Institution: University of Exeter

Unit of Assessment: 10 Mathematical Sciences

Title of case study: Development of mathematical models for Practice based Commissioning budgets for adult mental health in the UK

1. Summary of the impact (indicative maximum 100 words)

Professor Trevor Bailey of the University of Exeter led the methodological and computational development of new improved mathematical models to more fairly allocate resources, and particularly mental health resources, to GP practices in the UK within an interdisciplinary research team from the universities of Plymouth, Southampton and St Andrews. The mental health services component of NHS Practice based commissioning (PBC) introduced by the Department of Health (DoH) from 2007 onwards, deals with resource allocation for specialist healthcare for some 400,000 patients with severe mental illness. From 2009 to 2011, the team's mental health estimates, based upon the modelling efforts of Bailey, were used to set practice-level PBC budgets accounting for around £8 billion of NHS funding, the DoH describing this as a 'step-change improvement' in how mental health needs are modelled.

2. Underpinning research (indicative maximum 500 words)

Resource allocation in the UK NHS since 2007 has been progressively determined via Practice based commissioning (PBC), a reform introduced by the Department of Health (DoH) aimed at more engagement of GP practices, clinicians and health professionals in local funding decisions. PBC groups now determine and design effective responses to local patient needs and allocate resources against competing service priorities. However, at a national level, the setting of PBC budgets must still accord with the core NHS principle that 'individuals in equal need should have equal access to care, irrespective of where they live'. This is problematic because sufficient information is not collected to directly measure need for healthcare in different local areas for different conditions (as opposed to demand or utilisation of those services). Traditionally, the basic assumption underlying NHS resource allocation has therefore been that utilisation of healthcare services can be used to determine need indirectly by modelling the relationship between utilisation and socio-economic variables whilst correcting for supply factors. Information on the level of such socio-economic variables in small areas (such as practices) can then be used to allocate resources in a way that reflects needs.

However, despite the sophistication of some of the modelling involved, the use of local utilisation data as a proxy for need clearly runs the risk of reflecting and reinforcing existing inequalities in the relationship between underlying healthcare needs and the resources allocated to address them. Various published studies, including work [2,3] by Dr Alex **Gibson** (University of Exeter until 2005), have presented evidence for such inequalities in NHS resource allocation in England and questioned whether existing utilisation is an appropriate basis upon which to set fair target allocations commensurate with 'equal opportunity of access for equal needs'.

Against this background and building on Gibson's earlier work at Exeter, in 2007 Trevor **Bailey** (Professor of Computational Statistics, University of Exeter since 1986) collaborated with Plymouths Professor Sheena Asthana (Health Policy), Dr Alex Gibson and Dr Paul **Hewson** (also University of Exeter 2000-2005), and others from the Universities of Southampton and St Andrews, to pioneer an innovative approach to resource allocation based on morbidity (epidemiological evidence) rather than solely utilisation data. Bailey and his Exeter team led on formulation and development of the statistical modelling and computational aspects underpinning the work and Asthana and others involved in the team led on coordinating the health policy and data handling dimensions.

This team successfully won a tender in 2007 by DoH and National Institute for Health Services Research (NIHR) to undertake a feasibility study examining whether direct epidemiological

evidence could be used as a basis for setting health care capitations [4]. A key advantage of their novel approach to Person Based Resource Allocation (PBRA) was that it proposed directly modelling the relationship between morbidity and personal characteristics such as age, gender, ethnicity and socio-economic status, so largely circumventing the difficulty faced by utilisation-based approaches of having to disentangle legitimate need factors from illegitimate drivers of need associated with unmet need and supply-side factors. The need-based approach to PBRA developed during the feasibility study rested on a modelling framework formulated by Bailey which merged two separate methodologies. First, Bayesian modelling and population micro simulation techniques were used to generate estimates of the number of individuals experiencing designated categories of morbidity within the units to which resources are to be allocated. Second, estimates of the resource required by each of those individuals in order to meet their health care needs were developed either on the basis of national average historic use, or normative tariffs. A probabilistic approach was adopted throughout. Thus, all estimates produced were expressed not in terms of "averages" but in terms of 95% or 99% "Credible Intervals" whereby all of the uncertainty in the modelling was retained and made explicit. More detail on the results is given in Section 4.

Having shown their need-based PBRA approach to be feasible, the team was then commissioned in a subsequently funded research project to use their casemix modelling approach on more recent data to develop the PBC formula for the difficult area of Mental Health [5]. In a highly computational study using multi-processor MCMC algorithms devised by Bailey and Hewson, the probability of individuals falling into six mental health casemix groups was estimated from multinomial, multi-level Bayesian models fitted to some 40,000 HSfE data records and then applied to several million micro-simulated sub-populations within some 8,500 GP practices nationally The resulting needs estimates were then combined with resource needs for each group and aggregated to give the resource allocation for adult mental health for each individual practice.

These results were then used by the DoH in national resource allocation for mental health services in 2009-2011 as described more fully in Section 4. An account of the work was published in the Journal of Health Services Research Policy in 2011 [1].

3. References to the research (indicative maximum of six references)

Evidence of the quality of the research that underpins this case study is provided through the following peer-reviewed publications and grants secured through competitive funding sources.

[1]**Asthana S, Gibson A, Hewson P, **Bailey T**, Dibben C. (2011). General practitioner commissioning consortia and budgetary risk: evidence from the modelling of 'fair share' practice budgets for mental health, *J Health Serv Res Policy*, vol. 16, no. 2, 95-101.

[2]**Asthana S, **Gibson A,** Moon G, Brigham P. (2003). Allocating resources for health and social care: the significance of rurality, Health and Social Care in the Community, vol. 11, no 6, 486-493.

[3]**Asthana S, **Gibson A,** Parsons E. (1999). The geography of fundholding in southwest England: implications for the evolution of primary care groups, Health & Place, vol. 5, 271-278.

Key Supporting Grants

[4] S. Asthana, A. Gibson, **T. Bailey**, C. Dibbens. *The feasibility of developing an approach to Person Based Resource Allocation (PBRA) based on epidemiological data*. National Institute for Health Research (Policy Research Programme), 2007, £121,269.

[5] S. Asthana, A. Gibson, **T. Bailey**, C. Dibbens. *Developing a resource allocation formula at General Practice level based on individual patient characteristics (Person-Based Resource Allocation): Mental Health.* National Institute for Health Research (Policy Research Programme), 2008, £191,216.

** Papers that best indicate quality of underpinning research.

4. Details of the impact (indicative maximum 750 words)

Reporting directly to the DoH Advisory Committee on Resource Allocation (ACRA), Bailey and team successfully developed and implemented two different modelling frameworks during the feasibility study [4] referred to in Section 2. The first was aimed at acute specialities and illustrated in the project report [see evidence **item a**] through generation of GP practice based estimates of resource needs across England for the treatment of each of cardiovascular disease, endocrine/metabolic disease and diabetes. It involved modelling the log-odds of self-reported longstanding illness (LSI) in specific illness categories from individuals included in the Health Survey for England (HSfE) over a number of years. To do this Binomial multi-level Bayesian models including random effects and a range of individual, socio-demographic, socio-economic and geographical variables were employed. A computationally intensive micro-simulation of sub populations in each GP practice nationally was then generated using iterative proportional fitting applied to available OPCS small area census data tables. An age/sex/illness specific resource need distribution was then sampled for each sub-population from national historic costs drawn from the 'Hospital Episodes Statistics' (HES) dataset. Results were combined to derive an estimate of the total resource required to treat each condition within each GP practice.

The second approach pioneered by Bailey and the modelling team in the feasibility project study report [see evidence **item b**], and then subsequently refined in the second research project [5] referred to in Section 2 and its associated report [c], was aimed specifically at the difficult area of adult mental health. It sought to determine the probability that particular individuals will fall into one of a number of case mix categories based upon a classification of adult mental health care combining clinically agreed and coherent treatment pathways with iso-resource patient groups (i.e. groups of patients that make similar resource demands on the NHS). In order to implement this approach, adults in the HSfE are classified as having needs in five casemix mental health groups. Then, paralleling the modelling of the approach for acute specialties (except that a multinomial rather than binomial Bayesian hierarchical model is fitted), individuals' socio-demographic and other characteristics are related to their casemix category. This multinomial model is then applied to micro simulated sub-populations to obtain estimates of the number of people in each casemix category in each practice. Relative resource needs are attached to practices on the basis of national per capita costs within the casemix.

In **2009/10** primary care trusts in the UK spent £8.08 billion on secondary care mental health and an additional £8.37 billion in **2010/11** through PCB. The mental health component of PCB includes the Community Health Services budget for adult mental illness, child and adolescent psychiatry, forensic psychiatry and old age psychiatry. Services provided under the mental illness component include; continuing care, crisis teams, early psychosis intervention and hospitalisation.

In 2006, the department of health (DoH) released the PBC toolkit which was recommended for use in 2007 and is used by GPs and medical professionals to allocate resources to practices in the UK. In the period **2007-2009** results of the research described above were presented by Bailey and Asthana to the DoH Advisory Committee on Resource Allocation (ACRA) and influenced thinking in this group. ACRA was established in September 1997 as the successor body to the Resource Allocation Group (RAG). ACRA directly advises the Secretary of State for Health on the distribution of resources across primary and secondary care to ensure that these fully reflect local population need and operate as fairly as possible. Members include academics, NHS senior managers and GPs.

In **2009/10** the DoH implemented new changes to the toolkit [a] which included an entirely new methodology for the mental health component of the toolkit developed by Bailey and Asthana [see evidence **item b** and evidence **item c**]. It was described by the DoH in their PBC budget guidance for **2009/10** as *'The new methodology has undergone extensive testing by researchers and the department of health and we believe it provides a step change improvement in the way we model mental health need'*. In **2009/10** the model was used by PCTs, GPs and medical professionals

responsible for the practice based resource allocation to distribute £8.08 billion pounds worth of services for mental health.

In **2010/11** an 'improved' version of the methodology was implemented in the *Practice-based commissioning budget guidance for 2010/11* [evidence **item d**] which utilises a full multilevel model that separately captures individual and area-level effects. The new methodology was extensively tested by the Department of Health and was overseen by the advisory committee on Resource Allocations. According to the NHS *'Capturing both these effects makes the estimates more responsive to the needs of each practices population'*. Similarly in **2010/11**, the model was used to distribute £8.37 billion of primary care services for mental health. The National Audit Office's Cross-government landscape: Formula funding of local public services references the project [evidence **item e**] as having *'so far informed practice-based commissioning, and may also form the basis for allocations to clinical commissioning groups in the future'*.

According to the Chief Economist/Deputy Chief Analyst of the Department of Health, who is a member of ACRA [evidence **item f**]:

'It was Trevor Bailey who helped operationalize the new approach that did not rely on past utilization of service. This was particularly important for mental health where utilization data was patchy and represented the "old model" of service provision with over reliance on hospital inpatients. Trevor Bailey implemented an innovative approach based on directly observed morbidity indicators at individual level, rather than utilization at area level. This was known as Person Based resource Allocation (PBRA) and the technique was piloted in 2007 and successfully implemented in 2007/8. The highly computational technique using 40,000 Health Survey for England data records led to a new formula being used to set target allocations for £8bn of funding for mental health services for General Practice in 2009/10 and 2010/11, The new method, implemented by Trevor, proved to be practicable and had the added advantage that the resulting estimates of need included "confidence intervals" for different sized populations.'

5. Sources to corroborate the impact (indicative maximum of 10 references)

a. Department of Health Practice-based commissioning budget guidance for 2009/10 'Methodological changes and toolkit guide' References the research p.10. http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_094364

b. Asthana, S., Gibson, A., Bailey, T., Dibben, C., Hewson, P., Economou, T., Batchelor, D., Eastham, J., Craig, R., Scholes, S., Flowers, J., Jenner, D. *Person Based Resource Allocation (PBRA): The Feasibility of Developing a Need-Based Approach to PBRA*. Report to the Department of Health (Policy Research Programme). 2008. University of Plymouth. 118pp.

c. Asthana, S., Gibson, A., Bailey, T., Dibben, C., Hewson, P. Developing a Person Based Resource Allocation Formula for Setting Practice Level Mental Health Budgets: 2009/10 and 2010/11. Final Report April 2009. Universities of Plymouth, Exeter and St Andrews.

d. Department of Health Practice-based commissioning budget guidance for 2010/11 'Methodological changes and toolkit guide' References the research p.10 http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_111057

e. The National Audit Office. Cross-government landscape: Formula funding of local public services, July 2010 references research p.31 http://www.official-documents.gov.uk/document/hc1012/hc10/1090/1090.pdf

f. Letter of corroboration from Chief Economist/Deputy Chief Analyst, Department of Health who is a member of ACRA.