Hospital organisation, specialty mix and MRSA

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Policy HR/Workforce Management Planning Clinical		Estates Performance IM & T Finance Partnership working	
Document purpose:	The report is published for information		
ROCR ref:	n/a	**Gateway ref:**	9163
Title:	Hospital organisation, specialty mix and MRSA		
Author:	Department of Health		
Publication date:	18 December 2007		
Target audience:	n/a		
Circulation list:	n/a		
Description:	The report examines the factors behind the variation in MRSA rates between different hospitals.		
Cross ref:	n/a		
Superseded docs:	n/a		
Action required:	None		
Timing:	n/a		
Contact details:	Office of the Chief Analyst Room 558c, Skipton House Department of Health Skipton House 80 London Road London SE1 6LH		
For recipient's use:			

First published date

Published to DH website, in electronic PDF format only.
http://www.dh.gov.uk/publications

Executive summary

Almost 6,400 MRSA bacteraemias (bloodstream infections) were recorded in acute hospitals in England in 2006/07. These caused directly, or contributed to, hundreds of deaths, cost the NHS millions of pounds, and undermined patient confidence. However, the number of bacteraemias has recently been falling - by 13% since 2001/02. The ratio of MRSA bacteraemias to the number of admitted patients – the probability that a patient will acquire MRSA – has fallen steadily by 27% since 2001/2, and exceeds the decline in recorded cases because of rising admissions. Despite this decline, the variation in rates of MRSA between different hospitals remains high, and the aim of this paper is to understand the contribution of organisational factors that can help explain these variations in MRSA rates and how these relationships may have changed over time. A better understanding of the sources of these variations may help design and target policy interventions.

While a large literature studies patient-level or clinical risk factors associated with MRSA infection, there is less evidence regarding the impact of hospital-level characteristics, policies and performance on infection rates. We relate hospital MRSA rates to a variety of hospital characteristics that may be expected to influence infection rates. These include variables which are broadly within the control of individual Trusts (e.g. bed occupancy rates, cleanliness and the use of temporary staffing) as well as those beyond the immediate influence of Trusts (e.g. type, location and case mix of hospitals). We use data for all acute NHS Trusts in England from 2001/02 through 2005/06, given the unavailability of suitable individual level data. This paper does not, therefore, consider risk factors at the level of the individual patient. The methodology adopted has the advantage of being able to draw into a single framework many of the issues- both organisational and scientific- whilst the national scope of these data make the inferences of potential use in considering national level policy.

For several of the most important policy or performance variables- including levels of bed occupancy, hospital cleanliness and the use of temporary nursing staff- we find evidence of significant changes over time in their relationships with MRSA rates. In the early years of our analysis (2001/02 through 2003/04) each are significantly correlated with MRSA rates. Quantitatively, holding a large range of other factors constant, Trusts running at above 90% bed occupancy had MRSA rates more than 10% higher than those with bed occupancy below 85%. A Trust with twice the national average level of temporary nursing could expect an MRSA rate around 7% higher than average, all else equal, and a Trust with a cleanliness rating (as proxied by Patient Environment Action Team scores) 10% below the national average could expect an MRSA rate around 3% higher.

However, we find that each of these relationships is weaker and largely not statistically significant in recent years (2004/05 to 2005/06). Thus, Trusts with high bed occupancy rates, high levels of temporary nursing staff or low cleanliness scores no longer have significantly higher MRSA rates, other things equal. Simple tabular evidence helps provide a clear picture of these changes, showing, for instance, that hospitals with occupancy over 90% had, in 2006/07, MRSA rates little above those in Trusts with occupancy below 85%- in contrast to the period 2001-2004.

In one sense, the disappearance of these relationships is puzzling since there is evidence from various sources that factors such as high bed occupancy can make infection control more challenging, and the relationship was a robust one for the earlier period. One

possibility is that these factors *do* inherently make infection control more challenging but that Trusts have become significantly better in recent years at understanding and meeting these challenges.

Though it is difficult to test conclusively, a variety of policy initiatives may have played a role in recent years. The introduction, in 2004, of a high profile Government target for reducing MRSA (along with associated coverage in the media and research literature), may have provided a step change in focus and priority given to infection control. The Chief Medical Officer's report *Winning Ways,* in late 2003 emphasised the need for infection control teams to work effectively with bed managers and may thereby have provoked responses which served to lessen the link between bed occupancy, per se, and MRSA rates. Similarly, the *cleanyourhands* campaign, launched in late 2004, may have loosened the previously observed link between measured environmental cleanliness and MRSA. With respect to temporary staffing, measures such as the establishment of NHS Professionals and the NHS Employers Code of Practice sought to improve the quality, training and appropriateness of temporary staff, the achievement of which is consistent with our results.

A second explanation is that the Department of Health has, since 2004, targeted support to Trusts facing the biggest challenges in reducing their MRSA rates. There is evidence that Trusts which received earliest and most intensive support had the highest MRSA rates and were also more likely to have adverse bed occupancy, temporary staffing or cleanliness conditions. There is also evidence that Trusts receiving targeted support have reduced their MRSA rates more rapidly than average. This is again consistent with the results we observe. By targeting the high MRSA rate hospitals, the links from the most adverse structural circumstances to MRSA have perhaps been weakened.

It is important that these results should not be seen as grounds for complacency in tackling issues such as high bed occupancy, hospital cleanliness and the unnecessary use of temporary staffing. There are good reasons for tackling each on grounds other than infection control. In addition, while it appears that Trusts have become better at managing these challenges in recent years, it is recognised this has been achieved in a climate of unprecedented support and performance management.

Beyond these key policy variables, we find evidence that a variety of variables relating to Trusts' case mix, type and location are significant in explaining their MRSA rates. Other things equal, MRSA rates are consistently higher in specialist Trusts and lower in single specialty Trusts. Rates are higher in Trusts who treat older and relatively more male patients and those whose activities are disproportionately focussed on certain clinical specialties.

The location of the trust within England is found to be a significant factor in determining MRSA rate for reasons which are not well understood. In particular, Trusts in London are found to have significantly higher MRSA rates than other regions, other things being equal, though the gap seems to have narrowed in recent years. This effect is over and above differences between London Trusts and those elsewhere in other observable variables- for example, higher use of temporary nursing staff and a greater concentration of specialist hospitals. SHA regions with relatively low rates of MRSA, other things equal, are the East Midlands, North East, South Central and Yorkshire and the Humber.

Introduction

1. The aim of this paper is to investigate factors associated with Trust-level differences in MRSA rates, how these factors may have changed over time and the implications of these results for current and future policy.

2. It begins by summarising the medical context and proceeds to précis the nature and scale of the problem of MRSA in English hospitals. We next outline potential drivers of variations in MRSA rates before setting out the data and methods employed in this paper. We then present and discuss a summary of our results, ending with a concluding discussion. This paper is written for a lay audience. In accompanying annexes, we set out more technical and statistical details on our results.

Context

3. There were 6,381 meticillin-resistant *Staphylococcus aureus* (MRSA) bacteraemias (bloodstream infections) recorded in NHS acute Trusts in England in 2006/07. The exact human and financial cost of these is unknown but it is thought that MRSA contributes to or directly causes many hundreds of deaths each year and costs the NHS tens of millions of pounds[1]. All healthcare associated infections (HCAIs) combined cost at least £1bn per year and are thought to cause at least 5000 deaths annually. In addition, patient and public confidence in the NHS are undermined, affected patients' hospital stays are extended and consequently other patients may wait longer for treatment than would otherwise be the case.

4. *Staphylococcus aureus* (SA) are bacteria commonly carried on the skin (usually in the armpit or groin) or in the nose of healthy people. Around 30% of the general population is carrying SA bacteria at any one time[2]. This percentage is higher for hospital patients because they are more likely to be in contact with other carriers. SA bacteria can cause infections, many of which are relatively minor, such as pimples and boils, and can be treated easily with antibiotics.

5. However, SA bacteria can also cause serious infections such as surgical wound infections and pneumonia. In the past these serious infections were typically treated with penicillin or other related antibiotics. In the last few decades, however, treatment of these SA infections has become more difficult because some SA bacteria have become increasingly resistant to antibiotics. These bacteria became resistant first to penicillin and then meticillin. These resistant bacteria are called meticillin-resistant *Staphylococcus aureus* or MRSA. Around 3% of people in the general population are asymptomatically carrying MRSA bacteria at any time[3].

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[1] Analysis of death certificates by the Office for National Statistics suggests that MRSA was mentioned on around 1,600 death certificates in England and Wales in 2005. In around 470 cases MRSA infection was recorded as the underlying cause of death.

[2] http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4113886

[3] http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4113886

6. MRSA infections can occur to anybody in any setting but are by far most common in hospitals and other health care facilities. They primarily arise in hospitalised patients who are elderly or very sick or who have an open wound (e.g. a bedsore), have a tube going into their body (such as a urinary or intravenous catheter) or are immuno-suppressed.

7. MRSA is thought to be commonly spread through people having close contact with infected or colonised people and inadequate hand hygiene by healthcare workers is believed to be an important cause. However, MRSA infections can also be caused by "auto-infection", whereby people carrying MRSA on their skin can inadvertently become infected through the spread of those bacteria into their body, including the bloodstream. This can occur, for example, via devices such as catheters and intravenous lines. MRSA is almost always spread through physical contact, rather than through air or water.

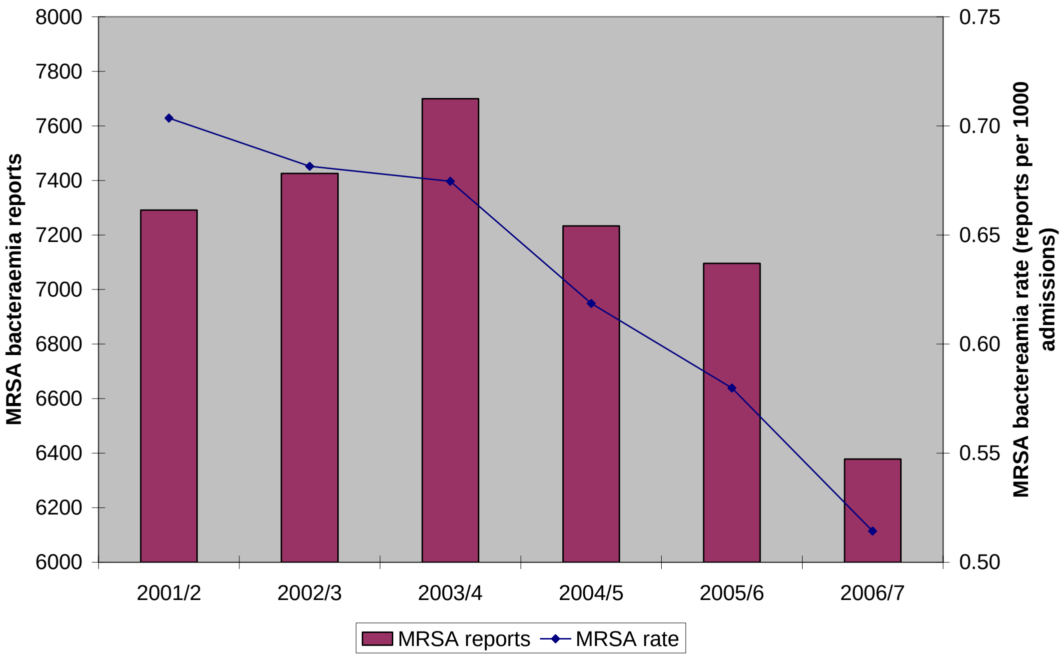
8. Acute NHS Trusts in England have, since 2001/02, been subject to a mandatory MRSA reporting scheme[4]. The scheme collects data on MRSA bacteraemia infections, but not on other types of MRSA infections. Bacteraemia (or bloodstream) infections occur when MRSA enters a normally sterile blood stream through either an intravenous catheter or a local site of infection (e.g. a wound, ulcer, or abscess). A bacteraemia describes the presence of MRSA in the bloodstream.

Nature and Scale of the Problem

9. In 2006/07, there were 6,381 MRSA bacteraemia infections in English acute hospitals, representing a reduction of around 12.5% since 2001/02. Figure 1 below shows the number of MRSA bacteraemia reports and rates (number of reports per 1000 hospital admissions) for each of the years since mandatory reporting began in 2001/01. We observe (in the solid bars) a rise in MRSA reports between 2001/02 and 2003/04 before a sharper fall in the past three years. However, the MRSA rate has fallen in each of the last five years, even in years in which MRSA reports were increasing. Overall, the MRSA rate, which can be thought of as the probability of a patient admitted to hospital acquiring an MRSA bacteremia, has fallen by around 27% since 2001/02, a more rapid reduction than that in reports. This reflects that the decline in reports has been accomplished despite steady growth in admissions.

[4] See http://www.hpa.org.uk/infections/topics_az/staphylo/staphylo_mandatory_surveillance.htm for further details. Data are also collected on meticillin sensitive *Staphylococcus aureus* (MSSA) infections.

Figure 1- MRSA reports and rates from 2001/2-2006/7[5]

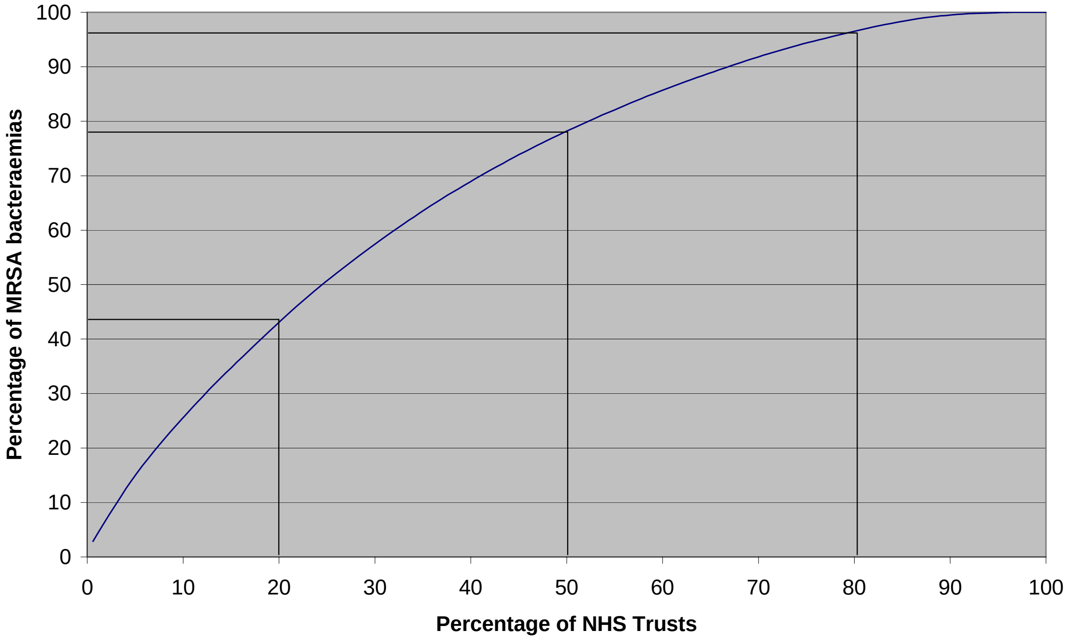


NB The solid bars indicate the raw number of MRSA bacteraemias. The thin line represents the number of MRSA bacteraemias per 1000 inpatient hospital admissions. Put differently, it reflects the likelihood that a given patient being admitted to hospital will become infected with an MRSA bacteraemia.

10. MRSA infections are not spread evenly between hospitals. Figure 2 below plots the cumulative number of MRSA cases), where Trusts are ranked in descending order of MRSA reports. Thus, we observe that one fifth of Trusts account for almost 50% of all MRSA cases and just below 80% of all MRSA cases are concentrated in around 50% of hospital Trusts. The 20% of Trusts with fewest MRSA infections account for only 5% of the national total.

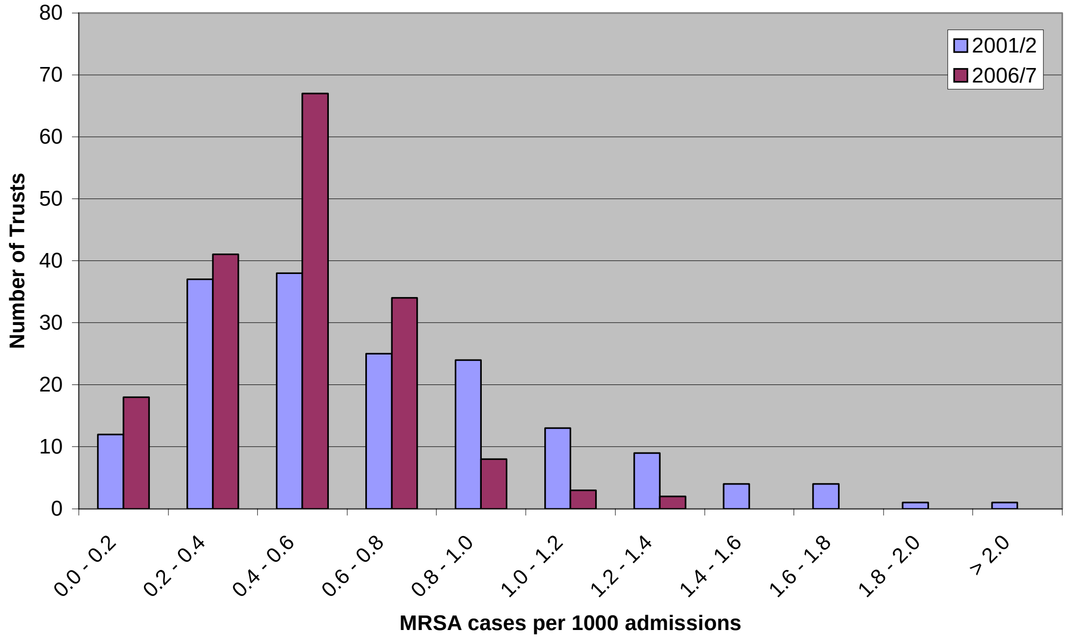
[5] Admissions data for 2006/7 have not yet been published, so all 2006/7 MRSA rates use 2005/6 admissions data.

Figure 2- Cumulative Frequency of MRSA Cases (2006/7)



11. Though one might expect the number of MRSA cases to vary according to the size of the hospital, expressing MRSA cases as a rate per 1000 admissions still shows a large amount of variation between Trusts. Figure 3 shows variation in the number of MRSA cases per 1000 admissions for both 2001/02 and 2006/07. We see that there remains a high degree of variation in MRSA rates, though by 2006/07 there has been compression at the top end of the distribution with fewer hospitals reporting very high rates and no Trusts reporting more than 1.4 cases per 1000 admissions.

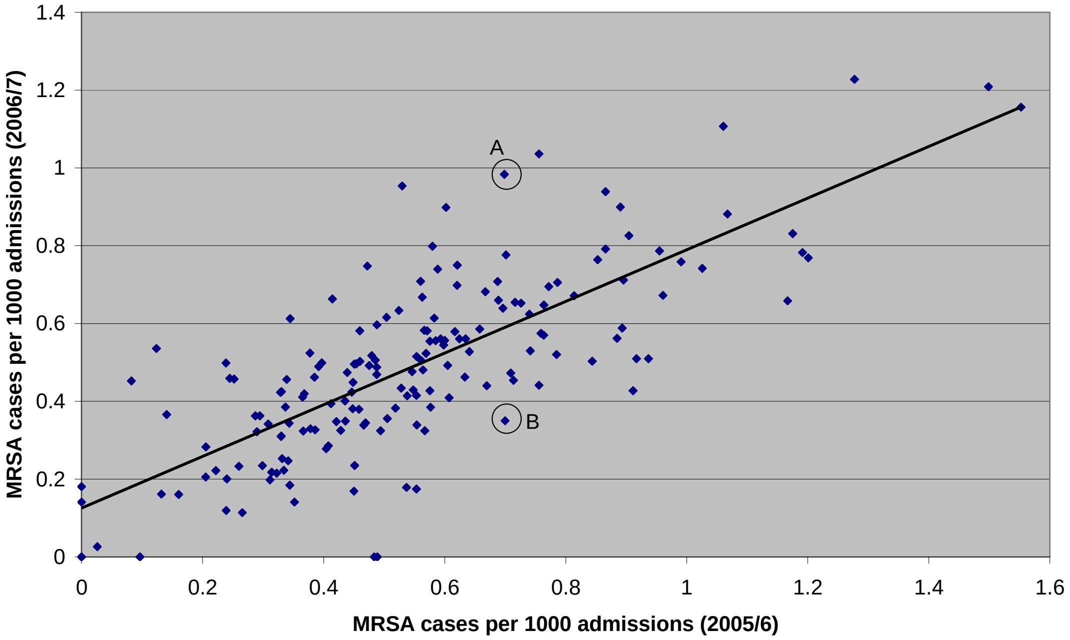
Figure 3- Variation in Trust Level Rates of MRSA Per 1000 Admissions (2001/02 and 2006/07)



12. The pattern of MRSA rates across hospitals also exhibits significant persistence over time. Figure 4 below plots Trust-level MRSA rates in both 2005/6 and 2006/7. For example, Trusts A and B both had an MRSA rate of around 0.7 per 1000 admissions in 2005/6. In 2006/7, Trust A's rate increased to around 1.0, while Trust B's fell to around 0.35. In general, we find a significant positive correlation, implying that variations in MRSA rates between hospitals are persistent over time- if a hospital has a high rate of MRSA in one year it is likely to have a high rate in the next year and vice versa[6].

[6] This pattern of persistence is similar when every year is compared with every subsequent year. The results are not shown here in the interests of brevity.

Figure 4- Persistence of MRSA Rates



Analysis

13. This paper analyses the variations in MRSA rates between acute Trusts and over time that we outlined above. It seeks to identify the major drivers of these variations and how these may have changed over time.[7] It also begins to assess possible underlying explanations and to examine policy implications of these results.

14. In the absence of appropriate individual level data which give evidence on both individual and hospital characteristics, the analysis is based upon Trust-level data and focuses on "macro" level or organisational factors (those which may determine susceptibility of particular hospitals to MRSA) and clinical specialty mix of different hospitals. As such, it treads challenging ground at the interface between biological and organisational drivers of infection. It seeks to analyse systematically a large number of potential drivers of infection rates at the hospital Trust level and searches for evidence of the relative importance and statistical significance of each.

15. Since we do not have individual level data, it does not consider patient specific factors nor does it examine different medical methods within specialties. The methodology was not designed for and should not be used to draw inferences at the individual patient level but it can, nevertheless, be of value in guiding where those influences might most productively be investigated.

[7] In this analysis we do not explore the possibility that variation in MRSA rates is caused by differences in reporting as opposed to true variation, although various forms of under-reporting will leave the conclusions unaffected.

16. The analysis is based upon five years of Trust-level data (2001/02 to 2005/06)[8], which have been explored in a variety of ways to test whether and how relationships may be changing over time[9].

17. Potential drivers of MRSA were selected on the basis of prior evidence in the literature, expert opinion and clinical judgement. The methods adopted to measure these drivers are discussed in more detail in the next section.

18. For a technical account of the model specification refer to Annex A.

Potential Drivers of MRSA- Rationale and Evidence from Other Studies

19. While a voluminous literature exists regarding patient-level or clinical risk factors associated with MRSA infection- and HCAI more widely- there is much less evidence regarding the impact of hospital-level characteristics, policies and performance on infection rates.

20. In assessing these types of variables, a broad distinction can be drawn between those policy or performance variables which are, to a greater or lesser extent, within the control of individual hospital Trusts (such as bed occupancy, relative staffing levels, cleanliness, the use of temporary staff and the availability of single rooms and isolation facilities) and those which are essentially beyond their immediate control (for example, their location, casemix, hospital type and hospital size).

21. We now discuss some of the key explanatory variables included in the analysis, their rationale and hypothesised relationships with infection rates and existing pertinent evidence from the literature[10].

Policy and Performance Variables

<u>Bed Occupancy</u>

22. High levels of bed occupancy may potentially impact upon infection control in several ways. Firstly, they will tend to increase the proximity of patients and increase the risk of direct and indirect patient-to-patient contact. They may also make it more difficult to clean thoroughly between patients or to leave beds "fallow" for a period following their occupation by an infected patient. High occupancy may also make it more difficult to isolate patients when there is an outbreak of infection, thereby increasing the risk to other patients. Finally, they may also increase the frequency with which patients are moved around a hospital, thus increasing indirect contact between patients and increasing the risk of inappropriate mixing of high risk and low risk patients.

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[8] 2006/07 is not yet included since although MRSA data are available for 2006/07, not all other variables in the dataset are yet available.

[9] Not all variables are available for each year. Where data were unavailable for a particular year they have been assumed to be the same as a previous or subsequent year or have been estimated by simple extrapolation

[10] This is intended as a short summary of the pertinent issues rather than a detailed or exhaustive literature review. Annex D includes a full list of all variables included in the analysis, along with details of their derivation and sources.

23. Cunningham et al. (2005) and Cunningham et al. (2006) found that high bed occupancy rates and turnover intervals are associated with MRSA rates in Northern Irish hospitals and English Hospitals respectively[11]. Bed occupancy in Northern Irish hospitals was found to have a significant correlation with MRSA rates in 2002/03 but not 2001/02. Cunningham et al. (2006) found a significant correlation between bed occupancy and MRSA rates in specialist English hospitals. Borg (2003) found a significant positive correlation between bed occupancy rates and MRSA rates in a 24-month assessment in a Hospital in Malta.

24. More recently, work by Fenn et al presented at the Royal Economic Society conference of 2007 found a positive relationship between bed occupancy levels and MRSA rates, using data from 2001-2005.

25. We are not, however, aware of any work which has sought to test separately the different underlying mechanisms- that we outlined above- that might explain a link between bed occupancy rates and infection.

26. Both Cunningham et al. (2006) and Borg (2003) suggest that high bed occupancy may affect MRSA rates through increased workload serving to reduce hand hygiene compliance amongst staff. In our multivariate analysis, we separately control for relative medical and nursing staffing levels (per occupied bed day) which implies that any residual relationship between occupancy and MRSA must be due to mechanisms other than an effect on workload and hand hygiene compliance.

27. We have tested the link between bed occupancy and MRSA in a variety of ways, in particular exploring whether there is a non-linear relationship between occupancy and MRSA rates. For example, we have tested whether there is a relationship at all levels of occupancy of whether the link appears only when occupancy rates become high. We have also tested whether the significance of any relationship becomes more pronounced at high levels of occupancy.

<u>Single Rooms</u>

28. It has been hypothesised that the availability of single rooms and/ or isolation facilities may affect infection rates by reducing direct and indirect contact between patients and by making it easier to isolate vulnerable or infected patients.

29. Wilcox and Wigglesworth (2006) found a positive relationship between isolation failures (i.e. when a patient was requested to be isolated but this did not occur) and the MRSA rate. However, their study also found that only 19% of single-bedded rooms were actually used for isolation purposes.

30. Jorge et al. (2005) compared the results of isolating or cohorting patients with not isolating them in the intensive care units of two London teaching hospitals over a one year period. They found that patients who were not isolated did have higher MRSA rates but not significantly higher.

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[11] Turnover interval is defined as the average length of time a bed remains unoccupied between admissions. This variable has not been used in this study as it has a linear relationship with bed occupancy and Average length of stay variables that we employ.

31. In our analysis, the variable we use is the proportion of total beds in each Trust that are provided in single rooms. Since, as noted above, there is evidence that most single rooms are not used for isolation purposes, we may not therefore expect to see a straightforward relationship between the availability of single rooms and infection rates.

Cleanliness

32. The potential link between environmental cleanliness and MRSA is a contentious one. Green et al. (2006), using data from English hospitals for 2001-2005, found that there is no consistent simple bivariate correlation between cleanliness measured by PEAT (Patient Environment Action Team) scores and incidence of MRSA. They also found a lack of evidence regarding the impact of the inanimate environment and MRSA incidence (which Dancer (1999)[12] conversely found to be significant). They question the reliability of PEAT scores in accurately rating hospitals' cleanliness as they are subjective and may not reflect microbiological cleanliness.

33. Many articles cited in a literature review by Murphy (2002) suggest that there may be an association between physical cleanliness and healthcare acquired infection (HCAI). Papers by Griffiths et al. (2000)[13] and Health Canada[14] claim that MRSA can be prevented with proper cleaning procedures of both the physical environment and staff hands. Dancer (1999)[15] found that in addition to reduced staffing levels in the NHS the 'contracting-out of hospital cleaning surfaces has further contributed to falling standards'. Marshal (1999) concurred with Dancer, claiming that contracting out lead to a poorer level of cleaning and higher infection rates. Collins (1988)[16] suggests a reason for this could be that extra cleaning was relatively easy to do with in house cleaners but contract cleaners are often less flexible, have strict working hours and therefore extra cleaning is harder to achieve.

34. Indisputably, irrespective of any direct scientific link between cleanliness of the hospital environment and HCAIs, it is clear that hospital cleanliness is of utmost importance for patients, their families, NHS staff and the public at large.

35. We test the effect of several explanatory factors relating to cleaning and cleanliness, relating to both "inputs" and "outputs":

(i) Expenditure on cleaning services (normalised by the size of hospital, as measured by occupied floor area)

(ii) The extent to which cleaning services in each Trust are contracted out

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[12] Dancer, S.J., (1999), " Moping up hospital infection". *Journal of Hospital Infection,* Vol. 43 p.85-100. (cited in Green et al. (2006))

[13] Griffith, C. J., Cooper, R.A., Gilmore, J., Davies, C., and Lewis, M. (2000). An evaluation of Hospital Cleaning Regimes and Standards. *Journal of Hospital Infection.* Vol. 45, p19-28. p.25 (Cited in Murphy (2002)).

[14] Health Canada (1998), "Supplement Infection Control Guidelines: Handwashing, Cleaning, (cited in Murphy 2002) Disinfecting and Sterilization in Health Care" *Canada Communicable Disease Report 24S8.* Dec. p31. (Cited in Murphy 2002).

[15] Dancer, S.J., (1999), " Moping up hospital infection". *Journal of Hospital Infection,* Vol. 43 p.85-100 (cited in Murphy (2002))

[16] Collins, B.J., (1988), "The Hospital Environment: How Clean should a hospital be?", *Journal of Hospital Infection,* Vol. 11 p53-56).

(iii) PEAT scores for hospital cleanliness, as published by the National Patient Safety Agency[17]

Temporary staffing

36. It has been hypothesised that Trusts with a greater reliance on temporary nursing staff might have higher rates of MRSA. Firstly, temporary nurses might be less conversant with local hand hygiene and other infection control procedures. Another possible mechanism is that temporary staff may move around more, both within and between hospitals, implying higher numbers of patient contacts per nurse and thus increased potential to spread bacteria. This may be particularly relevant in urban areas where many hospitals are close together and hence temporary staff are more likely to move within a day between hospitals. Thirdly, patients on wards with temporary staff may come into contact with more staff since temporary nurses often work shorter shifts than permanent nurses do.

37. We construct Trust-level estimates of the total proportion of nursing input that is accounted for by temporary staff (both agency and bank) in order to test the relationship between the use of temporary nurses and MRSA rates. As far as we are aware, no other studies have previously attempted to explore this relationship quantitatively.

Quality of Physical Environment

38. An older, lower quality physical environment is hypothesised to increase MRSA rates since it will make cleaning more difficult, might contribute to the persistence and spread of bacteria and might necessitate greater movement of patients around the hospital.

39. As a proxy for quality of the physical environment we use a measure of backlog spend required to allow the Trust to meet category B physical condition and health and safety standards (normalised by hospital size, as measured by occupied floor area).

Relative Staffing Levels- Overwork

40. Hand hygiene is known to be a major factor in the spread of infection in hospitals. Since systematic data on hand hygiene compliance are not available at Trust level, we test whether the numbers of nurses and consultants (relative to activity) appear to be correlated with MRSA. The hypothesis is that lower relative staffing levels, and thus potentially understaffing, might reduce hand hygiene compliance due to time pressure and hence lead to higher levels of MRSA.

41. There is some evidence in the literature to support this view. Karabey et al. (2002) observed hand-washing frequency in an Istanbul hospital's intensive care ward. They found that the incidence of hand-washing after contact that required it was 15% among nurses and 0% among doctors. They suggest that the high staff-

[17] It is recognised that PEAT scores are not a scientific measure of cleanliness and that PEAT scores also include wider environmental elements than simply "cleanliness". They are, however, the best available Trust level proxy measure for hospital cleanliness. Given the ongoing controversies about the true importance of cleanliness in preventing healthcare associated infections, it might be desirable to consider developing more accurate and scientific measures of hospital environmental cleanliness.

patient ratio may be the cause of the low compliance with hand hygiene procedure. Borg (2003) cites a paper by Vicca (1999) which claims that there is a significant relationship between nurse understaffing and MRSA spread.[18] Henderson (2006) cites Grundmann et al (2002)[19] who also found a significant relationship between staff deficits and potential transmission of MRSA.

42. In order to test the link between staffing levels and MRSA rates we use two variables: the number of nursing staff and the number of consultants (both normalised by the total number of occupied bed days[20]).

Variables Relating to Hospital Characteristics and Casemix

Hospital Type

43. It is well established that certain types of hospitals have lower rates of MRSA (e.g. single specialty Trusts) while others have higher rates than average (for example, specialist hospitals)[21]. Specialist hospitals[22] are likely to see a more complex casemix with more co-morbidities and perform more complex invasive procedures, which the case mix controls we adopt may not fully account for. Similarly, single specialty Trusts tend to be in particular specialties (e.g. ophthalmology, mental health) which generally see a less susceptible casemix and perform less invasive procedures.

44. In order to test the quantitative differences in MRSA between different Trust types (other things equal), we include dummy variables relating to specialist (tertiary) Trusts and single specialty Trusts. We also explore the robustness of our key findings by running the analysis on general acute Trusts only.

Space

45. It might be expected that hospitals with larger amounts of floor space per patient might have lower rates of MRSA because larger distances between patients are believed to make transmission of bacteria more difficult. Kibbler et al. (1998) found that extra beds in ward bays of a London hospital reduce the physical space between beds and found twice as many MRSA cases in a five-bedded medium dependency ward compared to a similar four-bedded ward. They controlled for the nursing levels by increasing these in wards with more beds.

46. We test the relationship between floor space and infection by correlating occupied floor space (in square metres) per available bed with MRSA rates[23].

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[18] Vicca, A.F., (1999) "Nursing staff workload as a determinant of meticillin-resistant Staphylococcus aureus spread in an adult intensive therapy unit. *Journal of Hospital Infection,* Vol. 43, p109-113.
[19] Grundmann, H., Hori, S., Winter, R., Tami, A., and Austin, D.J., (2002) "Risk Factors for the Transmission of Meticillin-Resistant Staphylococcus Aureus in an Adult Intensive Care Unit: Fitting a Model to the Data." *The Journal of Infectious Diseases,* Vol. 185, p 481-8. (cited in Henderson).
[20] Occupied bed days are used as they are considered a good proxy for total workload.
[21] See, for example: http://www.dh.gov.uk/PublicationsAndStatistics/Publications/PublicationsStatistics/PublicationsStatisticsArticle/fs/en?CONTENT_ID=4085951&chk=HBt2QD
[22] Large hospitals which usually provide teaching and regional specialist services.
[23] Occupied floor space per bed is considered a good proxy measure for the space between beds within a hospital Trust.

Location of the Trust

47. Trusts in different parts of the country may vary systematically in their MRSA rates. Some geographical dimensions may be captured and controlled for with other variables in our analysis. For example, the use of temporary nursing staff is higher in London than elsewhere. Similarly, London has a higher density of tertiary hospitals than many other parts of the country.

48. However, MRSA rates in different parts of the country may also vary because of factors over and above those captured elsewhere in the analysis, including characteristics of the local population. Therefore, we test whether there are systematic regional differences in MRSA rates by entering dummy variables which capture the Strategic Health Authority (SHA) within which each Trust is located.

Gender

49. There is evidence that MRSA rates tend to be higher in males than females. This phenomenon is not fully understood though it has been suggested that this may be linked to differences in colonisation rates caused by, for example, differences in hygiene. One might therefore expect Trusts with relatively more males in their casemix to have higher rates of infection, other things equal. To test this, we use a variable that measures the proportion of total inpatient admissions that are males.

Specialty Split

50. There is a large amount of evidence that MRSA rates vary by specialty, according to the underlying characteristics and clinical pathways of patients. Indeed, the MRSA surveillance scheme has recently been extended to include a breakdown of infections by specialty. Since our study is based upon aggregate Trust-level data, in order to test the effects of specialty casemix we explored whether the proportion of total Trust inpatient activity accounted for by 20 individual specialties is significantly correlated with overall MRSA rates. Those specialties for which a significant correlation existed were included in the model.

Average Length of Stay

51. For a given admitted patient, the probability of becoming infected is likely to increase with the patient's length of stay. For example, Lucet et al. (2005)[24] found a highly significant relationship between average length of stay and MRSA rates in an ICU. However, it is not clear whether length of stay *per se* is a driver of infection or whether it is a marker for underlying drivers such as diagnosis, procedure and severity of morbidity and co-morbidity.

52. In order to test the impact of average length of stay over and above other factors, we use a measure of the median length of stay of all admitted inpatients in each Trust[25].

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[24] Lucet, J.C., Paoletti, X., Lolom, I, et al. (2005), "Successful long-term program for controlling meticillin-resistant *Staphylococcus aureus* in intensive care units." *Intensive Care Med.* Vol. 31, p1051-7. (cited in Henderson (2006)).

[25] We consider median length of stay a better measure than mean length of stay in this context since mean length of stay at Trust level can become distorted by small numbers of patients with very long

Average age of Admissions

53. At the individual level, it is well documented that risk of MRSA infection tends to increase with age. Older patients tend to be, on average, sicker and more prone to infection and MRSA colonisation rates among the general population may be higher in older age groups. To test the impact of patient age at a Trust level we include in our analysis a variable which measures the average (mean) age of admitted inpatients.

Emergency Admissions

54. Other things equal, one might expect Trusts with a high emergency workload to have higher MRSA rates. Emergency admissions tend to be more complex and obviously make it more difficult to employ preventive measures such as screening for MRSA colonisation or the use of prophylactic antibiotics prior to surgery. To test this, we use a variable which measures the proportion of a Trust's total admissions which are emergency admissions.

Results and Discussion

55. The following section outlines the key results and discusses the implications. A technical specification of the model employed is included in Annex A and full results are in Annex B.

56. Tables 2 and 3 below show a summary of the results from our standard models. This separates the data into two pooled cross sections. The first (table 1) covers the first three years of data (2001/02 through 2003/04) and the second (table 2) covers the final two years of data (2004/05 through 2005/06). The reason why the data have been presented in this format is that results (including those from regressions on individual years of data) suggest that there have been significant changes in the structure of the relationship between MRSA rates and key explanatory variables- particularly "policy" variables- over the period studied. These changes would not be apparent if all five years of data were pooled in a single model[26].

57. Tables 1 and 2 show- for the first 3 years and last 2 years respectively- for each variable, the direction of its relationship with MRSA (positive or negative), the strength of statistical significance of the result and an indication of the implied economic or practical significance of each variable for MRSA rates (holding all other variables constant). Only variables found to be statistically significant or close to significant are included in the table[27]. Results from a number of variant models, including coefficients and standard errors, are detailed in Annex B and are referenced in the discussion which follows.

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stays. There is, in principle, a problem of reverse causation in assessing average length of stay- while increasing length of stay might cause an increase in infections, an increase in MRSA bacteraemias will also tend to increase average length of stay. Since the absolute risk of MRSA bacteraemia is very low (roughly 1 in every 1500 admissions), however, this latter effect will, in practice, be negligible.

[26] The results described in the text reflect a basic linear model but we discuss briefly in Annex B the robustness of these findings to various alternative model specifications.

58. The first column in Tables 1 and 2 below shows the variable while the second shows the sign of the relationship between that variable and the MRSA rate, *holding all other variables constant.* The third column indicates the strength of statistical significance of this relationship[28]. The final two columns give an indication of the economic or operational significance of the relationship by indicating the predicted impact on MRSA cases of a specified change in each variable, again holding all other variables constant.

59. We discuss the implications of these results (and of the other models included in Annex B) in what follows. The variables discussed are as defined in the previous discussion.

60. In aggregate, the variables in the model generally "explain" around 30-50% of observed variation in MRSA rates. This "goodness of fit" is relatively favourable in the context of this type of cross-sectional analysis[29].

[28] *** signifies significance at the 1% level, ** at the 5% and * at the 10% level. In other words, *** suggests that there is less than a 1% probability that the observed relationship has occurred by "pure chance" and that there is, in reality, no relationship between MRSA rates and the variable in question.
[29] Further details, including adjusted R^2 values are shown in the full results tables in Annex B.

Table 1- Practical/ Economic Significance of Variables (2001/02 through 2003/04)

Variable	Relationship with MRSA	Statistical significance	Operational / Economic Significance	
			Change in variable	Resulting change in MRSA rate
Specialist	+ve (relative to general acute trusts)	***	If a specialist trust	27.7% higher MRSA
Single Specialist	No significant relationship			
Cleanliness (PEAT score)	-ve	***	10% higher PEAT score than average	2.6% lower MRSA
Single Room	No significant relationship			
Average length of stay	No significant relationship			
Average Age	+ve	***	Average age of patients 1 year older than national average	1.3% higher MRSA
Emergency Admissions	+ve	**	Share of emergencies 10% higher than national average	2.0% higher MRSA
Bed occupancy 85% - 90%	No significant relationship			
Bed occupancy >90%	+ve (relative to occupancy <85%)	***	Bed occupancy above 90%	10.3% higher MRSA
Contract cleaners	-ve (relative to in-house cleaners)	*	Contract cleaning rather than in-house	5.7% lower MRSA
Backlog / m^2	No significant relationship			
Trauma & Orthopaedics Specialty	No significant relationship			
Ear, Nose & Throat Specialty	+ve	*	Share of Ear, nose and throat in total admissions 10% higher that the national average	0.36% higher MRSA
Ophthalmology Specialty	-ve	***	Share of Ophthalmology in total admissions 10% higher than national average	0.44% lower MRSA
Neurosurgery Specialty	+ve	***	Share of Neurosurgery in total admissions 10% higher than national average	0.15% higher MRSA
Nephrology Specialty	No significant relationship			
Space per bed	No significant relationship			
Total number of beds	+ve	*	Number of beds 10% higher than national average	0.50% higher MRSA
Male admissions	+ve	*	% share of male in total	2.4% higher MRSA

			admissions 10% higher than average	
Cleaning spend / m^2	-ve	*	10% more spent on cleaning/m^2 than the average	0.59% lower MRSA
Consultants per bed	No significant relationship			
Proportion of Temporary Nursing Staff	+ve	***	10% higher proportion of temporary nursing staff than the average	0.72% higher MRSA
North East SHA	-ve	***	Comparison to East of England SHA	21.6% lower MRSA
North West SHA	-ve	***	Comparison to East of England SHA	15.3% lower MRSA
Yorks & Humber SHA	-ve	***	Comparison to East of England SHA	22.4% lower MRSA
East Midlands SHA	-ve	***	Comparison to East of England SHA	21.5% lower MRSA
West Midlands SHA	No significant difference to the base region (East of England)			
London SHA	+ve	***	Comparison to East of England SHA	21.5% higher MRSA
South East SHA	-ve	***	Comparison to East of England SHA	18.2% lower MRSA
South Central SHA	-ve	***	Comparison to East of England SHA	22.1% lower MRSA
South West SHA	-ve	*	Comparison to East of England SHA	10.1% lower MRSA
2002/3*	-ve	***	Comparison to 2001/02, other things equal	10.5% lower MRSA
2003/4*	-ve	***	Comparison to 2001/02, other things equal	13.1% lower MRSA

* When compared to the base year (2001/02)

Table 2- Practical/ Economic Significance of Variables (2004/05 through 2005/06)

Variable	Relationship with MRSA	Statistical significance	Operational / Economic Significance	
			Change in variable	Resulting change in MRSA rate
Specialist	+ve (relative to general acute trusts)	***	If a specialist trust	12.2% higher MRSA
Single Specialist	-ve (relative to general acute trusts)	***	If a single specialist trust	31.7% lower MRSA
Cleanliness (PEAT score)	No significant relationship			
Single Room	-ve	**	Proportion of single rooms 10% higher than national average	0.77% lower MRSA
Average length of stay	No significant relationship			
Average Age	+ve	***	Average age of patients 1 year older than national average	0.83% higher MRSA
Emergency Admissions	No significant relationship			
Bed occupancy 85% - 90%	No significant relationship			
Bed occupancy >90%	No significant relationship			
Contract cleaners	No significant relationship			
Backlog / m^2	+ve	*	Backlog expenditure 10% higher than national average	0.19% higher MRSA
Trauma & Orthopaedics Specialty	No significant relationship			
Ear, Nose & Throat Specialty	+ve	*	Share of Ear, nose and throat in total admissions 10% higher that the national average	0.35% higher MRSA
Ophthalmology Specialty	-ve	***	Share of Ophthalmology in total admissions 10% higher than national average	0.64% lower MRSA
Neurosurgery Specialty	+ve	***	Share of Neurosurgery in total admissions 10% higher than national average	0.08% higher MRSA
Nephrology Specialty	No significant relationship			
Space per bed	No significant relationship			
Total number of beds	+ve	*	Number of beds 10% higher than national average	0.55% higher MRSA

Male admissions	+ve	*	% share of male in total admissions 10% higher than average	3.0% higher MRSA
Cleaning spend / m^2	No significant relationship			
Consultants per bed	No significant relationship			
Proportion of Temporary Nursing Staff	No significant relationship			
North East SHA	-ve	***	Comparison to East of England SHA	21.4% lower MRSA
North West SHA	No significant difference to the base region (East of England)			
Yorks & Humber SHA	-ve	***	Comparison to East of England SHA	20.0% lower MRSA
East Midlands SHA	-ve	**	Comparison to East of England SHA	18.2% lower MRSA
West Midlands SHA	No significant difference to the base region (East of England)			
London SHA	+ve	*	Comparison to East of England SHA	11.6% higher MRSA
South East SHA	No significant difference to the base region (East of England)			
South Central SHA	-ve	**	Comparison to East of England SHA	15.9% lower MRSA
South West SHA	-ve	*	Comparison to East of England SHA	9.8% lower MRSA
2005/6*	No significant relationship			

* When compared to the base year (2004/05)

Bed Occupancy

61. For the period 2001/02-2003/04, we find evidence that, all else equal, hospitals with rates of occupancy above approximately 90% have higher MRSA rates. Holding the other variables constant a trust with an occupancy rate above 90% could expect a 10.3% higher MRSA rate compared to a trust with an occupancy rate below 85%.

62. However, as table 2 shows, this positive relationship has ceased to exist in the last 2 years. In the period 2004/05 through 2005/06, there was no longer any significant relationship between high bed occupancy and MRSA rates, other things equal[30].

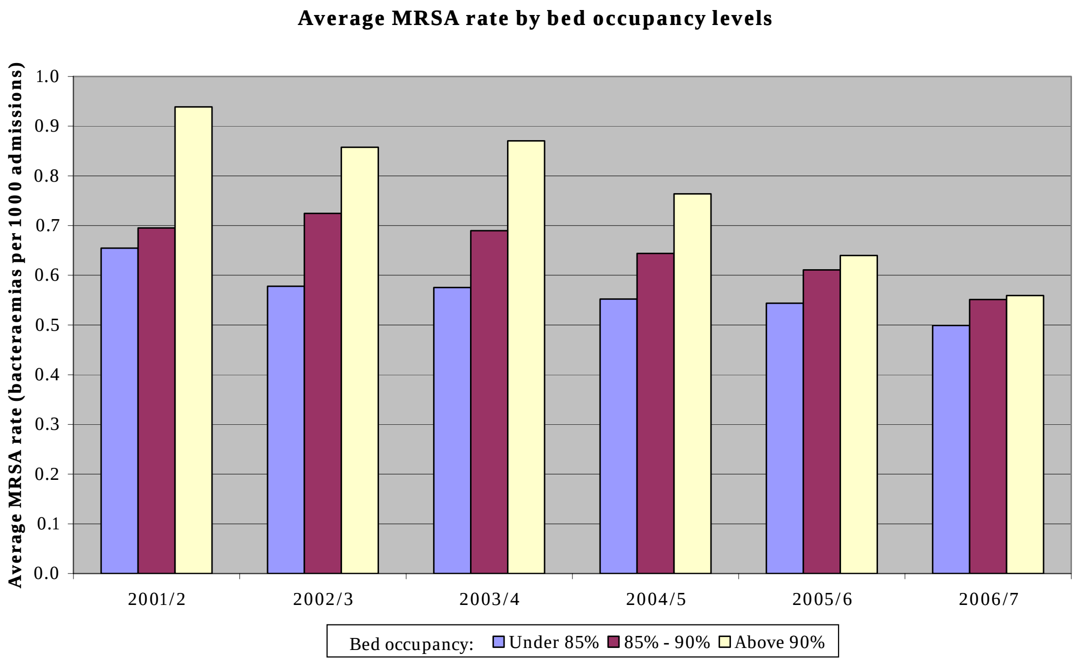
63. The apparent changing nature of the relationship between bed occupancy and MRSA rates is illustrated clearly by Figure 5 below. This shows, for each year

[30] Though, as noted above, full data are not yet available for 2006/07, preliminary results suggest that the apparent disappearance of the relationship between high occupancy and MRSA has continued in this most recent year.

from 2001/02 to 2006/07, average MRSA rates in hospitals separated into 3 bands of bed occupancy- those below 85%, 85-90% and above 90%. We see in 2001/02 that average MRSA rates were nearly 50% higher in Trusts running above 90% occupancy than those with occupancy below 85%, The picture remained similar in 2002/03 and 2003/04, but over the last 3 years MRSA rates in Trusts with high occupancy have fallen significantly and are now only very slightly higher than those in Trusts with lower bed occupancy.

64. Put differently, in 2001/02 40% more patients admitted to hospitals running above 90% occupancy contracted an MRSA bacteraemia than patients admitted to hospitals running at below 90% occupancy. By 2006/07, this differential had fallen to just 8%. After adjusting for differences in other characteristics, this difference is no longer statistically significant.

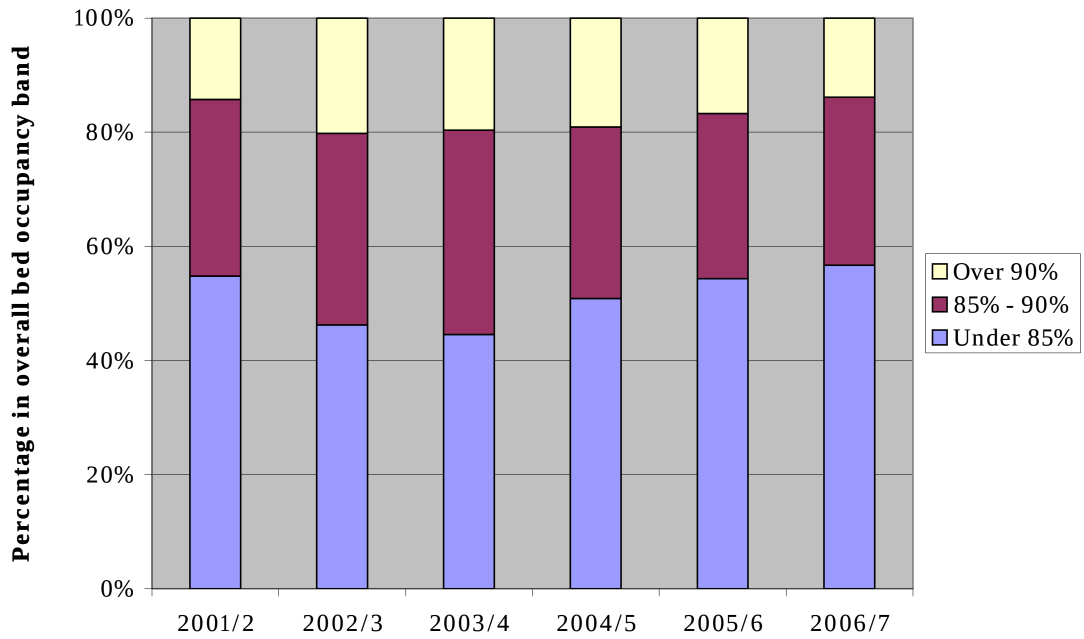
<u>Figure 5- Average MRSA rate by bed occupancy levels</u>



65. It is interesting to observe the lessening of the link between high occupancy and MRSA. While analysis of this type is not able to test the underlying reasons for this change, one possible explanation is that policy initiatives at a national and local level have been successful in helping more Trusts to become successful at handling the tensions between bed management and infection control. We discuss this in more detail in the concluding discussion.

66. It is also true that the number of Trusts operating at occupancy levels above 90% has fallen in recent years, while the proportion with occupancy below 85% has been increasing. This is illustrated by Figure 6 below.

Figure 6- Percentage of Trusts operating in different ranges of bed occupancy



Cleanliness

67. Again, for the first 3 years, we find evidence of a clear relationship between hospital cleanliness ratings[31] and MRSA rates. The implied effect is that a trust with a 10% higher PEAT score than the national average (holding other things equal) can expect an MRSA rate 2.6% lower.

68. It is important to be aware that this result does not necessarily imply a causal link between environmental cleanliness and MRSA infection. PEAT scores include a wide variety of elements and are subjective measures that are clearly not a perfect measure of hospital cleanliness.

69. As table 2 shows, we find that there is not a statistically significant relationship between PEAT scores and MRSA rates in the last 2 years (2004/05 and 2005/06).

70. Thus, the link between PEAT scores and MRSA rates appears to have weakened or disappeared over time. This would fit with the overall body of evidence which does not suggest a direct causal link between environmental cleanliness and MRSA infection. Though there is no definitive proof, this evidence is consistent with a theory that in the early years of MRSA mandatory surveillance, PEAT scores were a good proxy for wider infection control standards but that in recent years this link has weakened. It is also possible that policy initiatives such as the *cleanyourhands* campaign have loosened the primary mechanism- the hands of staff- through which environmental cleanliness might influence upon infection. We discuss this further in the concluding discussion.

[31] As measured by the Patient Experience Action Team (PEAT) visits and published by the Healthcare Commission.

71. The effect of using contract cleaners rather than in-house cleaning did not have a consistent relationship with MRSA rates- in the first 3 years there was a negative correlation (of borderline statistical significance) between contract cleaning and MRSA. That is, Trusts which had contracted cleaners tended to have lower MRSA rates (by around 6%) than those with in-house cleaners, other things equal.

72. However, Table 2 indicates that in the last two years there was no longer any significant relationship between whether cleaning was contracted out and MRSA rates.

73. In the first 3 years, expenditure on cleaning was found to have a negative association (of marginal statistical significance) with MRSA rates, other things equal- Trusts which spent more on cleaning tended to have lower MRSA rates, though the practical effect is quite small- increasing spend on cleaning by 10% is estimated to reduce MRSA rates by less than 1%. In the final 2 years, there was no longer any significant link between levels of spend on cleaning and MRSA rates.

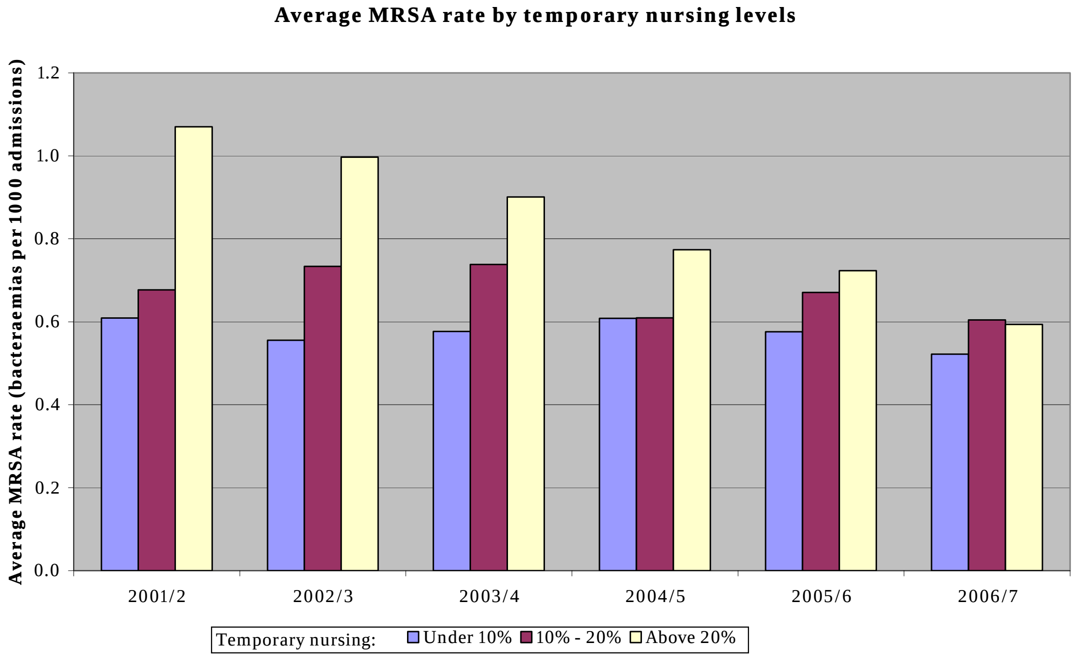
Temporary Nursing Staff

74. We found evidence of a positive correlation between the use of temporary nursing staff and MRSA rates in the first 3 years. Quantitatively, if a trust had a proportion of temporary staff 10% above the national average (e.g. 14.3% compared to a national average of 13%), they could expect, other things equal, to have a 1% higher MRSA rate. As discussed above, there are various mechanisms through which this relationship may take effect, though this study is not able to discriminate between these different hypotheses.

75. However, we see again that the relationship has substantially weakened in the last 2 years. Though there is still a slight positive correlation, this is of a much smaller magnitude and no longer statistically significant.

76. This trend is illustrated starkly by Figure 7 below. This shows that MRSA rates were nearly twice as high in Trusts with a high level of temporary nursing staff in 2001/02. However, this differential has been reduced sharply in recent years as MRSA rates in Trusts with high levels of temporary nursing have been reduced significantly. In the latest year (2006/07), there was no longer any significant relationship between the use of temporary nursing and MRSA rates.

Figure 7- Average MRSA rate by temporary nursing levels



77. We also tested the relative importance of agency nurses and bank nurses separately and found that both are separately positively correlated with MRSA rates in the first three years (with an effect of a similar magnitude, though that for agency staff was of borderline statistical significance) while neither was significantly correlated with MRSA rates in the last two years. This shift may be related to policy changes, the possibility of which is discussed in more detail in the concluding discussion.

Quality of the Physical Environment

78. The quality of the physical environment in a particular hospital is proxied by the estimated backlog spend which is required to allow each Trust to meet category B physical condition and health and safety standards. There does not appear to be a consistent relationship between this and MRSA rates, though in most recent years there is a suggestion that Trusts with higher levels of backlog (i.e. a poorer physical environment) may have slightly higher MRSA rates, other things equal. However, the practical effect is small- a Trust with backlog 10% above the national average could expect an MRSA rate 0.2% higher, other things equal.

Single Rooms

79. We found that, after controlling for other factors, there was no evidence of any link between the proportion of hospital beds which are in single rooms and the MRSA rate in that hospital in the first 3 years. However, in the final two years there was a statistically significant negative relationship. That is, hospitals with a higher proportion of single rooms have lower MRSA rates, other things equal. The practical significance is, however, quite small- a Trust with a proportion of single rooms 10% higher than the national average could expect an MRSA rate less than 1% higher, holding other factors constant.

80. The relationship between single rooms per se and infection is a complex one. As noted previously, how single rooms are used may be more important than the existence of single rooms per se in determining the spread of MRSA. A report cited previously suggested that only 19% of single bedded rooms are used for infection control purposes. However, these results suggest that, in recent years the proportion of single rooms within a Trust has become a more important correlate with MRSA rates. This would be consistent, for example, with a situation in which single rooms are now being used more effectively as a means of infection control.

Hospital Type

81. It has been reported in other work that, in comparison with general acute Trusts, specialist hospitals tend to have higher MRSA rates and single specialty hospitals lower rates. We found this relationship generally to hold, with specialist Trusts having a consistent and significant positive relationship with MRSA rates throughout the five years. The magnitude of this effect declined somewhat in the final two years but remained significant. The results above suggest that, other things equal, specialist trusts had MRSA rates, on average, 28% higher than general acute Trusts in the first 3 years and around 12% higher in the final 2 years. The results for single specialty trusts are less conclusive statistically (partly because the numbers of single specialty Trusts are quite small) but still have a large practical effect- single specialty Trusts had MRSA rates around 32% lower in 2004/05 through 2005/06 than general acute Trusts, holding everything else constant.

Average Age of Admissions

82. A significant positive relationship between the average age of admissions and the MRSA rate is clearly apparent. This result holds throughout the five years, though the magnitude of the relationship has fallen slightly over time. The results suggest that if the average age of admissions in a Trust were to be 1 year older than the national average, all else being equal, the trust could expect an MRSA rate around 1.3% higher (first 3 years) or 0.8% higher (final 2 years).

Emergency Admissions

83. The proportion of emergency admissions has a positive and significant affect on the MRSA rate in the first 3 years. The implication is that if the share of emergency admissions were 10% higher than average (all else equal) then the MRSA rate would be 2% higher on average. In the last 2 years, the association is still positive though falls short of statistical significance.

Number of Beds

84. The number of beds in a given trust was a scale factor used to measure the size of the Trust and examine whether that had any additional effect on MRSA rates, over and above hospital type and casemix. In general, there appears to be a small positive relationship (albeit of borderline statistical significance), implying that larger Trusts tend to have slightly higher MRSA rates than smaller Trusts, other things (hospital type, casemix etc) equal. The magnitude of the effect is, however,

small, implying that a Trust with 10% more beds than the national average has a MRSA rate around 0.5% higher.

Regional Effects

85. We examined the impact of geographical location on MRSA rates by separating Trusts into Strategic Health Authorities (SHAs). In this way, we were able to test whether there are systematic regional variations in MRSA rates, over and above the observed characteristics of Trusts. As Tables 2 and 3 show, the most striking result concerns London, which consistently has higher rates of MRSA than all other SHA regions, other things equal (though the magnitude of the differential appears to have lessened in the past 2 years).

86. The affect of a trust being located in London compared to the Eastern cluster is highly significant both statistically and economically. Trusts in London have, holding everything else constant, an MRSA rate, on average around 22% higher than the base Eastern cluster in the first 3 years, falling to around 12% higher in the last 2 years. This result is strengthened when a regression is run on only the general acute trusts which may suggest that high observed MRSA rates in London are not explicable simply on the basis of its concentration of tertiary hospitals.

87. The SHA regions with relatively low rates of MRSA, given the characteristics of their hospitals, are Yorkshire and the Humber, East Midlands, North East and South Central. This pattern appears fairly consistent over the last five years.

Male Admissions

88. The share of male admissions into a Trust was found to have a significant effect on the MRSA rate. In regression results shown in the table above it was found that, holding the other variables constant, a Trust with a share of males in total admissions 10% above the national average will have an MRSA rate around 2-3% higher. This enhanced vulnerability of males holds in all the variants of the model (see Annex B) and the quantitative effect appears larger in general acute trusts (refer to regression (iv) in Annex B). As noted above, there is a suggestion that MRSA colonisation rates may be higher in males which could help to explain this result.

Case Mix

89. Data concerning the fraction of patients in each Trust in each individual specialty was used to explore whether concentration of hospital activity in some specialties is associated with higher or lower MRSA rates than others. While these variables are primarily intended as controls, the evidence on case mix may still be of value in helping to focus further research.

90. We tested whether the proportion of total activity in each of more than 20 specialties is significantly correlated with MRSA rates and found that there are five specialties which, most frequently in our models, have statistically significant relationships- ear, nose and throat (ENT) , nephrology and neurosurgery have positive relationships and ophthalmology and trauma and orthopaedics negative relationships.

91. Quantitatively, if a Trust had a share of ENT in total activity which was 10% higher than the national average, they would expect an MRSA rate around 0.3-0.4% higher than national average, other things equal. Similarly, a 10% higher share of Neurosurgery for a trust would expect them to have a 0.1-0.2% higher MRSA rate. Although not significant in the regression outlined above the proportion of admissions in the nephrology specialty is generally positively associated with the MRSA rate. A share in ophthalmology 10% higher than the national average would lead a trust to expect a 0.49% lower MRSA rate and for Trauma and orthopaedics the same higher share would expect a 0.28% lower MRSA rate, holding other variables constant. These results are highly significant for neurosurgery and ophthalmology across all the models (see annex B for details in each regression) and significant for the majority of models for the ENT specialist. Nephrology and Trauma and Orthopaedics specialities are less significant although significant results can be found for some regressions (refer to annex B for details).

Other Variables

92. All other variables that have been tested (see Annex C for a full list) are found to be not significantly correlated with MRSA rates.

Concluding Discussion

93. Clearly, the most striking results from this analysis concern the way in which the relationship between MRSA rates and certain policy/ operational variables- notably bed occupancy, the use of temporary nursing staff and PEAT scores- appears to have markedly changed over time. While high occupancy, high use of temporary nursing staff and low PEAT scores were all significantly correlated with higher MRSA rates in the period 2001/02-2003/04, these relationships have all significantly weakened or disappeared by 2004/05-2005/06[32].

94. It is difficult to account definitively for these changes. One possibility is that, for a variety of reasons outlined above, these factors do inherently make infection control more challenging, that the nature of these challenges has not changed fundamentally in recent years, but that Trusts have become significantly better at understanding and rising to these challenges.

95. It is possible that this has been driven by a number of factors. The introduction of a high profile MRSA target in November 2004 clearly instigated a step change in the focus and priority given to infection control. Increasing awareness of (and perhaps reaction to) issues such as the risks posed by poor hospital cleanliness and high bed occupancy from media coverage and results in the literature in recent years may have helped in promulgating change.

96. In addition, various recent policy initiatives may also have played a role. For example, The Chief Medical Officer's *Winning Ways* report (December 2003) required Chief Executives to ensure that infection control teams work with bed managers to optimise bed use, while implementing procedures to minimise the risk of infection.

[32] Though we do not yet have all data, preliminary results suggests that this trend has continued in 2006/07.

97. The *cleanyourhands* campaign, launched in September 2004, has been instrumental in raising awareness of, and driving improvements in compliance with, hand hygiene. In doing so, it is possible that this has lessened the extent to which environmental hospital cleanliness (as measured by PEAT scores) might impact upon infection via the mechanism of staff hands.

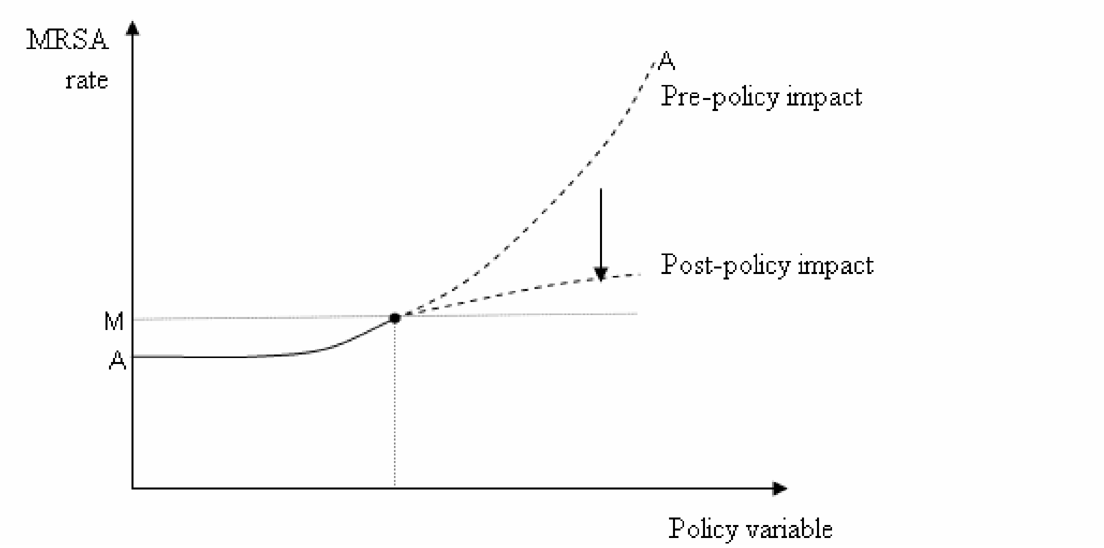
98. On the temporary staffing side, initiatives such as the establishment of NHS Professionals in 2004 and the NHS Employers Code of Practice for the recruitment and employment of temporary staff in the NHS have aimed to improve the quality and appropriateness of temporary staff working in the NHS. If they have succeeded in doing so, this may have served to loosen the link between the use of temporary nursing staff and MRSA rates which we have observed.

99. A second related explanation for the diminished influence of leading organisational factors is the *selectivity* of support. The Department of Health has, since 2004, targeted HCAI support to Trusts facing the biggest challenges in meeting their MRSA targets, through dedicated improvement teams and the Performance Improvement Network. Though a total of 102 Trusts have now benefitted from targeted support, Trusts which were the first to receive support were those with the highest MRSA rates which also tended to face the biggest challenges around bed occupancy, temporary staffing and cleanliness issues. There is evidence that these Trusts may have reduced their MRSA rates more rapidly than others (e.g. over the last year, Trusts receiving tailored targeted support reduced their MRSA rates by 19-33%).

100. One way of summarising how targeting hospitals with high MRSA rates may explain some of the change in the apparent relationship between MRSA rates and operational factors such as bed occupancy is illustrated by Figure 8 below. Initially (pre-policy impact) MRSA rates tended to increase with certain policy variables (such as bed occupancy or use of temporary nursing), as shown by the line AA. However, those Trusts with relatively high initial MRSA rates (above M) may have disproportionately benefited from the impact of policy. This may have led to the observed weakening or disappearance of the relationships between those policy variables and MRSA rates. Thus, policy initiatives may not have shifted the total curve AA downwards, but instead lowered it only for those hospitals with initial MRSA rates above M.

101. Only time will tell whether these shifts will be temporary or permanent. Certainly, Trusts have been subject to unprecedented levels of support, policy initiative and performance management on infection control in general, and the MRSA target in particular, in recent years. It would appear that these have, in aggregate, had a favourable impact, though whether this represents a permanent step change or a temporary shift depend on continuing high levels of support remains to be seen.

Figure 8- Policy variables and MRSA rates



102. These results are not, therefore, grounds for complacency in addressing issues such as high bed occupancy, the use of temporary staff and hospital cleanliness. There are various reasons which suggest that each of these add to the challenges of infection control and that, only by continuing concerted effort, will recent trends- and, in particular, the reduced tendency for challenging organisational circumstances to influence MRSA rates- be sustained. In addition, there are of course many reasons other than infection control for tackling these issues- for example, the impact of high bed occupancy on cancelled operations, trolley waits and inappropriate movement of patients, the implications of over-use of temporary staff for cost and continuity of care and the importance of hospital environment cleanliness for the perceptions and experience of patients, their families and the public.

Annex A- The Model Specification

The primary purpose of our model is to estimate the effect of hospital level characteristics such as bed-occupancy, staffing, hospital size, clinical mix, cleanliness etc on the observed distribution of MRSA rates across Trusts.

The model we adopt begins with a simple identity – equation (1) – in which the time dimension suffix is suppressed for convenience – relating the number of MRSA cases per period of time to the number of admitted cases in each speciality and the probability of a bacteremia.

$$(1) \quad M_j \equiv \sum_i X_{ij} P_{ij}$$

> M_j is total number of MRSA cases in hospital j
> X_{ij} is the probability that a patient entry hospital j in speciality i acquires an MRSA bloodstream infection
> P_{ij} is the number of patients entering hospital j in speciality i.
> f_{ij} is the fraction of patients at hospital j in speciality i.
> m_j is the proportion of admitted patients who acquire MRSA in hospital j.

We can divide both sides by the total number of entering patients and derive (2)

$$(2) \quad m_j \equiv \sum_i X_{ij} f_{ij}$$

Now we introduce a hypothesis for the specification for X_{ij}. We assume that X_{ij} can be written as an additive function of a clinical speciality element, β_i, and a set of hospital-level characteristics, indexed h, that have values that may vary between hospitals, z_{hj}. Thus, we assume that the consequence of each hospital level feature, $z_{hj,}$ for MRSA rates is independent of the clinical speciality concerned. (Our data allow this assumption to be relaxed, in principle). Thus we now assume $X_{ij} = \beta_i + g\,(z_{hj})$, and hence we can write

$$(3) \quad m_j = \underbrace{\sum \beta_i f_{ij}}_{\text{speciality mix characteristics}} + \underbrace{\sum_i g(z_{hj}) f_{ij}}_{\text{hospital level variables}} \qquad \text{thus,}$$

$$(3') \quad m_j = \sum \beta_i f_{ij} + g\,(z_{hj}),$$ using the fact that $\sum_i f_{ij} = 1$ and $g(z_{hj})$ is independent of i

Equation (3), with g linearised, provides our basic model, but we also estimate equation (4), which allows the MRSA rate to adjust only slowly over time to the drivers. Given that MRSA is an infection process that will evolve in locally determined and random ways, this appears appropriate. Inserting the time suffix, and linearizing g, gives our most general model:

$$(4) \quad m_{jt} = k m_{jt-1} + \sum_i \beta_i f_{ijt} + \sum_h g_h Z_{jht}$$

Our paper consists of discussing estimates of the parameters (k, β_i, g_h) in equation (4), with some model estimates constrained so that k = 0.

Empirical Strategy

The basic empirical strategy involved estimating variants of equations (3) and (4) above through ordinary least squares.

The dependent variable throughout is the MRSA rate expressed as the number of cases of MRSA recorded in a particular Trust in a year divided by the total number of admissions in that Trust. Thus, it can be thought of as the probability that a patient admitted in a particular Trust will contract MRSA during their hospital stay.

In Annex B, we present the results from a number of more sophisticated variant models, none of which made a material difference to the results. In the interests of brevity and simplicity, we do not show results from every alternative model specification we have tried. For example, we investigated using a logit transformation in order to constrain predicted values (i.e. probability of infection) between zero and one. We also experimented with pooling all 5 years of data into a single cross section and introduced fixed or random effects. However, for reasons explained in detail in the main paper, we believe that significant changes in key relationships make it undesirable to present a single pooled cross section of these data. We have not analysed in any detail dynamic models which introduce lagged dependent variables since our primary concern is with the total effect of changes in explanatory factors, which are captured in the static models we have estimated. A possible extension would be to estimate dynamic models able to separate the contemporaneous and cumulative effects of changes in explanatory variables.

Annex B- Regression Results

The table below shows full regression results from a range of different variant models. Coefficients are shown with standard errors in parentheses. One, two and three asterisks signify statistical significance at the 10%, 5% and 1% levels respectively.

In Table A, column i shows the results from the standard regression model (for the first 3 years and the last 2 years separately), which correspond to the results in tables 1 and 2 in the main paper. Column ii shows the same regressions run only on general and acute Trusts and column iii shows the same model for general and acute plus specialist Trusts (i.e. all Trusts excluding single specialty Trusts). Column iv shows the standard model but with temporary nursing staff separated into agency and bank elements.

In Table B, column i again shows the standard model for comparison. Column ii shows the results of regressions which use occupancy rates for general and acute beds only, rather than for all hospital beds. Column iii uses bed occupancy in 4 bands (below 85%, 85-90%, 90-95% and 95%+) while column iv separates bed occupancy into just 2 bands (below 90% and above 90%). Finally, column v allows the effect of bed occupancy on MRSA rates to vary when occupancy is above 90% (i.e. it tests whether occupancy of, say, 94% is associated with higher MRSA rates than, for example, 92%, other things equal.

Table A

Variable	Mean (SD)		(i) Standard Model		(ii) G&A Trusts		(iii) G&A/ specialists		(iv) Agency/ bank separate	
	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06
Dependent	0.656 (0.381)	0.565 (0.284)								
Specialist	0.26 (0.439)	0.26 (0.439)	0.277 *** (0.043)	0.122 *** (0.045)			0.213 *** (0.047)	0.075 (0.053)	0.278 *** (0.043)	0.118 *** (0.045)
Single specialty	0.104 (0.306)	0.104 (0.306)	-0.084 (0.086)	-0.317 *** (0.097)					-0.083 (0.086)	-0.307 *** (0.097)
PEAT	3.652 (0.815)	3.719 (0.653)	-0.072 *** (0.025)	-0.016 (0.02)	-0.029 (0.027)	-0.04 * (0.024)	-0.075 *** (0.026)	-0.022 (0.021)	-0.072 *** (0.025)	-0.018 (0.02)
Single room	0.161 (0.096)	0.174 (0.089)	-0.051 (0.149)	-0.441 ** (0.184)	0.145 (0.171)	-0.199 (0.227)	0.169 (0.156)	-0.308 (0.204)	-0.055 (0.151)	-0.482 *** (0.185)
ALOS	2.173 (1.052)	1.853 (1.146)	0.012 (0.015)	0.014 (0.015)	0.018 (0.037)	0.077 ** (0.038)	0.063 * (0.034)	0.062 ** (0.032)	0.012 (0.015)	0.014 (0.015)
Age	46.661 (8.201)	48.405 (8.32)	0.013 *** (0.002)	0.008 *** (0.003)	0.01 * (0.006)	0.002 (0.007)	0.012 *** (0.004)	0.012 ** (0.005)	0.013 *** (0.002)	0.008 *** (0.003)
Emergency	0.337 (0.093)	0.356 (0.102)	0.578 ** (0.233)	0.313 (0.23)	0.914 ** (0.361)	0.335 (0.328)	1.011 *** (0.31)	0.611 ** (0.27)	0.579 ** (0.233)	0.33 (0.229)
Occupancy8590	0.331 (0.471)	0.292 (0.455)	-0.009 (0.03)	-0.011 (0.033)	-0.005 (0.032)	-0.014 (0.036)	-0.005 (0.03)	-0.016 (0.033)	-0.009 (0.03)	-0.008 (0.033)
Occupancy90	0.179 (0.384)	0.179 (0.384)	0.103 *** (0.039)	0.012 (0.04)	0.097 ** (0.045)	-0.026 (0.052)	0.072 * (0.039)	0.005 (0.042)	0.103 *** (0.039)	0.019 (0.04)
Occupancy9095	0.166 (0.372)	0.145 (0.352)								
Occupancy95	0.013 (0.115)	0.035 (0.183)								
GAOcc8590	0.351 (0.478)	0.376 (0.485)								

GAOcc90	0.272 (0.445)	0.234 (0.424)								
Occupancy	0.844 (0.062)	0.84 (0.075)								
IntOcc8590	0.293 (0.412)	0.255 (0.398)								
IntOcc90	0.167 (0.356)	0.166 (0.356)								
Contract	0.402 (0.456)	0.4 (0.456)	-0.057 * (0.03)	-0.022 (0.032)	-0.033 (0.033)	-0.02 (0.038)	-0.061 ** (0.03)	-0.025 (0.033)	-0.057 * (0.03)	-0.016 (0.032)
Backlog	134 (161)	150 (202)	-0.00002 (0.00009)	0.00013 * (0.00007)	-0.00004 (0.00011)	0.00003 (0.00011)	-0.00002 (0.00009)	0.00012 (0.00009)	-0.00002 (0.00009)	0.00014 * (0.00007)
T&O	0.085 (0.117)	0.084 (0.117)	-0.19 (0.125)	-0.188 (0.131)	0.609 (0.939)	-0.25 (0.985)	-1.304 * (0.775)	-0.487 (0.83)	-0.192 (0.125)	-0.182 (0.131)
ENT	0.026 (0.019)	0.023 (0.017)	1.39 * (0.752)	1.505 * (0.877)	1.961 ** (0.993)	1.04 (1.268)	1.765 ** (0.738)	1.356 (0.877)	1.401 * (0.755)	1.554 * (0.876)
Ophthalmology	0.037 (0.078)	0.036 (0.077)	-1.194 *** (0.354)	-1.775 *** (0.658)	-1.82 ** (0.742)	-1.485 * (0.813)	-1.653 *** (0.605)	-1.379 ** (0.684)	-1.197 *** (0.355)	-1.716 *** (0.657)
Neurosurgery	0.006 (0.033)	0.006 (0.029)	2.302 *** (0.485)	1.264 *** (0.461)	-14.549 ** (6.421)	-16.043 (12.798)	7.987 *** (2.083)	8.4 *** (2.411)	2.302 *** (0.485)	1.258 *** (0.46)
Nephrology	0.007 (0.018)	0.008 (0.021)	1.07 (0.754)	-0.147 (0.664)	2.446 (1.79)	-2.45 ** (1.159)	1.203 (0.789)	-0.238 (0.677)	1.065 (0.755)	-0.151 (0.662)
Year2	0.333 (0.472)	0 (0)	-0.105 ** (0.044)		-0.055 (0.047)		-0.111 ** (0.044)		-0.105 ** (0.044)	
Year3	0.333 (0.472)	0 (0)	-0.131 *** (0.038)		-0.1 ** (0.045)		-0.139 *** (0.041)		-0.133 *** (0.039)	
Year4	0 (0)	0.5 (0.501)								
Year5	0 (0)	0.5 (0.501)		-0.035 (0.026)		-0.014 (0.033)		-0.021 (0.028)		-0.041 (0.027)

Space	132 (51)	139 (58)	-0.0003 (0.0004)	0.00001 (0.00061)	-0.0007 (0.0005)	0.0006 (0.0008)	-0.0003 (0.0004)	-0.0002 (0.0007)	-0.0003 (0.0004)	0.0001 (0.0006)
Beds	762 (422)	760 (420)	0.00007 * (0.00004)	0.00007 * (0.00004)	0.00006 (0.00005)	0.00005 (0.00006)	0.00006 (0.00004)	0.00004 (0.00004)	0.00007 * (0.00004)	0.00007 * (0.00004)
Male	0.488 (0.064)	0.494 (0.065)	0.5 * (0.256)	0.6 * (0.308)	0.928 ** (0.47)	1.501 *** (0.543)	0.376 (0.337)	0.41 (0.433)	0.494 * (0.258)	0.564 * (0.308)
Cleaning	19.8 (7.6)	25 (8.5)	-0.003 * (0.002)	-0.002 (0.002)	-0.004 ** (0.002)	-0.002 (0.002)	-0.004 ** (0.002)	-0.003 * (0.002)	-0.003 (0.002)	-0.002 (0.002)
Consultants	0.547 (0.344)	0.648 (0.429)	0.143 (0.107)	0.184 (0.117)	0.083 (0.173)	0.135 (0.209)	0.176 (0.132)	0.201 (0.146)	0.145 (0.108)	0.187 (0.117)
London	0.185 (0.389)	0.185 (0.389)	0.215 *** (0.059)	0.116 * (0.059)	0.342 *** (0.064)	0.208 *** (0.066)	0.256 *** (0.06)	0.14 ** (0.062)	0.215 *** (0.059)	0.125 ** (0.06)
North West	0.168 (0.374)	0.168 (0.374)	-0.153 *** (0.051)	-0.033 (0.056)	-0.156 *** (0.053)	-0.048 (0.067)	-0.155 *** (0.052)	-0.04 (0.058)	-0.154 *** (0.051)	-0.032 (0.056)
Yorks / Humber	0.087 (0.282)	0.087 (0.282)	-0.224 *** (0.062)	-0.2 *** (0.064)	-0.197 *** (0.061)	-0.224 *** (0.069)	-0.233 *** (0.061)	-0.203 *** (0.067)	-0.225 *** (0.062)	-0.2 *** (0.064)
South East	0.075 (0.264)	0.075 (0.264)	-0.182 *** (0.065)	0.003 (0.065)	-0.042 (0.076)	0.01 (0.084)	-0.111 * (0.065)	0.032 (0.068)	-0.182 *** (0.066)	0.01 (0.065)
West Midlands	0.116 (0.32)	0.116 (0.32)	-0.052 (0.055)	-0.007 (0.057)	-0.069 (0.053)	0.007 (0.06)	-0.045 (0.055)	0.003 (0.059)	-0.052 (0.055)	-0.008 (0.057)
East Midlands	0.052 (0.222)	0.052 (0.222)	-0.215 *** (0.067)	-0.182 ** (0.073)	-0.127 * (0.074)	-0.061 (0.082)	-0.162 ** (0.066)	-0.131 * (0.074)	-0.216 *** (0.067)	-0.177 ** (0.073)
South West	0.104 (0.306)	0.104 (0.306)	-0.101 * (0.054)	-0.098 * (0.056)	-0.112 ** (0.053)	-0.068 (0.06)	-0.064 (0.054)	-0.099 * (0.057)	-0.1 * (0.055)	-0.084 (0.057)
North East	0.046 (0.21)	0.046 (0.21)	-0.216 *** (0.074)	-0.214 *** (0.079)	-0.193 ** (0.078)	-0.141 (0.094)	-0.233 *** (0.073)	-0.228 *** (0.08)	-0.217 *** (0.075)	-0.212 *** (0.078)
South Central	0.064 (0.244)	0.064 (0.244)	-0.221 *** (0.065)	-0.159 ** (0.066)	-0.204 *** (0.078)	-0.234 ** (0.094)	-0.184 *** (0.066)	-0.15 ** (0.07)	-0.221 *** (0.066)	-0.158 ** (0.066)
Temp	0.122 (0.086)	0.101 (0.089)	0.593 *** (0.221)	0.142 (0.182)	0.333 (0.245)	0.207 (0.19)	0.574 ** (0.225)	0.094 (0.188)		

Agency	0.047 (0.044)	0.023 (0.024)							0.53 (0.355)	-0.72 (0.605)
Bank	0.075 (0.064)	0.075 (0.077)							0.622 ** (0.254)	0.23 (0.191)
Constant			-0.159 (0.208)	-0.174 (0.237)	-0.546 * (0.331)	-0.411 (0.361)	-0.247 (0.241)	-0.385 (0.294)	-0.157 (0.209)	-0.167 (0.236)
N			504	296	320	190	452	267	504	296
Adj. R sq			0.512	0.4471	0.3968	0.3063	0.5296	0.3961	0.511	0.4497

Table B

Variable	Mean (SD)		(i) Standard Model		(ii) G&A occupancy		(iii) Occupancy in 4 bands		(iv) Occupancy 90+		(v) Interactive occupancy	
	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06	2001-04	2004-06
Dependent	0.656 (0.381)	0.565 (0.284)										
Specialist	0.26 (0.439)	0.26 (0.439)	0.277 *** (0.043)	0.122 *** (0.045)	0.278 *** (0.043)	0.124 *** (0.045)	0.278 *** (0.043)	0.123 *** (0.044)	0.278 *** (0.043)	0.122 *** (0.044)	0.272 *** (0.043)	0.12 *** (0.044)
Single specialty	0.104 (0.306)	0.104 (0.306)	-0.084 (0.086)	-0.317 *** (0.097)	-0.089 (0.087)	-0.313 *** (0.096)	-0.083 (0.086)	-0.311 *** (0.097)	-0.083 (0.086)	-0.314 *** (0.096)	-0.102 (0.087)	-0.296 *** (0.097)
PEAT	3.652 (0.815)	3.719 (0.653)	-0.072 *** (0.025)	-0.016 (0.02)	-0.067 *** (0.025)	-0.019 (0.02)	-0.072 *** (0.025)	-0.014 (0.02)	-0.072 *** (0.025)	-0.017 (0.02)	-0.073 *** (0.025)	-0.018 (0.02)
Single room	0.161 (0.096)	0.174 (0.089)	-0.051 (0.149)	-0.441 ** (0.184)	-0.024 (0.151)	-0.445 ** (0.184)	-0.051 (0.149)	-0.428 ** (0.184)	-0.049 (0.149)	-0.439 ** (0.183)	-0.053 (0.149)	-0.417 ** (0.184)
ALOS	2.173 (1.052)	1.853 (1.146)	0.012 (0.015)	0.014 (0.015)	0.014 (0.015)	0.014 (0.015)	0.011 (0.015)	0.013 (0.015)	0.011 (0.015)	0.014 (0.015)	0.012 (0.015)	0.017 (0.015)
Age	46.661 (8.201)	48.405 (8.32)	0.013 *** (0.002)	0.008 *** (0.003)	0.013 *** (0.002)	0.008 *** (0.003)	0.013 *** (0.002)	0.009 *** (0.003)	0.013 *** (0.002)	0.008 *** (0.003)	0.014 *** (0.003)	0.009 *** (0.003)
Emergency	0.337 (0.093)	0.356 (0.102)	0.578 ** (0.233)	0.313 (0.23)	0.612 *** (0.234)	0.296 (0.23)	0.583 ** (0.233)	0.326 (0.229)	0.575 ** (0.232)	0.312 (0.229)	0.568 ** (0.233)	0.312 (0.229)
Occupancy8590	0.331 (0.471)	0.292 (0.455)	-0.009 (0.03)	-0.011 (0.033)			-0.009 (0.03)	-0.012 (0.033)				
Occupancy90	0.179 (0.384)	0.179 (0.384)	0.103 *** (0.039)	0.012 (0.04)					0.109 *** (0.035)	0.018 (0.035)		
Occupancy9095	0.166 (0.372)	0.145 (0.352)					0.107 *** (0.04)	-0.009 (0.043)				
Occupancy95	0.013 (0.115)	0.035 (0.183)					0.056 (0.108)	0.093 (0.073)				

GAOcc8590	0.351 (0.478)	0.376 (0.485)			0.007 (0.033)	0.001 (0.034)						
GAOcc90	0.272 (0.445)	0.234 (0.424)			0.061 (0.038)	0.04 (0.041)						
Occupancy	0.844 (0.062)	0.84 (0.075)									-0.53 (0.45)	0.423 (0.275)
IntOcc8590	0.293 (0.412)	0.255 (0.398)									0.029 (0.048)	-0.044 (0.043)
IntOcc90	0.167 (0.356)	0.166 (0.356)									0.18 ** (0.071)	-0.042 (0.057)
Contract	0.402 (0.456)	0.4 (0.456)	-0.057 * (0.03)	-0.022 (0.032)	-0.053 * (0.03)	-0.029 (0.032)	-0.058 * (0.03)	-0.024 (0.032)	-0.057 * (0.03)	-0.023 (0.032)	-0.062 ** (0.03)	-0.017 (0.032)
Backlog	134 (161)	150 (202)	-0.00002 (0.00009)	0.00013 * (0.00007)	-0.00002 (0.00009)	0.00013 * (0.00007)	-0.00003 (0.00009)	0.00013 * (0.00007)	-0.00002 (0.00009)	0.00013 * (0.00007)	-0.00002 (0.00009)	0.00013 * (0.00007)
T&O	0.085 (0.117)	0.084 (0.117)	-0.19 (0.125)	-0.188 (0.131)	-0.181 (0.126)	-0.169 (0.132)	-0.188 (0.125)	-0.184 (0.131)	-0.187 (0.124)	-0.182 (0.13)	-0.217 * (0.127)	-0.181 (0.131)
ENT	0.026 (0.019)	0.023 (0.017)	1.39 * (0.752)	1.505 * (0.877)	1.327 * (0.758)	1.403 (0.874)	1.397 * (0.753)	1.586 * (0.878)	1.379 * (0.751)	1.481 * (0.873)	1.455 * (0.754)	1.601 * (0.877)
Ophthalmology	0.037 (0.078)	0.036 (0.077)	-1.194 *** (0.354)	-1.775 *** (0.658)	-1.216 *** (0.357)	-1.769 *** (0.661)	-1.202 *** (0.355)	-1.856 *** (0.66)	-1.2 *** (0.353)	-1.761 *** (0.656)	-1.236 *** (0.356)	-1.992 *** (0.671)
Neurosurgery	0.006 (0.033)	0.006 (0.029)	2.302 *** (0.485)	1.264 *** (0.461)	2.282 *** (0.488)	1.208 *** (0.463)	2.305 *** (0.485)	1.305 *** (0.462)	2.294 *** (0.483)	1.24 *** (0.455)	2.369 *** (0.488)	1.147 ** (0.466)
Nephrology	0.007 (0.018)	0.008 (0.021)	1.07 (0.754)	-0.147 (0.664)	0.918 (0.767)	-0.135 (0.659)	1.059 (0.755)	-0.113 (0.663)	1.06 (0.753)	-0.134 (0.662)	1.078 (0.754)	-0.154 (0.662)
Year2	0.333 (0.472)	0 (0)	-0.105 ** (0.044)		-0.096 ** (0.044)		-0.106 ** (0.044)		-0.105 ** (0.044)		-0.108 ** (0.044)	
Year3	0.333 (0.472)	0 (0)	-0.131 *** (0.038)		-0.127 *** (0.039)		-0.132 *** (0.039)		-0.132 *** (0.038)		-0.133 *** (0.038)	
Year4	0 (0)	0.5 (0.501)										

Year5	0 (0)	0.5 (0.501)		-0.035 (0.026)		-0.035 (0.026)		-0.038 (0.026)		-0.035 (0.026)		-0.037 (0.026)
Space	132 (51)	139 (58)	-0.0003 (0.0004)	0.00001 (0.00061)	-0.0002 (0.0004)	-0.0001 (0.0006)	-0.0003 (0.0004)	0.00001 (0.0006)	-0.0003 (0.0004)	-0.00002 (0.0006)	-0.0002 (0.0004)	-0.00002 (0.0006)
Beds	762 (422)	760 (420)	0.00007 * (0.00004)	0.00007 * (0.00004)	0.00007 * (0.00004)	0.00007 * (0.00004)	0.00007 (0.00004)	0.00008 * (0.00004)	0.00007 (0.00004)	0.00007 * (0.00004)	0.00007 * (0.00004)	0.00007 * (0.00004)
Male	0.488 (0.064)	0.494 (0.065)	0.5 * (0.256)	0.6 * (0.308)	0.538 ** (0.258)	0.587 * (0.306)	0.496 * (0.256)	0.583 * (0.308)	0.497 * (0.256)	0.592 * (0.307)	0.527 ** (0.257)	0.591 * (0.307)
Cleaning	19.8 (7.6)	25 (8.5)	-0.003 * (0.002)	-0.002 (0.002)	-0.003 (0.002)	-0.002 (0.002)	-0.003 (0.002)	-0.002 (0.002)	-0.003 * (0.002)	-0.002 (0.002)	-0.003 * (0.002)	-0.002 (0.002)
Consultants	0.547 (0.344)	0.648 (0.429)	0.143 (0.107)	0.184 (0.117)	0.152 (0.108)	0.189 (0.119)	0.145 (0.107)	0.182 (0.117)	0.146 (0.107)	0.187 (0.116)	0.124 (0.108)	0.192 (0.117)
London	0.185 (0.389)	0.185 (0.389)	0.215 *** (0.059)	0.116 * (0.059)	0.214 *** (0.059)	0.11 * (0.059)	0.214 *** (0.059)	0.118 ** (0.059)	0.214 *** (0.059)	0.114 * (0.059)	0.227 *** (0.06)	0.11 * (0.059)
North West	0.168 (0.374)	0.168 (0.374)	-0.153 *** (0.051)	-0.033 (0.056)	-0.15 *** (0.052)	-0.03 (0.056)	-0.154 *** (0.051)	-0.039 (0.056)	-0.152 *** (0.051)	-0.031 (0.056)	-0.153 *** (0.051)	-0.033 (0.056)
Yorks / Humber	0.087 (0.282)	0.087 (0.282)	-0.224 *** (0.062)	-0.2 *** (0.064)	-0.221 *** (0.062)	-0.194 *** (0.064)	-0.225 *** (0.062)	-0.206 *** (0.064)	-0.222 *** (0.061)	-0.196 *** (0.063)	-0.227 *** (0.062)	-0.186 *** (0.065)
South East	0.075 (0.264)	0.075 (0.264)	-0.182 *** (0.065)	0.003 (0.065)	-0.174 *** (0.066)	-0.008 (0.065)	-0.186 *** (0.066)	-0.003 (0.065)	-0.184 *** (0.065)	0.0004 (0.0644)	-0.175 *** (0.066)	-0.0001 (0.065)
West Midlands	0.116 (0.32)	0.116 (0.32)	-0.052 (0.055)	-0.007 (0.057)	-0.048 (0.056)	-0.024 (0.058)	-0.053 (0.055)	-0.014 (0.057)	-0.054 (0.055)	-0.01 (0.057)	-0.046 (0.055)	-0.013 (0.057)
East Midlands	0.052 (0.222)	0.052 (0.222)	-0.215 *** (0.067)	-0.182 ** (0.073)	-0.217 *** (0.067)	-0.179 ** (0.073)	-0.216 *** (0.067)	-0.187 ** (0.073)	-0.215 *** (0.067)	-0.179 ** (0.073)	-0.213 *** (0.067)	-0.188 ** (0.073)
South West	0.104 (0.306)	0.104 (0.306)	-0.101 * (0.054)	-0.098 * (0.056)	-0.102 * (0.055)	-0.096 * (0.056)	-0.101 * (0.054)	-0.107 * (0.057)	-0.1 * (0.054)	-0.096 * (0.056)	-0.095 * (0.055)	-0.102 * (0.056)
North East	0.046 (0.21)	0.046 (0.21)	-0.216 *** (0.074)	-0.214 *** (0.079)	-0.21 *** (0.076)	-0.204 *** (0.079)	-0.216 *** (0.074)	-0.226 *** (0.079)	-0.212 *** (0.073)	-0.208 *** (0.077)	-0.223 *** (0.075)	-0.214 *** (0.078)
South Central	0.064 (0.244)	0.064 (0.244)	-0.221 *** (0.065)	-0.159 ** (0.066)	-0.22 *** (0.066)	-0.166 ** (0.066)	-0.221 *** (0.065)	-0.158 ** (0.066)	-0.221 *** (0.065)	-0.158 ** (0.066)	-0.215 *** (0.066)	-0.161 ** (0.066)

Temp	0.122 (0.086)	0.101 (0.089)	0.593 *** (0.221)	0.142 (0.182)	0.632 *** (0.221)	0.14 (0.181)	0.596 *** (0.221)	0.115 (0.183)	0.586 *** (0.219)	0.144 (0.181)	0.573 *** (0.221)	0.132 (0.181)
Agency	0.047 (0.044)	0.023 (0.024)										
Bank	0.075 (0.064)	0.075 (0.077)										
Constant			-0.159 (0.208)	-0.174 (0.237)	-0.242 (0.207)	-0.132 (0.237)	-0.156 (0.209)	-0.202 (0.238)	-0.16 (0.208)	-0.169 (0.236)	0.246 (0.401)	-0.52 (0.326)
N			504	296	504	296	504	296	504	296	504	296
Adj. R sq			0.512	0.4471	0.5054	0.4493	0.5111	0.4488	0.5129	0.449	0.5125	0.45

Annex C: Variables Used and Sources

Dependent Variable

- MRSA bacteraemia reports per 1000 admissions

Numerator: total number of MRSA bacteraemia reports
Source: Health Protection Agency staphylococcus aureus mandatory surveillance scheme, details available at
http://www.hpa.org.uk/infections/topics_az/staphylo/staphylo_mandatory_surveillance.htm, data available at
http://www.hpa.org.uk/infections/topics_az/hai/Mandatory_Results.htm

Denominator: total number of admissions divided by 1000
Source: Hospital Episode Statistics, details and data available at
http://www.hesonline.org.uk

Independent Variables

- Specialist Trusts

Dummy variable equalling 1 if the Trust is a specialist Trust and 0 otherwise
Source: details and data available at
http://www.hpa.org.uk/infections/topics_az/hai/Mandatory_Results.htm

- Single specialty Trusts

Dummy variable equalling 1 if the Trust is a single specialty Trust and 0 otherwise
Source: details and data available at
http://www.hpa.org.uk/infections/topics_az/hai/Mandatory_Results.htm

- Cleanliness (PEAT score)

The Trust's Patient Experience Action Team (PEAT) score
Source: details and data available at
http://patientexperience.nhsestates.gov.uk/clean_hospitals/ch_content/home/home.asp

- Single rooms availability

Proportion of all beds provided in single rooms
Source: Estates Return Information Collection (ERIC), details available at
http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

- Average length of stay

Median length of stay in days for all inpatient admissions
Source: Hospital Episode Statistics, details and data available at
http://www.hesonline.org.uk

- Average age of patients

Mean age of inpatients
Source: Hospital Episode Statistics, details and data available at
http://www.hesonline.org.uk

- Emergency admissions

Proportion of all inpatient admissions that were emergency admissions
Source: Hospital Episode Statistics, details and data available at
http://www.hesonline.org.uk

- Bed occupancy rate

Percentage of open and staffed beds (either total beds or general and acute only) which are occupied at midnight
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- Occupancy 85%- 90%

A dummy variable equalling 1 if a Trust has a total bed occupancy rate between 85% and 90%, 0 otherwise
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- Occupancy > 90%

A dummy variable equalling 1 if a Trust has a total bed occupancy rate over 90%, 0 otherwise.
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- Cleaning service type

A variable equalling 1 if Trusts contract out cleaning services and 0 if cleaning services are provided in-house. Where a Trust has a mixture of contract and in-house cleaning (e.g. in different hospital sites), this variable is a fraction derived by weighting cleaning service type by the number of beds
Source: Estates Return Information Collection (ERIC), details available at
http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

- Backlog expenditure per m^2

Numerator: expenditure required for Trust to achieve “Category B” physical condition standards
Source: Estates Return Information Collection (ERIC), details available at
http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

Denominator: Occupied m^2

Source: Estates Return Information Collection (ERIC), details available at http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

- Trauma and Orthopaedics

Proportion of total admissions that were in the Trauma and Orthopaedics specialty
Source: Hospital Episode Statistics, details available at http://www.hesonline.org.uk

- Ear, Nose and Throat

Proportion of total admissions that were in the Ear, nose and throat specialty
Source: Hospital Episode Statistics, details available at http://www.hesonline.org.uk

- Ophthalmology

Proportion of total admissions that were in the Ophthalmology specialty
Source: Hospital Episode Statistics, details available at http://www.hesonline.org.uk

- Neurosurgery

Proportion of total admissions that were in the Neurosurgery specialty
Source: Hospital Episode Statistics, details available at http://www.hesonline.org.uk

- Nephrology

Proportion of total admission that were in the Nephrology specialty
Source: Hospital Episode Statistics, details available at http://www.hesonline.org.uk

- Agency nursing staff

Proportion of nursing staff that are employed using outside agencies

Numerator: number of agency nurses
Source: From Trust and PCT financial returns, 2001/2 – 2005/6; Non-medical workforce census 2001, 2002, 2003, 2004, 2005

Denominator: total number of nurses
Source: Details and data available at
http://www.dh.gov.uk/PublicationsAndStatistics/Statistics/StatisticalWorkAreas/StatisticalWorkforce/StatisticalWorkforceArticle/fs/en?CONTENT_ID=4087066&chk=H9lFf3

- Bank nursing staff

Proportion of nursing staff that are employed on bank contracts

Numerator: number of bank nurses
Source: From Trust and PCT financial returns, 2001/2 – 2005/6; Non-medical workforce census 2001, 2002, 2003, 2004, 2005

Denominator: total number of nurses
Source: Details and data available at
http://www.dh.gov.uk/PublicationsAndStatistics/Statistics/StatisticalWorkAreas/StatisticalWorkforce/StatisticalWorkforceArticle/fs/en?CONTENT_ID=4087066&chk=H9lFf3

- Floor space per bed

Numerator: Total occupied floor space (in m^2)
Source: Estates Return Information Collection (ERIC), details available at http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

Denominator: total number of available beds
Source: Estates Return Information Collection (ERIC), details available at http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

- Number of beds

Number of beds in the Trust available to patients overnight.
Source: Details and data available at http://www.performance.doh.gov.uk/hospitalactivity/)

- Male

Proportion of all inpatient admissions that were male
Source: Hospital Episode Statistics, details and data available at http://www.hesonline.org.uk/

- Expenditure on cleaning

Numerator: total expenditure on cleaning services
Source: Estates Return Information Collection (ERIC), details available at http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

Denominator: total occupied floor space (in m^2)
Source: Estates Return Information Collection (ERIC), details available at http://www.dh.gov.uk/PolicyAndGuidance/OrganisationPolicy/EstatesAndFacilitiesManagement/PropertyManagement/PropertyManagementArticle/fs/en?CONTENT_ID=4117912&chk=F7BjNB

- Foundation Trusts

Dummy variable equalling 1 if the Trust is a Foundation Trust and 0 otherwise
Source: Details and data available at http://www.monitor-nhsft.gov.uk/register_nhsft.php

- Nurses per 1000 bed days

Numerator: number of (headcount) nurses
Source: Details and data available at http://www.dh.gov.uk/PublicationsAndStatistics/Statistics/StatisticalWorkAreas/StatisticalWorkforce/StatisticalWorkforceArticle/fs/en?CONTENT_ID=4087066&chk=H9lFf3

Denominator: 1000 bed days
Source: Hospital Episode Statistics, details and data available at
http://www.hesonline.org.uk/

- Consultants per 1000 bed days

Numerator: number of whole time equivalent consultants
Source: Details and data available at
http://www.dh.gov.uk/PublicationsAndStatistics/Statistics/StatisticalWorkAreas/StatisticalWorkforce/StatisticalWorkforceArticle/fs/en?CONTENT_ID=4087066&chk=H9lFf3

Denominator: 1000 bed days
Source: Hospital Episode Statistics, details and data available at
http://www.hesonline.org.uk/

- North East strategic health authority

A dummy variable equalling 1 if a Trust is in the North East SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- North West strategic health authority

A dummy variable equalling 1 if a Trust is in the North West SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- Yorkshire & the Humber strategic health authority

A dummy variable equalling 1 if a Trust is in the Yorkshire & Humber SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- East Midlands strategic health authority

A dummy variable equalling 1 if a Trust is in the East Midlands SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- West Midlands strategic health authority

A dummy variable equalling 1 if a Trust is in the West Midlands SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- East of England strategic health authority

A dummy variable equalling 1 if a Trust is in the East of England SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- London strategic health authority

A dummy variable equalling 1 if a Trust is in the London SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- South East strategic health authority

A dummy variable equalling 1 if a Trust is in the South East SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- South Central strategic health authority

A dummy variable equalling 1 if a Trust is in the South Central SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- South West strategic health authority

A dummy variable equalling 1 if a Trust is in the South West SHA, 0 otherwise
Source: Details and data available at http://www.nhs.uk/nacs/data.aspx

- Occupancy interaction 85%-90%

The occupancy 85%-90% dummy multiplied by the bed occupancy rate
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- Occupancy Interaction >90%

The occupancy dummy >90% multiplied by the bed occupancy rate
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- General and Acute bed occupancy

The bed occupancy rate for the hospitals bed in general and acute wards
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- General and acute bed occupancy 85%-90%

A dummy equalling 1 if the Trust's general and acute bed occupancy is between 85% and 90%, 0 otherwise
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- General and acute bed occupancy >90%

A dummy variable equalling 1 if a Trust's general and acute bed occupancy is above 90%, 0 otherwise
Source: Form KH03, details and data available at
http://www.performance.doh.gov.uk/hospitalactivity/

- Temporary Staff

Variable equalling the sum of the proportion of agency staff and bank staff

- London- Temporary Interaction

Variable equalling the multiplication of the temporary staff variable and the London dummy variable

- London- Specialist interaction

Variable equalling the multiplication of the Specialist dummy and the London dummy variable

Annex D- References

Bed Occupancy

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