Waiting Times and Attendance Durations at English Accident and Emergency Departments

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Executive summary

Waiting times in A&E have become the defining healthcare performance issue of our time, much like elective waiting times and hospital acquired infections have been in the past. Since 2004, the NHS in England has sought to ensure that patients spend no more than 4 hours in Accident and Emergency Departments. In recent years reported performance has deteriorated and, in the winter of 2017/18, almost one quarter of attendances at major A&E departments breached the target maximum duration. The decline in performance has been steady, sustained and almost ubiquitous.

Attempts to restore performance levels have waxed and waned whilst the media's interest in the target continues to grow. In 2018, NHS England announced plans to review all constitutional waiting times targets, reopening the intense debate about the value and impact of the 4-hour A&E target.

Whilst there is no shortage of commentary on the subject, there have been few detailed analyses of the factors that are driving increases in A&E attendance durations and 4-hour breaches. In the absence of clear causal explanations, responsibility for 'poor performance' is often levelled at A&E departments, with implications of poor management and inefficiency.

This report presents a detailed review of the demand-side, supply-side, practice and emergent factors that lead to 4-hour breaches with a particular focus on changes that have taken place since 2010. The report reviews both commonly cited causal factors and a range of more novel hypotheses. It sets out the causal theories underpinning each factor and seeks statistical evidence in support of them. Finally, the analysis scales the relative impact of each causal factor and aims to provide an explanation for the recent deterioration in A&E waiting times within the limits of national datasets. New insights emerge which have the potential to reshape the received wisdom about the performance of A&E departments, carrying important implications for healthcare policy and system leadership.

Key Findings

No single factor can explain the observed increase in 4-hour breaches since 2010; rather several factors have combined and interacted to add pressure on A&E departments and lengthen attendance durations.

Demand-side factors: The complexity and acuity of patients attending A&E has increased steadily. Patients presenting with complex conditions require more investigations and treatments, increasing attendance durations and the risk of a 4-hour breach.

Growth in the number of attendances at major A&E departments has been slow and has had only a minimal impact on attendance durations.

Supply-side effects: Inpatient occupancy levels have risen leading to increases in boarding times (the period between a decision to admit and an admission) and 4-hour breaches.

Data on staffing levels and facilities in A&E departments is limited. However, from the data that is available it appears that levels of medical and non-medical staffing and facilities in A&E (e.g. cubicles, trolleys) have not kept pace with changes in casemix and increases in practice intensity.

Practice factors: The way in which A&E departments manage patients has changed in recent years in two key respects. Firstly, patients are more likely to receive tests and investigations in A&E than was the case in the past. Secondly, some patients who would previously have been admitted are now being managed in A&E without the need for admission. These effects are seen even after adjusting for the increase in complexity and acuity of patients attending A&E.

One potential explanation links these changes with increases in bed occupancy. Increases in the frequency of tests and investigations may be the mechanism by which admission thresholds have been raised, allowing A&E departments to rule out serious complaints which might otherwise necessitate admission.

Whilst attendance durations may have been reduced for patients whose admission was avoided, the net effect of reducing thresholds for investigations in A&E has been to increase average attendance durations as a whole and the number of 4-hour breaches.

Emergent factors: The factors set out above mean that A&E departments are more likely to experience periods of pressure. But A&E departments have also become less resilient, taking longer to recover from periods of pressure than in the past. This means that the impact of pressure is sustained, affecting more patients and leading to more 4-hour breaches.

Taken together these factors can explain most of the deterioration in performance against the 4-hour target that has been observed in recent years.

Policy Implications

The casemix of patients presenting at A&E is changing with consistent trends towards greater complexity and acuity. When decisions were taken to reduce the 4-hour target level from 100% to 98%, and then to 95%, it was based on the premise that some patients "*could benefit from a longer period of active treatment in A&E*" (DH 2011). If one accepts this premise and the 4-hour standard is intended as a performance benchmark which is consistent over time, and common (fair) between providers, then there may be an argument for adjusting or stratifying the performance target to reflect differences and changes in casemix. Casemix-adjustment is not without its challenges, but it is an approach commonly used in other aspects of clinical and operational performance measurement. It is worth noting however, that the reductions in performance observed in recent years are far greater than can be explained by casemix changes alone.

Policy makers must consider the trade-off between increased durations in A&E and avoidable hospital admissions. Improvements against the 4-hour target could be delivered by increasing the bed stock and reversing the trends in investigation thresholds in A&E, but this will almost inevitably lead to an increase in admissions.

The number of investigations and treatments carried out in A&E has increased considerably in recent years. The increase in treatment rates has been driven almost entirely by changes in casemix; and whilst casemix also plays a part in the increase in investigations, almost half of the growth in investigations is attributable to changes in practice. These practice changes have generated c. 5 million additional tests in A&E per annum since 2010/11. Comprehensive, evidence-based guidelines setting out the circumstances in which tests and investigations in A&E add diagnostic value, may reduce the frequency of low value tests and could lead to reductions in A&E attendance durations without increasing admissions.

If performance levels are to be sustained, then the quantity of staff and facilities in A&E must increase in line with activity levels in A&E (i.e. the quantity of investigations and treatments) rather than the number of patient arrivals. More data on staffing is required to draw firm conclusions about the adequacy of resource levels in A&E departments.

Much of this analysis relies on the 'big data' that is generated as A&E departments record activities carried out. The quality of this data has improved in recent years, but data on A&E diagnoses remains patchy, denying the opportunity for important insights. Given the centrality of this variable to understanding casemix changes, and the impact of casemix on attendance durations, continued efforts to drive up the quality and consistency of diagnosis recording in A&E are warranted.

Further work on diagnostic imaging capacity, the availability of specialists to review patients in A&E and the impact of 7-day working may provide fresh insights and lead to service improvement opportunities.

1. The 4-hour A&E target

1.1 The target and its history

Targets for timely access to healthcare in an emergency are a feature of regulatory regimes in many countries. In England targets have been in place since 2004 and are expressed in terms of the maximum time from a patient's arrival at an accident and emergency department to the point at which the patient is discharged from the department or admitted to a hospital bed.

The government's initial expectation was that no patient should spend more than 4 hours in an A&E department. However, clinicians argued that in some special circumstances, it may be clinically preferable for patients to spend more than 4 hours in an A&E under close observation. The government responded by adjusting the target so that 98% of patients should be treated within 4 hours. In 2010, the target level was further reduced to 95% to allow greater time for complex investigations (DH 2011). When NHS England was established in 2012, the target was incorporated as an operational standard in the NHS Constitution. Following several years of performance deteriorations, the Government acknowledged that delivery of the 95% target level was unlikely to occur in the short term and instead set the NHS the aim of ensuring that at least 90% of patients were treated within 4 hours by September 2018.

The target has been consistently controversial and is rarely far from the headlines. Proponents point out that the target is simple, well understood and warranted given the relationship between timeliness of emergency treatment and mortality. Following an analysis of UK data, the National Bureau for Economic Research concluded that the 4-hour target has been successful in reducing waiting times as well as patient mortality (Gruber J, 2018). However, critics of the target commonly cite three problems; its distorting effect on operational practice, a lack of stratification or casemix adjustment and the risk that it may incentivise admissions that are not clinically warranted. The strength and bitterness of this debate is illustrated in a recent BMJ article and the responses it received (Campbell P 2017).

In recent months several senior NHS managers have entered the debate, asking whether the target should be retained, overhauled or scrapped altogether (Illman J 2018). A national review of waiting times targets was announced in 2018 and is due to report in March 2019.

Box 1: Data on A&E performance

Performance against the 4-hour target is reported by NHS providers to NHS England and is published on a monthly basis. This data sets out the numbers of patients seen in A&E departments each month and the number that are seen, treated and discharged within 4 hours. This data is regarded as the official source of information of timeliness of treatment in A&E departments.

A&E departments are classified into 4 types. Type 1 departments are 24-hour consultant-led units with full resuscitation facilities and designated accommodation for the reception of accident and emergency patients. Type 2 units are single-specialty consultant-led units such as specialist eye or dental services. Type 3 and 4 units may be nurse- or doctor-led facilities such as Minor Injury Units or Walk-in Centres. This report is primarily concerned with performance in Type 1 and 2 units.

Providers also submit more detailed data on each of the 20+ million A&E attendances that take place each year. This is cleansed and pseudonymised to create the Hospital Episode Statistics Accident and Emergency (HESAE) dataset. HESAE contains data on the demographic characteristics of patients (age, gender etc), arrival mode, clinical presentation, investigations and treatments conducted in the department. The dataset also includes a series of dates and times which describe the flow of a patient through the department. This rich source of information supports more detailed analysis of the factors that influence the timeliness of care and is therefore used extensively in this report. Whilst measures of timeliness of A&E treatment that are derived from HESAE do not always fully reconcile with the official performance reports, any differences are usually trivial.

1.2 Performance trends

Figure 1 shows the trends in the proportion of attendances at type 1 A&E departments that 'breach' the 4-hour target duration from April 2004 to September 2018. Following the introduction of the target in 2004, performance improved for six consecutive quarters. Performance then stabilised for approximately 5 years, with any residual variation following a clear seasonal pattern. When the target level was reset in 2010, performance levels immediately responded and held at the level for 2 years. From 2012 onwards however, performance steadily declined and, in the winter of 2017/18, almost one quarter attendances at type 1 A&E departments lasted longer than 4 hours.

Figure 1.1: Performance against the 4-hour A&E target, Type 1 Units, England, April 2004 - September 2018

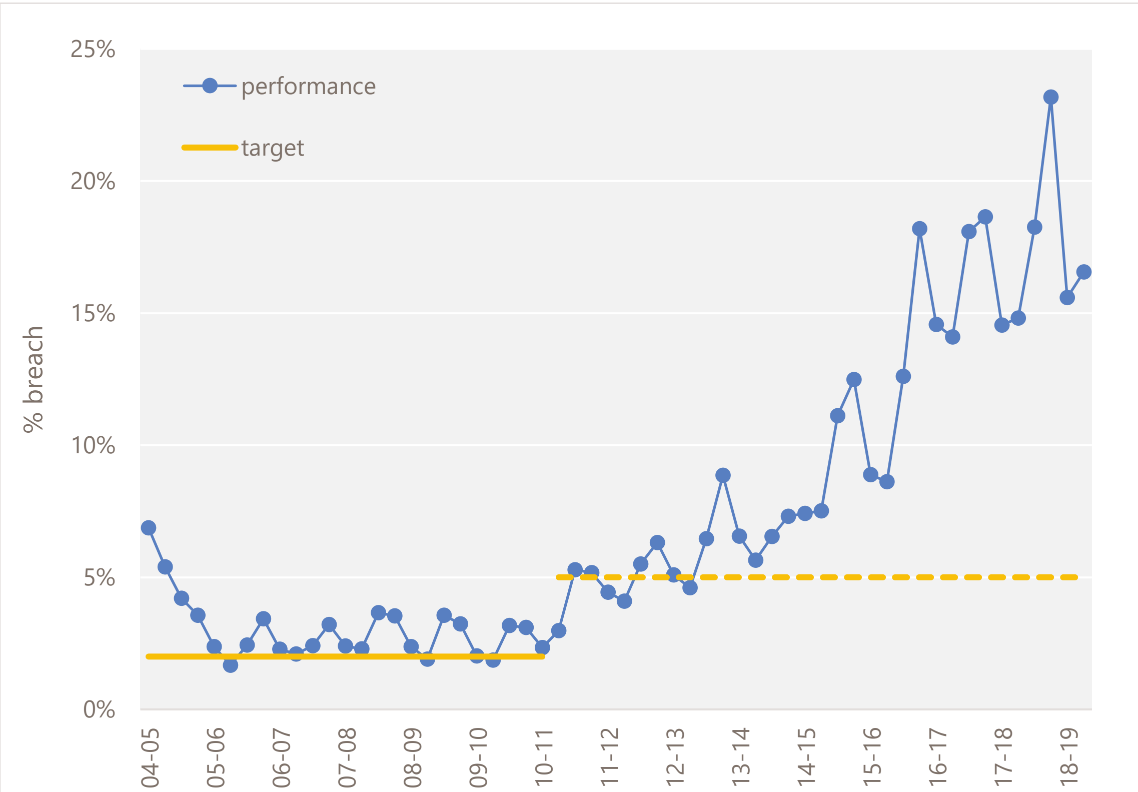
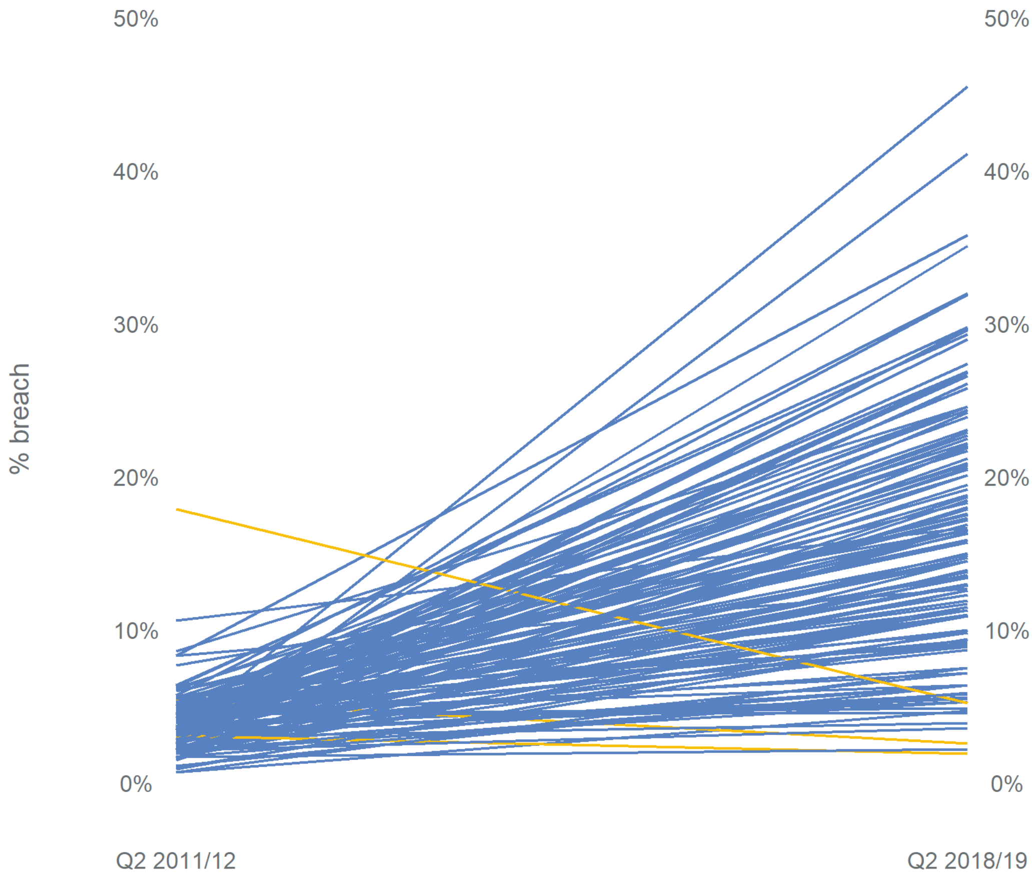


Figure 2 shows the change in performance against the 4-hour target between the second quarters of 2011/12 and 2017/18 for each of the 130 NHS providers where data is available.

Performance deteriorated in all but three providers and in most providers this deterioration was substantial.

Figure 1.2: Changes in performance against the 4-hour A&E target, Q2 2011-12 to Q2 2018-19 Each line represents a provider (n = 130)

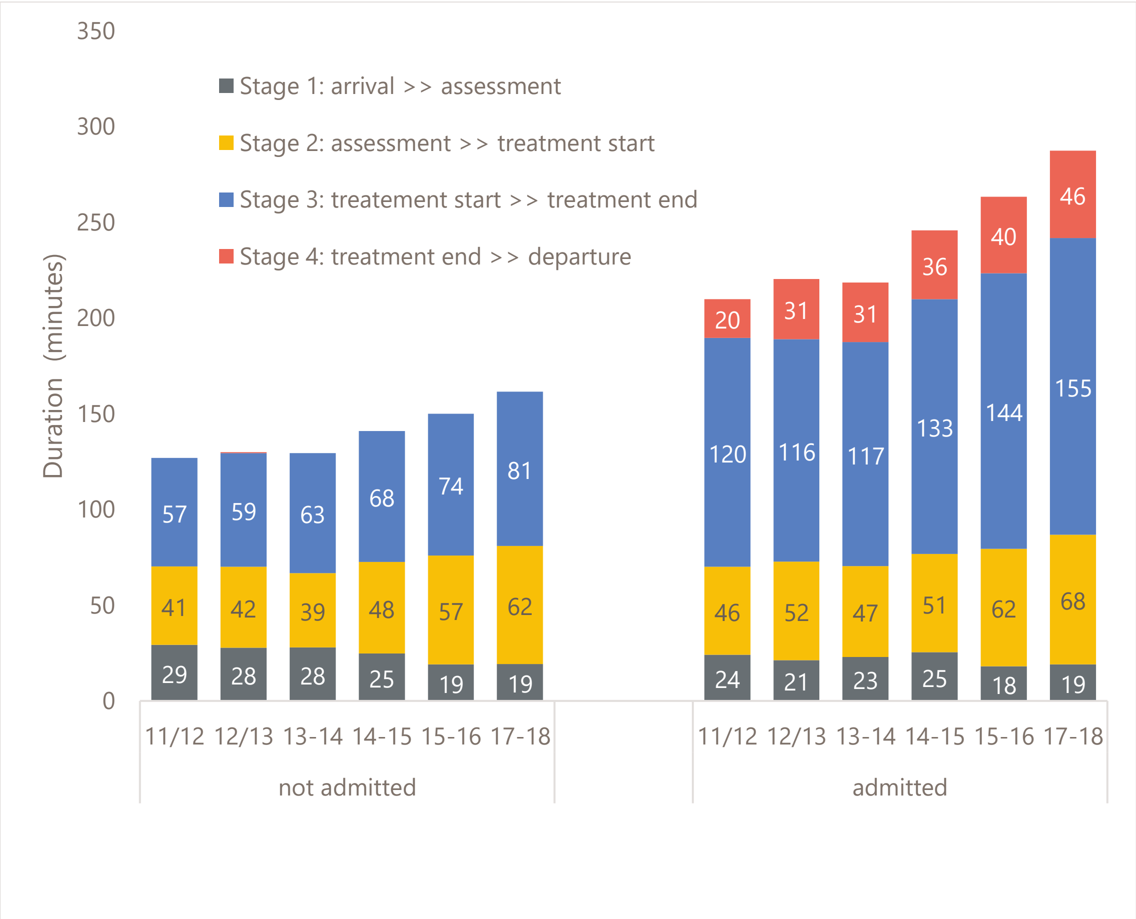


1.3 Components of attendance durations

A patient's visit to A&E is made up four stages. The first stage runs from a patient's arrival in the department to the point at which an initial assessment is carried out. The second stage starts from this initial assessment and continues until treatment begins and the third stage represents the period of treatment. The fourth stage runs from the end of treatment to the time when the patient leaves the department. In practice this fourth stage is only significant if a patient is subsequently admitted to a hospital bed. This is commonly referred to as the 'boarding' time.

Figure 1.3 shows the average (mean) duration of these four stages for patients who are admitted and those that are not, for each year from 2011-12 to 2017-18. Average treatment durations (stage 3) have increased each year for both admitted and non-admitted patients. From 2014/15 onwards, both groups of patients have also seen increases in the time from initial assessment to treatment start (stage 2). The average boarding time for admitted patients (stage 4) increased in most years and more rapidly since 2014/15.

Figure 1.3: Changes in the average duration in A&E by stage; England, 2011/12 to 2017/18



1.4 Causal theories for the decline in performance

A report published by the Health Foundation and Nuffield Trust in 2014 examined the patterns of A&E attendances and the causes of increased attendance durations in the period up to March 2014 (Blunt, I 2014). At this point, performance had begun to deteriorate but the proportion of attendances lasting more than 4 hours remained below

10%. The report concluded that the number of A&E attendances had increased somewhat (but no more than would be expected from population growth), and that high occupancy levels of inpatient beds had led to some increases in waiting times. The authors were unable to reach conclusions about the sufficiency of resource levels in A&E because of a lack of reliable data.

In 2017, analysis conducted by The Strategy Unit found that patients attending major A&Es were more unwell or more severely injured than those that attended in the past, and that some patients who would previously have been admitted to a hospital bed were now being managed entirely within the A&E department (Wyatt S 2017 & 2018).

The causal factors considered in these two reports represent the commonly proposed theories for increases in A&E attendance durations and the decline in performance against the 4-hour target. These and a range of more novel factors are considered in this report. The factors are classified into four groups: demand-side factors, supply-side factors, practice factors and emergent factors.

1.5 Causal loop diagrams

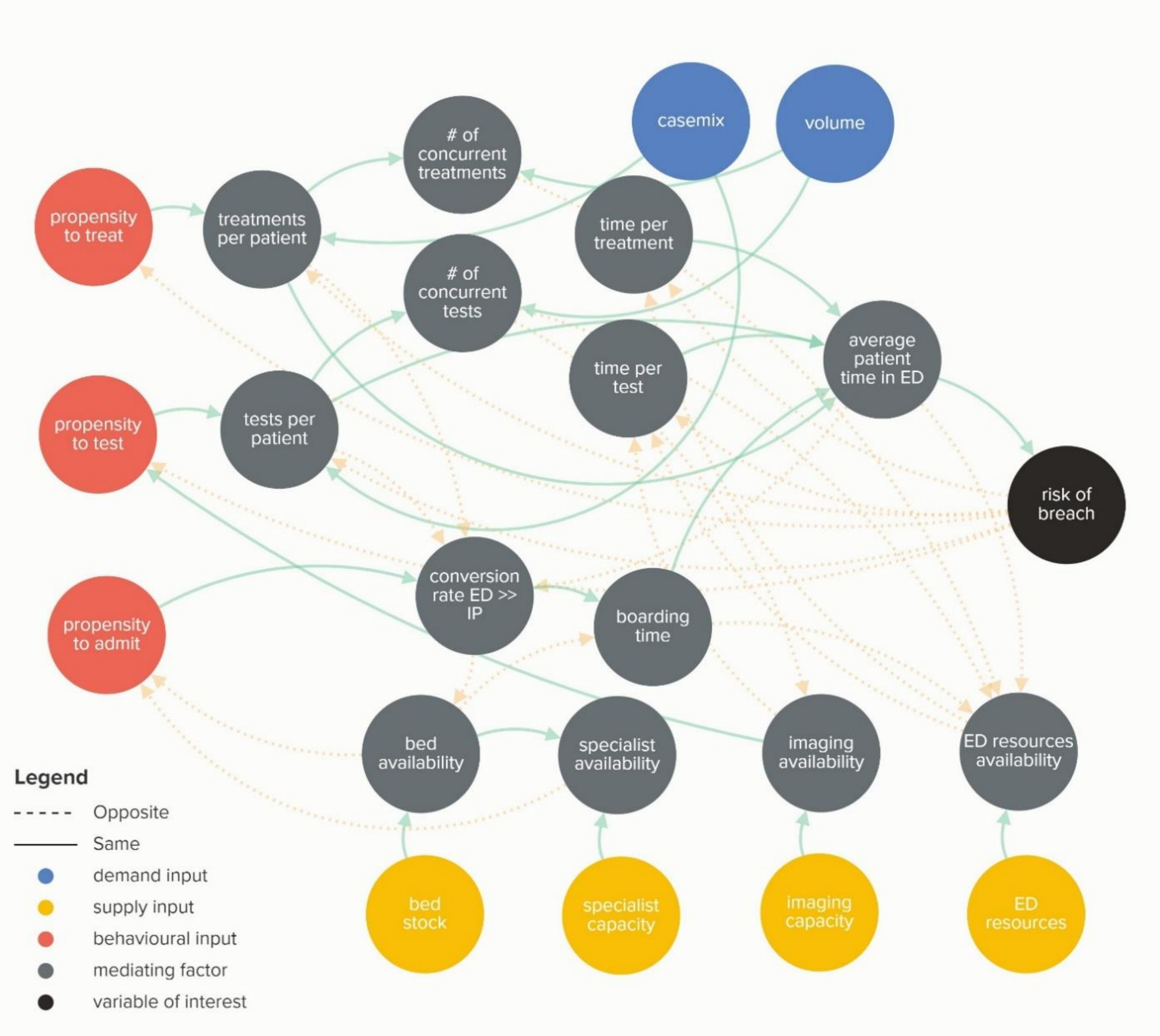
Whilst often cited, the mechanisms by which these causal factors might lead to increased attendance durations are rarely discussed. Understanding these mechanisms is a critical component for any robust analysis. In some cases, these mechanisms appear straightforward (e.g. if a bed is not immediately available for a patient then the boarding time might be expected to increase) but this is not the case for all factors.

In this report, causal loop diagrams are used to describe the possible relationships between attendance durations, potential causal factors, and a set of mediating variables.

Figure 5 represents a theoretical causal loop diagram and demonstrates the complex and manifold interactions between the causal, mediating and outcome variables. This is not meant to be a perfect model, but instead as a first effort, to aid transparency, reflection and to generate discussion. The model shows how demand-side factors (blue), supply-side factors (yellow) and practice factors (red) impact on the risk of a 4-hour breach (black) via a set of mediating variables (grey). A green arrow from one variable to another indicates that increases (or decreases) in the first variable leads to increases (or decreases) in the second . An orange dotted arrow from variable A and variable B indicates that an increase in variable A might be expected to lead to a decrease variable B.

As potential causal factors are considered later in this report, the relevant sub-sections of the causal loop diagram are isolated to demonstrate the mechanism by which the causal factor might lead to changes in A&E attendance durations.

Figure 1.4: Causal Loop Diagram – Theoretical Relationships Between A&E Durations, Potential Causal and Mediating Variables



1.6 The structure of this report

This report identifies and explores the evidence in support of a number of factors which may have led to or contributed to the increase in 4-hour breaches in A&E departments in England.

Chapter 2 focuses on factors relating to demand for A&E services: increased attendances and changes in casemix of patients who present at A&E departments.

In chapter 3, supply side factors are considered: exit block/inpatient occupancy, the levels of staffing and facilities in A&E and the availability of diagnostic imaging and the availability of specialists to review patients in A&E departments.

Chapter 4 explores the impact of changes in the practice or operations of A&E departments. In particular the report considers the impact of changes in thresholds for tests and investigations, treatments and admissions and the response to regulatory pressures.

Chapter 5 identifies and assesses the importance of an emergent factor – autocorrelation of breaches. This can be thought of as the resilience of A&E departments to recover from periods of pressure.

When considering whether a certain factor might have contributed to the rise in 4-hour breaches, we apply three tests:

- Is there a clear causal theory which connects the factor under consideration and the risk that a patient might breach the 4-hour target?
- Is there evidence from the data that the factor is associated with attendance durations or the risk of a breach?
- Is there a clear trend in the scale or frequency of the factor's occurrence over time?

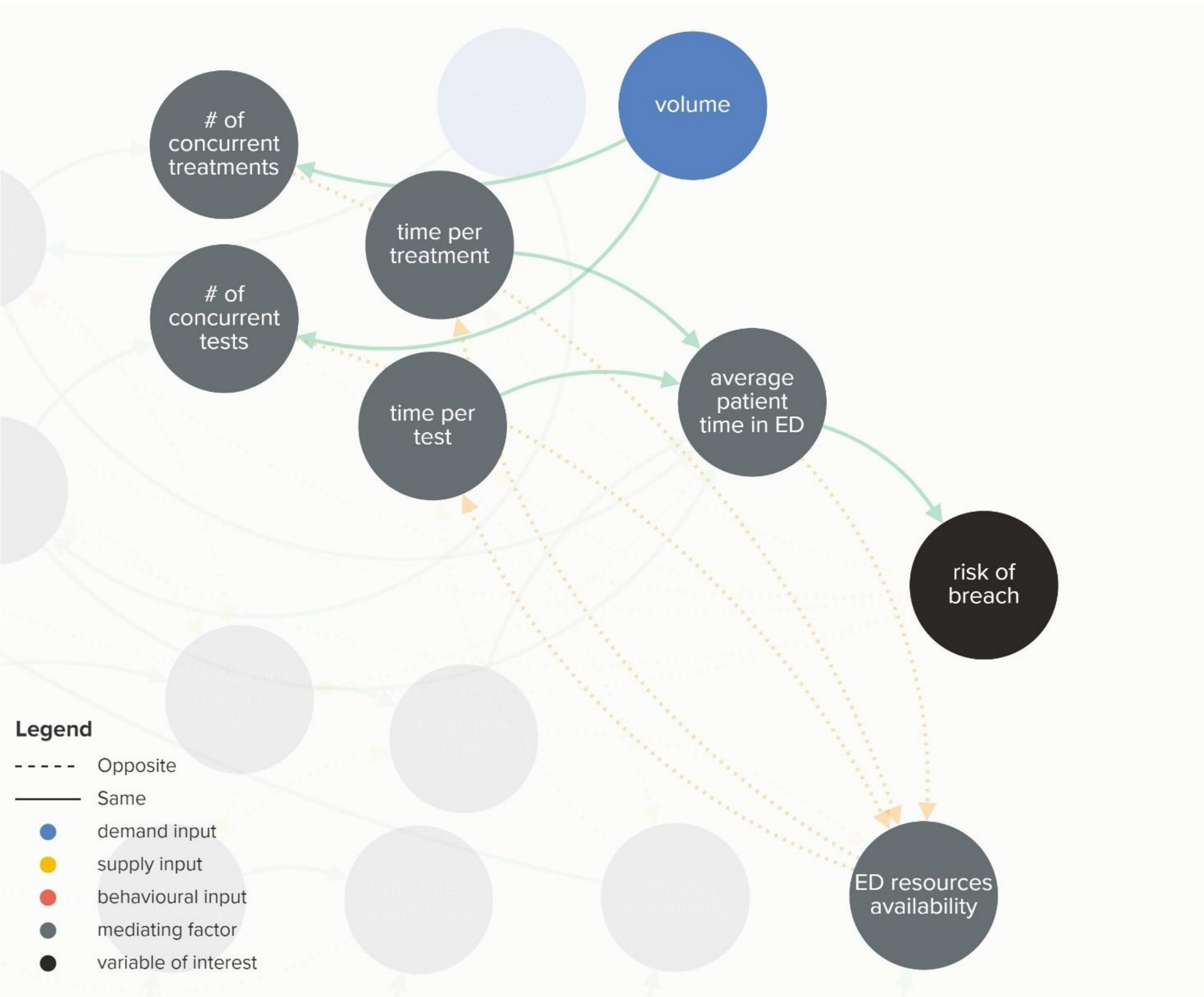
Chapter 6 brings together the various factors that pass these tests to understand, where data allows, the relative contribution to the observed increase in breaches.

2. Demand-side factors

2.1 Increases in attendances

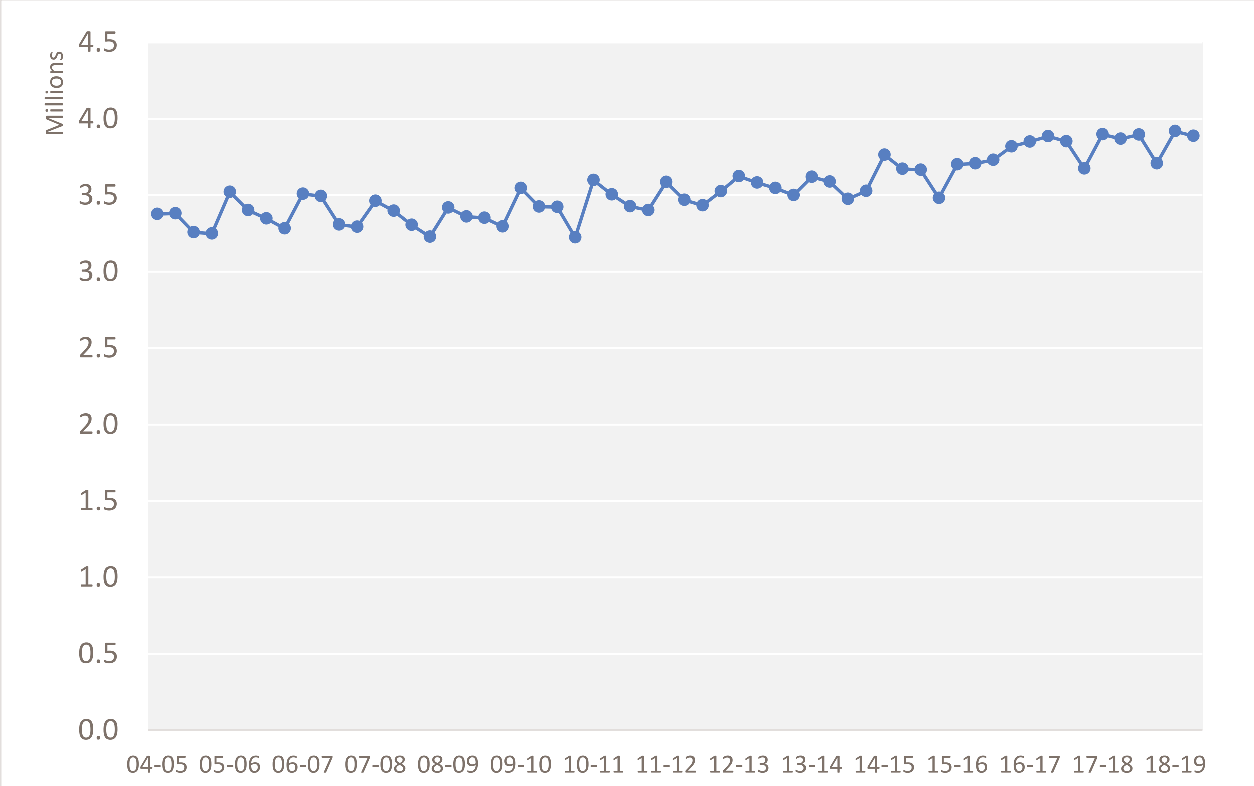
Demand increases is arguably the most commonly cited cause of the decline in performance against the 4-hour A&E. The theory here is clear: that if more patients attend A&E, then more treatments and tests are required; these compete for constrained staffing and facilities, increasing the duration of attendances.

Figure 2.1: Demand increases, causal diagram



And it is certainly the case that arrivals at type 1 A&Es have increased; from 13.3 million in 2004/5 to 15.4 million in 2017/18. The average growth rate of 1.1% is however substantially lower than the demand growth seen in other acute hospital services such as emergency admissions, ordinary elective admissions and outpatient attendances, and out of hospital services, such as General Practice consultations.

Figure 2.2: Attendances at Type 1 A&E Departments, England, April 2004 - September 2018



2.2 Casemix changes

Casemix changes are more difficult to track. Although casemix cannot be fully captured by a single variable, a patient's age, diagnosis and arrival mode are usually considered to be the most important casemix adjustment variables. In its work of 2017, the Strategy Unit found evidence that the casemix of patients attending A&E was becoming more complex. This took the form of slower growth in low acuity presentations and a gradual shift from injury presentations to illness presentations. Attendances for contusions or abrasions had fallen by 2.6%, for lacerations by 2.7% and for sprains by 4.2% per annum between 2010/11 and 2015/16, whereas admissions for respiratory conditions had grown by 4.6% and for cardiac conditions by 5.8% per annum over the same period.

Box 2: Diagnosis Recording in A&E Departments

Up to 12 distinct diagnoses can be recorded for each patient attendance in the Hospital Episode Statistics (A&E) dataset. The 'A&E Diagnosis' scheme is used to classify patient diagnoses. This system encodes information hierarchically about the patient's presenting condition, anatomical area and side. At its highest level, the system groups diagnoses into 39 types:

Laceration
Contusion/abrasion
Soft tissue inflammation
Head injury
Dislocation/fracture/joint injury/amputation
Sprain/ligament injury
Muscle/tendon injury
Nerve injury
Vascular injury
Burns and scalds
Electric shock
Foreign body
Bites/stings
Poisoning (inc overdose)
Near drowning
Visceral injury
Infectious disease
Local infection
Septicaemia
Cardiac conditions
Cerebro-vascular conditions
Other vascular conditions
Haematological conditions
CNS conditions (exc stroke)
Respiratory conditions
Gastrointestinal conditions
Urological conditions (inc cystitis)
Obstetric conditions
Gynaecological conditions
Diabetes / endocrinological conditions
Dermatological conditions
Allergy (inc anaphylaxis)
Facio-maxillary conditions
ENT conditions
Psychiatric conditions
Ophthalmological conditions
Social problems
Diagnosis not classifiable
Nothing abnormal detected

Levels of diagnosis recording in A&E varies considerably between NHS Trusts. Given the importance of diagnosis in any casemix adjustment process, analysis of A&E attendances and 4-hour breach levels presented in the remainder of this report focuses on a subset of 39 NHS Trusts with consistently high levels of diagnosis recording in A&E since 2010. The subset of NHS trusts is set out in technical appendix A.

The impact of casemix of A&E attendances durations is demonstrated by figure 2.3. Patients attending A&E by ambulance or with a respiratory condition are more likely to breach the 4-hour target than walk-in patients or patients with a laceration.

Figure 2.3: Distribution of A&E Durations for two conditions and by arrival mode, England Apr 2010 to Mar 2016 (notches indicate median attendance durations)

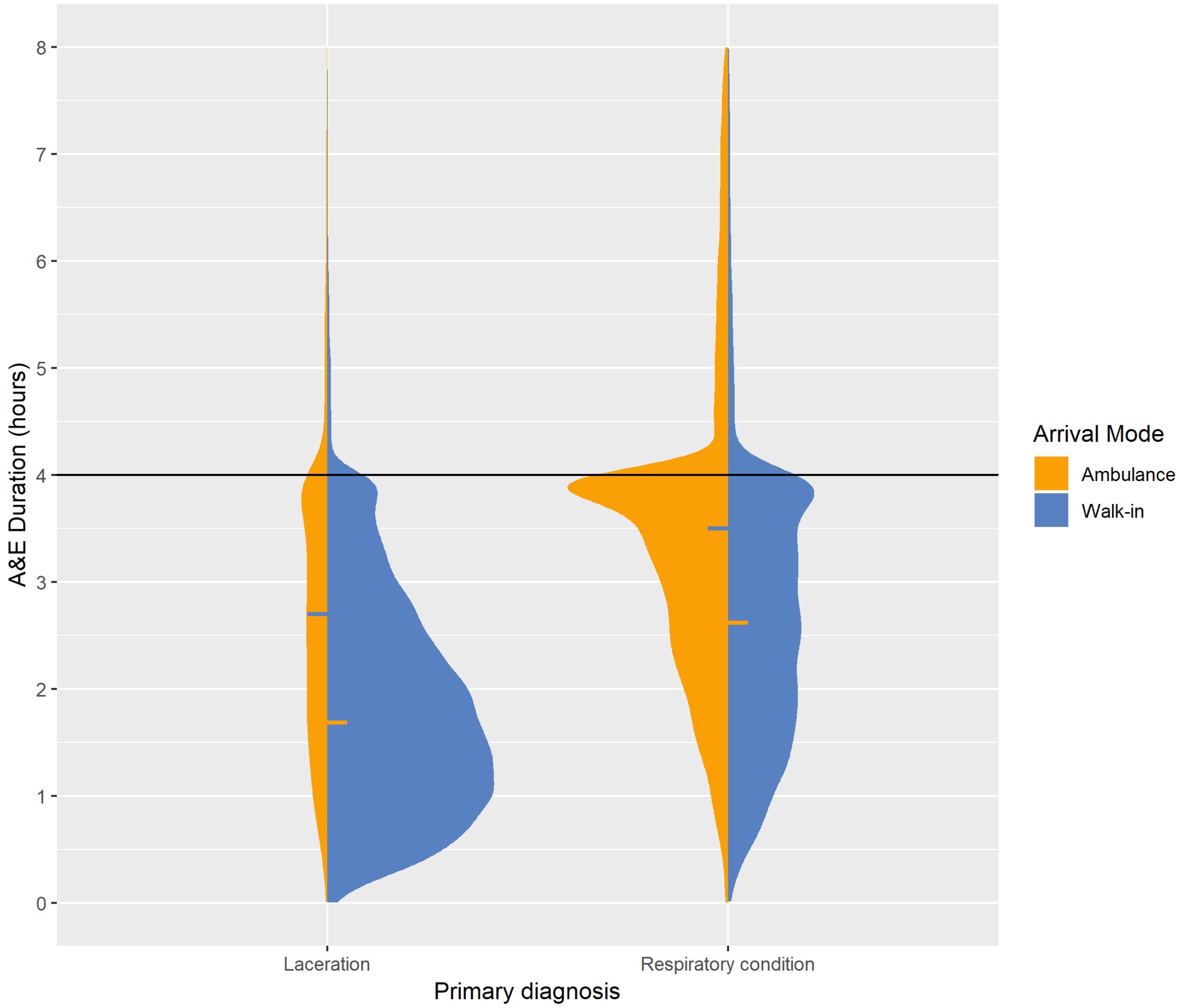
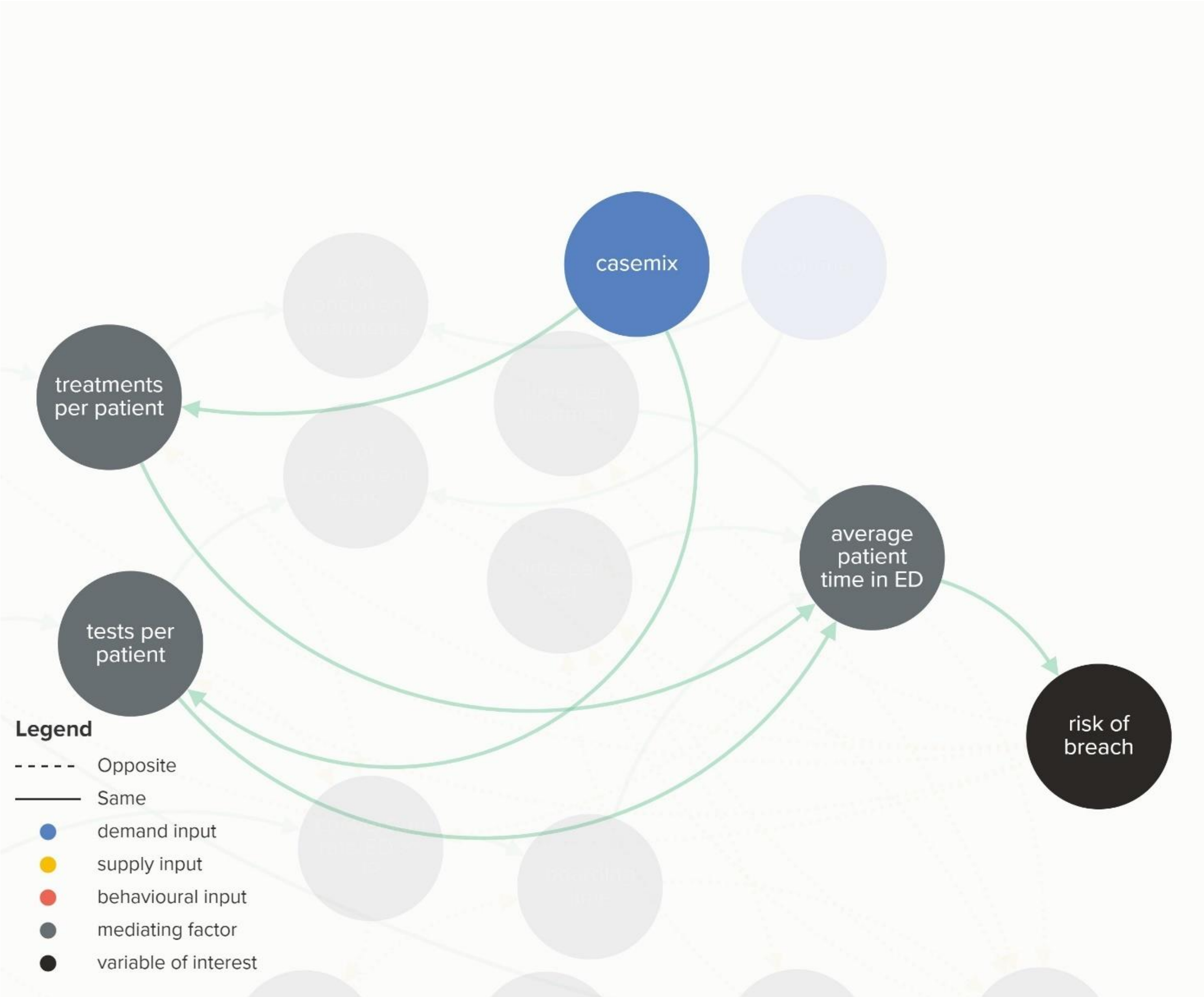


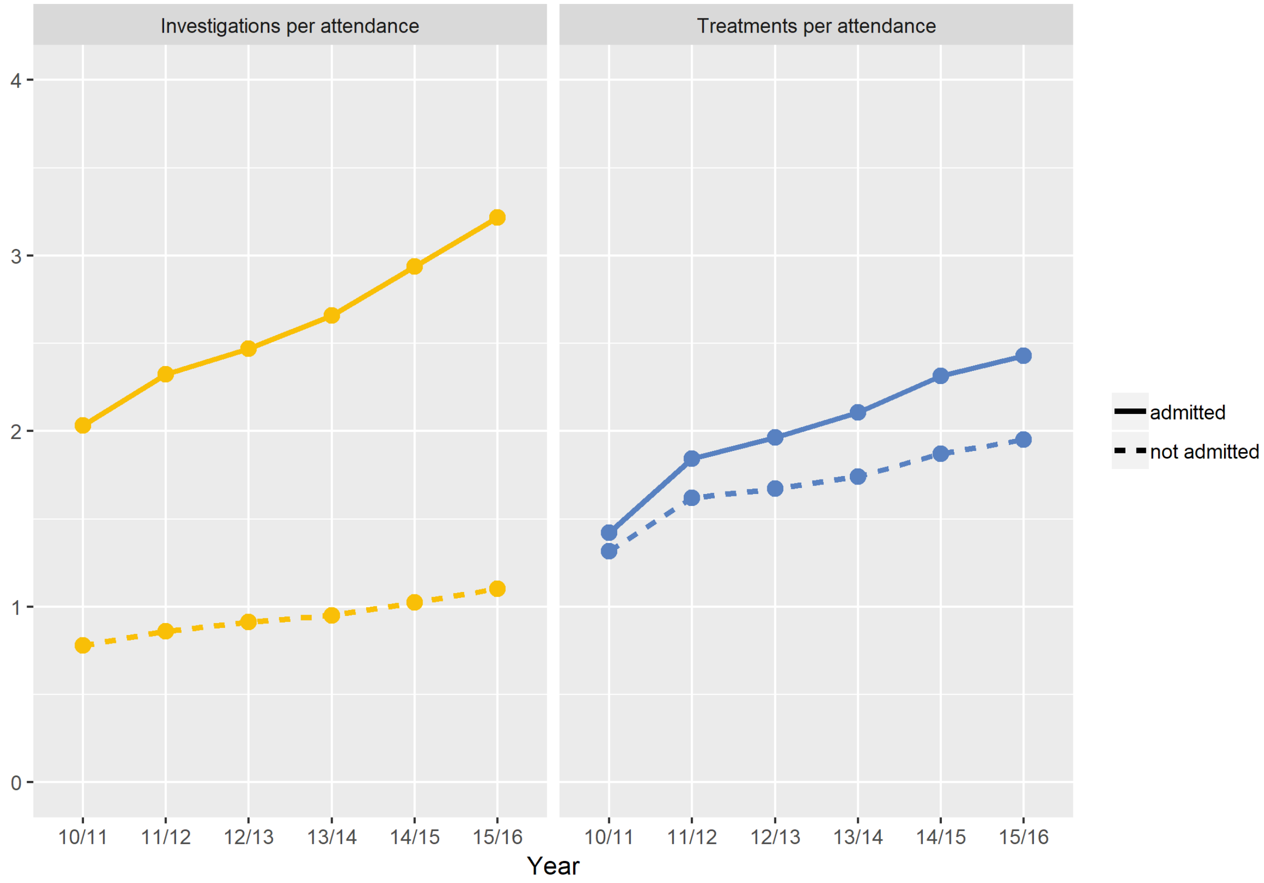
Figure 2.4 sets out a basic mechanism by which increases in complexity and acuity might lead to increases in 4-hour breaches; that a more complex patient requires more investigations and treatments increasing the patient's treatment duration in A&E.

Figure 2.4: Casemix increases, causal diagram (basic)



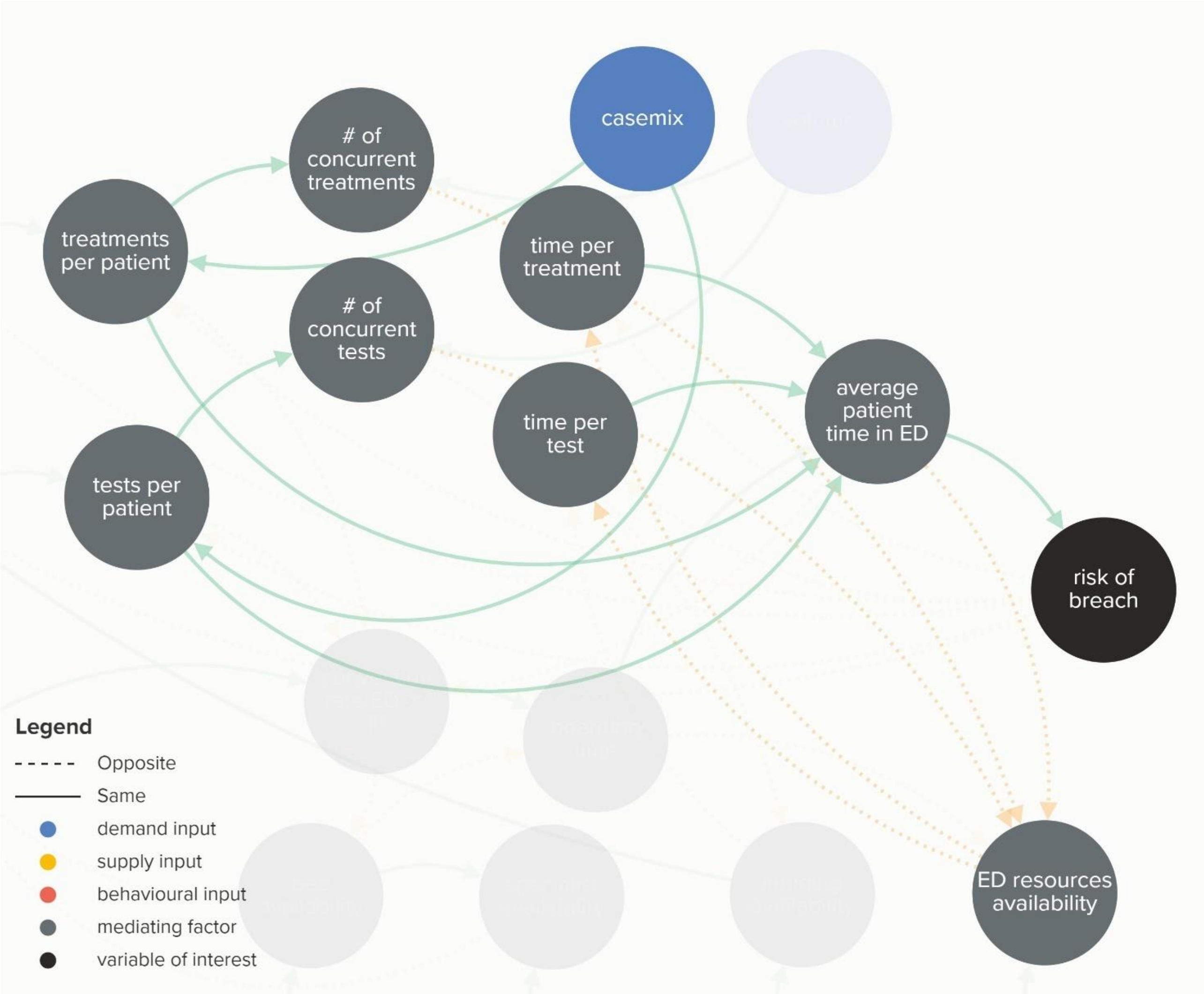
This is supported by data which indicates that the number of investigations and treatments carried out in A&E are growing at a faster rate than attendances, i.e. that there has been an increase in the average number of investigations and treatment per patient attendance.

Figure 2.5: A&E Investigations and Treatments per Patient Attendance, England 2010/11 to 2015/16



More complex consequences of increased casemix can also be identified. For example, as the average complexity of patients increases and more tests and treatments are required concurrently, constrained resources in A&E are spread more thinly, increasing the average time per treatment and the average duration in A&E.

Figure 2.6: Casemix increases, causal diagram (detailed)

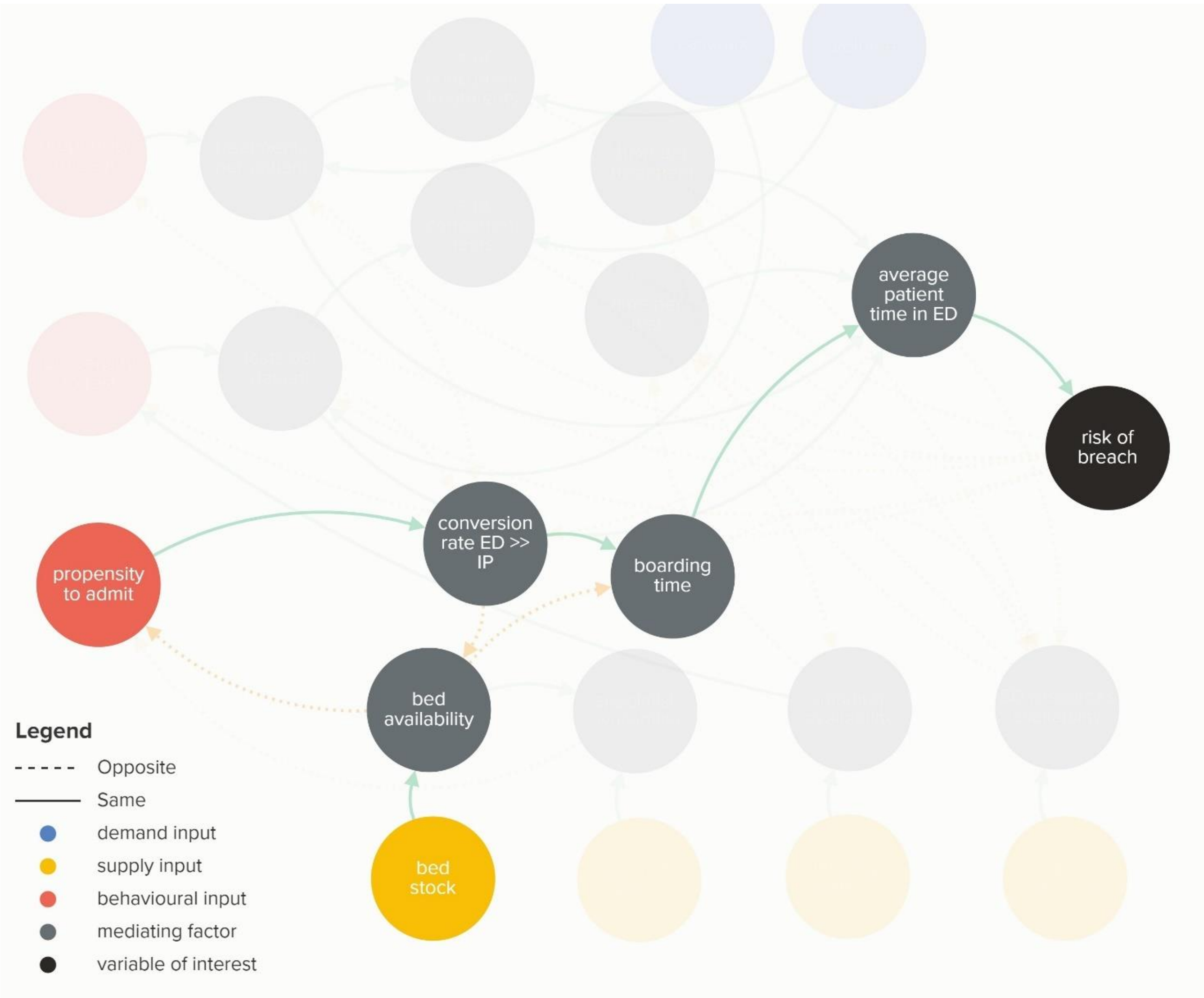


3. Supply-side factors

3.1 Inpatient beds, exit block and patient flow

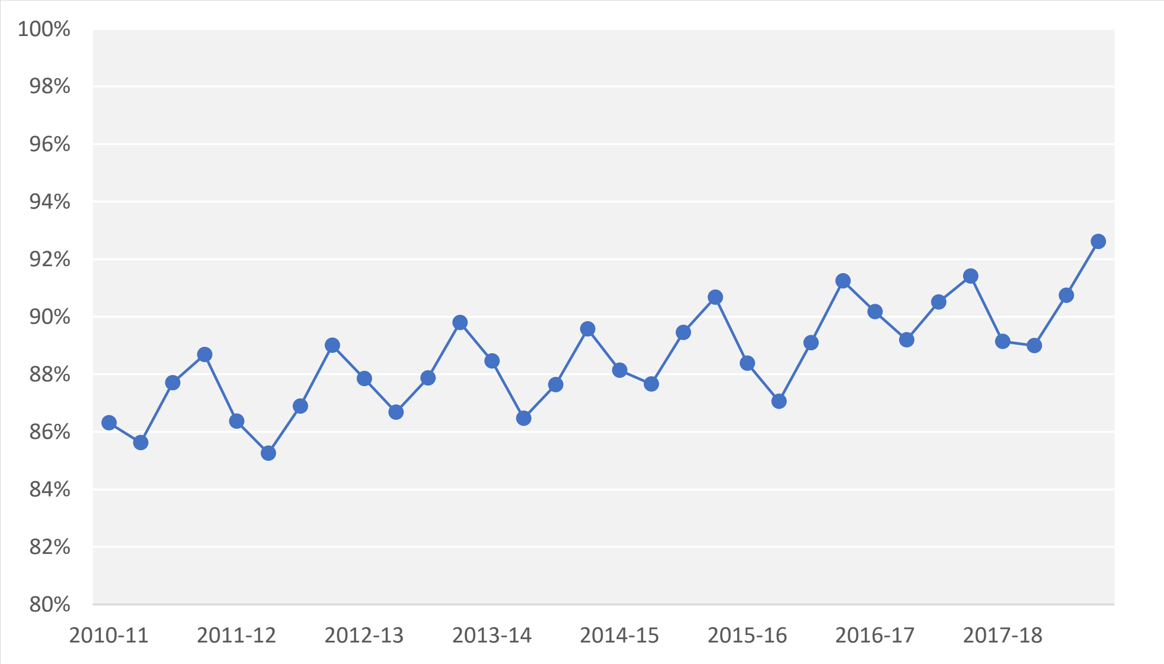
The exit block theory holds that patients that require admission spend more time boarding (e.g. waiting to be admitted once the decision to admit is taken) when bed occupancy rates are high and a bed in an appropriate ward is hard to find. The impact of exit block may however be moderated as admission thresholds respond to bed availability, but this in turn may lead to increases in A&E durations for non-admitted patients.

Figure 3.1: Exit block, causal diagram



Inpatient occupancy levels have increased steadily in recent years, from 87% in 2010/11 to more than 90% in 2017/18.

Figure 3.2: Occupancy Rate, General and Acute Overnight Beds, England, April 2010-March 2018

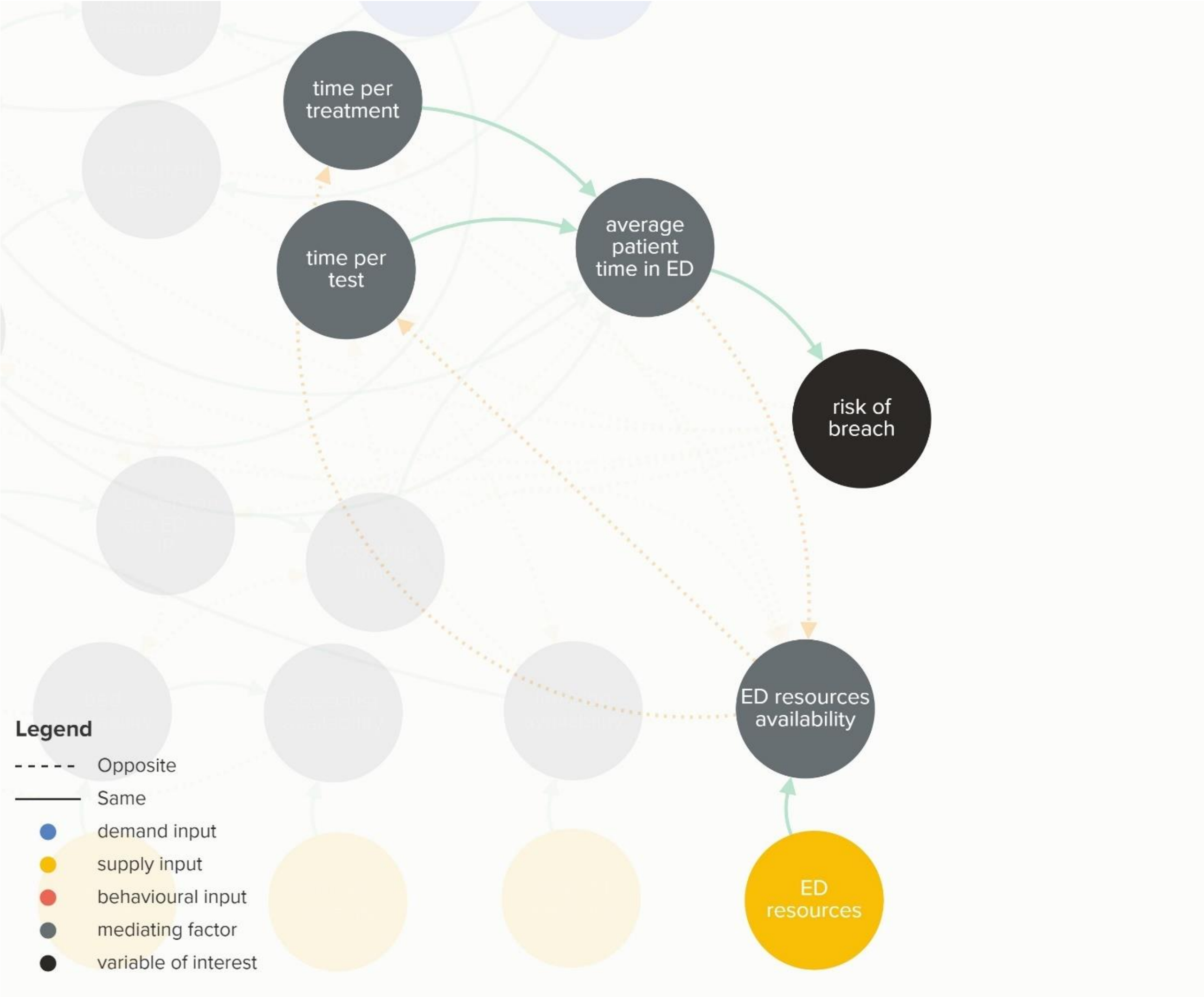


For patients admitted from A&E to an inpatient bed, average boarding time (the time between the decision to admit and an admission) has increased steadily from 20 minutes in 2011/12 to 46 minutes in 2017/18 (see figure 1.3).

3.2 Resource levels in A&E

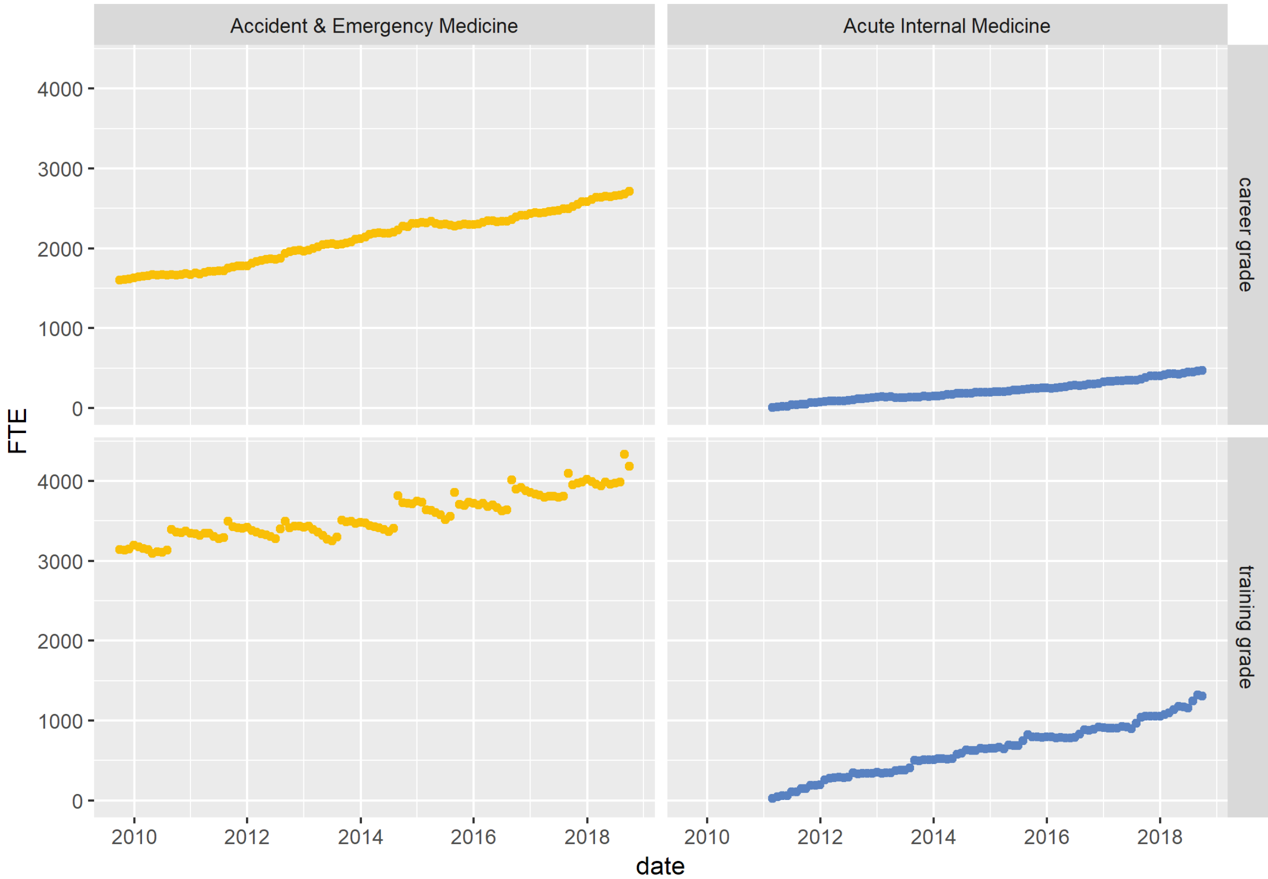
Inadequate levels of staffing or physical resources (e.g. minor/major cubicles, resuscitation trolleys) in A&E departments are sometimes cited as a cause of the deterioration in performance against the 4-hour target. If resource levels are reduced, then patients will wait longer for treatment and treatment and test times will increase. Data on A&E resources are however limited in breadth and granularity. The number of career grade and training grade consultants in accident and emergency or acute internal medicine are reported every month by NHS Digital.

Figure 3.3: A&E Resources, causal diagram



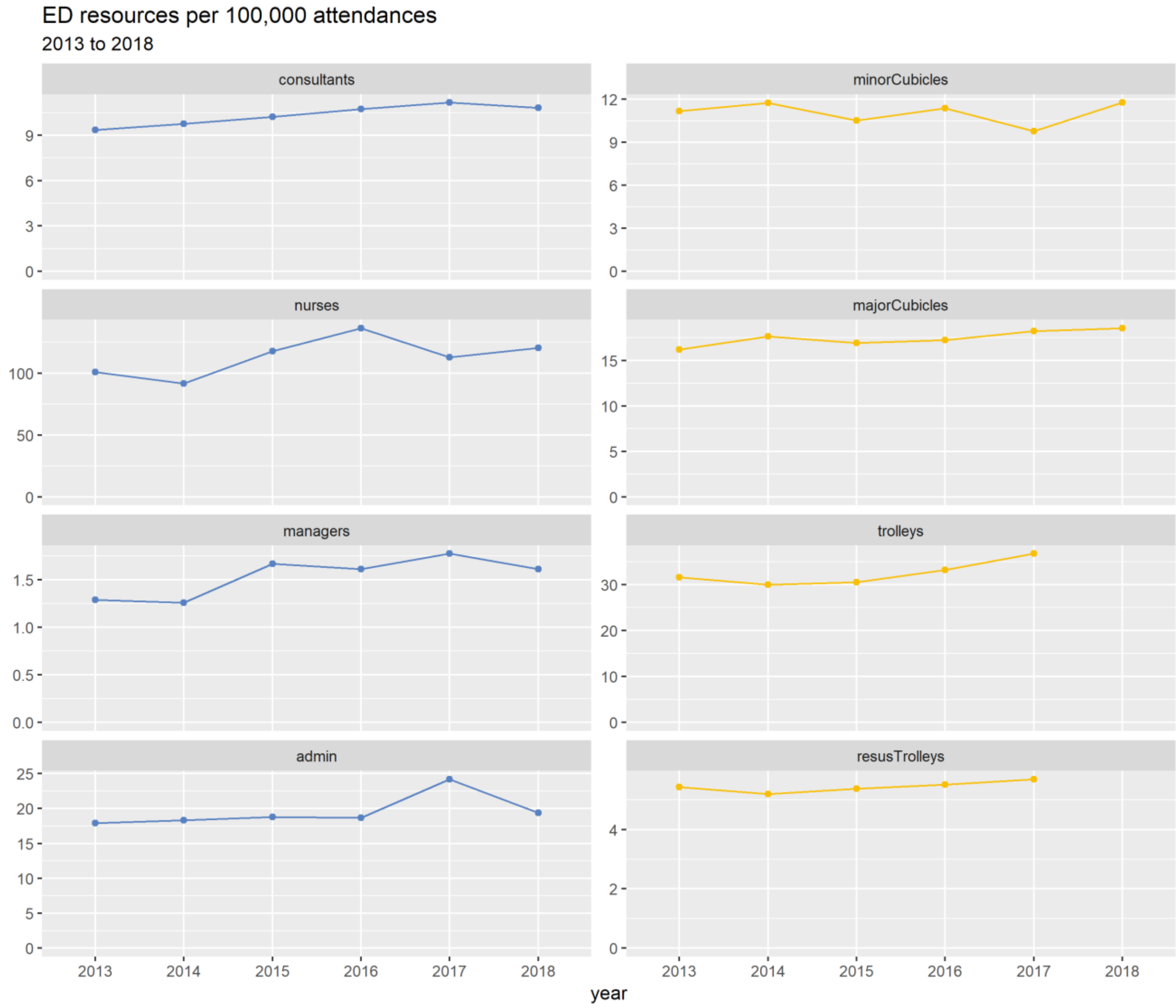
The numbers of accident and emergency medicine doctors have increased steadily since 2009, with career grade consultants increasing by 919 (6.4% per annum) FTE between January 2011 and January 2018 and training grade doctors increasing by 654 (2.6% per annum) over the same period. Acute Internal Medicine was introduced as a specialty in 2011 and by January 2018 there were more than 400 career grade consultants and 1,000 training grade doctors in this specialty.

Figure 3.4: A&E and Acute Internal Medicine Doctors; England September 2009- September 2018



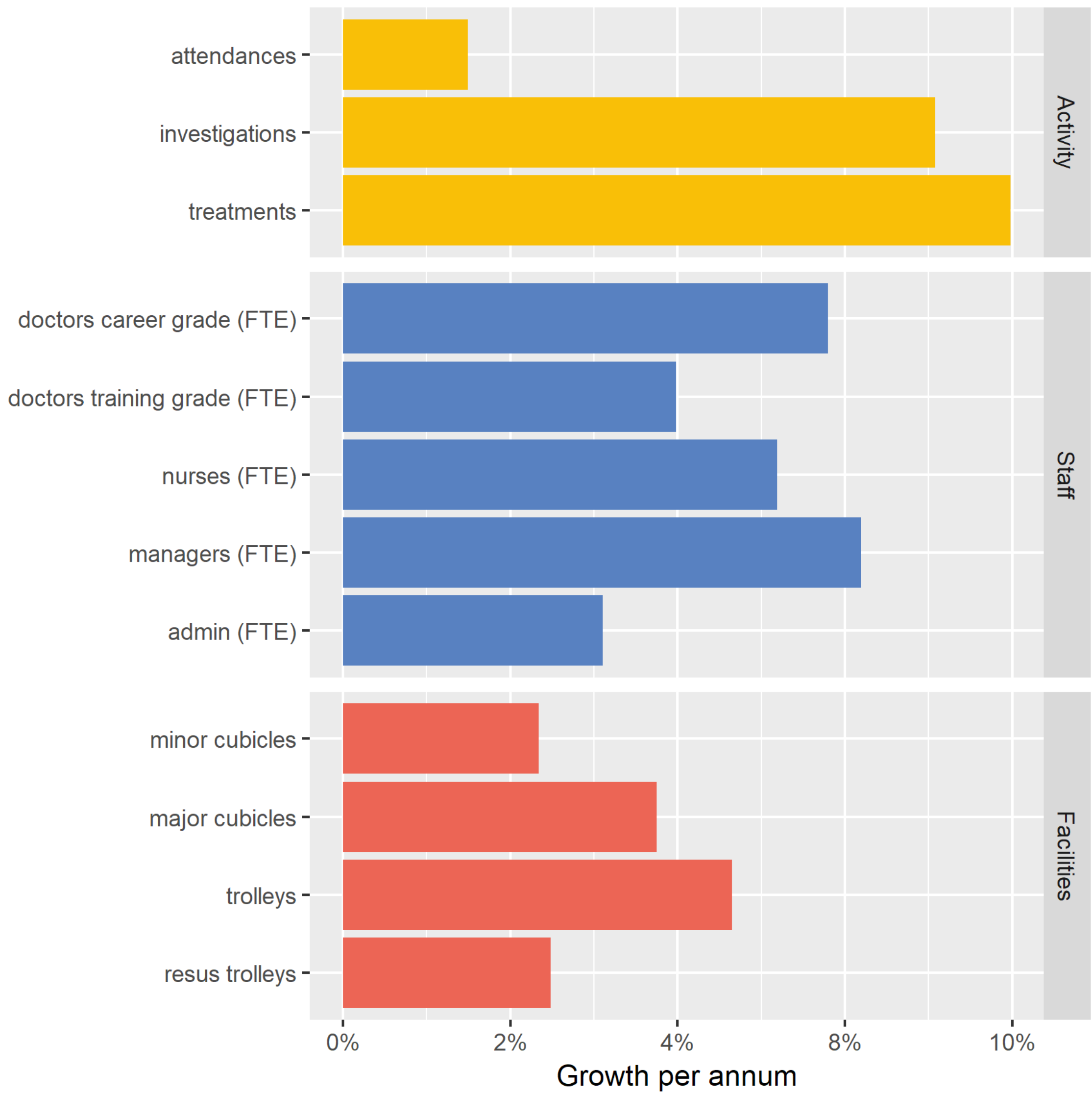
Data on other forms of A&E staffing and on physical resources is more difficult to obtain. Whilst no mandatory collection takes place, NHS Benchmarking operates a voluntary data collection process for Accident and Emergency departments. Data has been collected annually since 2013 on a wide range staff types and of different types of physical infrastructure. Provider data is anonymised and summarised as rates per 100,000 attendances. Whilst some providers have submitted data in each year, others have never submitted or submitted only once or twice. The national GIRFT (Getting it right first time) process sponsored the collection in 2018 and this led to substantial increases in the response rate. Time series assessments must therefore be treated with caution but nonetheless provide some indication of the changing levels of resources relative to activity.

Figure 3.5: A&E resource levels per 100,000 attendances; England 2013 to 2018 (providers making at least 2 submissions)



Bringing together data on growth of activity, staffing and resource levels, suggests that staffing and resource levels have increased at a faster rate than patient arrivals in A&E but have not kept pace with increase in activity levels in A&E departments.

Figure 3.6: Growth per annum in A&E activity, staffing and resource levels; England[1]



3.3 Access to diagnostic Imaging and availability of specialists

The availability of other hospital resources is also likely to impact on the A&E attendance duration of some patients. Patients requiring complex imaging investigations may have to compete for resource in the imaging department with admitted patients and outpatients. Other patients may require a review by a consultant working outside the A&E department (e.g. a specialist in respiratory medicine, a cardiologist etc). Access to these resources may

[1] Doctors – includes A&E and acute internal medicine specialists

impact on decisions to admit as well as on A&E attendance durations. Data on the availability of these resources is limited at present but local studies may provide insight.

4. Practice factors

The factors described above attempt to explain the deterioration of performance against the 4-hour standard in terms of supply and demand. To focus exclusively on these factors fails to recognise that A&E departments and the staff who work in them are active players in the system, responding to changes in demand, supply, regular pressure and advances in clinical practice. In this chapter we explore some potential practice explanations for changes in A&E attendance durations.

4.1 Test and investigation thresholds

The HESAE dataset records the delivery of 23 distinct types of tests and investigation that are carried out in A&E departments. Recording of these investigations impacts on hospital trust payment levels, but these payment arrangements have not changed substantially for many years. Most of these investigations take three forms: haematological tests, biochemistry and imaging.

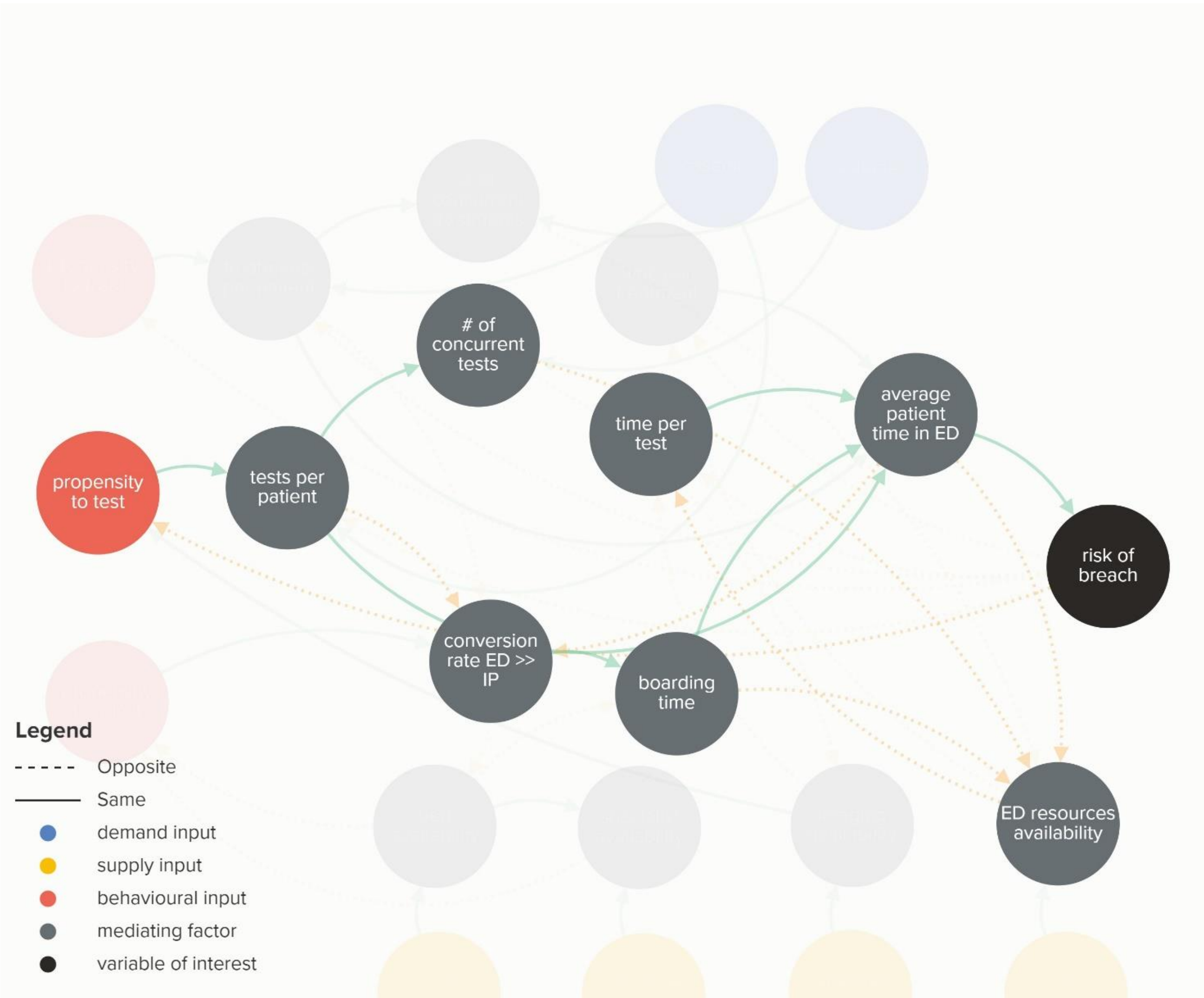
Figure 4.1: A&E Tests and Investigations

Haematology	Haematology Cross match	Clotting studies
Biochemistry	Biochemistry Cardiac enzymes Arterial/capillary blood gas	Toxicology Pregnancy test
Imaging	X-ray plain film MRI scan CT scan	Ultrasound GU contrast/tomography* Dental*
Other	Electrocardiogram Urinalysis Bacteriology Histology* Immunology*	Blood culture Serology Orthoptic tests Other

Investigations marked (*) occur in very low volumes in A&E (in less than 0.05% of attendances) and are therefore excluded from the subsequent analysis.

The quantity of tests and investigations carried out in A&E have increased by 67% between 2010/11 and 2015/16.[2,3] Growth in attendances can account for some of this growth but given that investigations are increasing at a faster rate than attendances, additional explanations must be sought. Casemix is a credible explanation for this excess growth, however a study in the US found that an increase in practice intensity was the principal factor driving increasing occupancy levels in emergency departments (Pitts, S 2012).

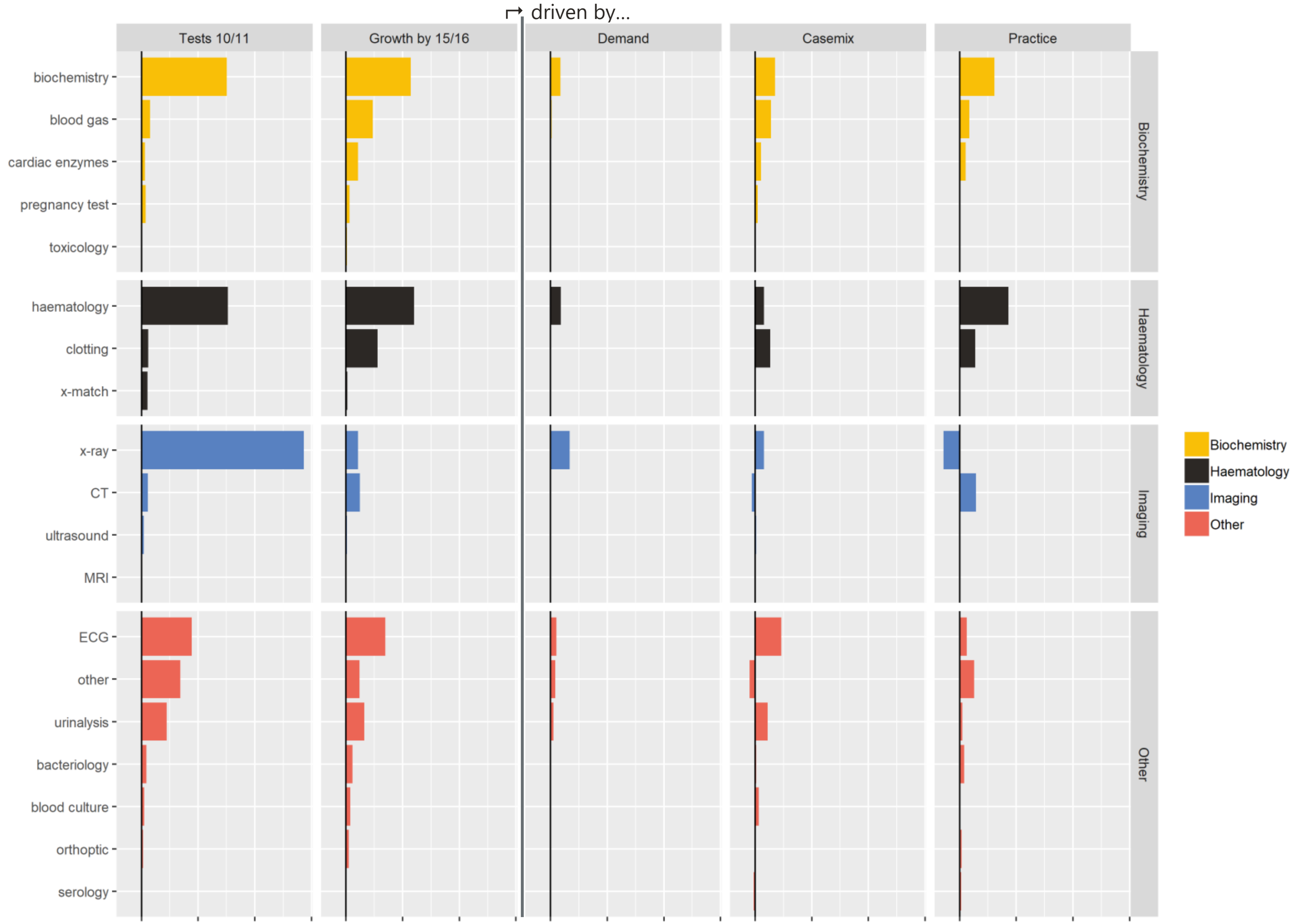
Figure 4.2: Propensity to Test, causal diagram (basic)



[2] For the purposes of this report, a test is considered to one or more instances of a particular text type such that two x-rays are counted as one test, but an x-ray followed by a CT scan is counted as two tests.
[3] Significant growth in tests has also been reported in primary care (O'Sullivan, J 2018)

We test this using regression (see the technical appendix B for details of the model data, specification and coefficients). The leftmost column in figure 4.3 below indicates the quantity of each type of test that was delivered in A&E departments in 2010/11. The next column illustrates the growth in tests that occurred between 2010/11 and 2015/16. The rightmost three columns show how this growth is attributable to attendance (demand) increases, casemix changes and practice changes. Practice changes are defined here as drivers of activity growth that cannot be explained by demand and casemix changes.

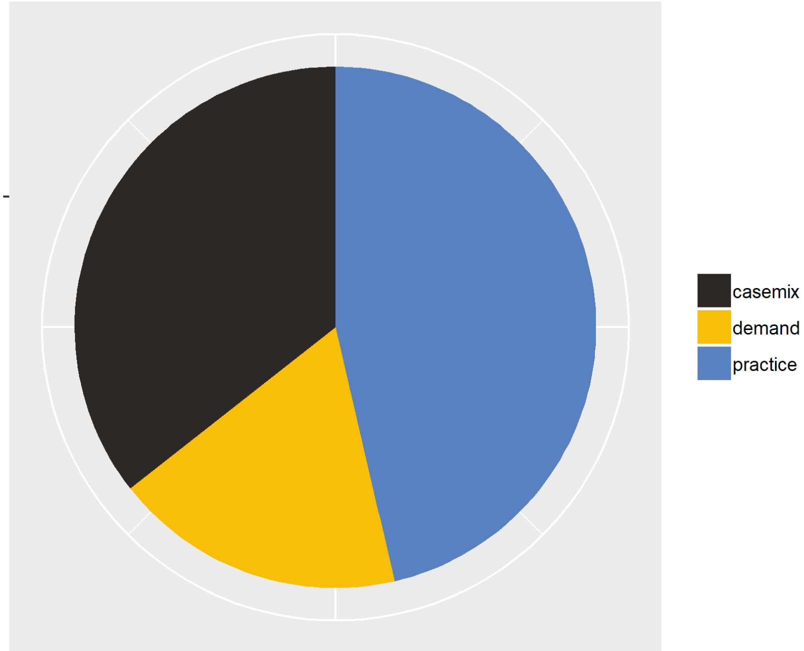
Figure 4.3: Growth in Tests explained by demand increases, casemix changes and practice changes; England, 2010/11 – 2015/16



This analysis suggests that whilst demand and casemix explain a significant proportion of the growth in tests, half of the growth is attributable to practice changes.

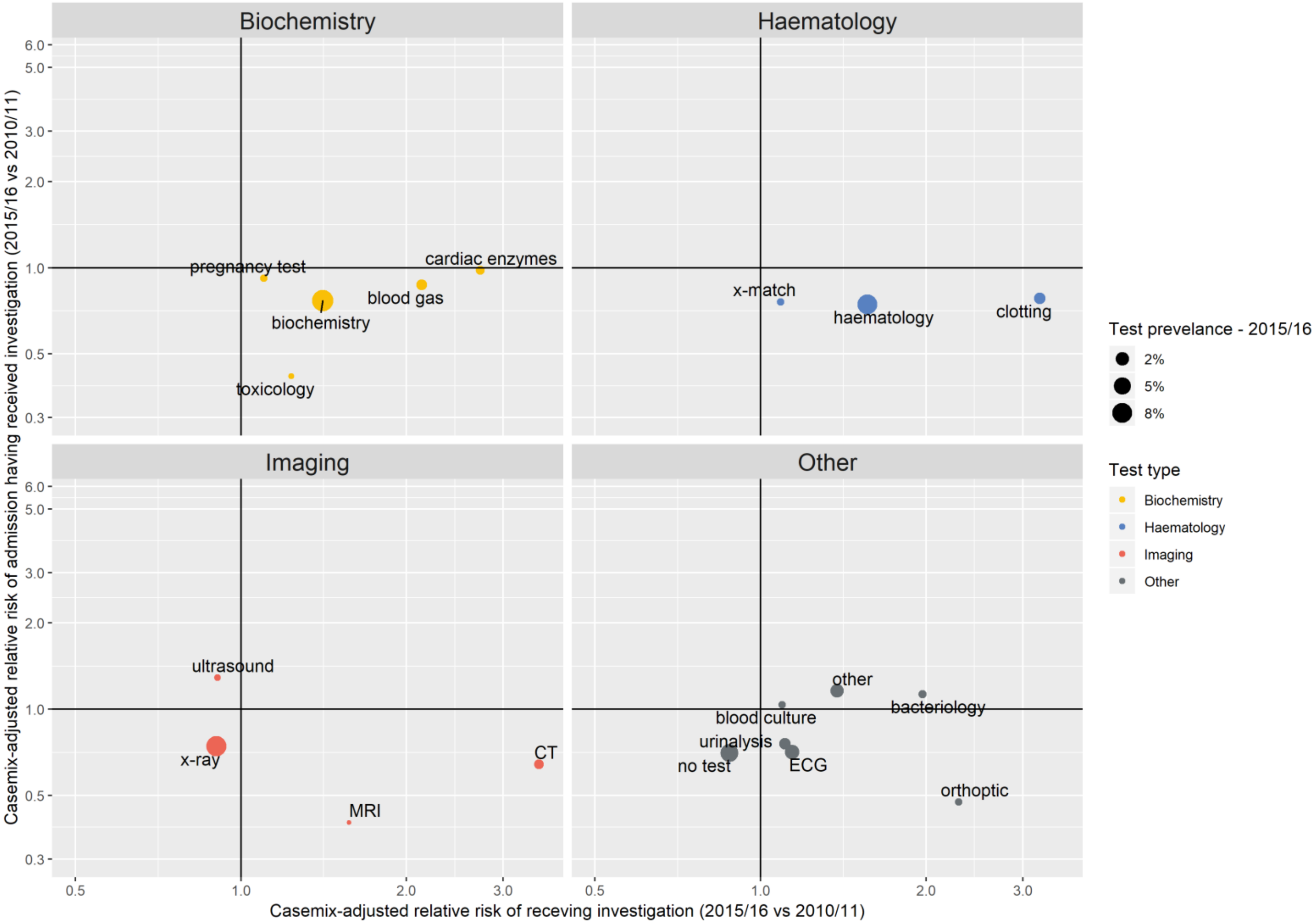
This analysis also indicates particular practice changes in relation to the provision of x-rays and CT scans. Some patients who would have received an x-ray if attending in 2010/11, have CT scans in 2015/16.

Figure 4.4 : Drivers of Growth in Investigations; England 2010/11 – 2015/16



This analysis raises a further question. Why, if there is such pressure in A&E departments, have the number of investigations per patient increased, even after adjusting for casemix? Figure 4.5 demonstrates the relationship between changes in thresholds for an investigation (horizontal axis) and thresholds for admission having received the investigation (vertical axis) between 2010/11 and 2015/16. Most investigations fall in the lower right quadrant suggesting that whilst patients are more likely to receive the investigation, they are less likely to be admitted having received the it. (See technical appendices B and C for details). This raises the possibility that additional investigations are being carried out to rule out serious complaints for which an admission may be required.

Figure 4.5: Casemix-adjusted relative risk of investigation, and of admission having received the investigation, 2015/16 vs 2010/11



4.2 Treatment thresholds

In addition to tests and investigations, HESAE also records the delivery of 56 distinct types of different treatment delivered in A&E departments. These can be classified as follows:

Figure 4.6: A&E Treatments

Wound management	Burns review* Dressing Dressing/wound review Sutures	Tetanus Wound cleaning Wound closure
Musculo-skeletal	Bandage/support Fracture review Joint aspiration* Loan of walking aid Manipulation	Physiotherapy Plaster of Paris Recall/x-ray review Sling/collar Splint
Surgical	Epistaxis control Incision & drainage Minor plastic procedure*	Minor surgery Removal foreign body
Cardio-vascular	Defibrillation/pacing* Observation/electrocardiogram, pulse oximetry	Parenteral thrombolysis* Pericardiocentesis* Resuscitation
Respiratory	Chest drain* Nasal airway* Nebuliser/spacer	Oral airway Positive airways pressure Supplemental oxygen
IV	Blood transfusion* Infusion fluids	Intravenous cannula Other Parenteral drugs*
Acute monitoring	Arterial line Central line*	Intubation & Endotracheal tubes Urinary catheter/suprapubic
Other	Anaesthesia Dental treatment* Eye Recording vital signs Lavage/emesis/charcoal/eye irrigation Other	Lumbar puncture* Medication administered Occupational Therapy Social work* Active rewarming* Cooling*
Minimal	Prescription/medicines prepared to take away	Guidance/advice only

Treatments marked (*) occur in very low volumes in A&E (in less than 0.05% of attendances). These treatments and those with minimal resource implications (prescriptions and advice/guidance) are excluded from the subsequent analysis.

The quantity of treatments carried out in A&E has increased by 73% between 2010/11 and 2015/16.

As with investigations, we perform an analysis to assess the extent to which this increase is driven by an increase in attendances, casemix changes and changes in practice. (See technical appendix D for details). In fact, in many cases, changes in practice appear to have led to reductions in treatments. The recording of vital signs is a notable exception.

Figure 4.7: Drivers of Growth in Investigations; England 2010/11 – 2015/16

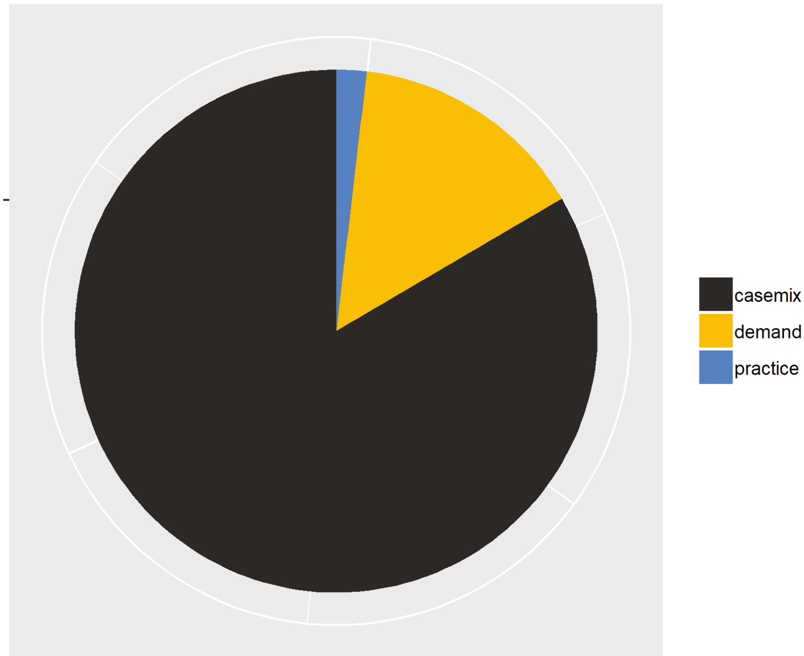
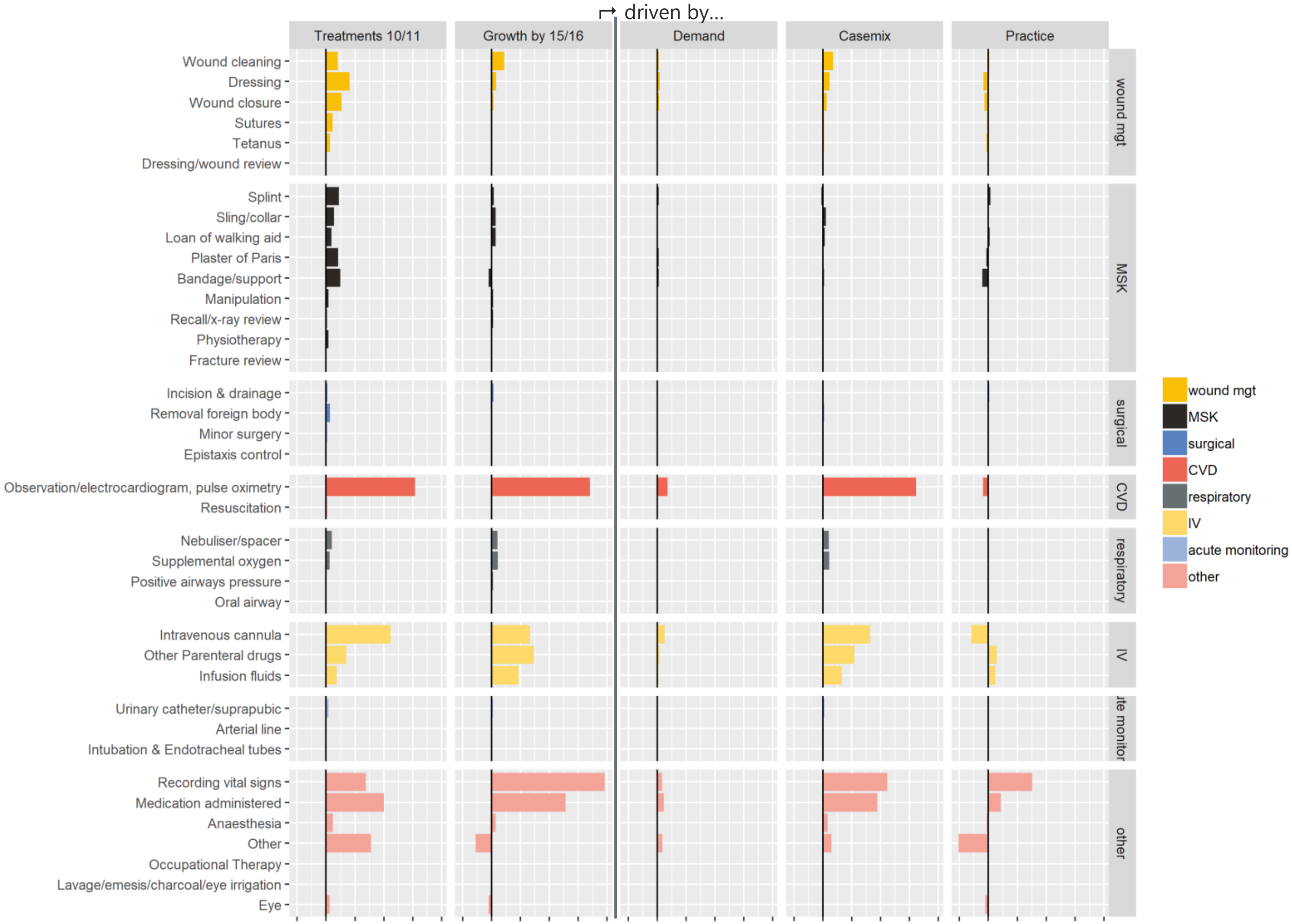


Figure 4.8: Growth in treatments explained by demand increases, casemix changes and practice changes; England, 2010/11 – 2015/16



4.3 Admission thresholds

On average, A&E patients admitted to an inpatient bed spend 50% more time in A&E than those who are discharged or referred elsewhere (see figure 1.3). Whilst some of this may be driven by differences in casemix between admitted and non-admitted patients, boarding time also appears to play a significant part.

In 2017, the Strategy Unit demonstrated that after casemix adjustment, the probability of admission for patients attending A&E had fallen sharply between 2010/11 and 2015/16 (Wyatt S, 2017 & 2018)

Figure 4.9: Propensity to admit, causal diagram (basic)

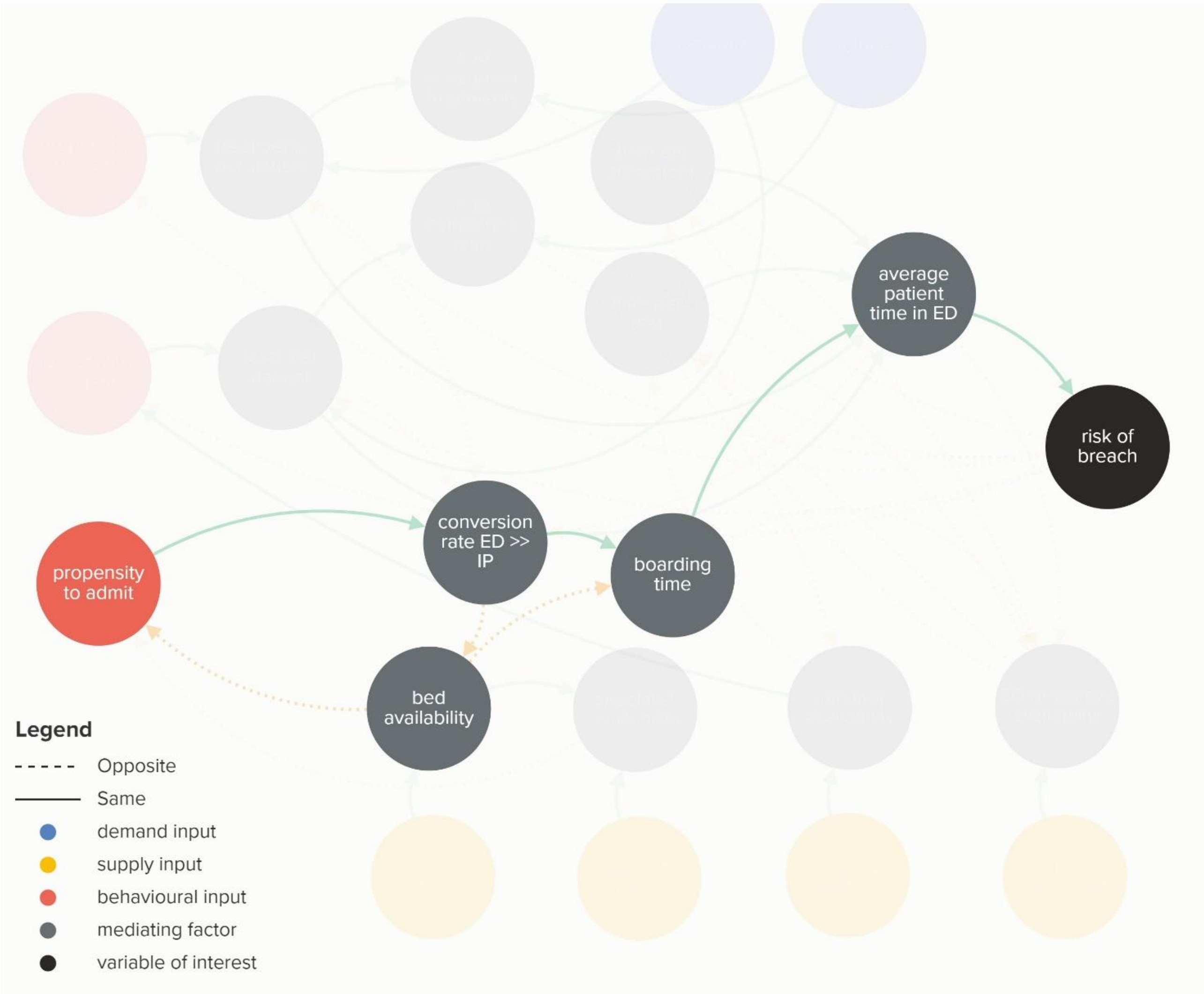
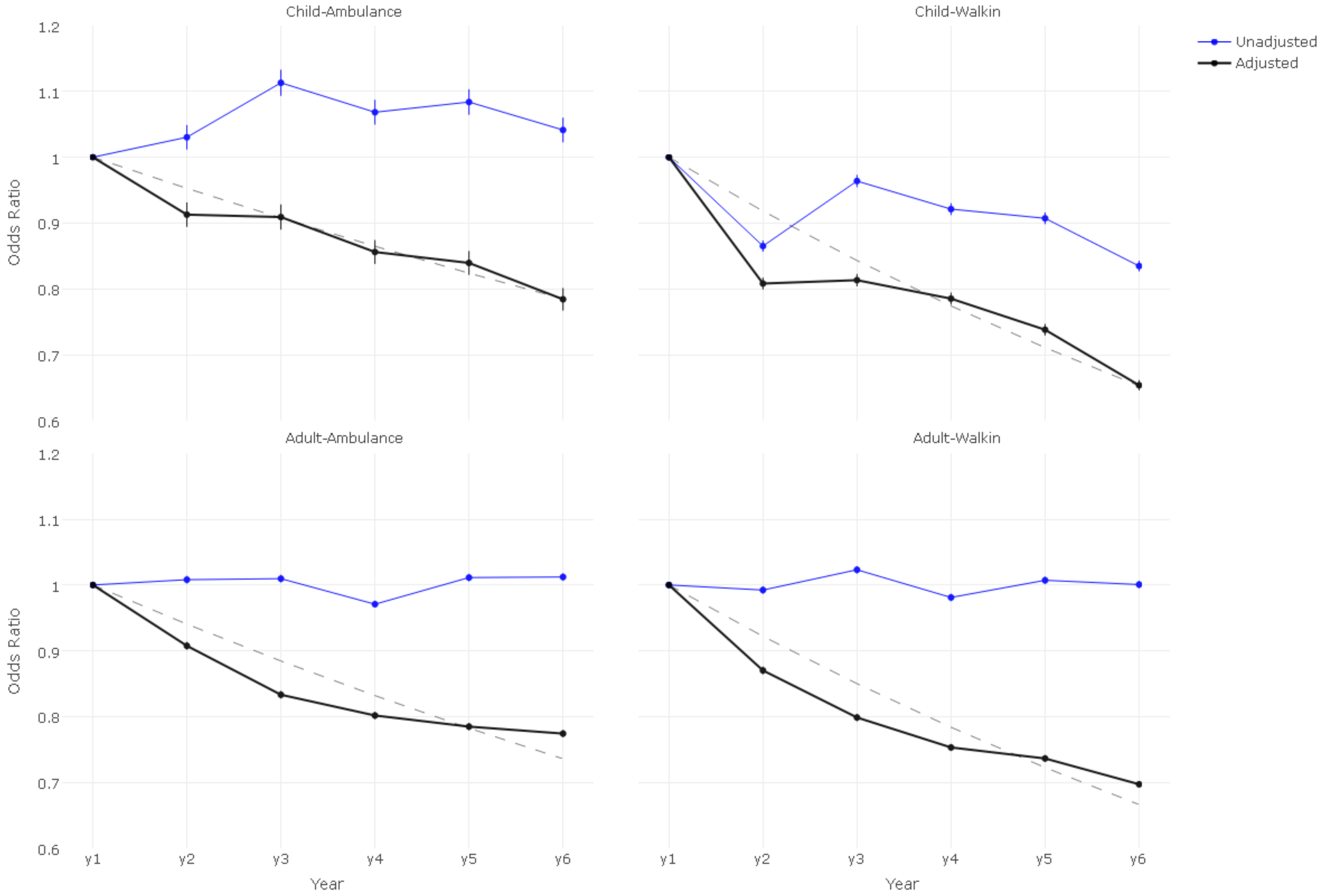


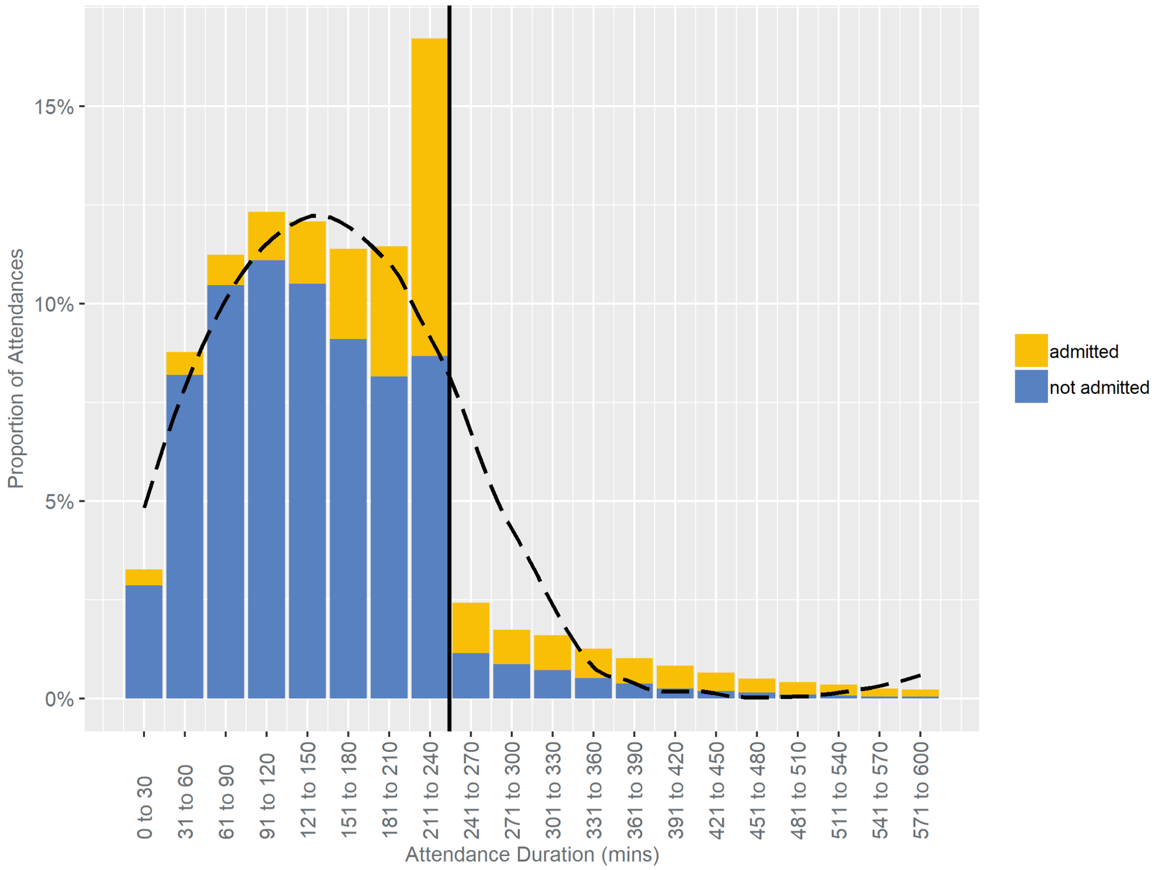
Figure 4:10 : Adusted and Unadjusted Odds of Admission by Year (Apr 2010 – Mar 2011 to Apr 2015 – Mar 2016)



4.4 Response to regulatory pressure

The formulation of the 4-hour target tends to focus attention on the timeliness of treatment of a small subset of patients attending A&E, causing a distortion in the distribution of attendance durations. Figure 4.11 illustrates this effect. A small number of patients are discharged within 30 minutes of arrival, but it is more common for patients to be discharged after 2 hours. The frequency of patients discharged at longer durations then decreases, but a significant spike in the frequency curve occurs in the 30 minutes leading up the 4-hour mark. This is followed by a commensurate trough in attendance durations after 4 hours. There are several potential explanations for this effect, but one is most consistently cited: that A&E staff identify a subset of patients who are likely to imminently breach the 4-hour target and expedite care and treatment to avoid such a breach. Similar efforts are not made for attendances that are expected to be substantially shorter or longer.

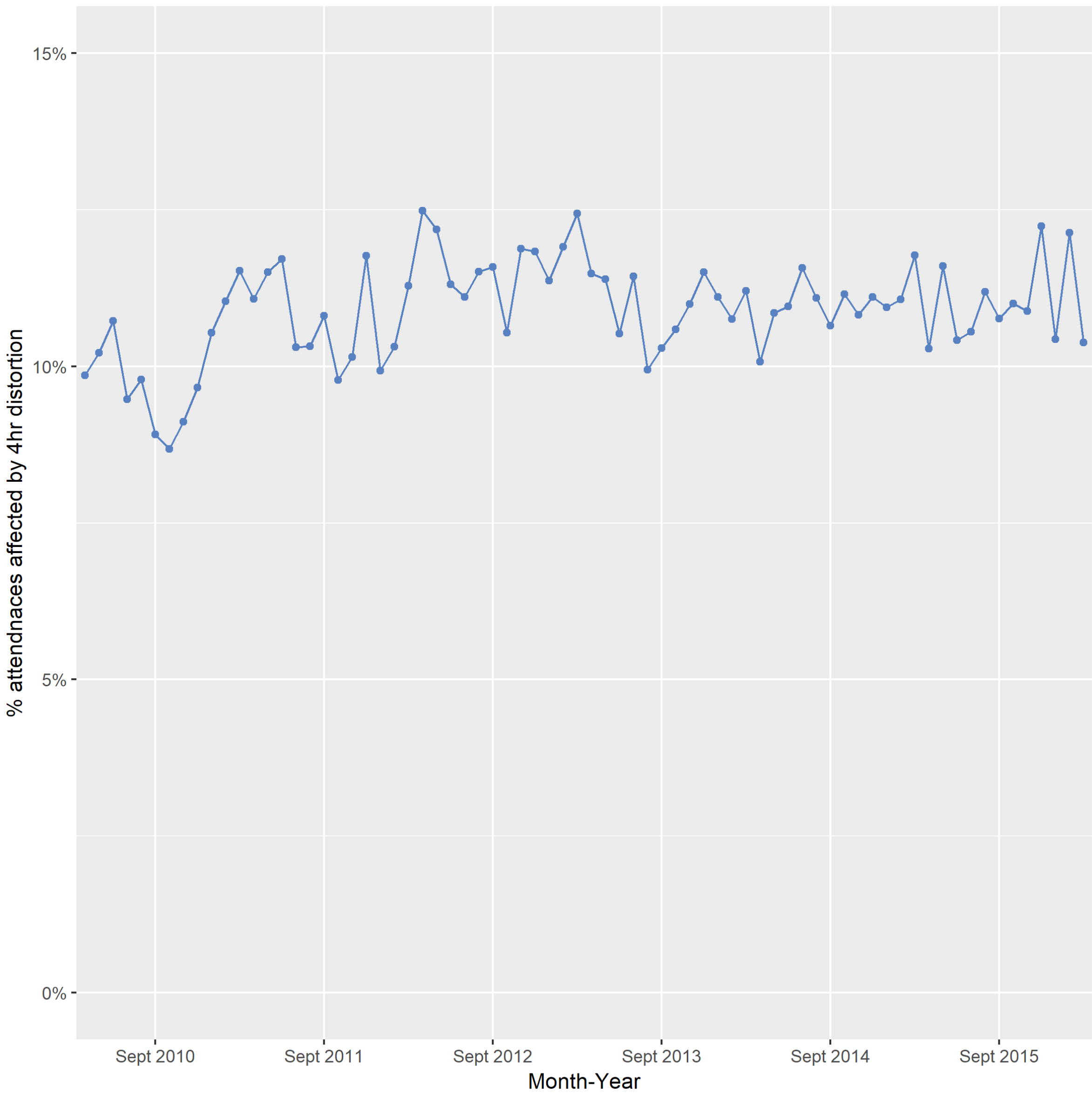
Figure 4:11: Frequency of Attendance Durations (30-minute intervals); 2015/16



It is feasible that this distorting effect may have increased or decreased in response to the regulatory pressure. To test this, it is first necessary to estimate the scale of the distorting effect.

This analysis takes a simple approach to this question. The scale of this distorting effect is estimated as the difference between the number of patients seen in the 30-minute interval prior to the 4-hour target (211-240 minutes) and the average of the two 30 minute periods either side of this interval (181-210 minutes and 241-270 minutes). The figure below uses this approach to estimate the proportion of attendances affected by the 4-hour target for each month from April 2010 to March 2016. Following some initial increases in 2010/11 when the target level was reset from 98% to 95%, there has been little change in the size of the distorting effect. This implies that the ability of the current A&E system to distort the distribution of attendance durations is marginal (c. 10%) and stable. This is plausible because distortion requires the use of limited management resources.

Figure 4.12: A&E Distortion Effect, England Apr 2010 – Mar 2016



5. An emergent factor

5.1 Autocorrelation, service resilience and the backlog effect

Breaches of the A&E target do not occur independently of each other; they are clustered in space (provider) and time. The degree to which events (e.g. breaches of the 4-hour target) are dependent on past events can be measured using a metric known as autocorrelation.[4] The presence of autocorrelation is evident to anyone with experience of A&E departments. When the department experiences a shock (e.g. when demand exceeds the resources available in ED or elsewhere in the hospital), then a backlog of patients builds up and a cluster of breaches can be expected. In these circumstances a patient may breach the 4-hour target not because of the complexity of their condition, the investigations or treatments carried out, or the number of simultaneous patient arrivals, but instead because of the lagged effects of the shock.

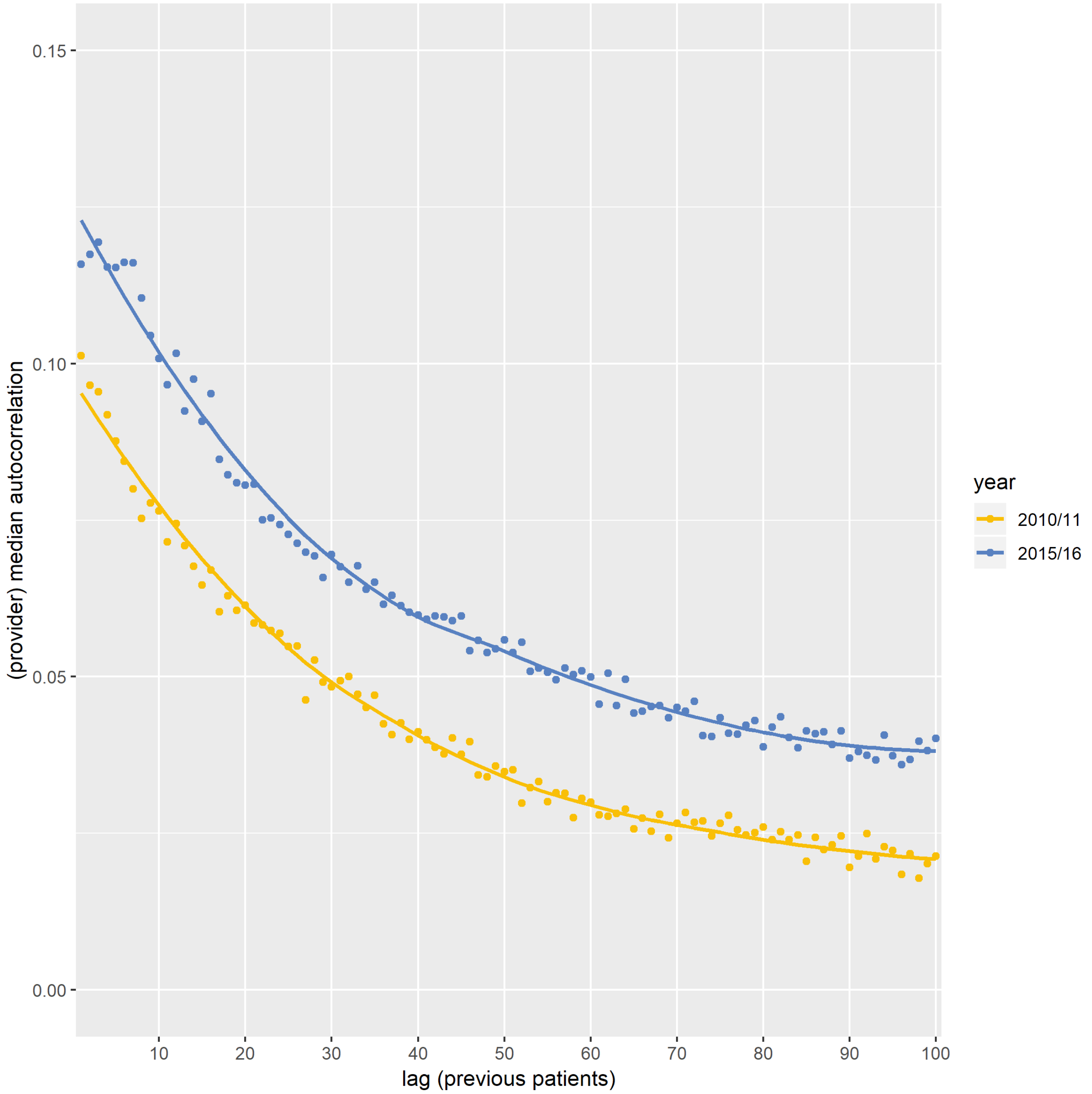
Figure 5.1 shows the presence of autocorrelation in 4-hour breaches in each year between 2010/11 and 2015/16. The effects are not substantial and so do not exert a strong influence over any given patient but accumulate across large patient populations. If a patient breaches the 4-hour target, then the next patient has a small increased chance of breaching. These effects diminish (such the impact on the second subsequent patient is smaller and the third subsequent patient is smaller still) but persist (such that even the chance of breach of the 100th subsequent patient is influenced marginally).

The presence of autocorrelation exerts a multiplier effect on 4-hour breaches. If the level of autocorrelation is static year to year, but the background level of breaches increases (e.g. due to changes in casemix or bed occupancy), then autocorrelation will serve to increase breaches further still. And if autocorrelation also increases then this multiplier effect is amplified.

Figures 5.1 demonstrates that autocorrelation has increases in both strength and persistence.

[4] Autocorrelation takes values from +1 to -1. A value of 0 indicates no autocorrelation.

Figure 5.1: Provider Median Breach Autocorrelations, England 2010/11 and 2015/16
Points show correlations for lags for up to 1-100 consecutive patients



6. Combining the effects

6.1 Modelling approach

The analysis presented above provides evidence in favour of the causal influence of some factors on performance against the 4-hour target in A&E, and against others. In particular it suggests that changes in patient casemix, attendances levels, thresholds for investigation and admission, bed occupancy and levels, staffing levels and facilities in A&E and autocorrelation are likely to have played a part in performance changes, but that changes in treatment thresholds or in the response to regulatory pressures are not. But this analysis says little about the relative contribution each of these factors has had on the observed performance deterioration.

The relative impact of these factors is estimated here using a nested modelling approach. The analysis starts by estimating the increased chance (the odds ratio), that a patient might breach the 4-hour target in 2015/16 compared to 2010/11. Crucially, this first stage analysis does not take account of factors relating to the patient's characteristics, levels of demand, resource or changes in practice. Then the analysis explores how these increased odds of breach reduce after specific factors are taken into account. The model builds incrementally, adding one factor at a time until all potential explanatory factors are included. If at this stage there are no residual increased odds of breach then one might conclude that deterioration in performance can be explained by these factors.

Data in staffing and physical resource levels is not sufficiently detailed or granular to be included in this modelling exercise, so any residual increased odds of breach may be explained by changes in these factors.

The analysis is conducted on a random sample of ½ million attendances to A&E departments with consistently high levels of diagnosis recording, between April 2010 and March 2016. Logistic regression was used given the binary nature of the outcome variable (breach y/n). Analysis was conducted in R (v3.5.1). Further details of inclusion / exclusion criteria, model specification and model results can be found in technical appendix E.

Figure 6.1: Composition of Nested Regression Models

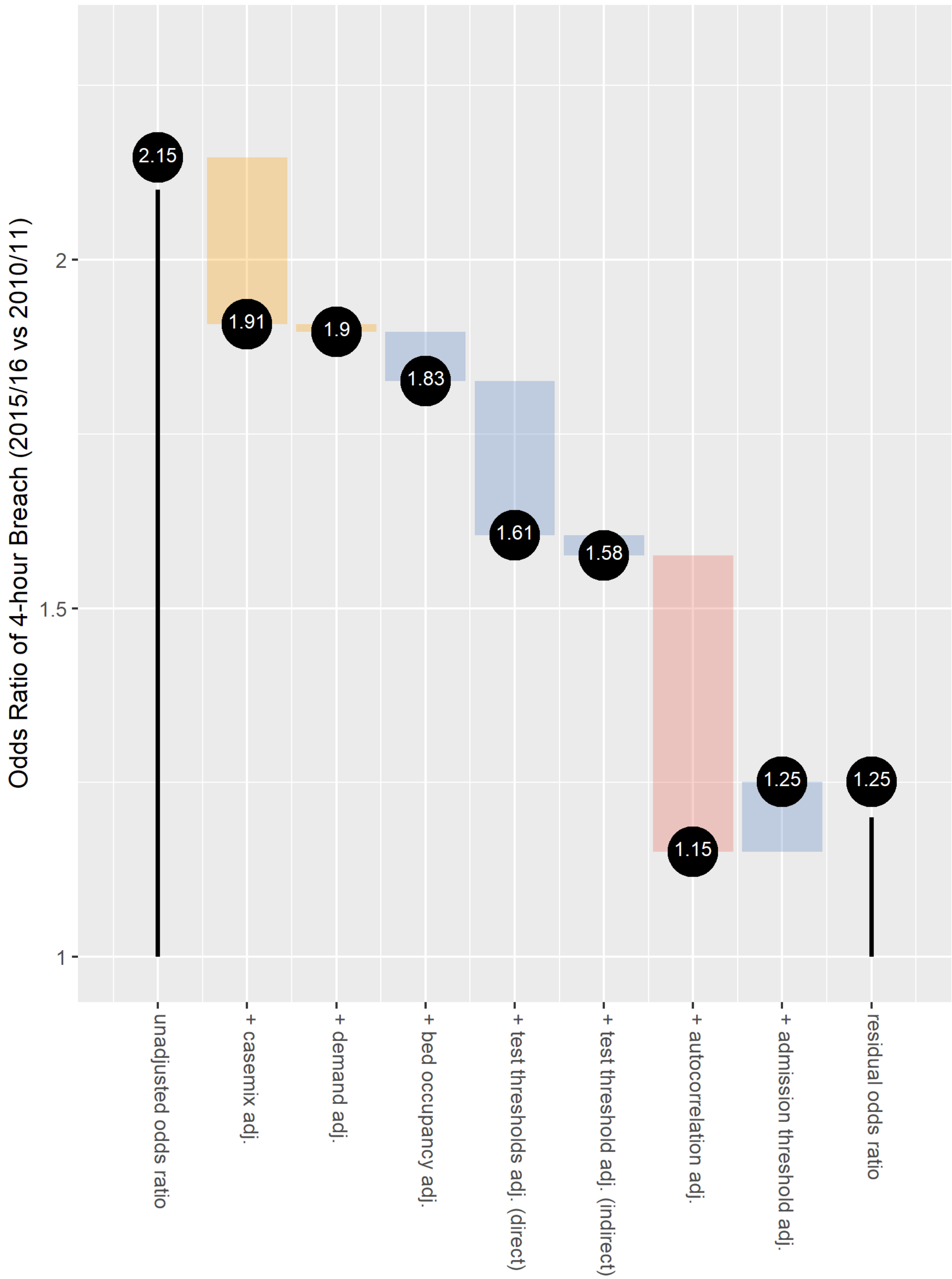
Nest level	Adjusted for	Variables included (in addition to those in the previous level)
1	provider	provider
2	+ casemix	the index patient's age group, sex, IMD decile, arrival mode, diagnosis, arrival month, arrival day, arrival hour, prior attendances and admissions[5]
3	+ demand	number of patients arriving in the same 15-minute interval as the index patient
4	+ bed occupancy	elective and emergency inpatients as a proportion of the total number of beds available in the 15-minute window of the index patient's arrival
5	+ investigation thresholds (direct)	index patient investigations by type
6	+ investigation thresholds (indirect)	average number of investigations for patients arriving in the same 15-minute interval as the index patient
7	+ autocorrelation	average duration of patients leaving the department in the 2 hours prior to the index patient's arrival
8	+ admission thresholds	index patient admitted (y/n)[6]

It is likely that some of the explanatory factors listed above will be colinear. As such, the order in which these factors are introduced into the model will influence the proportion of increased odds of breach that each factor is seen to explain. The reduction in the odds of breach seen when a factor is introduced at in, say, nest level 3, represents the additional explanatory power that this variable provides having taken account of all variables in higher nest levels.

[5] Including interaction between diagnosis and arrival mode
[6] Including interaction between admitted (y/n) and bed occupancy

6.2 Modelling results

Figure 6.2: factors contributing to the increased odds of 4-hour breach (2015/16 vs 2010/11)



Our model suggests that patients were 2.15 times more likely to breach the 4-hour target in 2015/16 compared with 2010/11. However, after controlling for changes in patient casemix, attendances levels, thresholds for investigation and admission, bed occupancy and autocorrelation, this increased odds to breach falls to 1.25. In effect these factors appear to explain the largest part of the observed deterioration in performance against the 4-hour target.

Changes in casemix and investigation thresholds play a significant role in increasing the frequency of 4-hour breaches with the increase in bed occupancy playing a somewhat smaller part. Increases in the number of A&E attendances appear to have had only a minimal effect. The impact of reduced investigation thresholds is offset to some extent by increases in admission thresholds. The presence and increase in autocorrelation is the single largest factor; this might be thought of as the inability of A&E to recover quickly from periods of increased pressure. This has a multiplier-effect, increasing the impact of other factors.

Given the data presented in section 3, it is reasonable to speculate that the autocorrelation effect and the residual (unexplained) increased odds of breach might be driven, at least in part, by the fact that A&E resource levels (staffing and facilities) have failed to keep pace with increases in activity in A&E departments.

For regulatory purposes, it may be useful to consider which of these factors falls under the direct control of a hospital trust (blue factors in the chart below) and which can only be addressed at a system level (yellow factors).

Results of similar models stratified by admission status are shown in appendix F. Although the increased odds of a 4-hour breach are much smaller for non-admitted patients, the relative impact of the causal factors on the increased odds of a 4-hour breach are broadly similar for admitted and non-admitted patients.

7. Conclusions

The analysis presented in this report identifies and scales many of the factors that have led to the increases in breaches of the 4-hour A&E target.

The casemix of patients presenting at A&E is changing with consistent trends towards greater complexity and acuity. When decisions were taken to reduce the 4-hour target level from 100% to 98%, and then to 95%, it was based on the premise that some patients "*could benefit from a longer period of active treatment in A&E*" (DH 2011). If one accepts this premise and the 4-hour standard is intended as a performance benchmark which is consistent over time, and common (fair) between providers, then there may be an argument for adjusting or stratifying the performance target to reflect differences and changes in casemix. Casemix adjustment is not without its challenges, but it is an approach commonly used in other aspects of clinical and operational performance measurement. It is worth noting however, that the reductions in performance observed in recent years are far greater than can be explained by casemix changes alone.

The report provides evidence in support of the exit block theory. As inpatient beds are occupied at higher and higher levels, boarding times have lengthened, and this has led to an increase in 4-hour breaches.

A&E departments have increased admission thresholds, managing some patients within A&E who would in the past have been admitted. A&E departments have reduced the thresholds for tests and investigations in A&E, presumably to discount diagnoses which might necessitate admission. The combined effect of these changes to admission thresholds and investigation thresholds has led to increased durations in A&E and an increase in the number of breaches.

Levels of medical and non-medical staffing and physical resources in A&E (e.g. cubicles, trolleys) have increased at a faster rate than the number of attendances but have not kept pace with changes in casemix and practice intensity. A lack of detailed data makes it difficult to reach definitive conclusions about the adequacy of staffing and resource levels, but this appears to be a good candidate contributor in the list of factors that have led to increased 4-hour breaches and the reduced resilience in A&E departments to recover from periods of pressure. Greater certainty would require a concerted effort to systematically collect and report physical staffing rotas and resource levels in A&E departments.

This analysis highlights the importance of considering performance in the round. Avoiding emergency admissions has been the focus of national health policy for many years and there is good evidence that A&E departments have achieved this by increasing admission thresholds. But this in turn has contributed to the deterioration in performance against the 4-hour target. Policy makers must consider the trade-off between increased durations in A&E and avoidable hospital admissions. Improvements against the 4-hour target could be delivered by increasing the bed stock and reversing the trends in investigation thresholds in A&E, but this will almost inevitably lead to an increase in admissions. More nuanced approaches may be worth considering. Whilst reduced investigation thresholds in A&E appears to be the mechanism by which admission thresholds have been increased, it is not clear whether all of the additional tests have added value. Policy makers may wish to consider commissioning a thorough review of the evidence relating to the circumstances in which tests and investigations in A&E add diagnostic value. Reducing the frequency of low value tests could lead to reductions in A&E attendance durations without increasing admissions.

The notion that changes in diagnostic imaging capacity and the availability of specialists to review patients might have led to changes in 4-hour breaches is underpinned by sound theory but is difficult to evidence in practice using national datasets. Local studies may provide additional insight here.

Given that this report was unable to provide a complete explanation for the increased level of 4-hour breaches, new theories should be sought and pursued. Given capacity constraints in A&E departments, there may be value in considering the unintended consequences of 7-day working for the delivery of the 4-hour target.

Whilst solutions to the problem of increased 4-hour breaches may lie in tackling the underlying causes directly, lateral thinking may generate fresh approaches. The use of scribes in A&E departments is good example of such an approach (Waller 2019).

Technical Appendix

Appendix A - Trusts with high and consistent level of diagnosis recording in A&E

RA9	Torbay and South Devon NHS Foundation Trust
RAJ	Southend University Hospital NHS Foundation Trust
RBD	Dorset County Hospital NHS Foundation Trust
RBN	St Helens and Knowsley Hospital Services NHS Trust
RBS	Alder Hey Children's NHS Foundation Trust
RBT	Mid Cheshire Hospitals NHS Foundation Trust
RC9	Luton and Dunstable University Hospital NHS Foundation Trust
RCF	Airedale NHS Foundation Trust
RCX	The Queen Elizabeth Hospital, King's Lynn, NHS Foundation Trust
RDE	East Suffolk and North Essex NHS Foundation Trust
REP	Liverpool Women's NHS Foundation Trust
RHM	University Hospital Southampton NHS Foundation Trust
RHQ	Sheffield Teaching Hospitals NHS Foundation Trust
RHU	Portsmouth Hospitals NHS Trust
RJL	Northern Lincolnshire and Goole NHS Foundation Trust
RJN	East Cheshire NHS Trust
RJR	Countess of Chester Hospital NHS Foundation Trust
RLT	George Eliot Hospital NHS Trust
RMC	Bolton NHS Foundation Trust
RNQ	Kettering General Hospital NHS Foundation Trust
RNZ	Salisbury Health Care NHS Trust
RP5	Doncaster and Bassetlaw Teaching Hospitals NHS Foundation Trust
RP6	Moorfields Eye Hospital NHS Foundation Trust
RQ3	Birmingham Women's and Children's NHS Foundation Trust
RQQ	Hinchingbrooke Health Care NHS Trust
RR7	Gateshead Health NHS Foundation Trust
RRV	University College London Hospitals NHS Foundation Trust
RTE	Gloucestershire Hospitals NHS Foundation Trust
RTF	Northumbria Healthcare NHS Foundation Trust
RTK	Ashford and St Peter's Hospitals NHS Foundation Trust
RTR	South Tees Hospitals NHS Foundation Trust
RTX	University Hospitals of Morecambe Bay NHS Foundation Trust
RVW	North Tees and Hartlepool NHS Foundation Trust
RWF	Maidstone and Tunbridge Wells NHS Trust
RX1	Nottingham University Hospitals NHS Trust
RXC	East Sussex Healthcare NHS Trust
RXF	Mid Yorkshire Hospitals NHS Trust
RXR	East Lancashire Hospitals NHS Trust
RYR	Western Sussex Hospitals NHS Foundation Trust

Appendix B – A&E Investigations Models – Odds of Investigation

Two binary logistic regression models (with and without casemix adjustment), for each of 19 A&E investigations. Analysis conducted in R v 3.5.1 with the MGCV package.

Dependent variable – Investigation carried out (y/n)

Independent variable – arrival year (6 levels)

Casemix adjustment independent variables - age (GAM), sex (2 levels), IMD15 deprivation quintile (5 levels), arrival mode (2 levels), diagnosis (38 levels), arrival month (12 levels), arrival weekday (7 levels), arrival hour (24 levels), travel time (GAM), prior admissions and attendances in last 28 days (3 levels), prior admissions and attendances in last 29-365 days (3 levels). Interaction terms for arrival mode – diagnosis and age - sex.

n = 500,000 randomly sampled type 1 A&E attendances between 2010/11 and 2015/16 from trusts listed in appendix A.

		Odds Ratio of Investigation (2015/16 vs 2010/11)	
Ref	**Investigation**	**Unadjusted**	**Adjusted**
05	Biochemistry	1.72	1.43
16	Cardiac enzymes	3.58	2.73
17	Arterial/capillary blood gas	3.45	2.14
18	Toxicology	1.86	1.23
21	Pregnancy test	1.64	1.10
03	Haematology	1.77	1.59
04	Cross match blood/group and save serum for later cross match	1.26	1.09
14	Clotting studies	4.59	3.24
01	X-ray plain film	0.90	0.90
10	Ultrasound	1.17	0.91
11	Magnetic Resonance Imaging	1.78	1.57
12	Computerised Tomography	3.28	3.50
02	Electrocardiogram	1.62	1.15
06	Urinalysis	1.61	1.11
07	Bacteriology	2.37	1.97
19	Blood culture	2.26	1.09
20	Serology	10.69	7.00
23	Refraction, orthoptic tests and computerised visual fields	2.60	2.29
99	Other	1.29	1.38

Model coefficients for other covariates available on request.

Appendix C – A&E Investigations Models – Odds of Admission having Received Investigation

Binary logistic regression model. Analysis conducted in R v 3.5.1 with the MGCV package.

Dependent variable – Admitted (y/n)

Independent variables - age (GAM), sex (2 levels), IMD15 deprivation quintile (5 levels), arrival mode (2 levels), diagnosis (38 levels), arrival year (6 levels), arrival month (12 levels), arrival weekday (7 levels), arrival hour (24 levels), travel time (GAM), prior admissions and attendances in last 28 days (3 levels), prior admissions and attendances in last 29-365 days (3 levels) investigation carried out (binary variable for each of 19 tests). Interaction terms for arrival mode – diagnosis, age – sex and investigation - arrival year

n = 500,000 randomly sampled type 1 A&E attendances between 2010/11 and 2015/16 from trusts listed in appendix A.

		Odds Ratio of Admission having received investigation (2015/16 vs 2010/11)	
Ref.	**Investigation**	**Unadjusted**	**Adjusted**
05	Biochemistry	0.76	0.63
16	Cardiac enzymes	0.86	0.95
17	Arterial/capillary blood gas	0.73	0.68
18	Toxicology	0.54	0.23
21	Pregnancy test	1.18	0.90
03	Haematology	0.69	0.60
04	Cross match blood/group and save serum for later cross match	0.51	0.37
14	Clotting studies	0.73	0.48
01	X-ray plain film	0.98	0.67
10	Ultrasound	1.95	1.57
11	Magnetic Resonance Imaging	1.00	0.28
12	Computerised Tomography	0.63	0.39
02	Electrocardiogram	0.79	0.51
06	Urinalysis	1.01	0.65
07	Bacteriology	1.38	1.35
19	Blood culture	1.08	1.19
23	Refraction, orthoptic tests and computerised visual fields	0.12	0.44
99	Other	1.45	1.20

Model coefficients for other covariates available on request.

Appendix D – A&E Treatment Models – Odds of Treatment

Two binary logistic regression models (with and without casemix adjustment), for each of 40 A&E investigations. Analysis conducted in R v 3.5.1 with the MGCV package.

Dependent variable – Investigation carried out (y/n)

Independent variable – arrival year (6 levels)

Casemix adjustment independent variables - age (GAM), sex (2 levels), IMD15 deprivation quintile (5 levels), arrival mode (2 levels), diagnosis (38 levels), arrival month (12 levels), arrival weekday (7 levels), arrival hour (24 levels), travel time (GAM), prior admissions and attendances in last 28 days (3 levels), prior admissions and attendances in last 29-365 days (3 levels). Interaction terms for arrival mode – diagnosis and age - sex.

n = 500,000 randomly sampled type 1 A&E attendances between 2010/11 and 2015/16 from trusts listed in appendix A.

		Odds Ratio of Treatment (2015/16 vs 2010/11)	
Ref	**Treatment**	**Unadjusted**	**Adjusted**
01	Dressing	1.07	0.79
03	Sutures	0.96	0.80
04	Wound closure (excluding sutures)	1.00	0.74
24	Tetanus	0.85	0.51
34	Wound cleaning	1.89	1.07
35	Dressing/wound review	2.24	1.14
02	Bandage/support	0.69	0.57
05	Plaster of Paris	0.92	0.84
06	Splint	1.04	1.16
09	Physiotherapy	0.85	0.64
10	Manipulation	1.45	1.15
32	Recall/x-ray review	2.32	1.58
33	Fracture review	2.36	1.09
36	Sling/collar cuff/broad arm sling	1.36	1.01
53	Loan of walking aid (crutches)	1.56	1.26
08	Removal foreign body	1.00	0.72
11	Incision & drainage	2.09	1.63
20	Minor surgery	1.19	0.92
37	Epistaxis control	2.45	1.55
19	Resuscitation/cardiopulmonary resuscitation	1.78	0.88
21	Observation/electrocardiogram, pulse oximetry/head injury/trends	2.25	0.94
25	Nebuliser/spacer	1.82	0.88
39	Oral airway	5.08	3.39

Ref	Treatment	Odds Ratio of Treatment (2015/16 vs 2010/11)	
		Unadjusted	Adjusted
40	Supplemental oxygen	2.47	0.89
41	Continuous positive airways pressure/nasal intermittent positive pressure ventilation/bag valve mask	8.55	4.81
12	Intravenous cannula	1.51	0.74
29	Other Parenteral drugs	2.95	1.41
43	Infusion fluids	3.29	1.63
15	Intubation & Endotracheal tubes/laryngeal mask airways/rapid sequence induction	1.86	0.97
17	Urinary catheter/suprapubic	1.35	0.69
42	Arterial line	2.03	0.92
14	Lavage/emesis/charcoal/eye irrigation	1.45	0.78
23	Anaesthesia	1.42	0.75
27	Other (consider alternatives)	0.56	0.34
30	Recording vital signs	4.20	2.13
51	Medication administered	2.30	1.22
52	Occupational Therapy	5.37	4.25
55	Eye	0.10	0.10
22	Guidance/advice only	2.05	0.95
57	Prescription/medicines prepared to take away	1.83	1.11

Model coefficients for other covariates available on request.

Appendix E – Nested Breach Models

8 binary logistic regression models.

Analysis conducted in R v 3.5.1.

Dependent variable – 4 hr breach (y/n) i.e. attendance duration > 240 minutes

Nest level	Independent variables (in addition to those in the previous level)
1 (provider)	Provider (39 levels), arrival year (6 levels)
2 (+casemix)	the index patient's age group (, sex (2 levels) , IMD quintile (5 levels), arrival mode (2 levels), diagnosis (39 levels) , arrival month (12 levels) , arrival weekday (7 levels), arrival hour (24 levels) , prior admissions and attendances in last 28 days (3 levels), prior admissions and attendances in last 29-365 days (3 levels). Including interaction between diagnosis and arrival
3 (+demand)	number of patients arriving in the same 15-minute interval as the index patient
4 (+bed occupancy)	elective and emergency inpatients as a proportion of the total number of beds available in the 15-minute window of the index patient's arrival
5 (+investigation thresholds (direct))	index patient investigations by type
6 (+investigation thresholds (indirect))	average number of investigations for patients arriving in the same 15-minute interval as the index patient
7 (+autocorrelation)	average duration of patients leaving the department in the 2 hours prior to the index patient's arrival
8 (+admission thresholds)	index patient admitted (y/n). Including interaction between admitted (y/n) and bed occupancy.

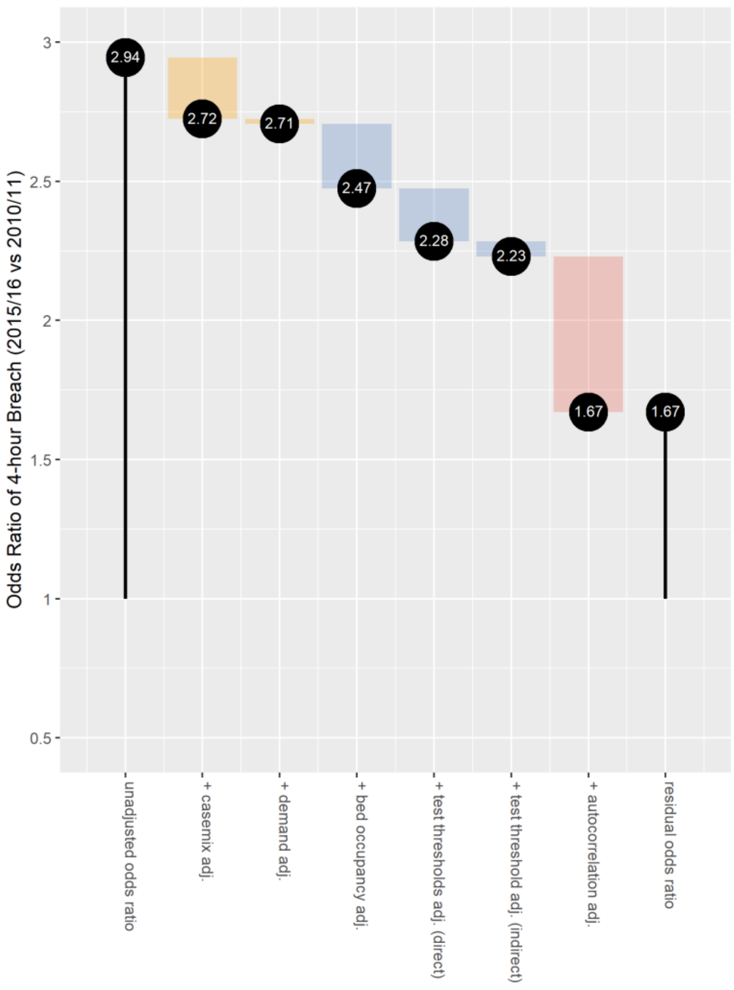
n = 500,000 randomly sampled type 1 A&E attendances between 2010/11 and 2015/16 from trusts listed in appendix A.

Nest level	Adjusted for	Odds ratio of 4-hr breach (2015/16 vs 2010/11)	95% confidence interval
1	provider	2.146	[2.226-2.069]
2	+ casemix	1.907	[1.986-1.832]
3	+ demand	1.897	[1.975-1.821]
4	+ bed occupancy	1.826	[1.906-1.749]
5	+ investigation thresholds (direct)	1.605	[1.677-1.536]
6	+ investigation thresholds (indirect)	1.575	[1.647-1.507]
7	+ autocorrelation	1.151	[1.206-1.099]
8	+ admission thresholds	1.251	[1.311-1.194]

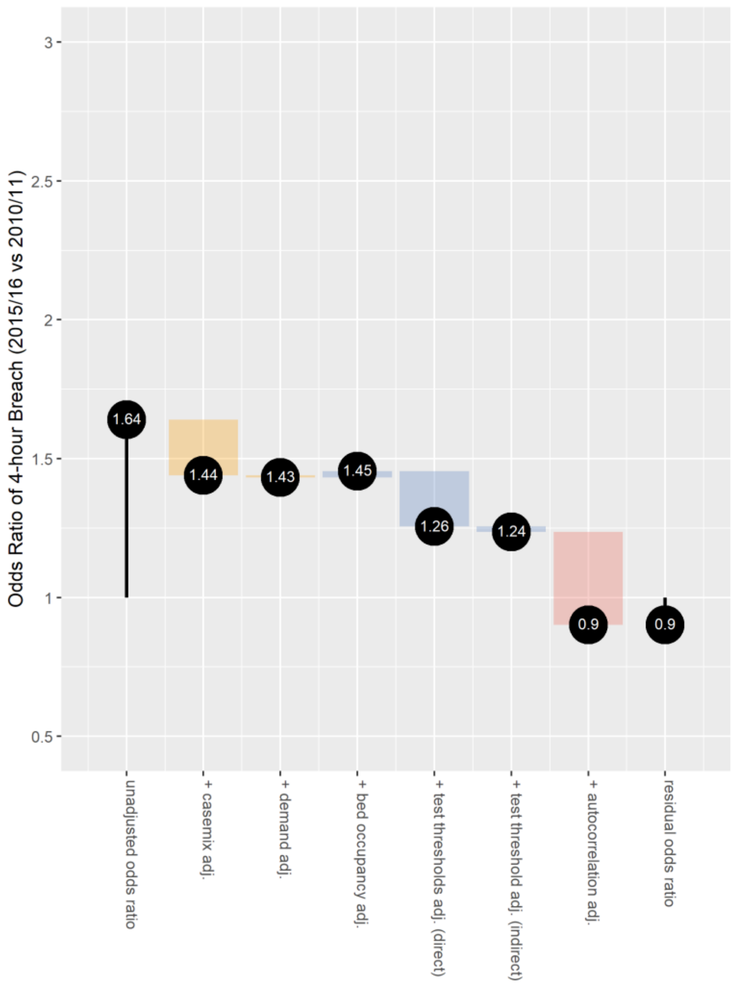
Model coefficients for other covariates available on request.

Appendix F – Results of Nested Breach (y/n) Models Stratified by Admission (y/n)

Admitted Patients



Non-admitted Patients



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