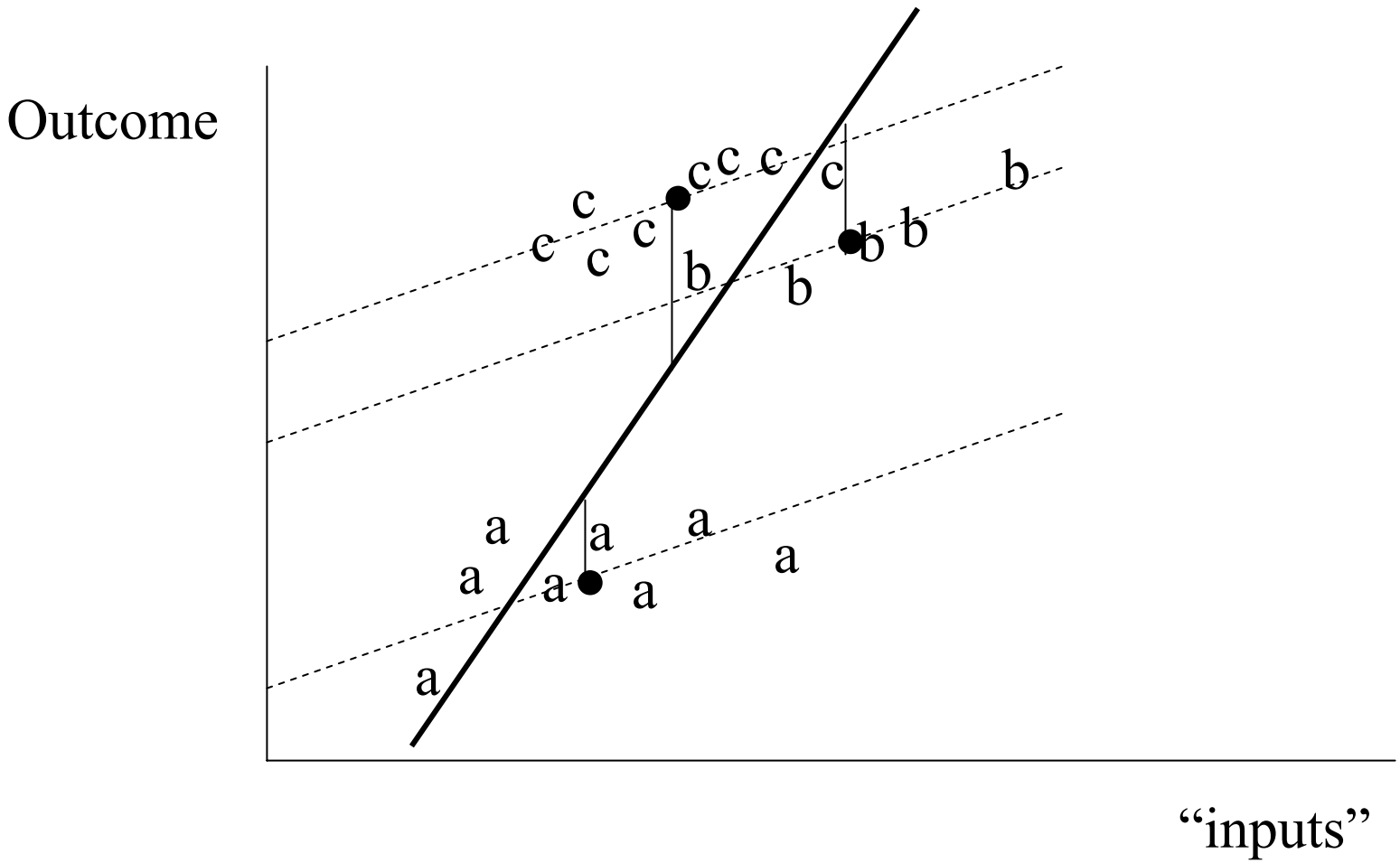
Performance models using only aggregate data



Disaggregate data



Changes in performance ranking based on hierarchical structure



The aggregate model

$$\bar{y}_k = \beta_0 + \bar{\boldsymbol{x}}_{1k}\boldsymbol{\beta}_1 + \bar{u}_k$$

The Basic Multilevel Model

$$y_{ijk} = \beta_0 x_0 + \beta_1 x_{1ijk} + v_{0k} + u_{0jk} + e_{0ijk}, \qquad (1)$$

- y_{ijk} is performance in small area i within district j within region k;
- x_0 is a constant;
- x_{1ijk} represents the needs index x_1 in small area i ;
- b_0 is the mean intercept across all small areas;
- b_1 is the mean slope across all small areas;
- v_{0k} is the random error for region k;
- u_{0jk} is the random error for district j within region k;
- e_{0ijk} is the random error for small area i within district j within region k.

Region and District Effects

The terms v_{0k}, u_{0jk} and e_{0ijk} are error components, each with zero mean and constant variances σ_v^2, σ_u^2, σ_e^2.

The proportion of variance attributable to the regional level is:

$$\rho_v = \frac{\sigma_v^2}{(\sigma_v^2 + \sigma_u^2 + \sigma_e^2)} \qquad (2)$$

and the proportion of variance attributable to the district level is:

$$\rho_u = \frac{\sigma_u^2}{(\sigma_v^2 + \sigma_u^2 + \sigma_e^2)} \qquad (3)$$

3. The data

The Empirical Study

- 14 indicators of health authority performance
- 1991 data from all England
- 4,985 small areas (population about 10,000)
- 186 district health authorities (population about 250,000)
- 14 regional health authorities (population about 3,000,000)
- Inputs:
    - Population “needs” index
    - No expenditure data (assume already fairly financed).

Domains of Performance

- Health outcome (3 indicators)
- Clinical quality (2 indicators)
- Access to health care (5 indicators)
- Efficiency (4 indicators)

(a) Health Outcome

smr064	**Standardised mortality ratio for ages 0-64** *Ratio of observed deaths from all causes in an area to the expected given the local age/sex profile*
smr6574	**Standardised mortality ratio for ages 65-74** *Ratio of observed deaths from all causes in an area to the expected given the local age/sex profile*
sir074	**Limiting long standing illness for ages 0-74** *Ratio of observed number of people reporting limiting illness to the expected given the local age/sex profile*

(b) Clinical Quality

emold	**Emergency admissions of older people** *Ratio of the rate of over 65 emergency admissions originating from an area to the expected given the age, sex and specialty of a patient*
deaths	**Deaths following hospital surgery** *Ratio of 30 day perioperative mortality after elective and non-elective surgery to the expected given the age, sex and case severity of a patient*

(c) Access to health care

wtsurg	**Waiting time for routine surgery** *Ratio of actual waiting time in days for routine surgery to the expected given the age, sex and specialty of a patient.*
wtradio	**Waiting time for radiotherapy** *Ratio of actual waiting time for radiotherapy to the expected given the age & sex of a patient.*
wtlong	**Percentage of those on waiting list waiting for over 12 months** *Proportion of elective surgery admissions waiting for over a year, standardised for patient characteristics*
gpaccs	**Accessibility to general practitioners (GPs)** *Indicator of relative accessibility given the supply of GPs, the distance to surgeries and competition from local populations*
electeps	**Number of elective surgery episodes** *Ratio of standard surgery procedures originating from an area to the expected given the age, sex and specialty of a patient*

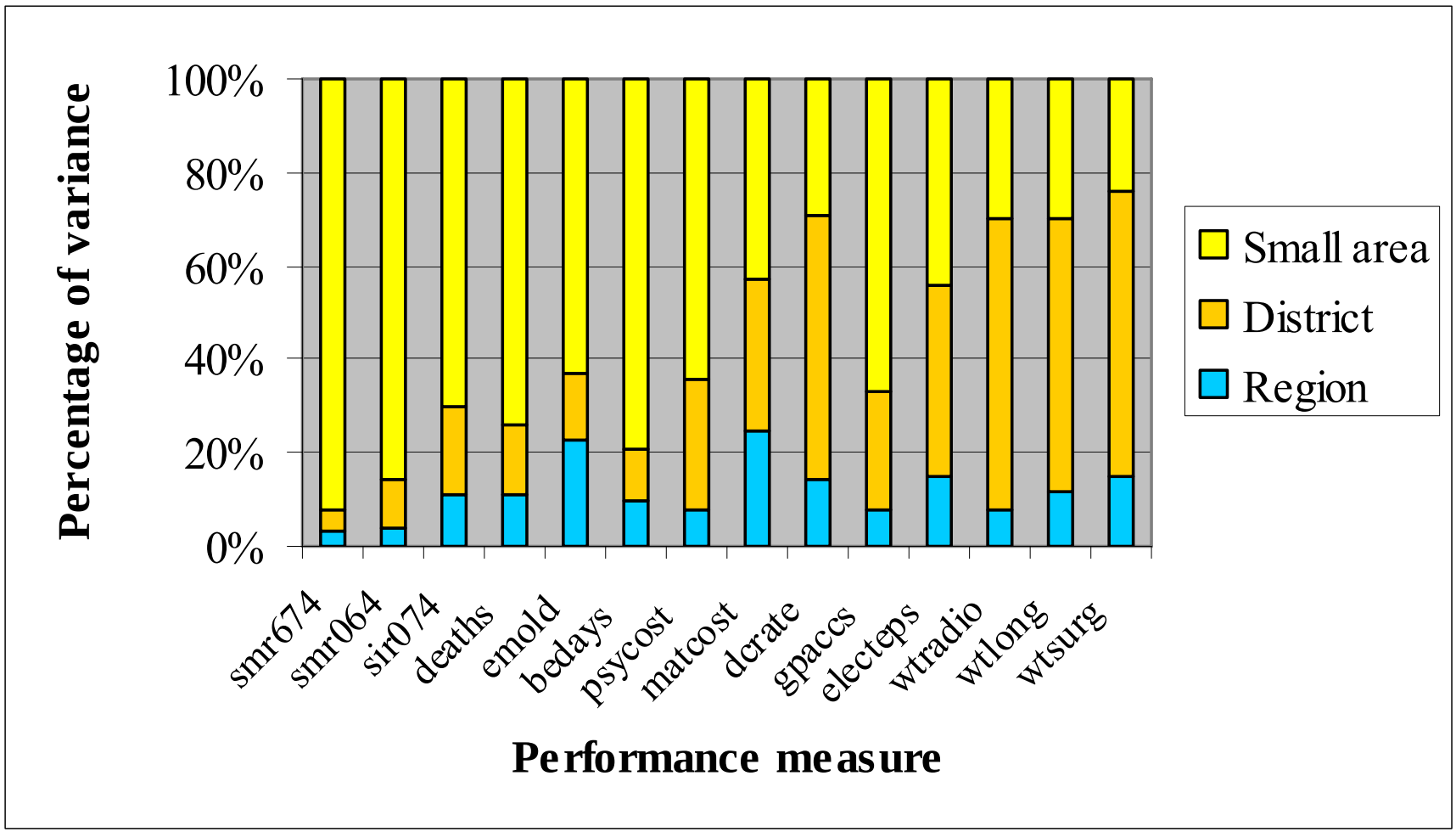
(d) Efficiency

dcrate	**Day case rate** *Proportion of elective episodes in routine surgery treated as day cases standardised for patient characteristics*
bedays	**Length of stay** *Ratio of actual bed days for elective and nonelective standard surgery to the expected given the age, sex and specialty of a patient and national averages*
matcost	**Maternity costs** *Ratio of specialty specific fixed and variable costs for episodes to the expected given national averages*
psycost	**Psychiatry costs** *Ratio of specialty specific fixed and variable costs for episodes to the expected equivalent given the age and sex of a patient and national averages*

4. Partitioning variance

Variability in performance indicators attributable to health authorities

Source: Hauck, K., Rice, N., Smith, P. (2003), "The influence of health care organizations on indicators of health system performance", Journal of Health Services Research and Policy, 8(2), 68-74.



Model for smr6574

	Coefficient	Standard Error
β_0	99.71	0.76
β_1	23.82	0.32
σ_{v0}^2	6.69	3.06
σ_{u0}^2	11.22	1.91
σ_{e0}^2	191.00	3.90
ρ_v	0.03	
ρ_u	0.05	

β_0 : coefficient of the intercept

β_1 : slope coefficient on need

σ_{v0}^2 : variance of the region effects

σ_{u0}^2 : variance of the district effects

σ_{e0}^2 : variance of the small area effects

ρ_v : proportion of conditional variance attributable to regions

ρ_u : proportion of conditional variance attributable to districts

Model for wtsurg

	Coefficient	Standard Error
β_0	0.988	0.025
β_1	0.030	0.003
σ_{v0}^2	0.006	0.003
σ_{u0}^2	0.025	0.003
σ_{e0}^2	0.010	0.000
ρ_v	0.15	
ρ_u	0.61	

β_0 : coefficient of the intercept

β_1 : slope coefficient on need

σ_{v0}^2 : variance of the region effects

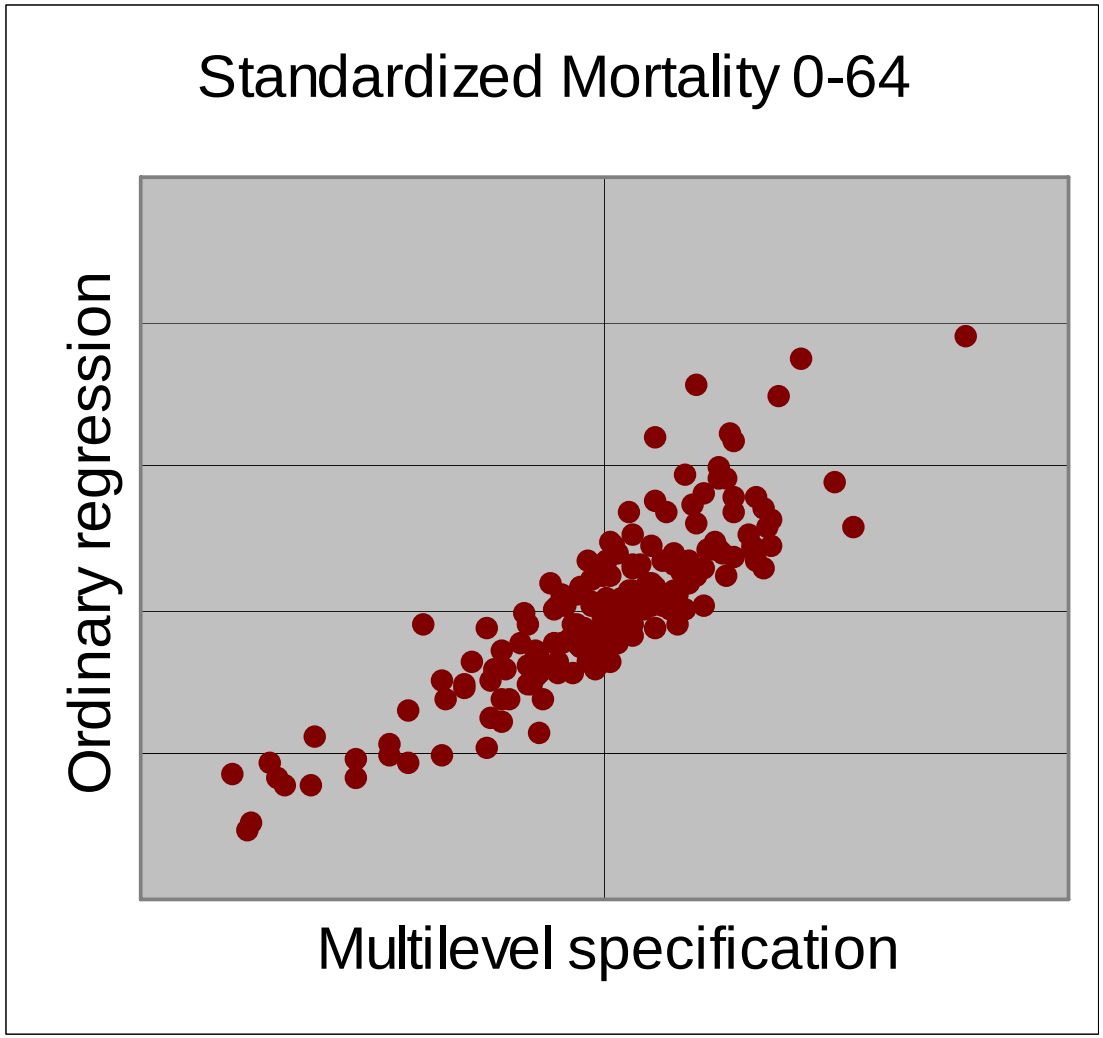
σ_{u0}^2 : variance of the district effects

σ_{e0}^2 : variance of the small area effects

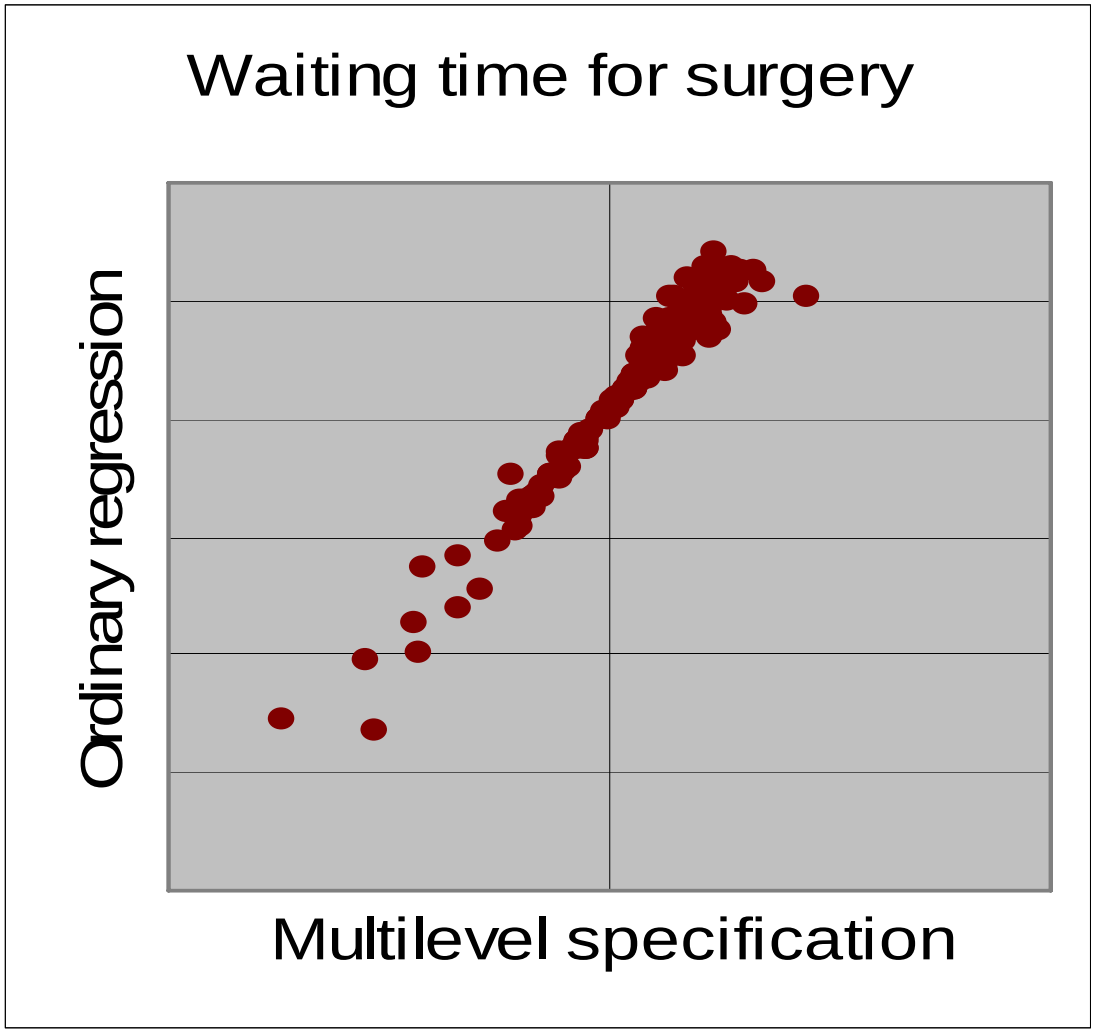
ρ_v : proportion of conditional variance attributable to regions

ρ_u : proportion of conditional variance attributable to districts

Comparison of scores 1



Comparison of scores 2

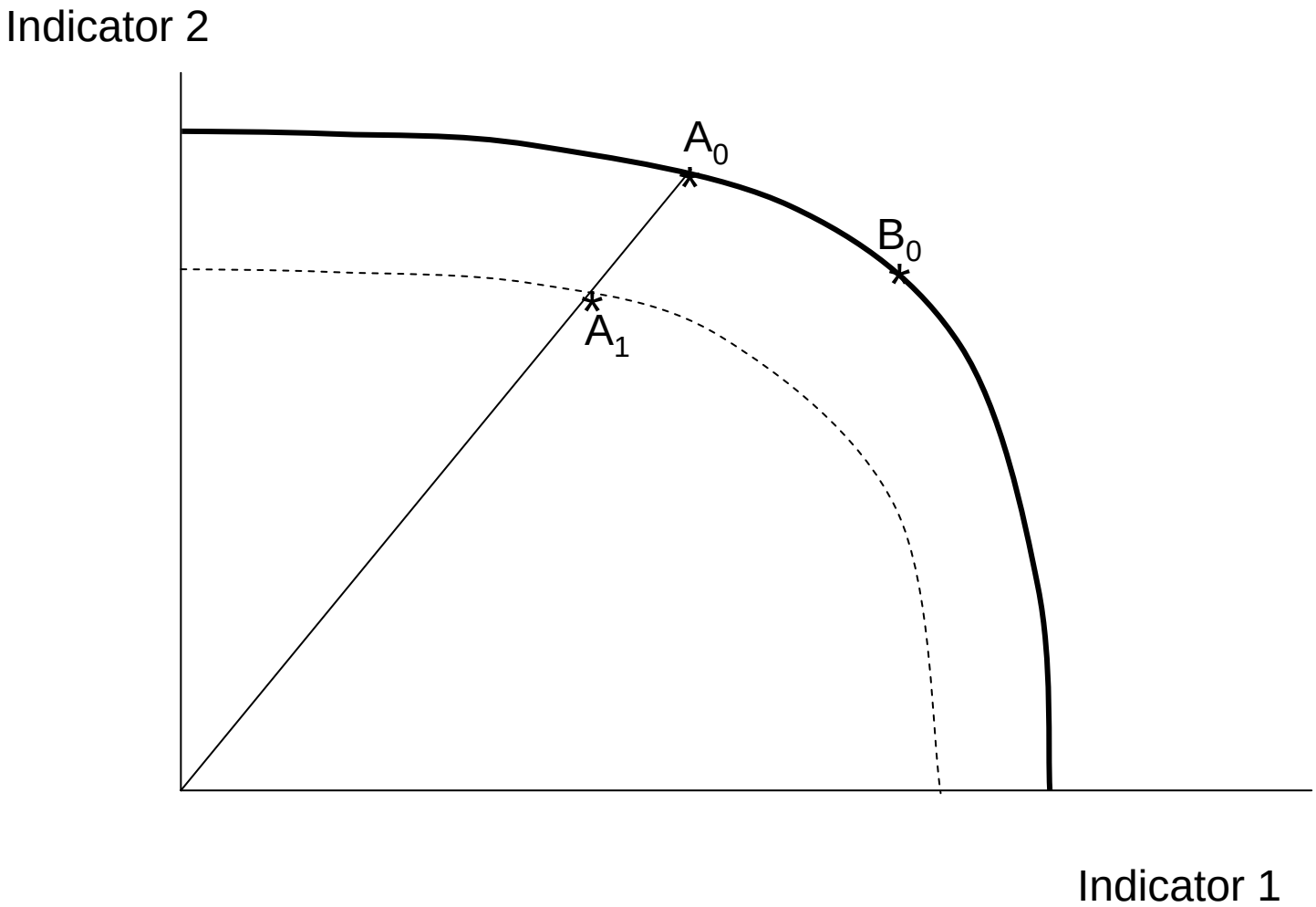


Impact of multilevel specification

	Mortality 0-64	**Waiting time**
Districts	186	175
Correlation	0.86	0.99
Biggest jump	-79 places (63 to 142)	+49 places (68 to 19)
Average jump	22 places	8 places

5. Linking the indicators

Two performance measures correlation structure



Influences on the correlation structure

- Different aggregate levels of aggregate resources
- Different environmental factors
- Different levels of organizational efficiency
- Trade-offs between performance measures
- Organizational effects on data quality.

Martin, S. and Smith, P. (forthcoming), "Multiple public service performance indicators: towards an integrated statistical approach", *Journal of Public Administration, Research and Theory*.

Seemingly unrelated regressions

$$y_{ik} = \beta_{0i} + \boldsymbol{x}_{1ik}\boldsymbol{\beta}_{1i} + \boldsymbol{e}_{ik}$$

Indicator	$i = 1,2,\ldots,I;$
Organization	$k = 1,2,\ldots,K$

$$E\left(\boldsymbol{e}_{ik}\boldsymbol{e}_{ph}'\right) = \sigma_{ip}$$

The multivariate multilevel model

$$y_{ijk} = \beta_{0i} + \boldsymbol{x}_{1ijk}\boldsymbol{\beta}_{1i} + u_{0ik} + e_{0ijk}$$

Indicator	$i = 1,2,\ldots,I;$
Small area	$j = 1,2,\ldots,J;$
Organization	$k = 1,2,\ldots,K$

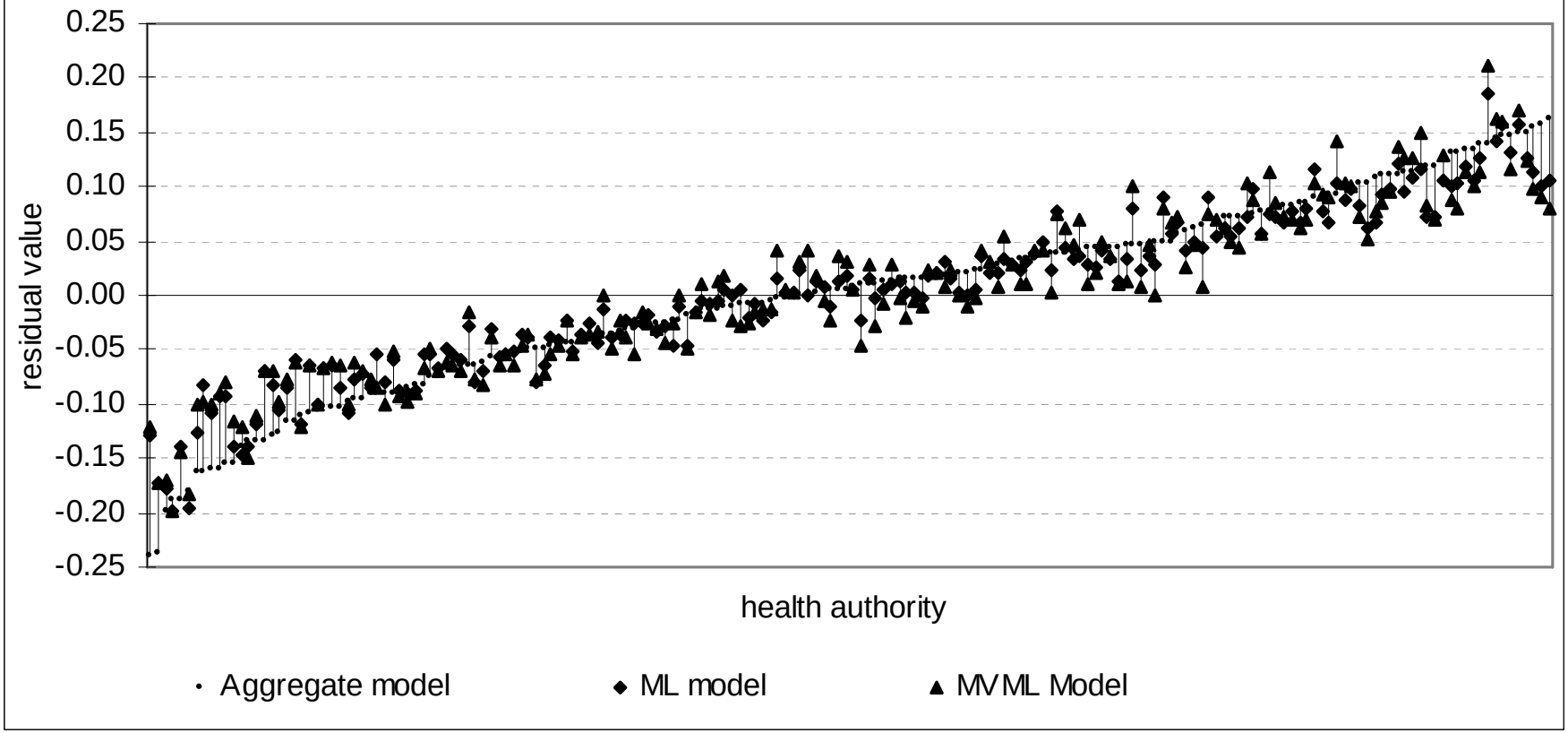
$$\operatorname{cov}(u_{0ik}, u_{0pk}) = \sigma_{u,ip}$$

The multivariate multilevel model: correlation of health authority effects

	smr 0-64	smr 65-74	sir 074	emold	deaths	wtsurg	wtradio	wtlong	gpaccs	electeps	dcrate	matcost
smr6574	0.73*											
sir074	0.62*	0.91*										
emold	0.00	0.15*	0.05									
deaths	0.17*	0.30*	0.26*	0.41*								
wtsurg	-0.16*	-0.22*	-0.20*	-0.13*	-0.03							
wtradio	0.00	0.00	0.16	0.00	0.00	-0.10						
wtlong	-0.12	-0.25*	-0.21*	-0.13	-0.07	0.95*	-0.13					
gpaccs	0.26	0.47*	0.48*	0.21*	0.21*	0.10	0.00	0.05				
electeps	-0.15	-0.32*	-0.25*	-0.13	-0.13	0.32*	-0.07	0.34*	-0.07			
dcrate	0.00	-0.18	-0.12	0.00	0.00	0.40*	-0.26	0.38*	0.00	0.35*		
matcost	0.10	0.00	0.10	0.02	-0.04	0.14	0.26*	0.12	0.07	-0.16*	-0.15	
psycost	0.16	0.15	0.27*	0.09	-0.20*	0.13	0.14*	0.11	0.28*	-0.09	-0.05	0.21*

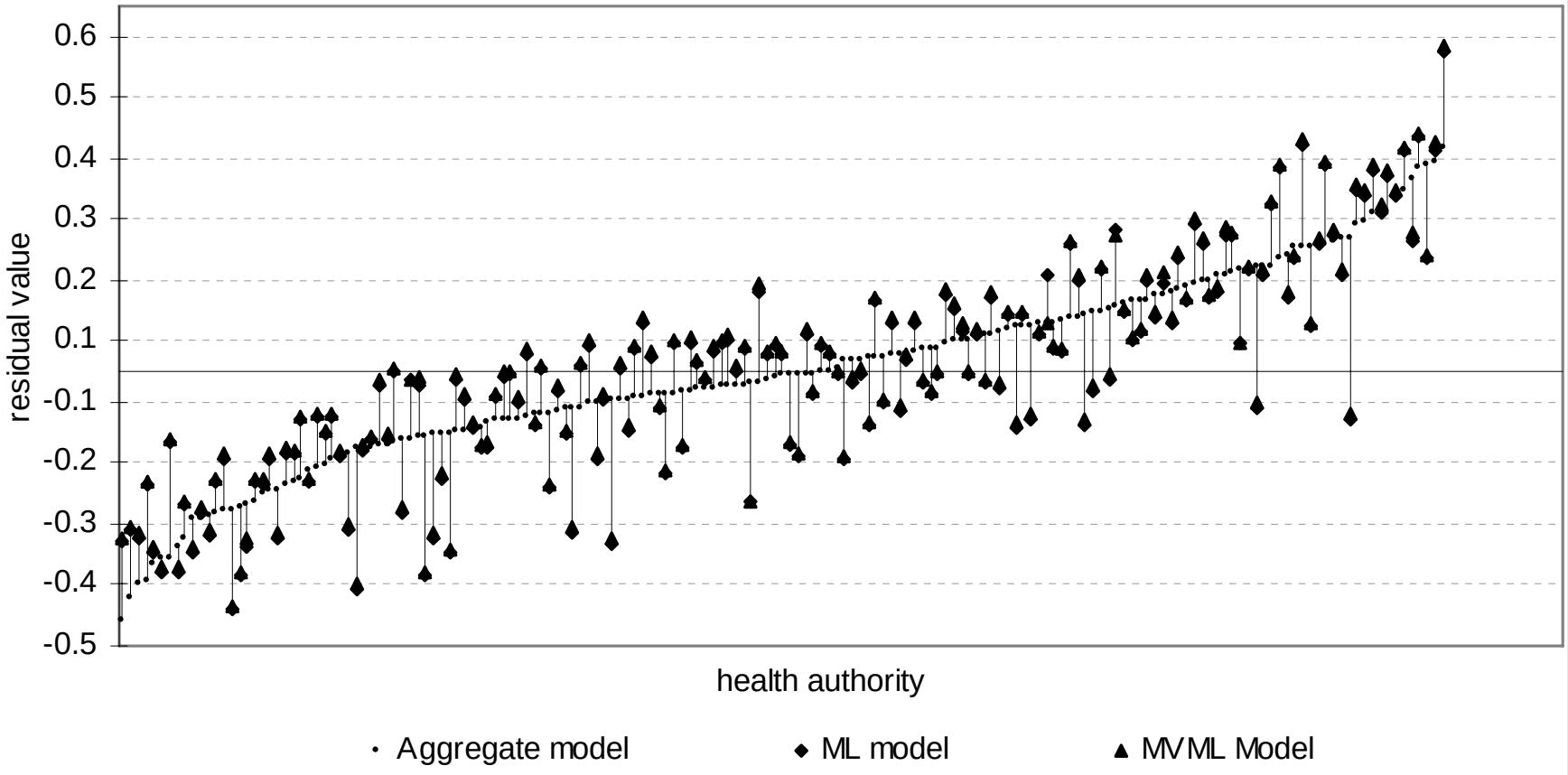
Source: Hauck, K. and Street, A. (forthcoming), "Performance Assessment in the Context of Multiple Objectives: a Multivariate Multilevel Analysis", *Health Economics*.

Figure 4: SMR6574-Standardized mortality ratio (ages 65-74)
Sensitivity analysis Health Authority effects



Source: Hauck, K. and Street, A. (forthcoming), "Performance Assessment in the Context of Multiple Objectives: a Multivariate Multilevel Analysis", *Health Economics*.

Figure 8: WTSURG - Waiting time for routine surgery
Sensitivity analysis Health Authority effects



Source: Hauck, K. and Street, A. (forthcoming), "Performance Assessment in the Context of Multiple Objectives: a Multivariate Multilevel Analysis", *Health Economics*.

6. Explaining health authority effects

Health authority variables

- **Medics**: mental and dental staff per capita,
- **Nurses**: Nursing and midwifery staff per capita,
- **Admin**: administrative and clerical staff per capita,
- **Ancill**: ancillary staff per capita, actual over expected
- **Teach**: teaching district, 1=yes, 0=no
- **Maint**: % revenue expenditure on estate maintenance
- **Buildingcd**: buildings in physical condition c&d
- **Cancel**: % theatre sessions cancelled
- **Gprefer**: ratio of decisions to admit to GP referrals (general surgery & urology).

SMR6574 authority level covariates

```
Number of obs      =      4234
Number of groups   =       157
R-sq:  within  = 0.3086
       between = 0.6280
       overall = 0.4076
------------------------------------------------------------------------------
      smr674 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       oldal |   .2177917   .0190798    11.41   0.000     .1803961    .2551874
       scare |   .0099144   .0171551     0.58   0.563     -.023709    .0435377
       unemp |   .2287982   .0108065    21.17   0.000     .2076179    .2499785

      medics |  -.0001528   .0002072    -0.74   0.461    -.0005589    .0002532
      nurses |   .0003209   .0004999     0.64   0.521    -.0006589    .0013007
       admin |  -.0004283   .0006117    -0.70   0.484    -.0016272    .0007706
      ancill |   .0003701   .0003515     1.05   0.292    -.0003187     .001059
       teach |  -.0138471   .0159269    -0.87   0.385    -.0450633    .0173692
       maint |   2.661875   .9461094     2.81   0.005     .8075349    4.516216
    building |   -.000096   .0002787    -0.34   0.731    -.0006423    .0004503
      cancel |   .0005758   .0009647     0.60   0.551     -.001315    .0024666
     gprefer |  -.0000142   .0000888    -0.16   0.873    -.0001882    .0001598
       _cons |    .969247   .0312796    30.99   0.000       .90794    1.030554
-------------+----------------------------------------------------------------
     sigma_u |  .07779579
     sigma_e |  .16022847
         rho |  .19076814   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

WTSURG authority level covariates

```
Number of obs      =      3834
Number of groups   =       146
R-sq:  within  = 0.0228
       between = 0.1099
       overall = 0.0823
------------------------------------------------------------------------------
      wtsurg |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       oldal |  -.0359473   .0130204    -2.76   0.006    -.0614668   -.0104277
       scare |   .0154748   .0116566     1.33   0.184    -.0073717    .0383213
       unemp |   .0360276   .0074225     4.85   0.000     .0214798    .0505754

      medics |  -.0004902     .00038    -1.29   0.197     -.001235    .0002546
      nurses |  -.0020193    .000923    -2.19   0.029    -.0038283   -.0002103
       admin |   .0009943   .0011206     0.89   0.375    -.0012021    .0031907
      ancill |   .0017642   .0006703     2.63   0.008     .0004504     .003078
       teach |  -.1062963   .0294356    -3.61   0.000    -.1639889   -.0486037
       maint |  -1.877043   1.694238    -1.11   0.268    -5.197688    1.443602
    building |   .0008665   .0005338     1.62   0.104    -.0001796    .0019127
      cancel |  -.0002306   .0018182    -0.13   0.899    -.0037941     .003333
     gprefer |   .0002158   .0001645     1.31   0.189    -.0001065    .0005381
       _cons |   .9949446   .0573132    17.36   0.000     .8826127    1.107276
-------------+----------------------------------------------------------------
     sigma_u |  .15098689
     sigma_e |  .10095577
         rho |  .69104751   (fraction of variance due to u_i)
```

7. Conclusions

- Use of disaggregate data can materially improve the quality of statistical models of performance.
- Inferences about performance using aggregate data may be seriously biased if performance is correlated with inputs.
- Simultaneous modelling of performance measures accommodates important links between indicators.
- Multivariate multilevel modelling may yield distinct improvements in estimates of comparative performance.
- Potential for exploring determinants of organizational performance.
- More work is required on methodology

Jacobs, R., Smith, P. and Street, A. (forthcoming), *Measuring efficiency in health care: analytic techniques and health policy*, Cambridge: Cambridge University Press.