Work in progress on the Australian and New Zealand Intensive Care (ANZICS) Database

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Dr John L. Moran

An outline of my talk today

1. The ANZICS adult patient database (APD)
2. ANZICS mortality and LOS outcomes 1993–2003
3. Quantitative indices reflecting provider 'process-of-care'
4. Concluding comments

Overview

The ANZICS Adult Patient Database is the largest (bi-national) intensive care database in the world.

Currently contains $> 700,000$ intensive care submissions collected from 138 intensive care units (ICUs) in Australia and New Zealand since 1987.

Evolved from humble beginnings in recognition of the integral importance of high-quality databases to the *practice, management, research and audit of clinical services*.[1]

Major advantage of a national database: ability to capture large amounts of data across a broad spectrum of diagnoses and interventions → *especially important in critical care medicine.*

Intensive care is expensive: consumes an estimated AUS$500m to AUS$1b per annum.

[1] Black, *Lancet* 1999

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A nice position paper describing the ANZICS APD

Journal of Critical Care (2006) **21**, 133–141

ELSEVIER

Journal of Critical Care

Development and implementation of a high-quality clinical database: the Australian and New Zealand Intensive Care Society Adult Patient Database

Peter J. Stow[a], Graeme K. Hart[b,c], Tracey Higlett[c,*], Carol George[a], Robert Herkes[d], David McWilliam[d], Rinaldo Bellomo[e] for the ANZICS Database Management Committee

[a]*ANZICS Adult Patient Database (APD), Melbourne, Victoria 3053, Australia*
[b]*ANZICS Database Management Committee, Melbourne, Victoria 3053, Australia*
[c]*ANZICS Research Centre for Critical Care Resources (ARCCCR), Melbourne, Victoria 3053, Australia*
[d]*Intensive Care Unit, Royal Prince Alfred Hospital, Sydney, NSW 2050, Australia*
[e]*Intensive Care Research, Austin Hospital, Melbourne, Victoria 3084, Australia*

Stow *et al*:

- origins of ANZICS APD up to December 2003
- 444,147 case records
- collect raw physiology data
- 121/167 Australian and 10/27 New Zealand ICUs
- data submissions from contributing ICUs are voluntary.

Database evaluated according to criteria of the Directory of Clinical Audit Databases (DoCDAT) and the Arts *et al* framework.[2]

Overall: ANZICS APD is a high-quality database representative of the Australian population; it does have some weaknesses:

- completeness of recruitment $< 80\%$
- some queries about reliability of coding (lack of intra-rater and inter-rater reliability testing).

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Hospital level and locality

In Australia and New Zealand, critical care services may be provided in

- *tertiary, metropolitan, rural* or *private* hospitals;
- *distances* between centres are often *large*, and there may be geographical or other barriers to the transfer of patients between different levels of care.
- Private and public funding models may result in differences in clinical practice.
- In Australia, 50% of hospital care is private.

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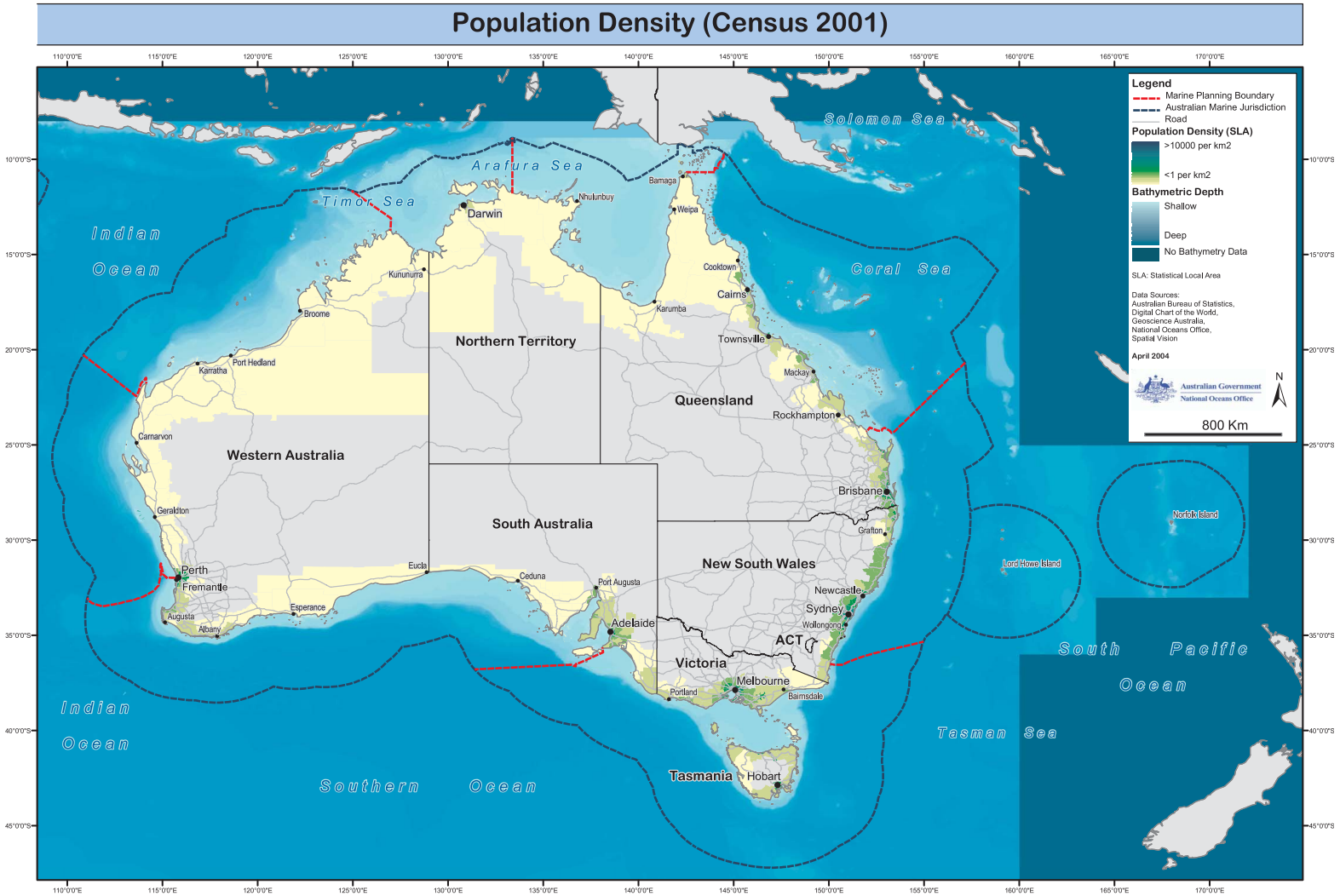
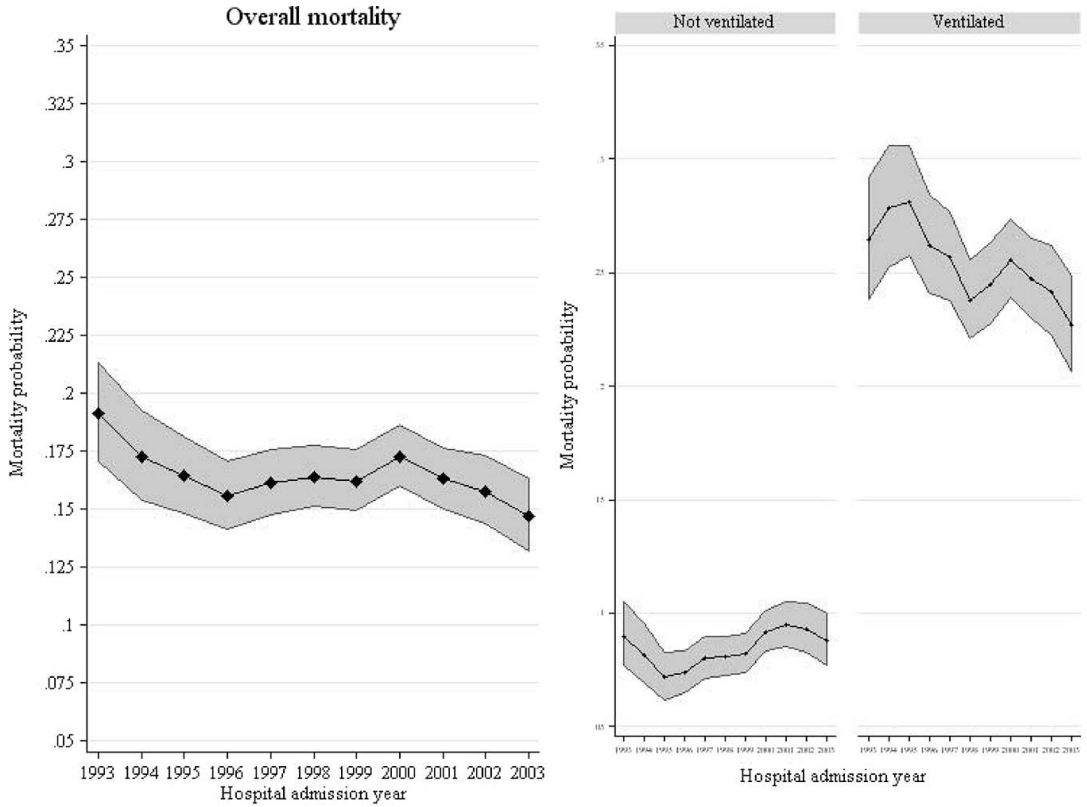


National Oceans Office, Australian Bureau of Statistics

Mortality and association with mechanical ventilation

Moran *et al*, *Critical Care Medicine* **35** 2007



$n = 223,129$, overall mortality 16.1%, mean LOS 3.6 days. Hospital mortality decreased 4% over 11 years.

SMRs for individual ICUs

- Considerable uncertainty has been apportioned to estimates of mortality as reflected in the Standardised Mortality Ratio (SMR).[3]

- Full 'explanatory' models are preferable to the limited purview of 'algorithmic' (APACHE, SAPS, MPM) models
  - Acute Physiology and Chronic Health Evaluation.

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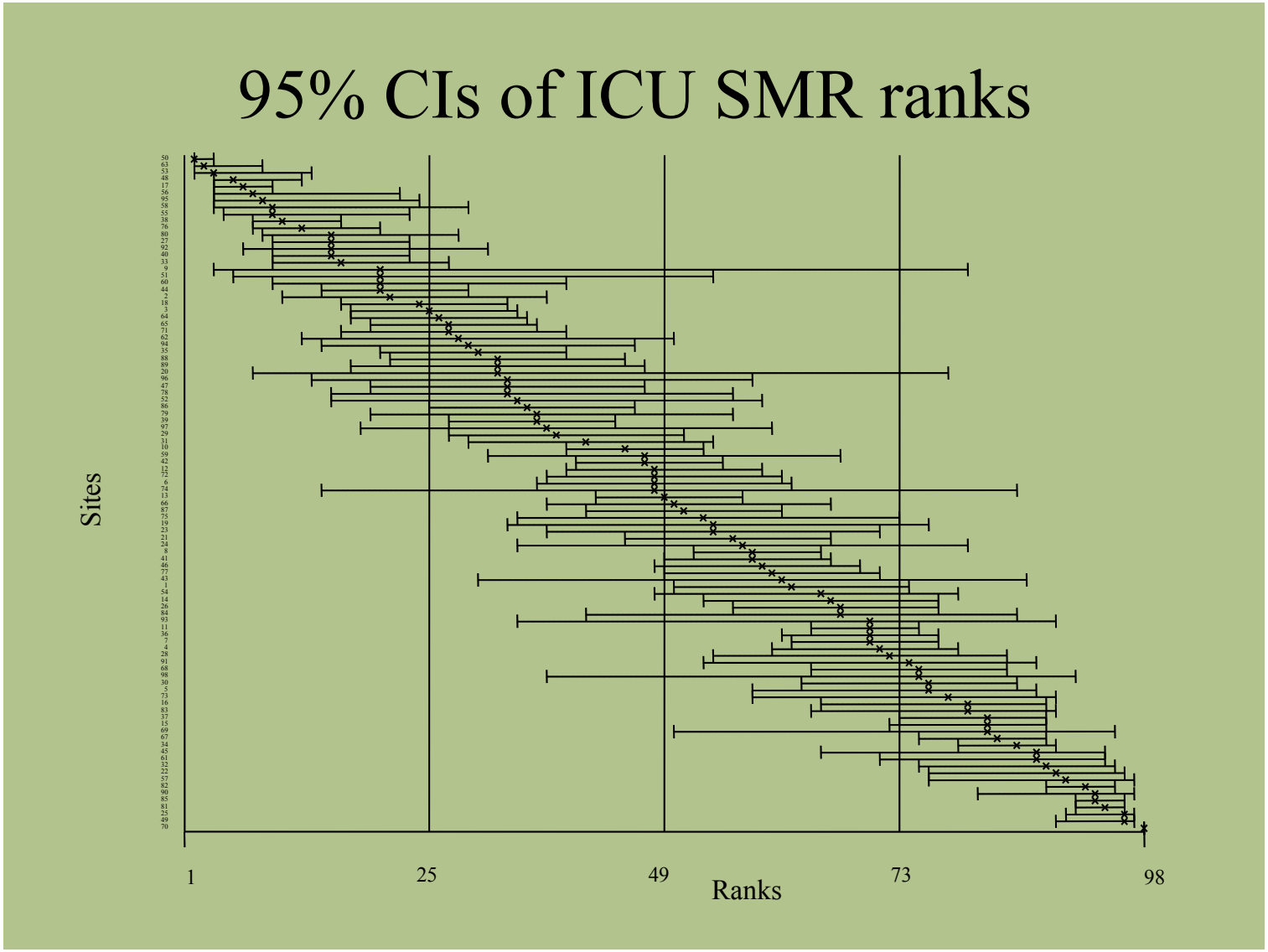
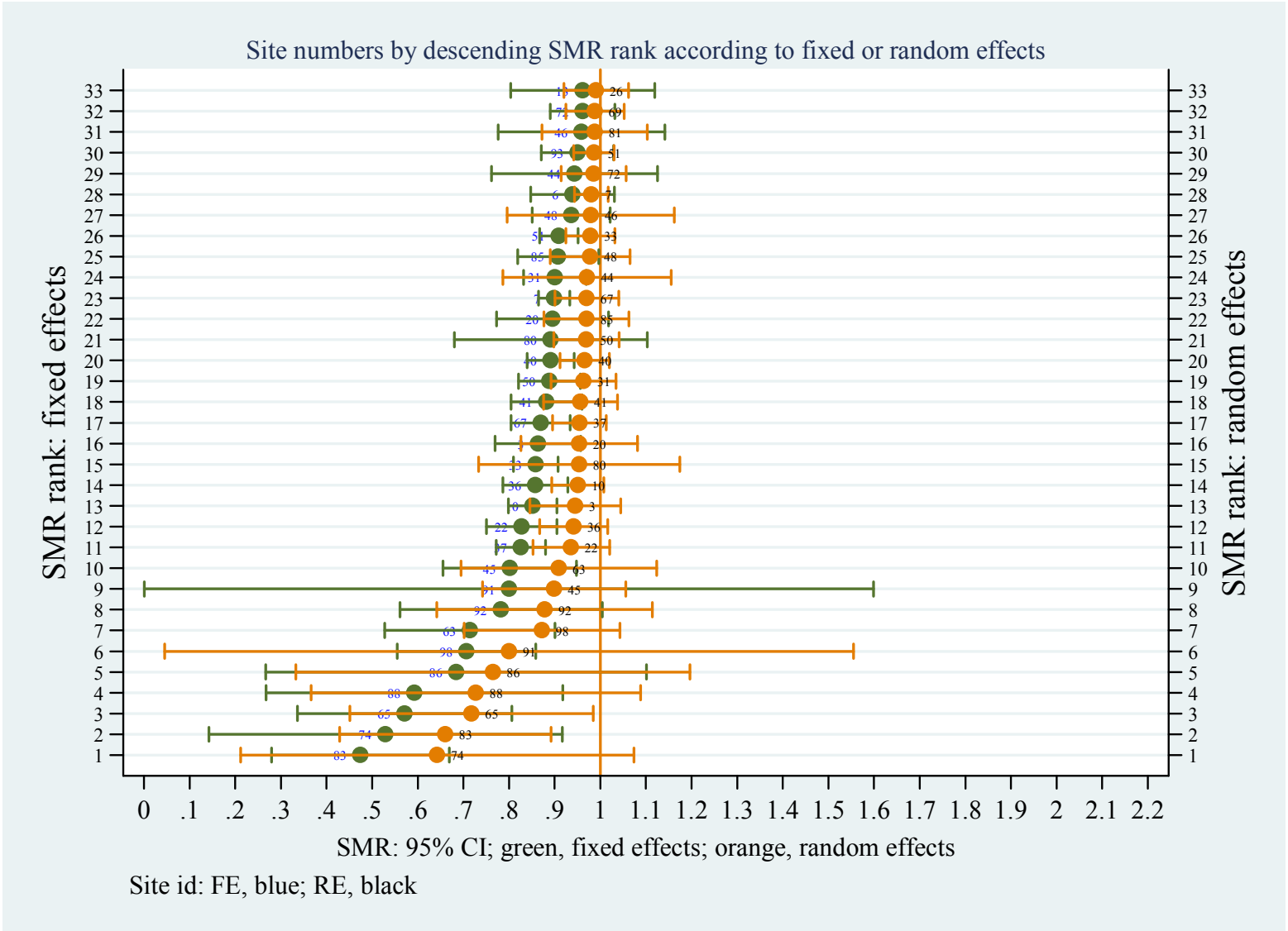
Bootstrapped CIs of ranks (1993 – 1997)



Rank SMR order for FE and RE models 1993 – 2003



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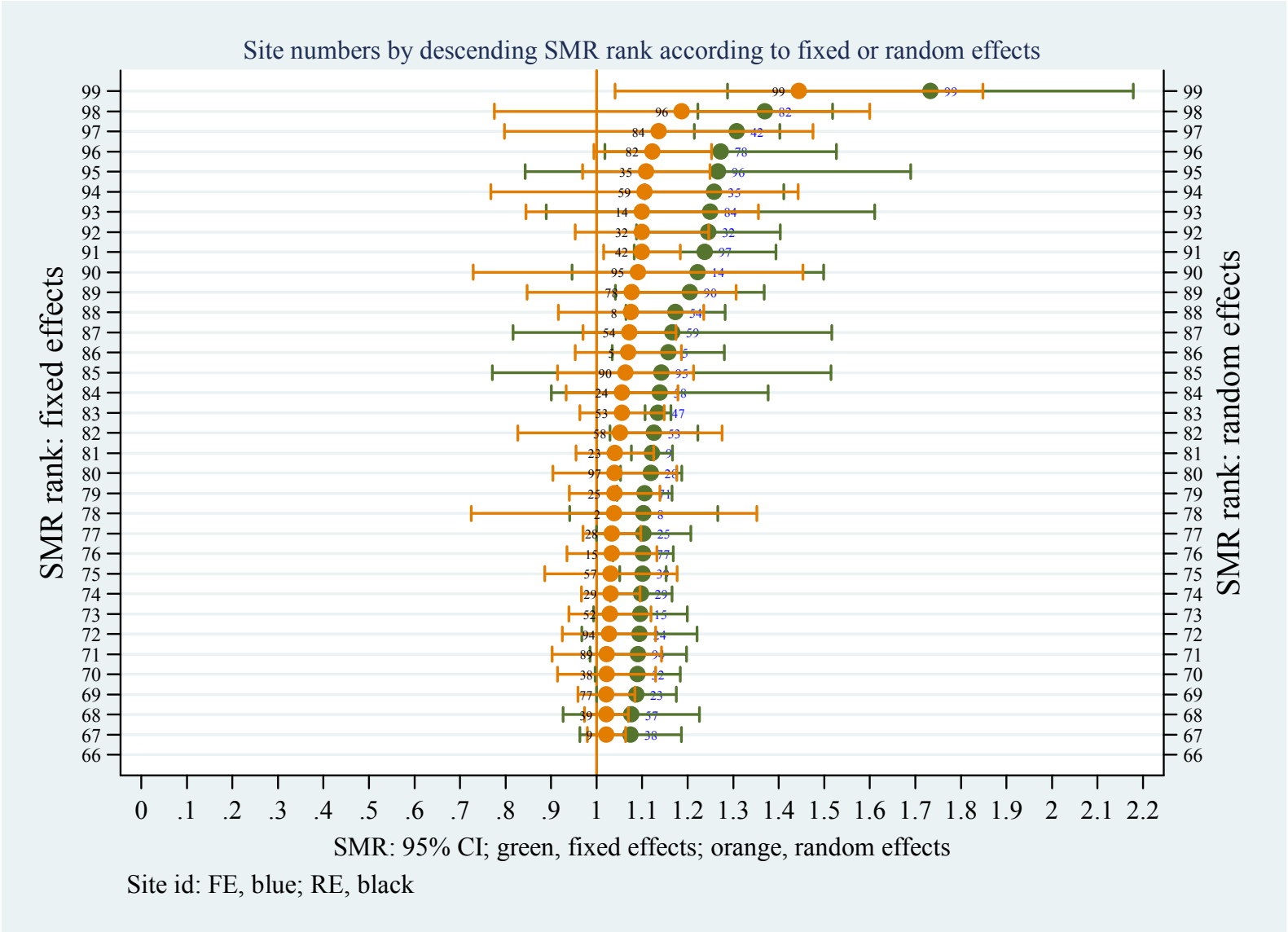

The outcomes paradigm

Is now a **dominant influence** within medicine, and *critical care* is no exception.[4]

In the USA

- *Cleveland Health Quality Choice*
- initially greeted with some enthusiasm
- but upon its demise, described as either *martyr* or *failure*.

In the UK

- the performance of the paediatric cardiac surgical service at the Royal Bristol infirmary.

In Australia

- ANZICS data-base initiative
- the inquiry into the Bundaberg Base Hospital, Queensland.[5]

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APACHE II and 'provider' comparisons

APACHE II[6] and exploration of risk adjusted mortality in a cohort of 13 ICUs

- established the notion of 'institutional' or 'provider' comparisons within critical care, and
- introduced SMRs to the critical care literature.

From wherein has ensued a discordant debate regarding the relationship between the SMR and ICU *performance* or *quality*:

- SMR and its variability is problematic
- "*mortality is unlikely to be a sufficient statistic for quality*" (Spiegelhalter 1999)
- scoring systems at best describe 'elements' of performance.[7]

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Process I

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- looked at quality of care components
- at the sampled case-record level
- using both *structured explicit* and *implicit* review.

Although clinicians' *subjective* assessment criteria

- identified differences between high and low mortality rate outliers
- ***not*** confirmed for any condition where *explicit structured process* criteria were used.

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Process II

Subsequent efforts to **locate a relationship** between mortality and 'quality of care' have been grounded in chart review and have been largely unsuccessful:

- in a surgical environment (Gibbs *et al* 2001)
- in a general medical setting (Best *et al* 1994, Thomas *et al* 1993, Park *et al* 1990)

'Prevalent care processes'

- have **not** established a strong relationship.

Pitches *et al* on mortality and quality of care: *Do hospitals with higher risk-adjusted mortality rates provide poorer quality care?* [9]

- the "*notion that hospitals with higher risk-adjusted mortality rates have poorer quality care is neither consistent nor reliable*".

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Increase the sensitivity of process measures?

This argument has been advanced because of the *large sample sizes* required to demonstrate small to modest changes in (mortality) outcome.

However, the felicity with which process may be measured is no guarantee that "*measuring ... process and reporting performance will improve outcomes*".[10]

There is a also certain circularity in these arguments ...

- reliance on *outcome measures* is criticised from the standpoint of *process-of-care*
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Our strategy: patient efficiency

There would be advantage in establishing a quantitative index which would subsume the diversity of process-of-care.

Would enable *provider ranking* and *formalised comparison* with both indices of, and ranks based upon, mortality outcomes.

Idea: measure the patient's ability to maximise 'output'

- in particular, *length of stay*
- for a given set of physiological inputs, *e.g*, individual patient component variables in APACHE II.

Conceptual foundation: from **econometrics**

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Technical efficiency

The objective of producers can be as simple as seeking to avoid waste

- by obtaining *maximum outputs* from given *inputs*
- or, by *minimizing input use* in the production of given *outputs*[11].

The notion of *productive efficiency* corresponds to what we call *technical efficiency*.

M.J. Farrell (*JRSS A* 1957) was the first to measure productive efficiency empirically using linear programming techniques.

- He showed how to decompose cost efficiency into its technical and allocative components, and
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The influence of Farrell's work

Data envelope analysis (DEA)

In an innovative study of patients with severe head trauma

- Nathanson *et al*[12] used DEA to calculate individual patient 'efficiency' scores based upon the ability to *maximise cerebral perfusion pressure* (output)
  - for a given set of physiological inputs: temperature, MAP, serum osmolality, arterial $PaCO_2$;
  - patients with high efficiency scores had improved functional outcomes on ICU discharge.

Of greater significance for us:

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Production frontier models

A *stochastic production frontier* model:

$$y_i = f(x_i; \beta) \exp(v_i) TE_i \quad i = 1, \ldots, I \quad \text{producers}$$

y_i is the scalar output of producer i, x_i is a vector of inputs used by producer i, and β is a vector of 'technology' parameters to be estimated;

$$TE_i = \frac{y_i}{f(x_i; \beta) \exp(v_i)}$$

- y_i achieves its maximum feasible value iff $TE_i = 1$
- $TE_i < 1$ measures the *shortfall of observed output* from the *maximum feasible output* in an environment characterised by $\exp(v_i)$, which can vary across producers.

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Technical efficiency for ANZICS patients

Stochastic production frontier model (log-linear f):[13]

$$\log y_i = \beta_0 + \sum_{j=1}^{k} \beta_j \log x_{ij} + v_i - u_i$$

where $TE_i = \exp(-u_i)$

- y_i is ICU/ hospital length of stay
- x_{ij}s are acute physiology score and chronic health evaluation variables
- $v_i \sim N(0, \sigma_v^2)$, $i = 1, \ldots, 215515$ (can vary across locality/level)
- $u_i > 0$, here assumed exponentially distributed
  - and allowed to be a function of appropriate individual explanatory variables.
  - Patient efficiency scaled $[0, 1]$.

[13] Stata^{TM} module $frontier$

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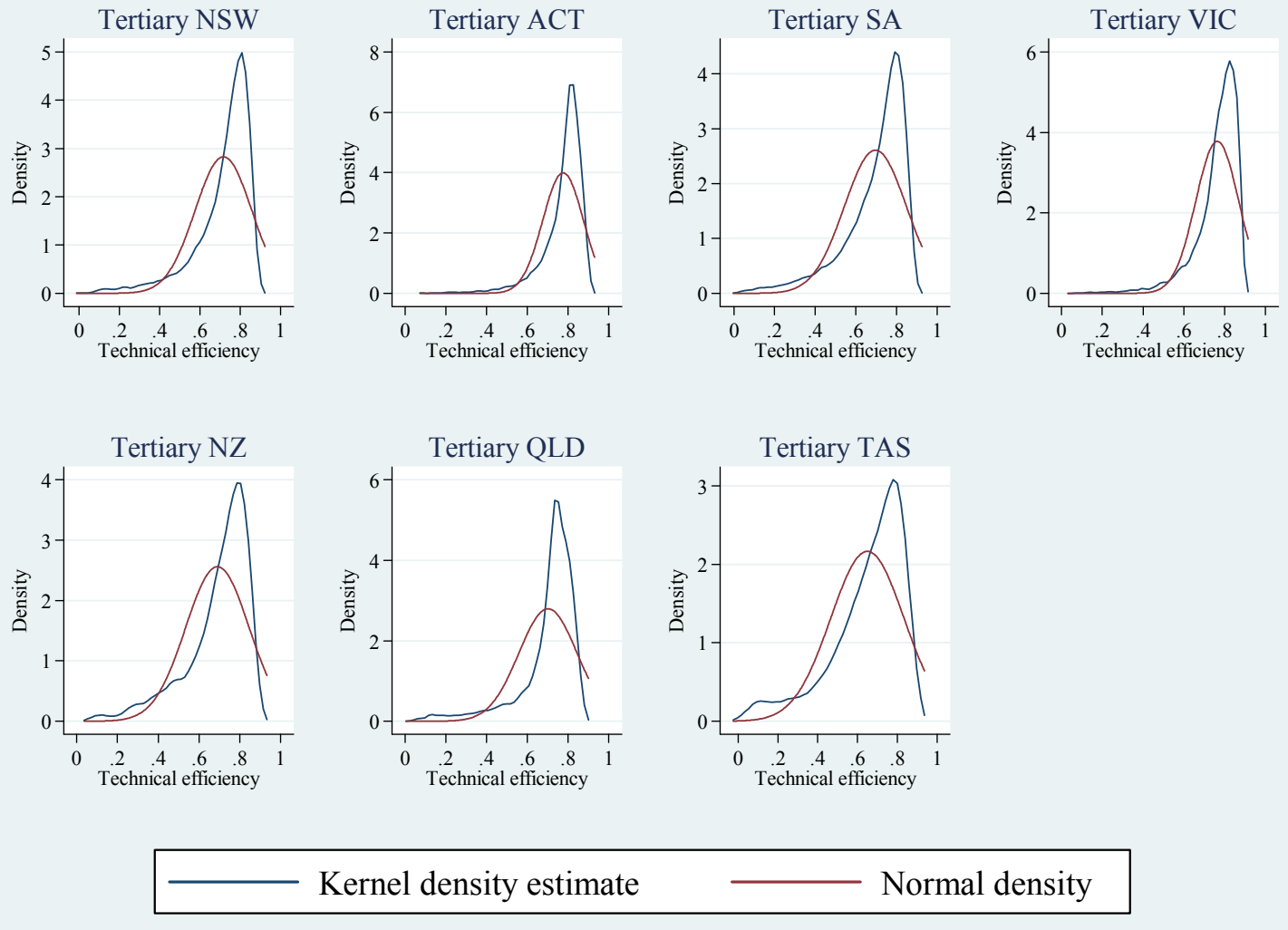
- x_{ij}s are acute physiology score and chronic health evaluation variables
- $v_i \sim N(0, \sigma_v^2)$, $i = 1, \ldots, 215515$ (can vary across locality/level)
- $u_i > 0$, here assumed exponentially distributed
  - and allowed to be a function of appropriate individual explanatory variables.
  - Patient efficiency scaled $[0, 1]$.

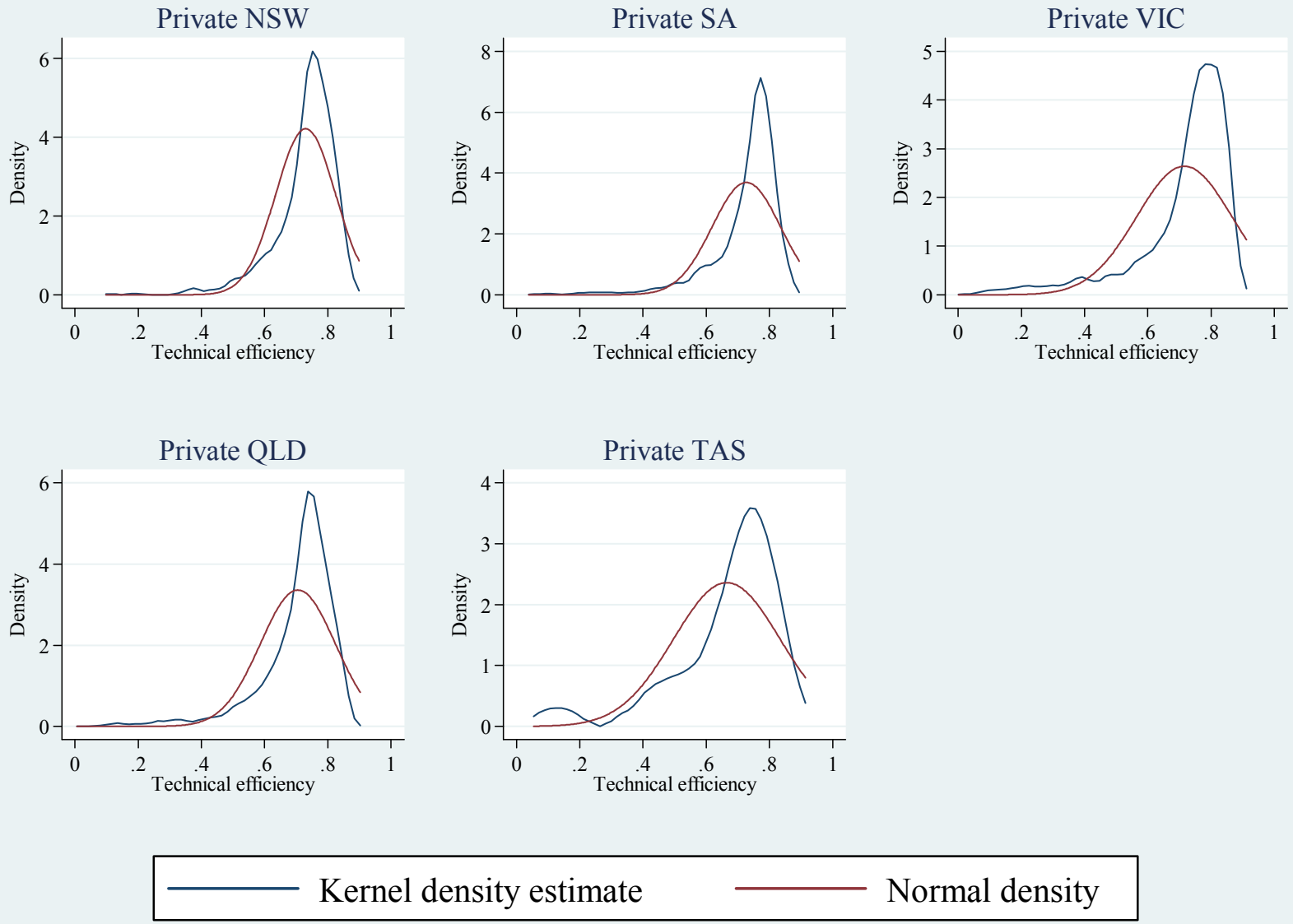
[13] Stata^{TM} module *frontier*

Patient efficiency for tertiary hospitals by locality

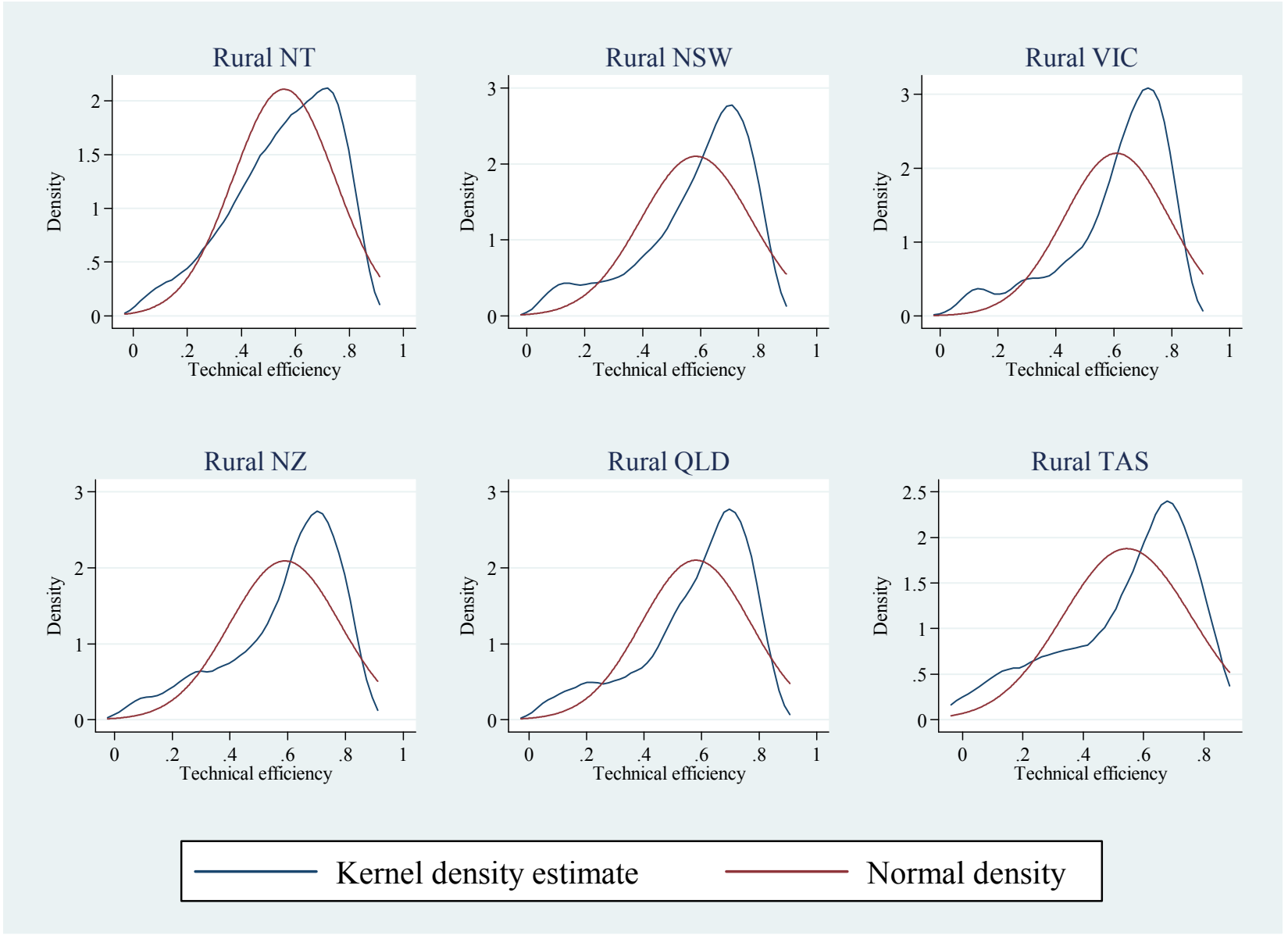
Patients alive at discharge



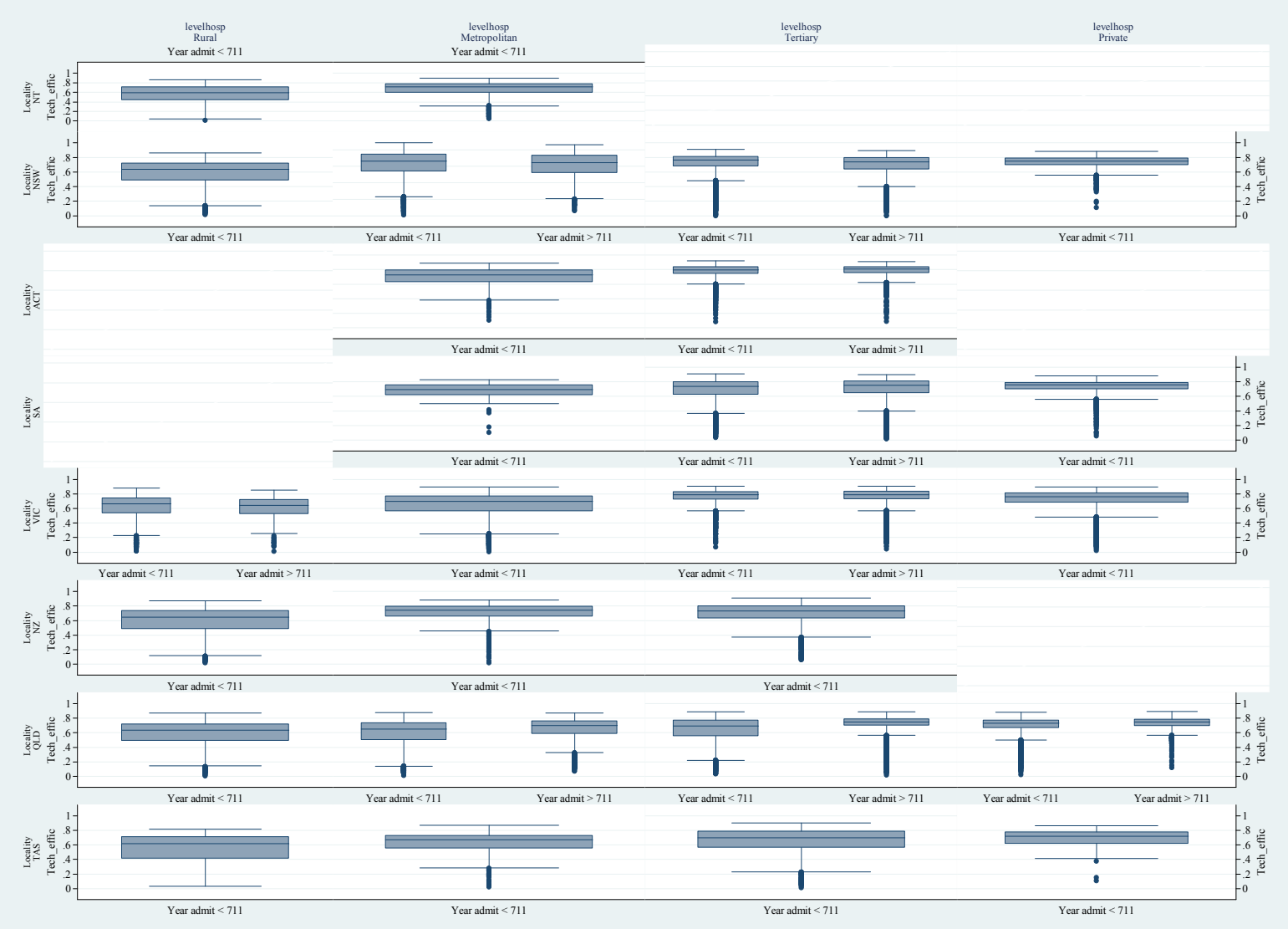
Patient efficiency for private hospitals by locality



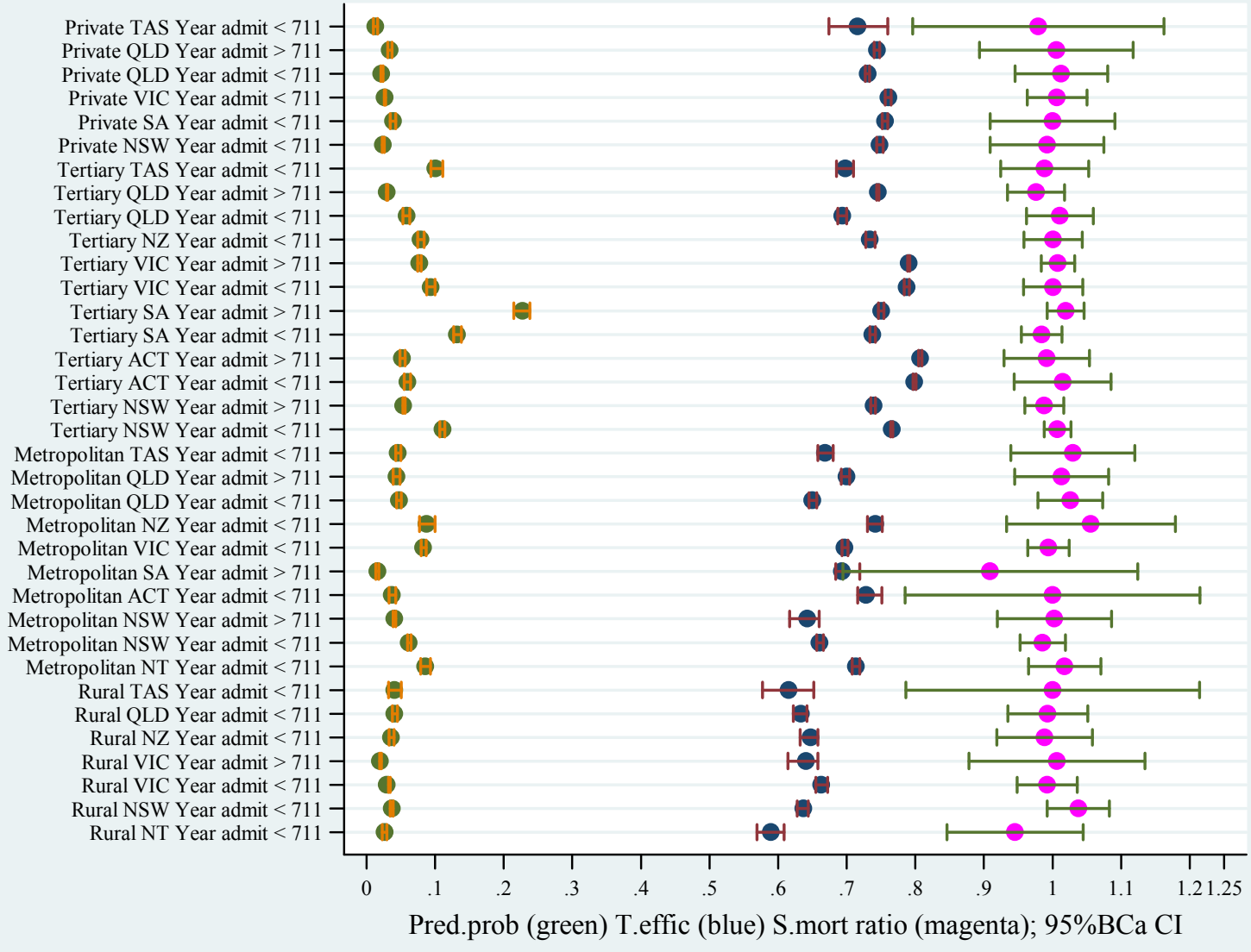
Patient efficiency for rural hospitals by locality



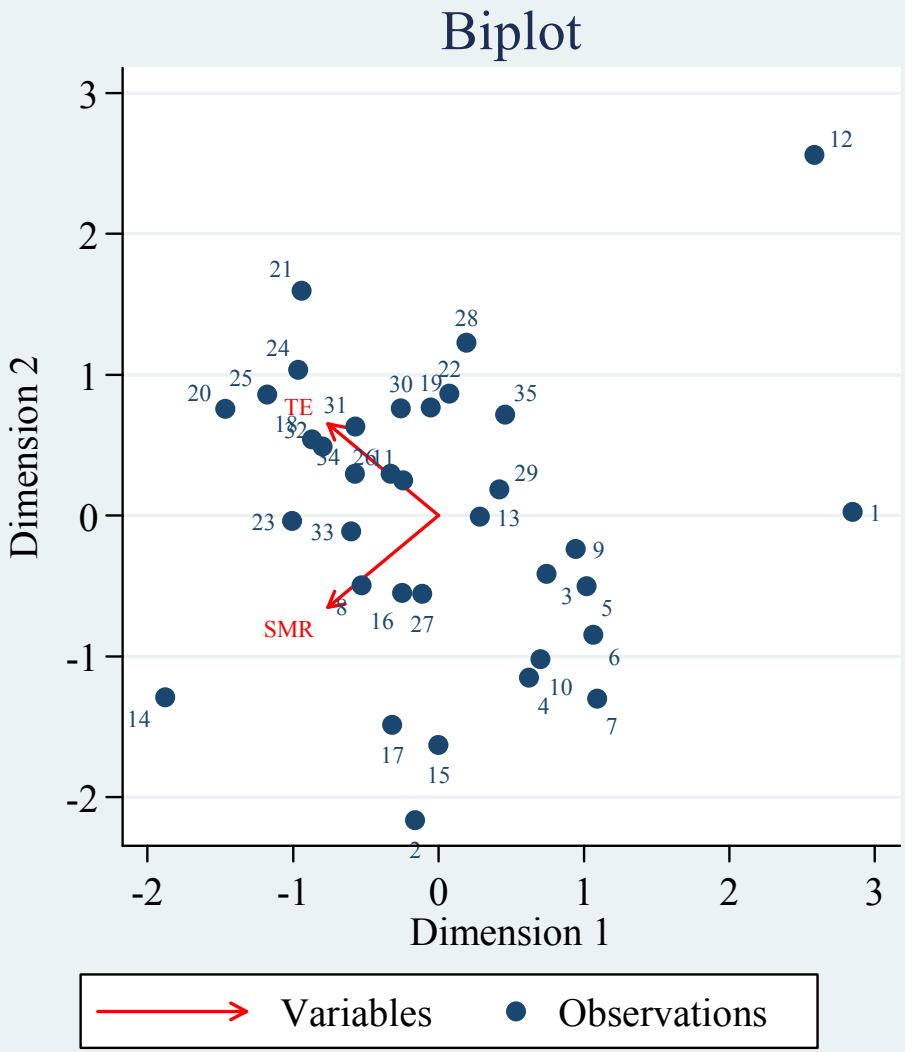
Patient efficiency by hospital locality/level/size



ANZICS 1993–2003 (N=35)



ANZICS 1993–2003: biplot of median TE and SMR



TE of SA tertiary hospitals: real correlates with hospital policy

ICU LOS efficiency (mean) estimates: geographical location & yearly admission number

	Yearly admissions < 711				*Yearly admissions > 711*			
ICU geographical locality	*Rural*	*Metropolitan*	*Tertiary*	*Private*	*Rural*	*Metropolitan*	*Tertiary*	*Private*
Northern Territory	0.616	0.719						
New South Wales	0.625	0.683	0.729	0.754			0.723	
Australian Capital Territory		0.692					0.748	
South Australia			0.709				0.758	
Victoria	0.591	0.673		0.707			0.756	
New Zealand	0.683	0.723	0.724					
Queensland	0.644	0.644	0.647	0.721		0.685	0.741	
Tasmania	0.579	0.632	0.649					

Conditional length of stay (CLOS)

Idea: time course of 'hazard of patient ICU/hospital discharge' reflects the (time course of) *process-of-care*.

Silber and co-workers $1999 - 2004$[14] defined CLOS as *the length of stay after a stay is prolonged*:

- the *prolongation day* estimated by Hollander-Proschan statistics: 'new worse than used'.
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- *"By studying CLOS, one can determine when the rate of hospital discharge begins to diminish - without the need to directly observe complications . . . CLOS aids in the analysis of a hospital's management of complicated patients ..."*

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  - *patients within providers*: for Australia, individual ICUs/hospitals by hospital level (rural, metropolitan, tertiary, private) and geographical locality (i.e., by state)
- Survivors
  - we define LOS of non-survivors as >> maximum LOS of alive discharges
  - $n = 181,100$, no censoring
  - obtain hazard of hospital (or ICU) discharge via kernel density smoothing.
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  - $n = 34,415$: LOS of survivors defined >> maximum LOS of deaths.

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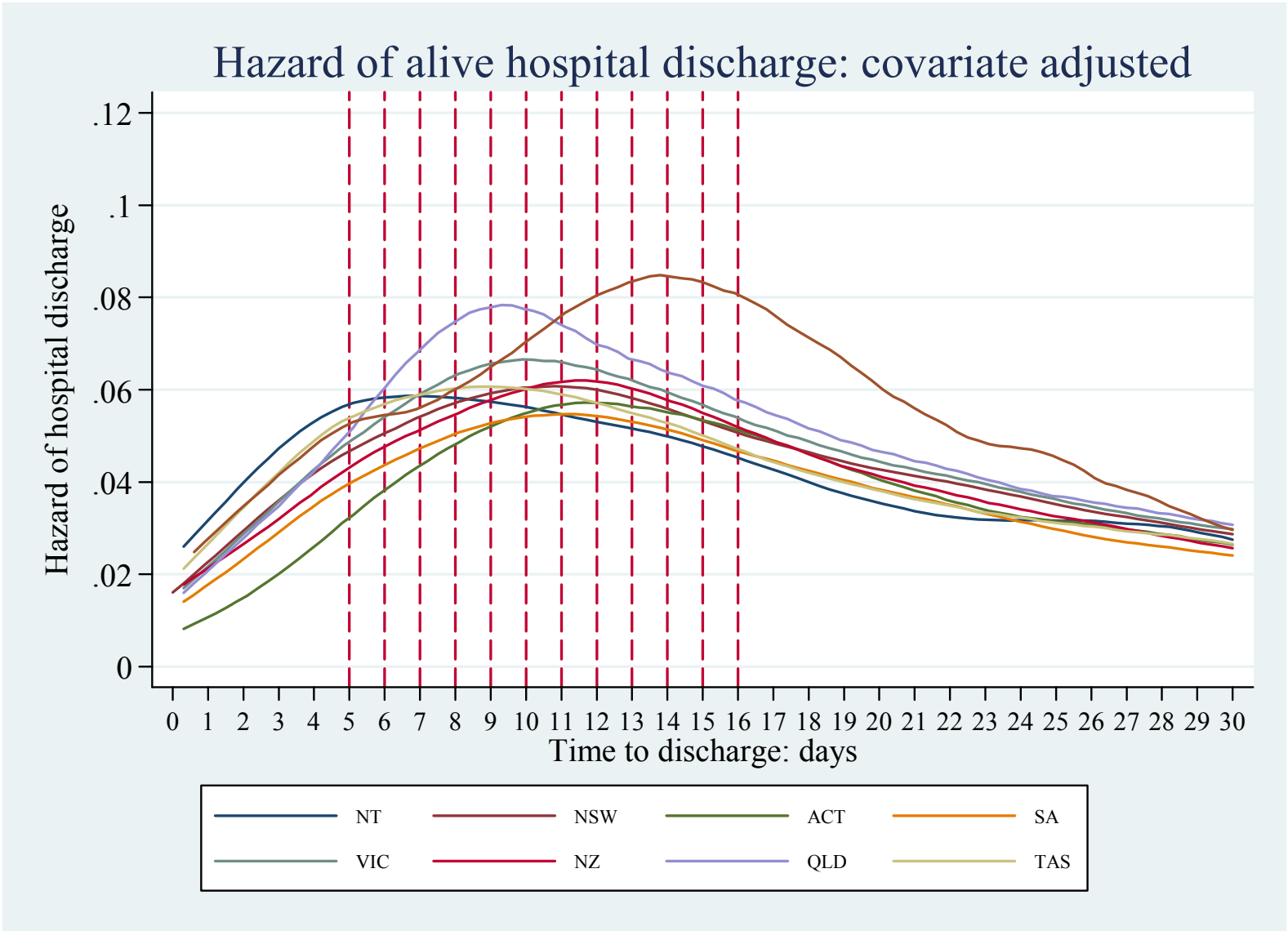
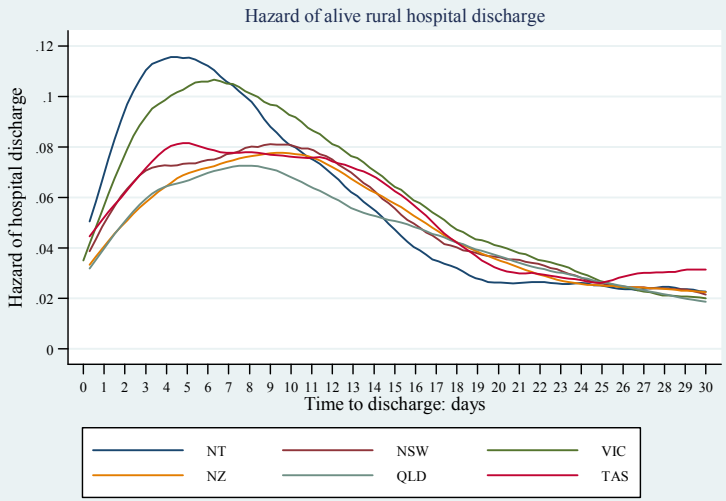
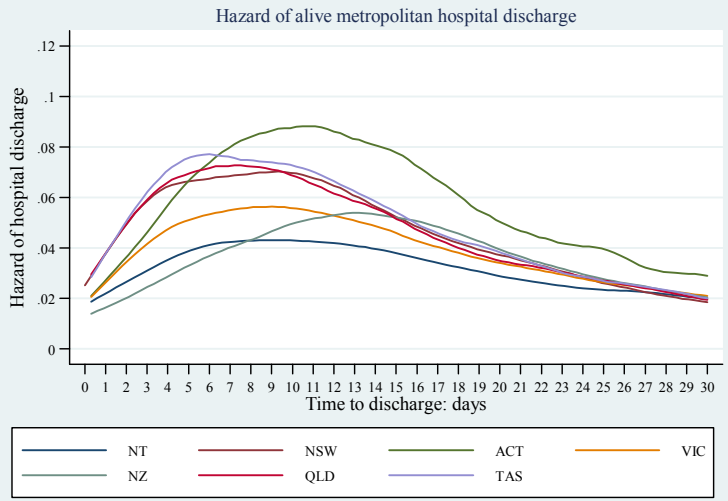
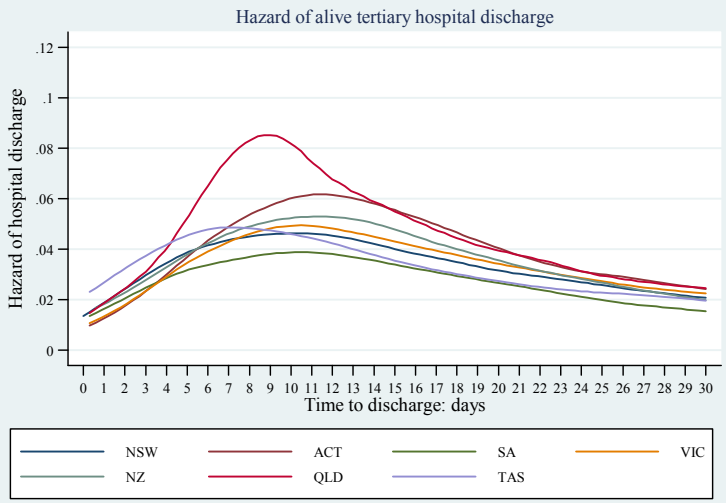
ANZICS hazard of discharge by location

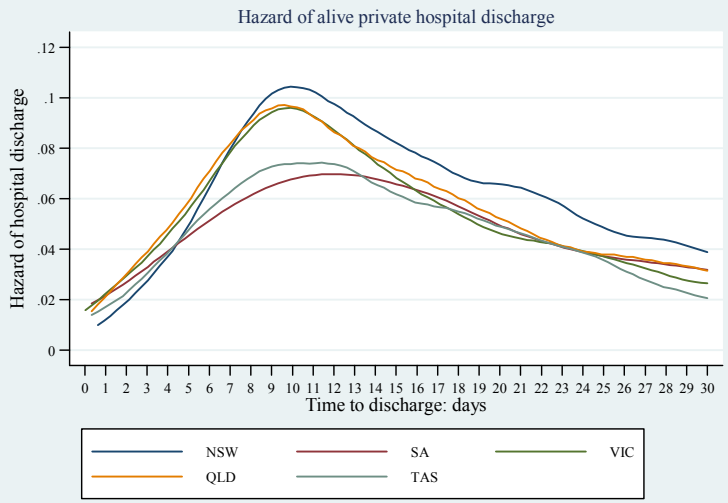


ANZICS hazard of discharge alive by hospital level

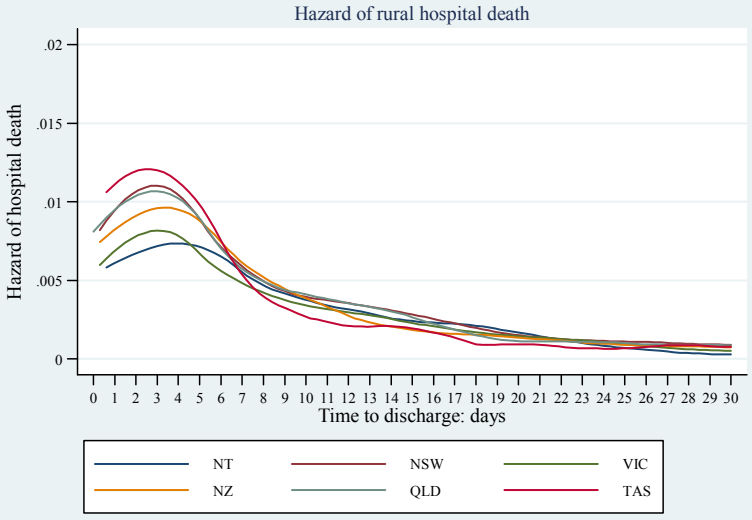


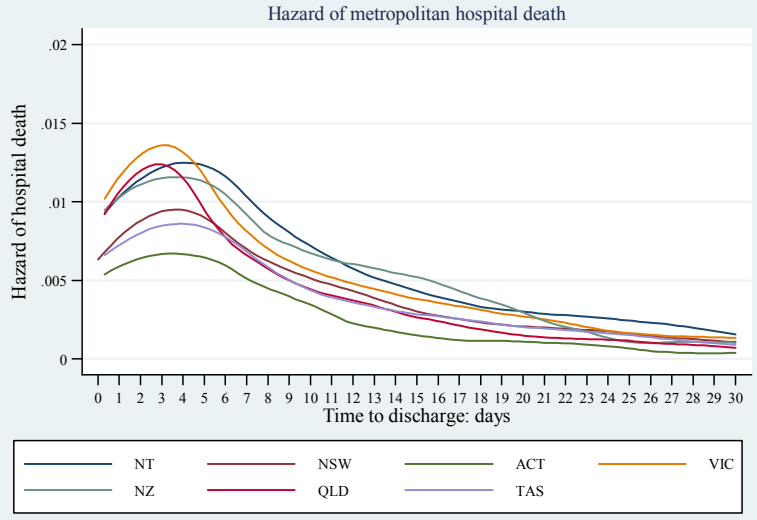


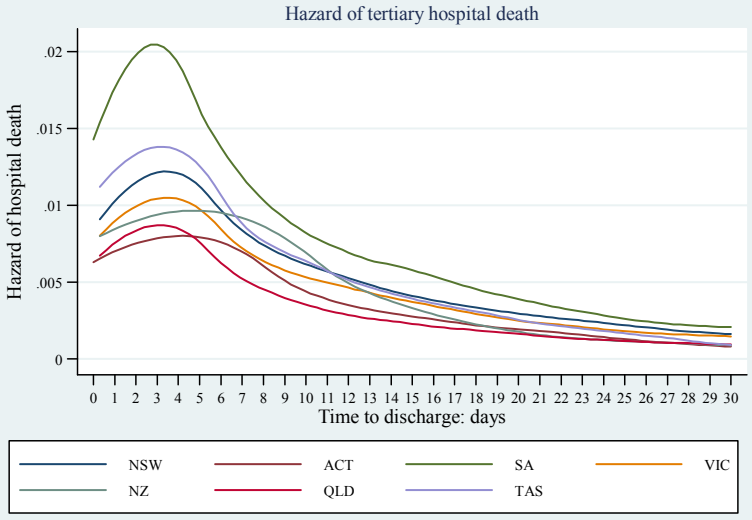


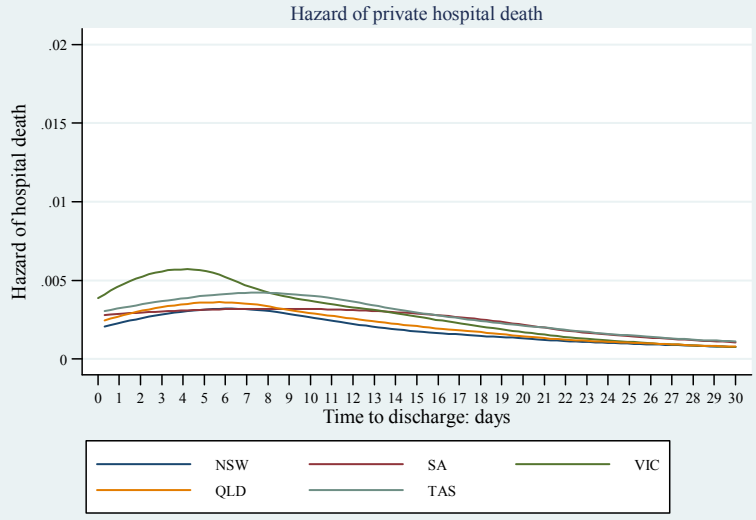


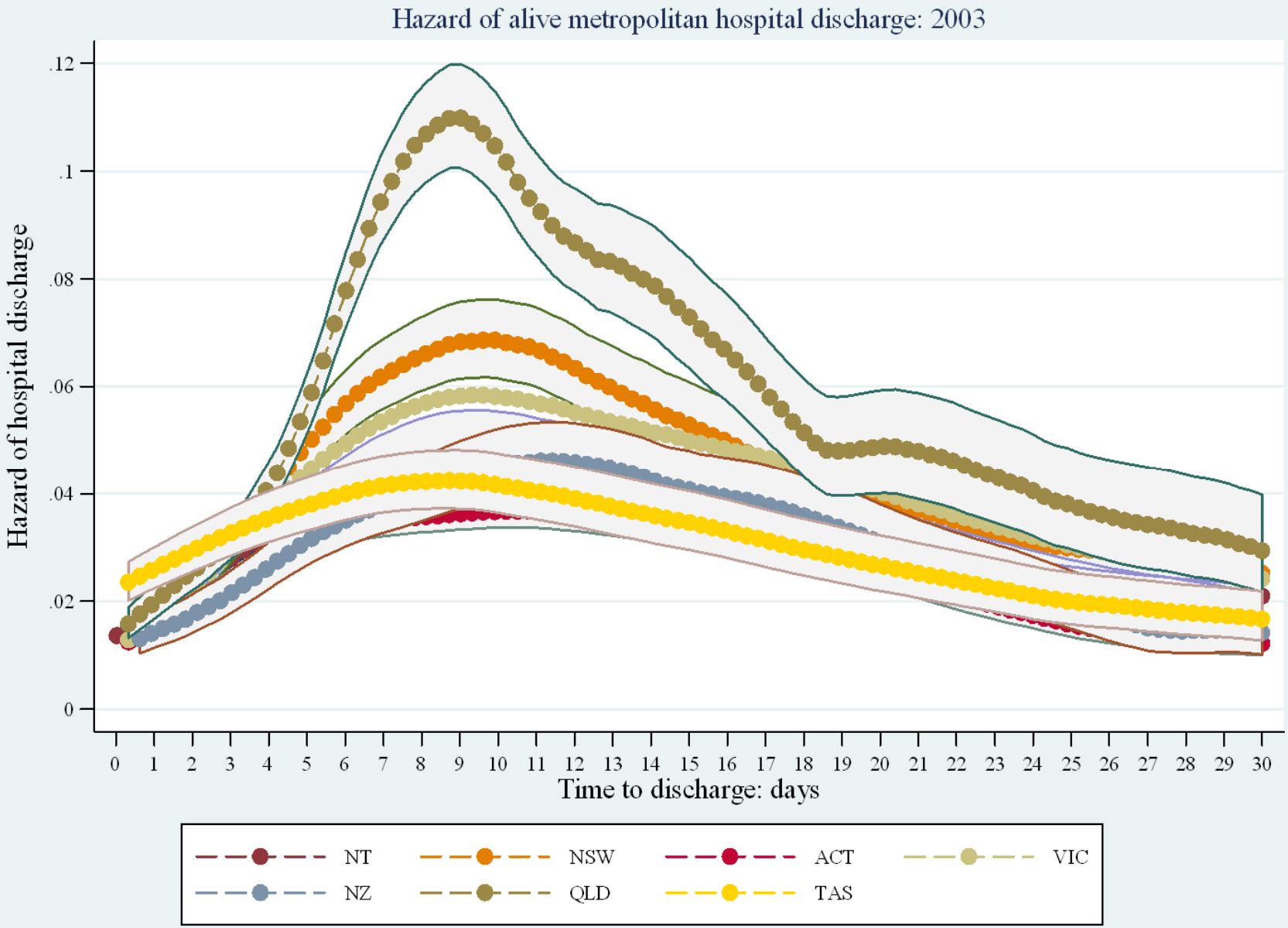
ANZICS hazard of death by hospital level










Hazard of alive metropolitan hospital discharge: 2003
Hazard of hospital discharge
.12
.1
.08
.06
.04
.02
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Time to discharge: days
NT
NSW
ACT
VIC
NZ
QLD
TAS

Pharmacokinetic measures to summarize hazard curves

Aim: find parametric distribution or similar to fit the smoothed hazard profiles

- the associated parameter estimates will serve as *indices of performance* of various descriptor units.

Use simple survival measures:

- time to peak hazard, TMAX
- area under curve, AUC
- peak hazard, CMAX
- 'elimination rate', KE.

Justification: a (random effects) first-order compartment model provides a reasonable fit to the data.

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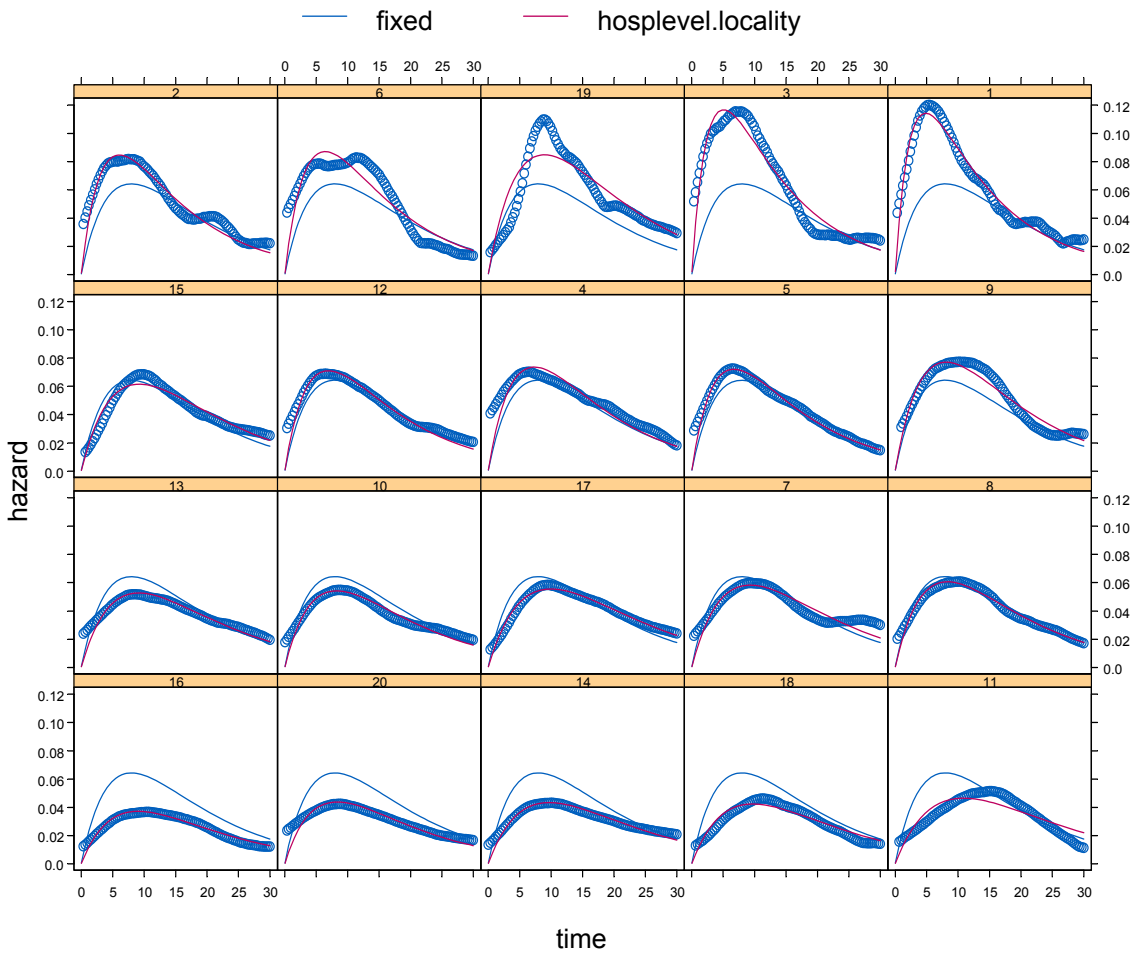
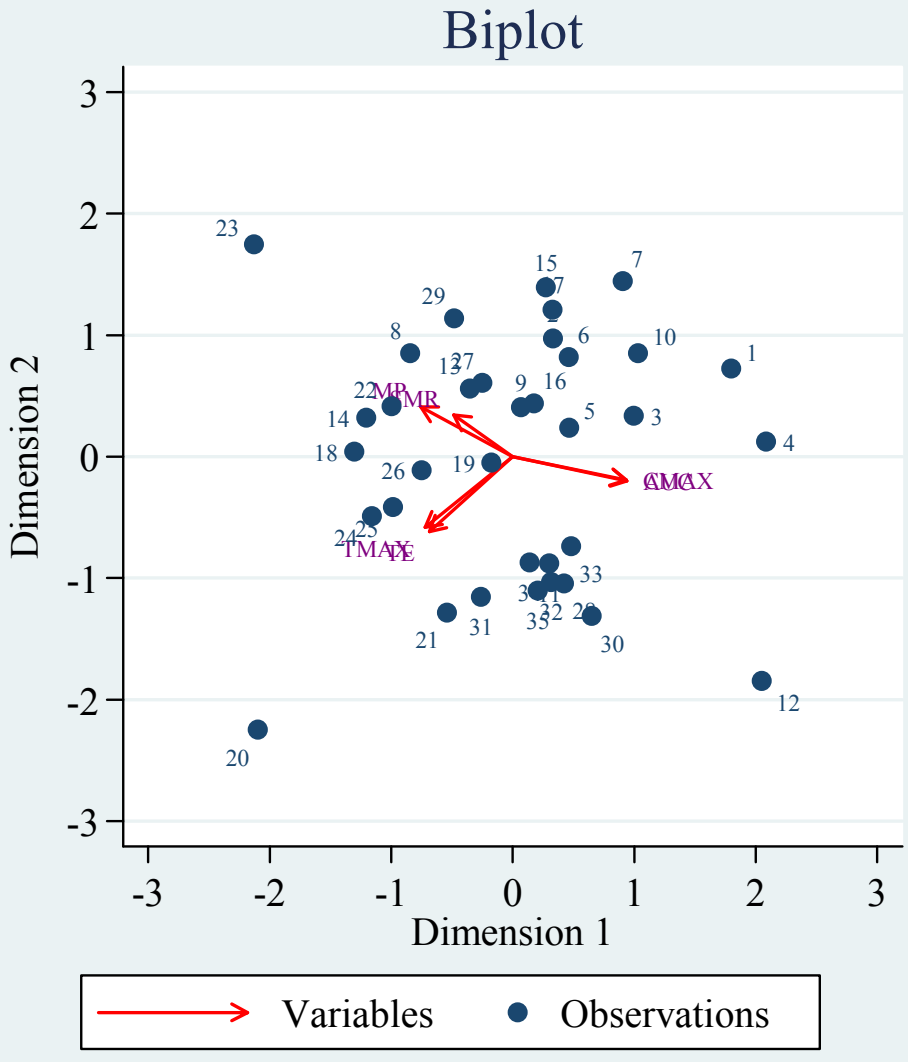
ANZICS survivors: SSfol

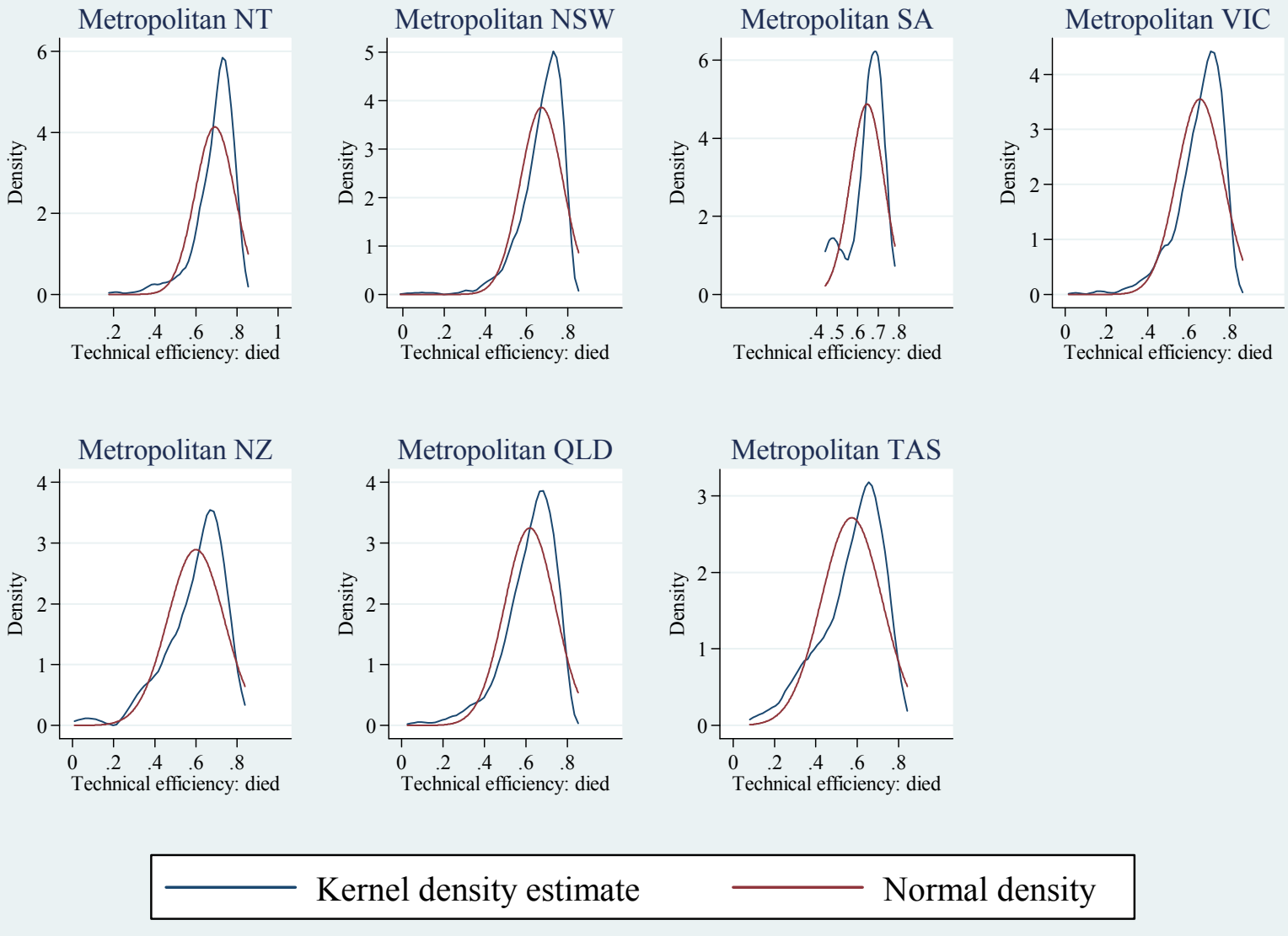
Hospital-level:locality (20 levels)



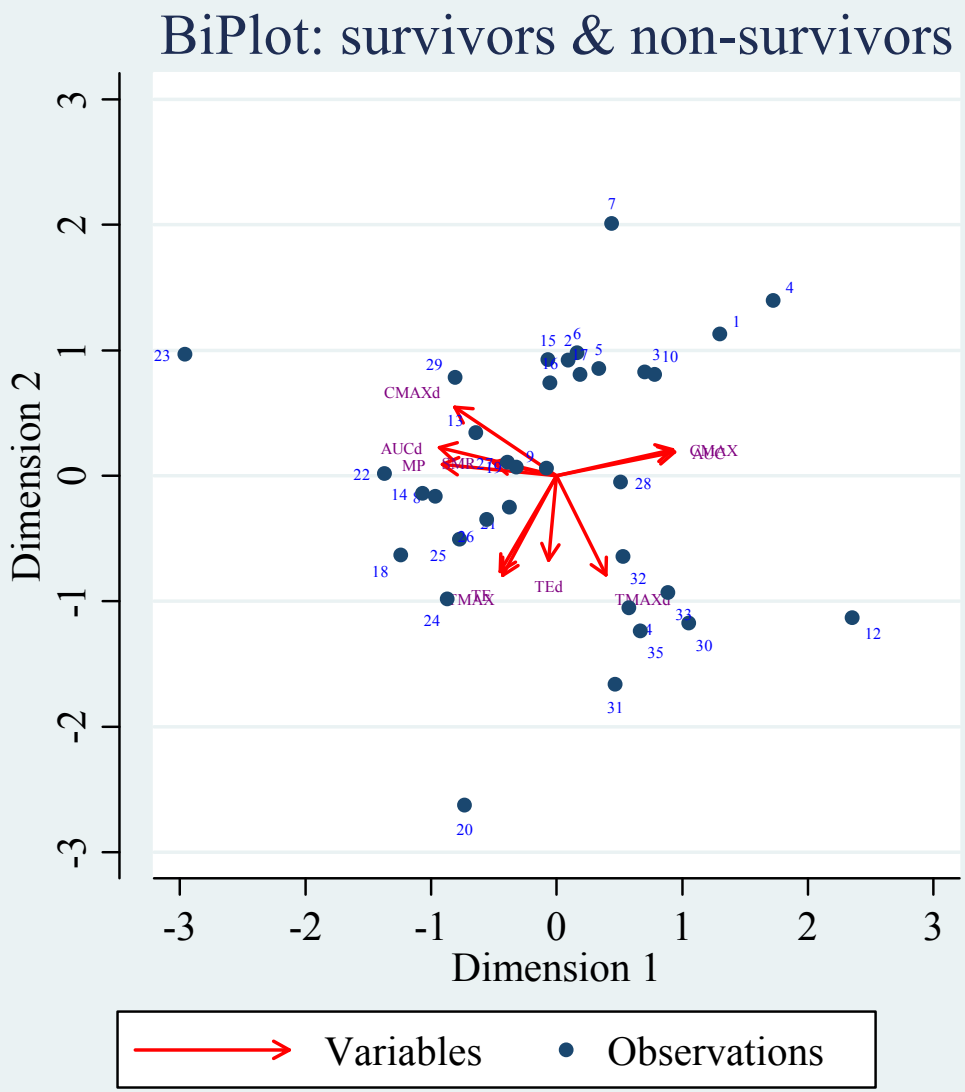
ANZICS survivors: mortality, TE and CLOS by hospital locality/level/size



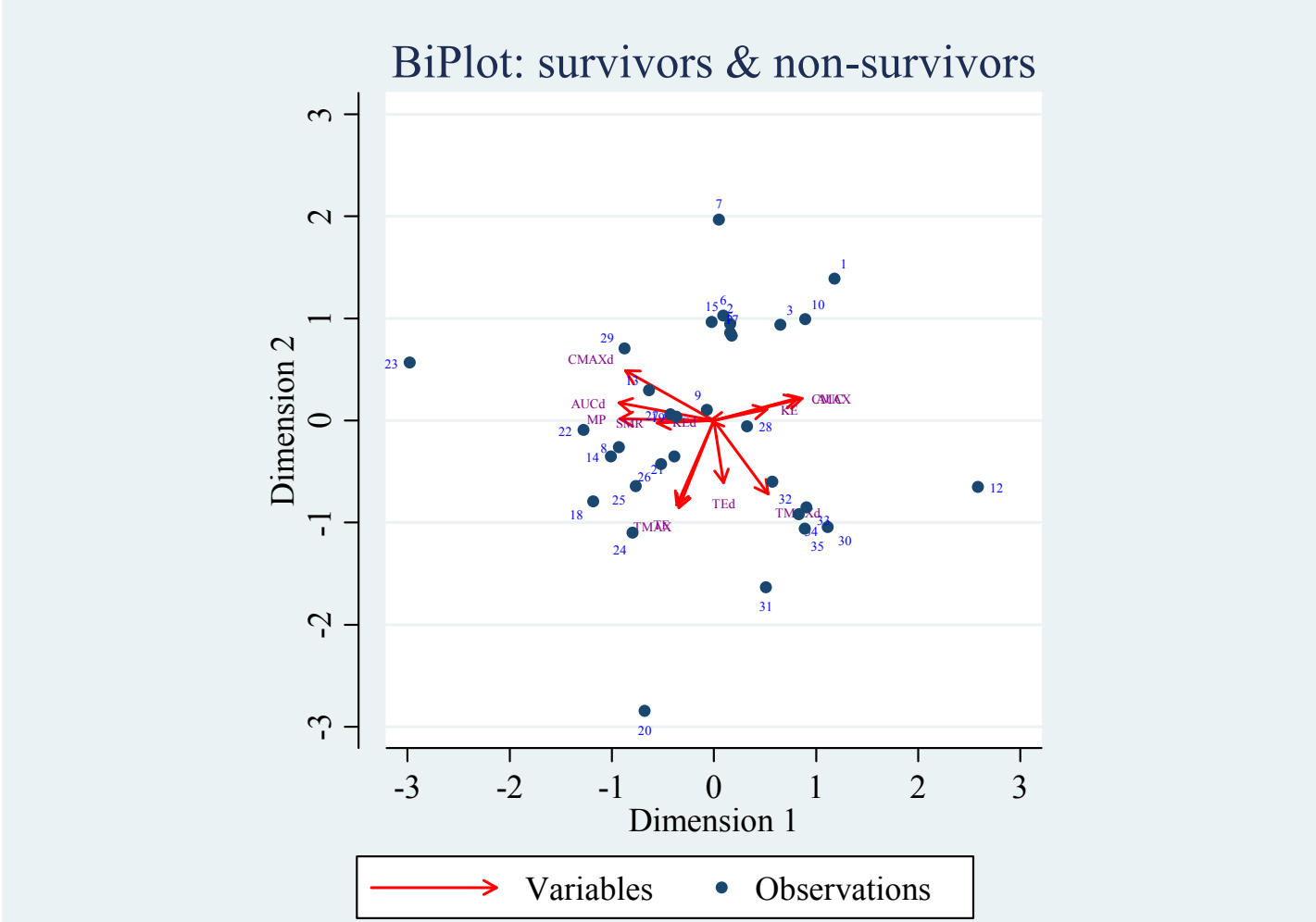
TE of deaths for metropolitan hospitals by locality



Survivors and non-survivors: mortality, TE and CLOS by hospital locality/level/size



Now adding KE by hospital locality/level/size



The future?

The 'third revolution' in medical care[15] dates back to Florence Nightingale in the mid-19th century in the UK and Ernest Codman in the early 1900s in the US[16].

Disquiet has been generated by the past and current publishing of mortality outcome data.

The establishment of quantitative indices of patient *process-of-care* may be a valuable complement to *mortality outcome*, both at the administrative and clinical level.

Our focus

- critically-ill patients within the ICU
- recognise patient groups in cardiac surgery, acute myocardial infarction, stroke, pneumonia and acute renal failure, where similar outcome endeavours have been established.

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[15] Relman Assessment and Accountability *NEJM* 1988

[16] Spiegelhalter 1999; Iezzoni 1996.

The future?

The 'third revolution' in medical care[15] dates back to Florence Nightingale in the mid-19th century in the UK and Ernest Codman in the early 1900s in the US[16].

Disquiet has been generated by the past and current publishing of mortality outcome data.

The establishment of quantitative indices of patient *process-of-care* may be a valuable complement to *mortality outcome*, both at the administrative and clinical level.

Our focus

- critically-ill patients within the ICU
- recognise patient groups in cardiac surgery, acute myocardial infarction, stroke, pneumonia and acute renal failure, where similar outcome endeavours have been established.

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[15] Relman Assessment and Accountability *NEJM* 1988

[16] Spiegelhalter 1999; Iezzoni 1996.