Mixed Public-Private Provision in Healthcare: Evidence from the English National Health Service

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Abstract

Public health systems are often under strain, with patients facing crowding and long waits in public hospitals. To increase competition and ease supply constraints in public health care systems, governments to contract with private providers alongside public incumbents. This paper studies a policy reform in England that enabled elective orthopedic patients to receive treatment at private hospitals paid for by the government. Using variation in exposure to the reform due to locations of existing private hospitals, I find that the policy increased volume of elective admissions and reduced emergency readmission rates and wait times. Private hospitals treat less severe patients, increasing average complexity of patients in the public sector. Despite this, the observed effects are driven largely by improvements at public hospitals. Effects are concentrated in markets with low preexisting public sector capacity, providing evidence that relaxing capacity constraints is a key channel.

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1 Introduction

Aging populations and the rapid growth of costly new technologies has placed many public healthcare systems under strain, with patients facing long waits and crowding. Governments often look to the private sector in an attempt to ease congestion in the public system and increase competition. Governments may contract with the private sector for delivery of publicly-funded care (Hart, Shleifer and Vishny 1997, Besley and Malcomson 2018) or encourage people to pay privately for care (Besley and Coate 1991, Laine 2019). These reforms are controversial, with critics arguing that private hospitals provide low quality care and drain resources from the public system by cream-skimming healthier patients and diverting scarce inputs like physician time. In this paper I develop a framework for understanding the effects of private entry and investigate this empirically in the context of a reform in the English National Health Service (NHS) that enabled publicly-insured elective patients to receive treatment at private hospitals paid for by the government. This reform was designed to stimulate competition between hospitals and to relieve crowding and long waits in the public system.[1] I estimate the causal effects of this reform on patient outcomes, including emergency readmissions and wait times.

Private entry has at least two effects. First, it causes some patients who would have received treatment at public hospitals to be treated at private hospitals. For these patients, the causal effect of entry is measured by how quality of private hospitals compares to public incumbents. Second, private entry may have an indirect effect on patients remaining at public hospitals. Competitive pressure may incentivize public hospitals to improve (Gaynor, Moreno-Serra and Propper 2013, Gaynor, Propper and Seiler 2016); conversely competition can reduce quality if hospitals make financial losses on marginal patients (Gaynor, Ho and Town 2015, Moscelli, Gravelle and Siciliani 2021). Private entry also reduces demand for public hospitals. Where the public system is capacity-constrained there may be long waits and crowding (Hoe 2022), so this reduction in demand may improve quality at public hospitals. On the other hand, if private providers 'cream-skim' profitable patients either by directly selecting them or by offering services that differentially attract profitable patients, this can worsen the financial position of public hospitals and may reduce quality. Private hospitals may be able to attract healthcare workers away from public hospitals with higher wages (Collier and Scally 2015, Pollock and Kirkwood 2009).

All citizens and residents of England are eligible to receive free healthcare paid for out of general taxation. Until the mid-2000s tax-funded acute care was provided almost entirely in government-owned and managed hospitals, with a small parallel private-pay sector. From 2007-2009 a nationwide reform allowed public patients to receive treatment free at the point of service at any private hospital accepting public patients. The government pays public and private hospitals the same price per patient, with this price set by the government. 80% of existing private hospitals chose to participate. Private hospitals treat less complex patients than public hospitals and lack intensive care units, but they offer lower wait times and amenities such as private rooms.

[1] Average annual bed occupancy is above 90% in NHS hospitals (Ewbank, Thompson and McKenna 2017), compared with an estimated 60% in private hospitals prior to the reform (Raffel 2007)

In this paper, I first develop a conceptual model to understand the effects of entry on patient outcomes. Average effects of entry depend on the causal effects of being treated at a private hospital for patients shifted into private hospitals by the reform, and on the effects of entry on quality of public incumbents. I identify three key channels through which private entry can affect quality of a public incumbent: increasing elasticity of demand with respect to quality effect (the 'competitive effect'), reducing demand for the incumbent at a given level of quality (the 'capacity effect') and altering the average severity of patients treated (the 'cream-skimming effect').

I exploit the NHS reform allowing private entry to estimate the causal effects of private entry on patient outcomes, including risk-adjusted emergency readmission and wait times. I use administrative data containing the universe of publicly-funded inpatient admissions, and supplement this with several other data sources, including counts of private pay patients, area demographic data, data on hospital facilities and finances, and quality inspection results. I focus on orthopaedic admissions, which account for more than half of private hospital activity in the period I study.

My analysis proceeds in three stages. First, I estimate the causal impact of private entry at the hospital-market level, using difference-in-differences to compare local hospital markets more versus less exposed to entry because of the preexisting locations of private hospitals. Private entry increases total number of elective orthopaedic admissions per 1,000 people, reduces risk-adjusted emergency readmission and reduces wait times. Entry into a market also has small positive spillovers on *emergency* orthopaedic patients, even though they are not treated in public hospital. Second, I decompose the effect of entry into the direct effect of reallocating patients to private hospitals and the indirect effect on patients remaining at public hospitals. I estimate an instrumental variables difference-in-differences model, where I instrument choice of private hospital with differential distance, controlling explicitly for exposure to public hospital spillovers generated by the reform. I find that almost the entire quality effect and half the wait time effect comes from improvements at impacted public hospitals. Finally, I investigate mechanisms. I allow for heterogeneity of the effects of entry by baseline HHI and public sector capacity, measured using number of hospital beds and operating theaters per 1,000 people. I find both the readmission and wait time effects are concentrated in markets with low public sector capacity, providing evidence that easing of supply constraints is a key channel for the observed effects.

1.1 Contribution and related literature

This paper advances knowledge of the economics of private entry and competition in public services by developing a framework for understanding how competition interacts with capacity constraints and cream-skimming and investigating this empirically in the context of a large policy reform.

The empirics of this paper build on earlier papers on the effects of privatization in the NHS: Cooper, Gibbons and Skellern (2018) investigate the effects of the first limited wave of reform on public incumbents, finding that entry worsens case-mix but increases efficiency. The authors lack data on patients treated at private hospital, so cannot estimate overall quality effects. Beckert and Kelly (2021) estimate a patient demand model after the reform and quantify welfare gains arising from adding private hospitals to the choice set. They do not consider welfare gains arising from changes at public hospitals. The closest paper to this is Kelly and Stoye (2020), who argue that privatization increased aggregate supply of hip replacements. They find a reduction in wait times but do not observe any change in quality. In addition, several papers compare public and private hospitals, finding quality is comparable once differences in case-mix are accounted for (Moscelli et al. 2018, Browne et al. 2008, Chard et al. 2011) Besley and Malcomson (2018) propose and calibrate a theory model to evaluate the welfare effects of allowing private entry and calculate the optimal reimbursement price for private hospitals.

This paper also contributes to the broader literature on entry and competition in healthcare. These papers are surveyed by Gaynor, Ho and Town (2015). This study is most closely related to previous papers on the effects of earlier pro-market reforms in the English NHS. Gaynor, Moreno-Serra and Propper (2013), Cooper et al. (2011) and Gaynor, Propper and Seiler (2016) Competition between public hospitals improved outcomes for AMI and coronary artery bypass grafting (Gaynor, Moreno-Serra and Propper 2013, Cooper et al. 2011, Gaynor, Propper and Seiler 2016) but worsened quality for elective procedures including hip and knee replacement Moscelli, Gravelle and Siciliani (2021) There is also evidence from the entry of cardiac specialty hospitals in the US that entry into healthcare markets may improve overall quality (Barro, Huckman and Kessler 2006, Cutler, Huckman and Kolstad 2010), but that specialty hospitals also cream-skim less costly patients (Barro, Huckman and Kessler 2006, David et al. 2014).

My work also contributes to understanding the differences between public and privately-owned providers (Sloan 2000). In healthcare, there is a long theoretical and empirical literature documenting differences in government, non-profit and for-profit hospitals (Duggan 2000, Newhouse 1970). There is also a large literature on privatization of public health insurance, specifically Medicare Advantage and Medicaid Managed Care in the US. This literature is somewhat mixed. Most of the work on Medicare Advantage literature concludes that private plans reduce spending with little change in health outcomes (Curto et al. 2021), although recent work indicates substantial variation in mortality between different private plans (Abaluck et al. 2021). In Medicaid managed care however, some studies conclude that privatization increases mortality and worsens health (Aizer, Currie and Moretti 2007, Duggan, Garthwaite and Wang 2021). One of the key differences may be whether enrollees retain a choice to stay with the public option.

Outside of healthcare, this project is closest to work on charter schools and vouchers for private school systems, since it considers a largely public system subject to private entry. Much of the work on charter schools uses admissions lotteries to evaluate effectiveness (Epple, Romano and Zimmer 2016, Angrist, Pathak and Walters 2013). This paper is closest to work evaluating the aggregate effects of charter entry on education markets (Gilraine, Petronijevic and Singleton 2021).

2 Background

In the UK health care is free at the point of use and financed by general taxation. Most acute care is provided by the National Health Service (NHS) in publicly-owned hospitals, which receive a fixed payment per admission from the government. Payment per admission is determined by 'healthcare resource groups', standardized groupings of clinically similar treatments.[2] There is a small parallel private pay system accounting for 7% of overall acute hospital expenditure (LaingBuisson 2019), in which individuals can purchase private medical insurance or pay out-of-pocket to receive care at private hospitals. The advantage of paying privately is lower wait times and amenities such as private rooms.

The NHS outsourcing reforms proceeded in two stages. In the first smaller wave from 2005, private hospitals called were established in specific locations chosen by the government. Private firms were awarded block contracts, with an average payment per admission approximately 10% greater than the payment to public hospitals (House of Commons Health Committee 2010).[3] In the second much larger wave of reform, phased in from 2007-2009, any private hospital could offer services to NHS patients through the 'Extended Choice Network'. Table 1 shows a timeline of NHS privatisation reforms. Patients are referred for hospital care by their primary care doctors and can choose appointment slots at public hospitals and participating private hospitals through a common referral system. Public and private hospitals receive the same price per NHS patient.[4][5] This price is set through an administrative process based on hospital-reported average costs from previous years. Private hospitals almost all treat private patients as well as NHS patients. They are able to prioritize private-pay patients for operation slots and then fill additional capacity with NHS patients.[6]

Of the 160 private hospitals in the UK prior to the reform, 128 chose to enter the NHS market. More than 80% of entering hospitals were owned by the four largest health care firms. Three of these companies (BMI, Spire and Ramsay) are for-profit and the fourth (Nuffield) is not for profit. Figure 1 shows a map of public and private hospital sites treating NHS patients in 2012. Figure 2 shows total government spending on elective admissions by specialty in 2012. The effects of the reform were overwhelmingly concentrated in orthopaedics, especially in procedures such as hip and knee replacement with long wait times. Appendix table 8 shows fraction of spending in private hospitals for the most common orthopaedic procedures. Figure

[2] The system is similar to diagnosis related groups (DRGs) in US Medicare.

[3] These contracts were known as 'take or pay' since the NHS paid the full amount whether or not the specified procedures were performed. Some centres carried out considerably fewer surgeries than specified in the contract.

[4] When their initial contracts ended, the first wave private providers also switched to prospective payment. The running of three of these hospitals was eventually transferred back to the NHS.

[5] If public hospitals are struggling to treat everyone on their wait list, they can also sub-contract services to the private sector, in which case they negotiate prices directly with the sub-contracted entity. In practice, this accounts for only a small fraction of NHS-funded activity taking place in private hospitals.

[6] Hospitals may intentionally restrict access for NHS patients to boost private demand e.g. the Chief Executive of a private hospital wrote the following memo to staff: 'I have had numerous discussions... regarding the lack of differentiation between NHS and private patients, and there is significant anecdotal evidence to suggest that the lack of differentiation has had a negative effect on our private patient referrals. I now wish to implement with immediate effect a new rule which will mean that operations on NHS Choose and Book patients will not be able to take place until at least four weeks following their outpatient consultation.'

Table 1: Timeline of NHS reforms.

2004	First-wave private hospital block contracts start.
2006	NHS patients given choice of at least 4 public hospitals.
2007	First private hospitals added to NHS online booking system.
2008	Patients can choose any participating private hospital in England.

3 shows the number of NHS-funded elective orthopaedic admissions from 2001-2012. Panel (a) shows the absolute number of admissions and panel (b) shows the number of admissions per 10,000 people over 60. From 2007/8, the number and fraction of procedures taking place at private hospitals increased rapidly,[7] reaching almost 20% by 2013/14.

The privatization reforms took place during a period in which there was a significant increase in spending in the NHS. The government also enacted other reforms aimed at promoting competition. In 2003, the government moved from paying hospitals block contracts to paying per admission. In 2005-2006, the government began allowing public patients to choose between different public hospitals. This reform has been extensively studied elsewhere (Cooper et al. 2011, Gaynor, Moreno-Serra and Propper 2013, Gaynor, Propper and Seiler 2016, Moscelli, Gravelle and Siciliani 2021). There are two other relevant reforms. First, wait time targets for elective surgery were imposed and became steadily more stringent. Second, penalties for hospital readmission were introduced from the 2011/2012 financial year onwards. To isolate the effects of the reform I study from these other policy changes, I rely on the fact that area level exposure to private entry depends on the preexisting locations of private hospitals.

[7] The administrative admissions data for procedures conducted in Independent Sector Treatment Centers is incomplete until around 2008/09.

Figure 1: Locations of public and private hospitals in England, 2012

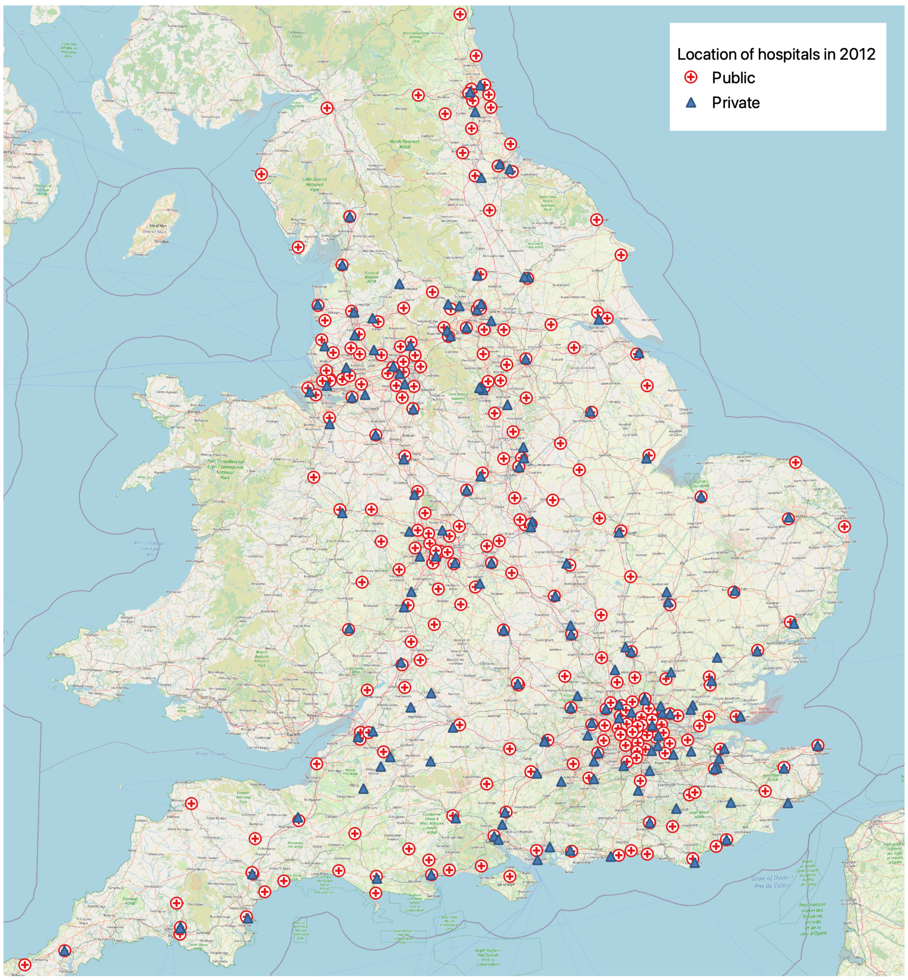


Figure shows locations of all public and private hospital sites with 50 or more hip or knee replacements in financial year 2012

Figure 2: Total government spending by specialty, 2012

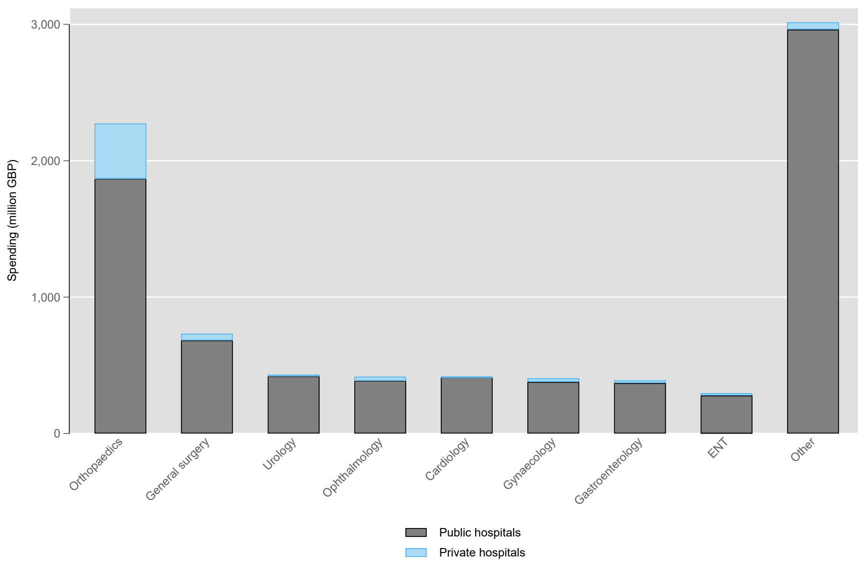


Figure includes all NHS-funded planned admissions in England. Where a single admission is associated with multiple episodes of care, specialty is assigned based on the first episode. Payment for an admission is calculated based on the 2012/13 'tariff'. Calculations do not include adjustments to payments to account for market

Figure 3: Volume of government-funded orthopaedic admissions 2003-2013

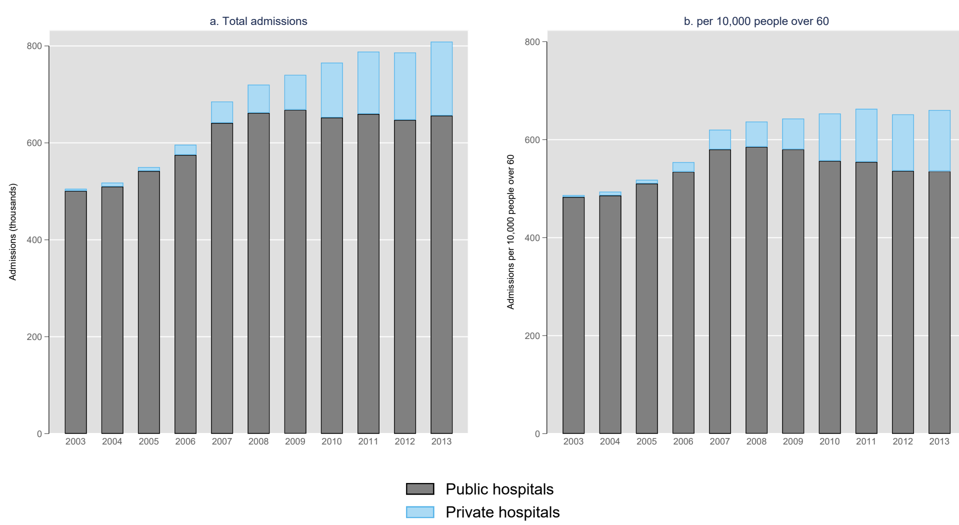


Figure includes all NHS-funded planned orthopaedic admissions in England.

3 Conceptual framework

In this section I outline a stylized model to illustrate the channels through which entry affects quality. First, entry causes some patients to receive treatment at private hospitals. Second, it has an indirect effect on patients remaining at public hospitals. I outline three key mechanisms through which entry may affect quality of a public incumbent: increasing competition, reducing demand and increasing severity of patients treated.

3.1 Aggregate effect of entry

I consider a market with N patients and a single public incumbent. Before private entry, the public hospital has quality α^{gov}_{pre} and treats the entire patient pool.[8] After the reform, a single private hospital enters with quality α^{priv}. Demand for the private hospital is $D_p \in (0, N)$. After entry, the public hospital has quality α^{gov}_{post}. The overall effect of the reform on quality is as follows:

$$\bar{\alpha}_{pre} - \bar{\alpha}_{pre} = \underbrace{\frac{D_p}{N}(\alpha^{priv} - \alpha^{gov}_{post})}_{\substack{\text{reallocation}\\ \text{effect}}} + \underbrace{(\alpha^{gov}_{post} - \alpha^{gov}_{pre})}_{\substack{\text{public hospital}\\ \text{quality change}}} \tag{1}$$

The signs of both the reallocation effect and the public hospital quality change are ambiguous. The private hospital may offer higher or lower quality than the public incumbent. A hospital with lower clinical quality can have positive market share because patients care about other hospital attributes such as distance and amenities, and because quality is imperfectly observed. Private entry may have positive or negative effects on quality of the public incumbent; three mechanisms are outlined below.

3.2 Effect of entry on quality of public incumbent

The public hospital chooses quality $\alpha \in [\underline{\alpha}, \bar{\alpha}]$. It produces quality-adjusted health care services $x = \alpha\theta q$, where q is number of patients and θ is average patient severity. More severe patients are more costly to treat, requiring longer stays and more input from health care workers. Cost is increasing and weakly convex in x: $C' = C_x > 0$ and $C'' = C_{xx} \geq 0$. C depends symmetrically on quality, output and patient severity. Increasing marginal cost can be thought of as a 'soft' capacity constraint. It is consistent with a hospital with fixed capital (i.e. beds and operating theaters) facing diminishing marginal returns to labor, or facing upward sloping supply of its inputs.

The hospital faces a fixed price per admission p and treats quantity of patients $q(\alpha)$. I allow for the hospital to have an intrinsic preference for quality $h(\alpha)$ beyond the profit motive (Sloan 2000). For a public hospital, $h(\alpha) > 0$, $h'(\alpha) > 0$ and $h''(\alpha) < 0$, $\forall\alpha$. For a private hospital $h(\alpha) = 0$, $\forall\alpha$ and the hospital is a pure profit maximizer. The hospital is subject to the constraint that revenues minus costs are weakly greater than zero.

[8] This implies that private entry and quality changes of public hospitals do not cause people to substitute into NHS-funded treatment either from no treatment or from paying privately for treatment. This assumption is described in more detail in the research design section. I also investigate its importance empirically in the appendix.

The public hospital's maximization problem is:

$$\begin{aligned} \max_{\alpha} \quad & U(\alpha) = q(\alpha)\left[p + h(\alpha)\right] - C(\alpha\theta(\alpha)q(\alpha)) \\ \text{s.t.} \quad & q(\alpha)p - C(\alpha\theta(\alpha)q(\alpha)) \geq 0 \end{aligned} \tag{2}$$

Before the reform, the patient treats the entire pool of patients so $q(\alpha) = N$. Patient severity is average severity across the population $\theta(\alpha) = \bar{\theta}$. If the budget constraint does not bind, quality choice satisfies the following first order condition:[9]

$$h'(\alpha) - C'(\alpha\bar{\theta}N)\bar{\theta} = 0 \tag{3}$$

The hospital sets marginal benefit from increasing quality equal to marginal cost of increasing quality. Quality is decreasing in demand N, and average patient severity $\bar{\theta}$.[10] With inelastic demand and a slack budget constraint, increasing payment per admission p has no effect on quality. Without an intrinsic motive to produce high quality output, the incumbent sets quality equal to its minimum level $\underline{\alpha}$ to minimize its cost of production. This is one rationale for using public providers to increase quality when there are local monopolies and demand is inelastic Besley and Malcomson (2018).

Now consider entry of a private provider. Demand for the public incumbent is $q(\alpha) = N - D_p(\alpha)$, where $q(\alpha) \in (0, N)$ and $q'(\alpha) \geq 0$ for all values of α. $q'(\alpha) > 0$. In addition, the private hospital treats the less complex patients, increasing average severity of patients remaining at the public incumbent: $\theta(\alpha) \geq \bar{\theta}$. As the public incumbent increases its quality it draws progressively less severe patients from the private entrant so $\theta'(\alpha) \leq 0$. The first order condition for the incumbent is as follows:

$$\begin{aligned} & q'(\alpha)\left[p + h(\alpha)\right] + q(\alpha)h'(\alpha) \\ & \qquad - C'(\alpha\theta(\alpha)q(\alpha))\left[\theta(\alpha)q(\alpha) + \alpha\theta(\alpha)q'(\alpha) + \alpha q(\alpha)\theta'(\alpha)\right] = 0 \end{aligned} \tag{4}$$

Because demand depends on quality, there is now an additional incentive to increase quality $q'[p + h] > 0$, which raises marginal benefit of quality. On the other hand, the intrinsic benefit of raising quality is reduced because number of patients is smaller. On the cost side, the reduction in demand at the public hospital reduces marginal cost of increasing quality since the hospital is moved down its cost curve. This effect is muted by an increase in patient severity. However, because demand is now responsive to quality, marginal cost of quality also includes the cost of treating the marginal patient attracted to the hospital by an incremental increase in quality.

To sign the effect of entry on quality, evaluate the the post-reform first order condition (4) at the pre-reform choice of quality α_{pre}. If this is positive, net marginal benefit of quality is positive, implying that entry increases quality. Substitute for $h'(\alpha_{pre}) = C'(\alpha_{pre}\bar{\theta}N)\bar{\theta}$ using 3. Denote the increase in patient severity at a given level of α as $\theta_s(\alpha) = \theta(\alpha) - \bar{\theta}$. Net

[9] Appendix A considers the case in which the budget constraint binds.

[10] See Appendix A for proofs.

marginal benefit of quality is as follows:

$$NMB^{post}(\alpha_{pre}) = \underbrace{q' [p + h] - \alpha_{pre} C'(\alpha_{pre}\theta q) [\theta q' + \theta' q]}_{\substack{\text{competitive} \\ \text{effect}}} \quad (5)$$
$$\underbrace{+ q\bar{\theta} \left[C'(\alpha_{pre}\bar{\theta}N) - C'(\alpha_{pre}\theta q) \right]}_{\substack{\text{capacity} \\ \text{effect} \geq 0}}$$
$$\underbrace{- q\theta_s C'(\alpha_{pre}\theta q)}_{\substack{\text{cream-skimming} \\ \text{effect} \leq 0}}$$

where $\theta(\alpha_{pre})$ is denoted θ, $q(\alpha_{pre})$ q, and $h(\alpha_{pre})$ h for legibility. Net marginal benefit consists of three components: the competitive effect, the capacity effect and the cream-skimming effect.

The 'competitive effect' arises because after entry, demand is responsive to quality. It is the net surplus on the marginal patient attracted to the hospital by an increase in quality from α_{pre}. The sign of this effect is ambiguous. This net surplus is increasing in p and $h(\alpha_{pre})$ and decreasing in marginal cost. Surplus is also more likely to be positive when average severity declines a lot with an increase in quality, since this reduces the increase in severity-adjusted quantity occurring as the hospital raises its quality.

The 'capacity effect' arises because the reduction in demand resulting from entry moves the hospital down its marginal cost curve. The capacity effect is weakly positive because $\bar{\theta}N > \theta q$, $C' > 0$ and $C'' \geq 0$. Severity-adjusted quantity always decreases, because before entry the hospital is treating all patients and after the reform it only treats a subset. If there are no capacity constraints and marginal cost is constant $C(\alpha\theta q) = k\alpha\theta q$, then the capacity effect is equal to zero. But if C is strictly convex throughout its support, then the capacity effect is strictly positive. The capacity effect is larger when the marginal cost curve is steeper (C_{xx} is higher) and when demand for the private hospital is higher for a given α.

The 'cream-skimming effect' arises because the private hospital treats the healthier patients, increasing complexity. This is strictly negative for $\theta(\alpha_{pre}) > \bar{\theta}$ and zero for $\theta(\alpha_{pre}) = \bar{\theta}$. This is because the increase in severity induced by entry raises the hospital's marginal cost of increasing quality for $\theta q C'$ for any given quantity of patients. Note that cream-skimming also plays a role in both the capacity effect and the competitive effect. Cream skimming reduces the drop in severity-adjusted output that occurs after entry, reducing the size of the capacity effect. The effect of cream skimming on the competitive channel is more subtle. On the one hand it increases $\theta(\alpha_{pre})$, which increases $\theta q'$ and $C'(\alpha\theta q)$. On the other hand, it mutes the increase in severity-adjusted output that arises from an increase in quality by drawing in less severe patients.

In general, the effect of entry on quality of the public incumbent is ambiguous. However, there are some special cases where it is possible to sign the effect. If quality is not responsive to demand ($q' = 0$) and there is no cream skimming ($\theta(\alpha) = \bar{\theta}$ and $\theta'(\alpha) = \bar{\theta}$, $\forall\alpha$, then private entry unambiguously increases quality through the capacity channel. This could be the case if the only salient dimension is horizontal differentiation between hospitals, for example if patients simply visit their closest hospital irrespective of quality or if patients are unable to perceive quality differences and choose on the basis of amenities offered. If quality is not responsive to demand and there are no supply constraints so that marginal cost is constant but entry increases patient complexity, then private entry unambiguously reduces quality through the cream-skimming channel. This could be the case if sick patients always visit the public hospital because it possesses an intensive care unit, irrespective of its choice of quality inputs per patient.

This model is extremely stylized. To focus on the public hospital, I treat the private hospital's quality as exogenous. In practice the private hospital is a strategic actor that chooses clinical quality and non-clinical amenities to maximize its profit. There are also at least two mechanisms missing. First, this model abstracts away from fixed costs. If fixed costs are high then a reduction in demand due to private entry can raise average costs despite lowering marginal costs, pushing the hospital towards its budget constraint. Relatedly, a hospital can make fixed cost quality improvements, such as purchasing improved equipment. With fewer patients, a hospital may not be able to cover the cost of these quality improvements. Secondly, I assume that the public hospital's cost function is unchanged by entry. This will not be true if private entry has general equilibrium effects in the market for inputs, for example by driving up the spot wage for doctors or nurses working overtime.[11] This could increase C, C' and C''. On the other hand, entry may cause the incumbent to improve efficiency, potentially lowering cost of producing a given level of quality.

4 Data and summary statistics

4.1 Data Sources

The main data source is the Hospital Episode Statistics (HES), an administrative dataset containing 100% of government-funded hospital admissions in England. HES contains information about location of treatment, medical procedures carried out and patient diagnoses, including the 'primary' diagnosis or reason for admission, as well as chronic conditions. It also contains patient demographic information, including age, sex, race/ethnic group and location of residence. Location of residence is defined at the lower-level super output area (LSOA), a census unit with mean population of approximately 1,500. I map LSOA to neighbourhood deprivation.[12]

I supplement HES with several other datasets. I use the UK's National Joint Registry, which contains monthly data on the number of joint replacements conducted in England. This dataset includes both publicly-funded and privately-funded procedures. I use this to identify the location of private hospitals prior to the policy reform, and to investigate substitution between public and private-pay procedures as a result of the reform. I also supplement the quality measures with data from government inspection reports and public data on hospital facilities, including the presence of intensive care facilities, staffing, number of beds and number of operating theaters.

[11] Nurses are paid a salary and receive 1.5 times their normal hourly rate for overtime. In practice shifts are frequently short-staffed and hospitals buy time from locums or staffing agencies.

[12] I use the income component of the 2007 Index of Multiple Deprivation (ONS 2016)

4.2 Sample selection

The primary analysis uses all planned admissions in the period 2003-2012 that have orthopaedics as the main treatment specialty. For the baseline market-level analysis, I assign patients to a hospital market based on their closest public hospital site one year prior to the reform in 2006. I restrict the set of possible hospital sites to public hospitals conducting 100 or more hip and knee replacements, to ensure markets are defined around acute hospitals able to conduct the most common orthopaedic procedures. I calculate geodesic distance from a patient's residence to each hospital using the population-weighted centroid of their LSOA of residence.

I define a market as being 'treated' by private entry if there is a private hospital located within the market that conducts 50 or more NHS-funded hip and knee replacements in one or more of the post-reform years 2009-2012. Data on NHS admissions taking place at private hospitals is incomplete for the first wave of reforms. I deal with this issue in two different ways: in the main pooled analysis I exclude the years 2007-2008 as a 'phase-in' period and I conduct robustness checks excluding areas with first wave private hospitals. More detail on sample construction is given in Appendix A2.

My primary measure of quality of hospital care is emergency readmission for any reason within 30 days of initial discharge from hospital. I also look at the effect of entry on wait-times, defined as the difference in weeks between the date on which a physician decided to admit the patient and the actual admission date. Because wait time targets are changing over the sample period, I also construct an indicator variable for whether a patient's wait time was less than the target in place at the time of admission.

4.3 Summary statistics

Table 2 shows summary statistics for patients in the sample one year prior to the reform in 2006. Panel A shows characteristics of patients in markets with and without entry. Patients in markets that go on to have entry are 1.4 percentage points more likely to be over 50, 3.1 percentage points more likely to be White and 2.5 percentage points less likely to live in the most deprived decile of neighbourhoods. The Charlson comorbidity index is a weighted count of a patient's medical conditions, for example diabetes, heart disease, chronic obstructive pulmonary disease and kidney disease.[13] Patients in markets that go on to receive entry have a slightly lower average Charlson index than patients in non-entry markets, but this difference is marginally significant ($p = 0.07$). Patient B shows emergency readmission rate, wait time and length of stay for patients in markets with and without entry. Pre-reform emergency readmission is not significantly different between patients in markets with and without entry. Wait times are 1 week longer in markets that go on to have private entry.

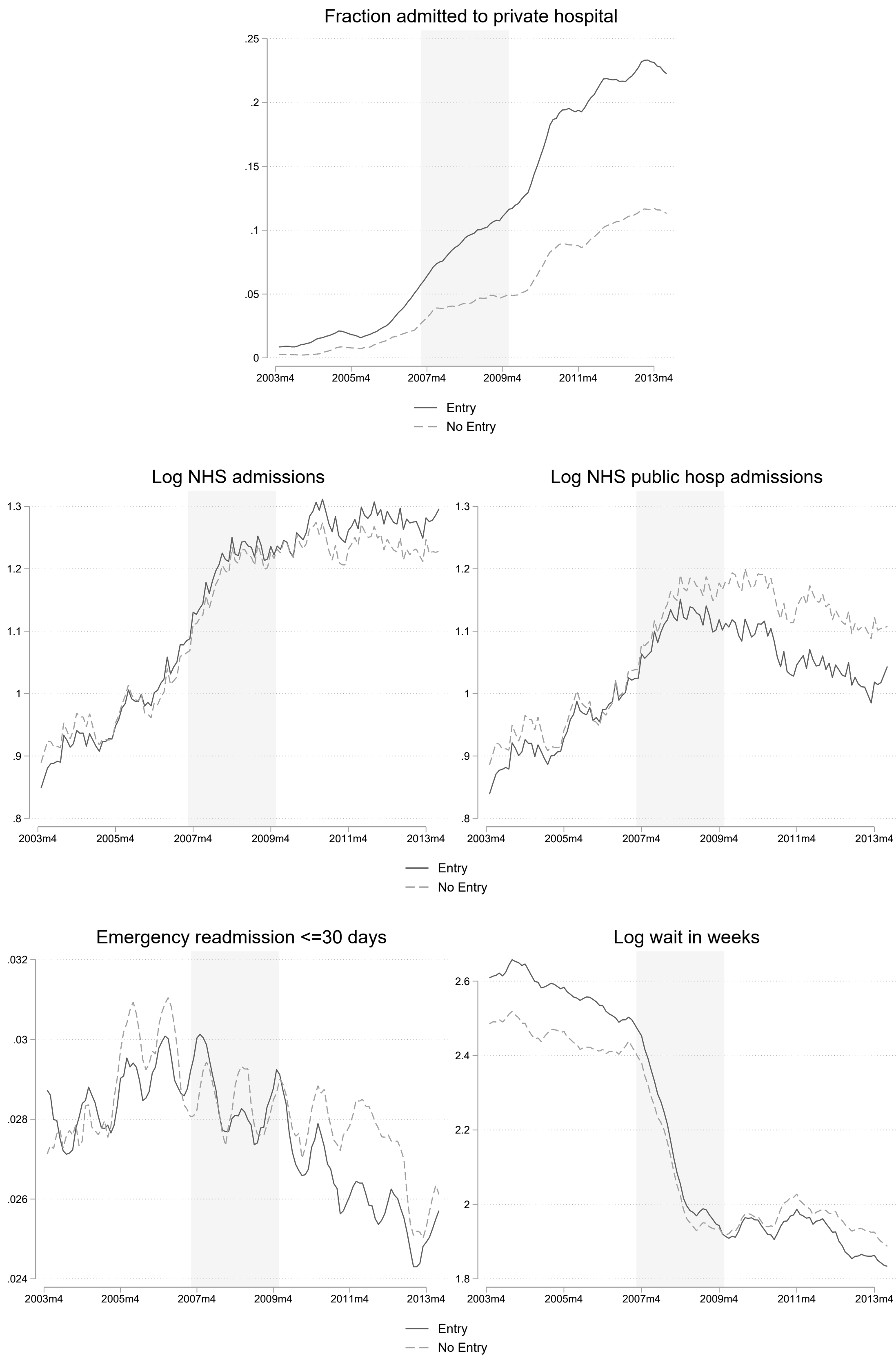
Panel C shows market-level characteristics of markets with and without entry. Markets with entry are on average a third larger than markets without entry. Consistent with the patient level data, they have older and less deprived populations. Most strikingly, markets that go on to have entry are substantially more concentrated prior to the reform, with an average Herfindahl-Hirschman Index (HHI) of 5,739, compared with 5,063 in markets without entry.

[13]The full list of conditions and weights included in the Charlson index are given in Appendix B

Figure 4 plots variables in entry and no entry markets over time. The first row shows the fraction of NHS planned orthopaedic admissions treated in private hospitals over time for hospital markets with and without entry. The shaded region indicates the two years over which the reform was phased in. When the reform began in 2007, less than 5% of NHS patients were treated in private hospitals. By the middle of 2011, more than 20% of NHS patients were treated in private hospitals in markets with private entry, compared with approximately 10% for markets without entry. The growth in private admissions in the areas without entry indicates substantial spillovers from treatment to neighboring areas. The second row of figure 4 shows monthly log volume of elective orthopaedic admissions per 1,000 people over 50 in entry and non-entry areas. Volume of admissions increases over this period in both entry and non-entry areas. The raw figures show a small increase in overall number of admissions, and a decrease in the number of admissions.

The third row of figure 4 shows monthly emergency readmission rate and log wait times for patients in areas with and without entry. Raw emergency readmission rates are very similar in entry and no entry areas prior to the reform, but decline more in entry areas post-reform. As seen in table 2, pre-reform waits are higher in entry markets. Wait times decline substantially over the period in markets with and without entry. This reflects the fact that wait times were subject to progressively tighter wait time targets, declining from 18 months in 2001 to 17 weeks in March 2008. Pre-reform wait times are higher in areas that go on to have private entry. After the reform, this relationship flips and areas with entry have lower average wait times.

Figure 4: Raw trends in volume and outcomes in markets with and without entry



Plots show the monthly moving average of the variables for hospital markets with and without private entry.

Table 2: Pre-reform summary statistics (2006)

	All	Entry	No entry
Panel A: Patient characteristics			
Average age	53.14	53.44	52.80
	(19.54)	(19.46)	(19.57)
% of patients over 50	61.71	62.25	60.87
	(48.61)	(48.48)	(48.81)
% of patients female	53.66	53.75	53.69
	(49.87)	(49.86)	(49.86)
% of patients white	94.11	95.47	92.43
	(23.55)	(20.80)	(26.45)
Charlson comorbidity index	0.191	0.188	0.191
	(0.560)	(0.555)	(0.560)
% of patients in most deprived decile	7.83	6.95	9.42
	(26.87)	(25.43)	(29.21)
Panel B: Patient care and outcomes			
Emergency readmission rate	0.0292	0.0293	0.0295
	(0.1684)	(0.1688)	(0.1691)
Wait time (weeks)	17.38	17.68	16.72
	(12.25)	(12.20)	(12.03)
Length of stay (days)	2.25	2.24	2.22
	(4.20)	(4.24)	(4.10)
Panel C: Market characteristics			
Population	259,954	293,050	219,932
	(113,501)	(109,638)	(105,441)
% of people over 50	34.60	35.26	33.80
	(5.34)	(4.13)	(6.45)
% annual population growth	0.61	0.60	0.62
	(0.44)	(0.38)	(0.51)
% of people in most deprived income decile	9.04	7.87	10.56
	(11.18)	(9.61)	(12.74)
Planned orthopaedic admissions per 1,000 pop.	12.07	12.34	11.74
	(3.06)	(2.90)	(3.24)
Herfindahl-Hirschman Index	5,433	5,739	5,063
	(1,771)	(1,676)	(1,821)
Number of patients	587,519	368,918	210,434
Number of markets	190	104	86

Panels A and B give the mean and standard deviation for variables calculated using Hospital Episode Statistics patient-level data including all planned orthopaedic admissions in 2006. Panel C gives the unweighted mean and standard deviation for variables calculated using market-level data. Population and deprivation measures are calculated using Office of National Statistics public data.

5 Research design

Estimating the causal effect of private entry on patient outcomes requires addressing two main empirical challenges. First, patients choose whether to attend a public or private hospital, so it is necessary to account for patient selection into hospitals. In particular, private hospitals treat patients who are less medically complex. Second, private hospitals are not randomly located across the country. They tend to be located in markets with older and less socioeconomically deprived populations. I tackle these challenges using two different empirical strategies. I first conduct a market level difference-in-differences analysis comparing changes in patient outcomes in hospital markets with and without private entry. Pooling over all patients allows me to estimate the aggregate effects of the reform. In my second approach, I develop a method to explicitly decompose the effects of entry into reallocation to private hospitals and effects on local public hospitals exposed to entry. Finally I investigate possible mechanisms.

5.1 Market-level difference-in-differences

The aim of the market-level analysis is to understand the causal effect of private entry into a market on volume and patient outcomes. I use difference-in-differences to test whether there was a differential change in patient outcomes in hospital markets in which a private hospital entered compared with markets without entry. Treatment is defined at the market level and the analysis includes all public patients treated at public and private hospitals. The key identifying assumption is that in the absence of the policy, outcomes in areas with private entry would have changed in parallel to outcomes in areas without private entry.

The main advantage of this approach is that it allows me to capture both direct effects of the policy that come from re-allocating patients to private hospitals as well as any spillovers to public hospitals. Including both public and private patients in the analysis ensures that my estimates are not biased by selection of healthier patients into private hospitals. The main drawback to this approach is that by defining treatment at the hospital market level, I introduce substantial noise in the treatment variable, since there is within-market variation in the extent to which individuals are exposed to the policy based on their location. This will tend to bias against finding an effect.

I first estimate the effect of private entry on total number of admissions in a market, and admissions to public and private hospitals. I collapse the admissions data to the market-month level and estimate the following specification:

$$Y_{mt} = \sum_{s=2003}^{2012} \beta_s \text{entry}_m \times \mathbf{1}\{y(t) = s\} + \delta_m + \gamma_t + \epsilon_{mt} \tag{6}$$

where m indexes local health care market, t is time in months and $y(t)$ is calendar year. Y_{mt} is total number of elective orthopaedic admissions in a market per 1,000 people aged 50 and above. The treatment variable entry_m is a dummy equal to 1 if there is a private hospital treating NHS patients in the market in the post-reform period. γ_m is a vector of market dummies and γ_t is a vector of year and month dummies. Standard errors are clustered at the market level.

To estimate the effect of entry on patient outcomes using admissions-level data, I run the following specification:

$$Y_{imt} = \sum_{s=2003}^{2012} \beta_s \text{entry}_m \times \mathbf{1}\{y(t) = s\} + \phi X_{it} + \delta_m + \gamma_t + \epsilon_{imt} \tag{7}$$

where i indexes individual. Y_{it} is emergency readmission within 30 days of discharge, log wait time or a dummy equal to 1 if wait time is less than the national target. X_{it} is a vector of patient characteristics, including procedure fixed effects, age-bands, sex, non-white, Charlson comorbidity index, a vector of 31 comorbidities, including hypertension, cardiac arrhythmia, diabetes and cancer [14] and dummies for deciles of neighborhood income deprivation[15]. As in the volume regressions, δ_m is a vector of market dummies and γ_t is a vector of year and month dummies. To summarize the impact over the post-period, I also estimate a pre-post version of the same specification:

$$Y_{imt} = \beta \text{entry}_m \times \text{post}_t + \phi X_{it} + \delta_m + \gamma_t + \epsilon_{imt} \tag{8}$$

where post_m is a dummy variable equal to 1 for the years 2009-2012 after the reform, and all other variables are specified as in equation 7 above. In the pooled specification, I exclude the phase-in period of the reform in 2007-2009. To estimate the overall effect of entry, I multiply β by average private share across all markets divided by the difference between average private share between entry and non-entry markets.

There are two major threats to the validity of the research design. First, the policy may have induced changes to the case-mix that are not fully controlled for in regression specification 7. For example, the policy change may have induced people who would have paid for private care to switch to receiving NHS care either because they can receive care at their preferred private hospital (albeit with a wait) or because of a reduction in waits or quality improvement within the NHS. Relatedly, the policy change may have induced primary care doctors to lower their threshold for hospital referrals because of a perceived reduction in wait times. I investigate this in several different ways. First, I test whether the reform affected observable case-mix by estimating the baseline specification 8 with observable measures of patient complexity, including age and comorbidities on the left hand side. Second, I run the analysis for *emergency* orthopaedic admissions: these patients generally share the same facilities and are seen by the same physicians and nurses as elective orthopaedic admissions, but are not subject to selection concerns. I also test for stability of the treatment effect as covariates are added to the model (Oster 2019).

Another threat to validity is the possibility that an existing private hospital's decision to enter the public market is correlated with other market-level changes. Specifically, private hospitals may be more likely to enter in locations where underlying demand for health care is increasing or case-mix is changing. To check this, I run placebo tests investigating the effect of entry on volume and casemix of emergency admissions in orthopaedics and overall, as well as

[14] The full list of included comorbidities is given in Appendix B.

[15] The deprivation measure is the 'Index of Multiple Deprivation' measure calculated for the lower-level super output area (LSOA)

for non-deferrable conditions.[16] I also run an alternative specification in which I instrument for observed private entry with a dummy equal to 1 if there was a private hospital in the market prior to the reform in 2006. In this version of the model, the identifying assumption is that in the absence of the policy, outcomes in areas with a private hospital prior to the reform would have trended in parallel to areas without a private hospital prior to the reform.

I also conduct several robustness checks. I estimate the model with alternate definitions of treatment, including observed private market share and simulated private market share using a simple logit choice model based on distance. I also estimate the baseline regressions with alternate market definitions: (i) primary care trusts, the administrative areas used to allocate health care funding and (ii) markets defined based on the most visited public hospital in the pre-reform period and (iii) assigning census areas based on closest public hospital and then aggregating up to the NHS organization level. separately estimating the effect of first and second wave private entrants. Finally, I conduct a matching exercise in which I match small census areas in treated markets with similar areas in untreated markets.

5.2 Decomposing effects of the reform into reallocation and public hospital exposure

The second objective of the empirical analysis is to decompose the effects of entry into the direct effect of reallocating patients to private hospitals and the indirect effect of entry on public hospitals. The main identification challenge is that patients who are healthier select into treatment at private hospitals. To overcome this selection issue, I instrument for treatment at a private hospital using a patient's differential distance to a private hospital (distance to the nearest private hospital minus distance to the nearest public hospital). To separately identify the effect of exposure to entry on public hospitals, I exploit the fact that census areas are differently exposed to direct and indirect effects depending on the exact locations of public and private hospitals.

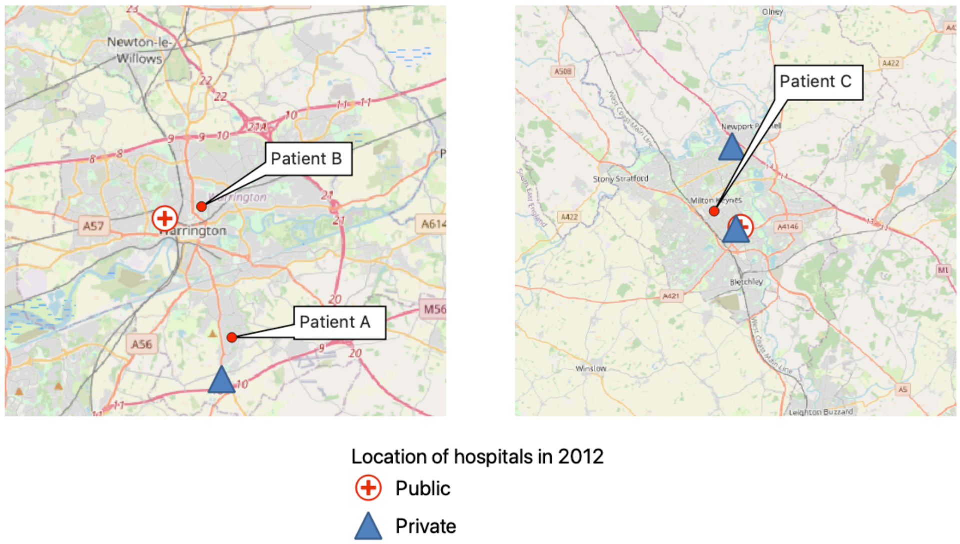
To illustrate this variation, consider a city with a single incumbent public hospital and a private hospital located in a suburb (figure 5, left panel). After the reform, someone who lives in the suburb (patient A) is more likely to visit the private hospital than someone living on the other side of town (patient B), so A is more exposed to the reallocation effect of the reform than B. But since their outside option is being treated at the same public hospital, A and B have the same exposure to the indirect 'spillover' effect on the incumbent. Patient C in the right hand panel has a higher exposure to the indirect effect of entry than A and B, because her local public hospital has two private hospitals nearby. A patient's likelihood of visiting a private hospital is correlated with how exposed her local hospital is to private entry; separately identifying these two effects requires that they are not perfectly collinear. This would be violated if every private hospital was collocated with a public hospital.

To implement this approach, I use the following specification:

$$Y_{ilt} = \beta_{\text{priv}} \text{private}_{it} + \beta_s S_l \times \text{post}_t + \phi X_{it} + \delta_l + \gamma_t + \epsilon_{ilt} \tag{9}$$

[16] Non-deferrable conditions are defined as those for which admissions on weekend days are not significantly different from admissions on week days (Card, Dobkin and Maestas 2008)

Figure 5: Illustration of identifying variation for decomposition



where private_{it} is a dummy variable equal to 1 if a patient is treated at a private hospital and S_l is an area-level measure of exposure to the indirect effect of the reform, described below. δ_l is a vector of census area fixed effects and all other variables are defined as in the market-level regressions and standard errors are clustered at the census area level. The coefficient β_s is the effect of an increase in public hospital exposure to entry. The coefficient β_{priv} is the effect of going to a private hospital compared with a public hospital in the post-period. I implement this IV-difference-in-differences using standard two-stage least squares, instrumenting for private_{it} with differential distance quartiles interacted with a dummy for the post period. The exclusion restriction requires that differential distance only affects outcomes through moving a patient to the private hospital *conditional* on her public hospital exposure. The exclusion restriction is vulnerable to misspecification of the public hospital exposure variable. [17]

I calculate area-level public hospital exposure S_l in three stages. First, I calculate share of each census area treated at a private hospital in the post period. Second, I calculate private entry exposure for each public hospital. This is a weighted average of the census area private shares in a hospital's market, where the census-area weights are given by the share of a hospital's patients coming from that area one year prior to the reform in 2006. Finally, I calculate an area level measure of public hospital exposure. This is an average of

[17] In the health economics and health services literature, differential distance is commonly used to instrument for receiving a particular intervention e.g. instrumenting for treatment with cardiac catheterization using differential distance between the nearest hospital without a catheterization lab and the nearest hospital with a cath lab. But in the presence of spillovers to neighboring hospitals, the exclusion restriction fails. For example, if opening a catheterization lab at one hospital results in a change in quality for neighboring hospitals (e.g. they improve quality to retain patients or their quality deteriorates as they lose cardiologists to the new lab) than differential distance is correlated with these spillovers. In general, if the correlation between own likelihood of receiving a treatment and exposure to spillovers is positive, the estimate of the treatment effect will be biased upwards if spillovers are positive and downward if spillovers are negative.

the exposure measure for all local public hospitals, weighted by 2006 patient flows.

5.3 Mechanisms

Finally, I investigate the channels for improvement outlined in the conceptual framework. To investigate the competition and capacity channels, I estimate a version of the model in which I allow for potentially differential effects of entry across markets with lower vs higher pre-reform market competition and capacity:

$$\begin{aligned} Y_{imt} = \beta_1 \text{entry}_m \times \text{post}_t + \\ + \text{lowcomp}_m \left[\beta_2 \text{entry}_m \times \text{post}_t + \eta_2 \text{post}_t\right] + \\ + \text{lowcap}_m \left[\beta_3 \text{entry}_m \times \text{post}_t + \eta_3 \text{post}_t\right] + \\ + \phi X_{it} + \delta_m + \gamma_t + \epsilon_{imt} \end{aligned} \tag{10}$$

where lowcomp_m is a dummy variable equal to 1 if the market pre-reform HHI greater than 5,000. Ceteris paribus, the competitive effect of entry will be bigger in markets that have little competition at baseline. The variable lowcap_m is a dummy for whether the market has low pre-reform capacity. I collect several measures of capacity in 2006, including number of beds, number of critical care beds, number of operating theaters, all scaled by population, and average percent occupancy. I then run principal component analysis and extract the first principal component as a composite measure of capacity. The dummy lowcap_m is equal to 1 if the capacity measure is below median. The inclusion of $\text{lowcomp}_m \times \text{post}_t$ and $\text{lowcap}_m \times \text{post}_t$ allows for outcomes to change differentially after the reform in low competition and high capacity areas [18] I estimate another version of model 10 that replaces the dummy for highly concentrated markets with a dummy for markets with low pre-reform supply.

6 Results

6.1 Market-level difference-in-differences

This section summarizes the results of the market level analysis. Figure 6 shows the effect of entry into a market on number on share of NHS-funded patients treated at private hospitals. Entry of a private hospital increases percent of NHS-funded patients treated at a private hospital by 9.7 percentage points relative to a post-reform mean of 15%. Since the exposure to private entry is substantial in 'control' areas, to calculate the overall effect of the reform I scale the β coefficients in the regressions by the share of patients moved into private hospitals by being in a 'treated' rather than control market: $\widetilde{\beta} = \frac{0.154}{0.0967}\beta \approx 1.59\beta$.[19]

Figure 6 also shows the effect of entry on NHS-funded elective orthopaedic admissions per 1,000 people over 50. The figure plots the coefficients on the interactions between private

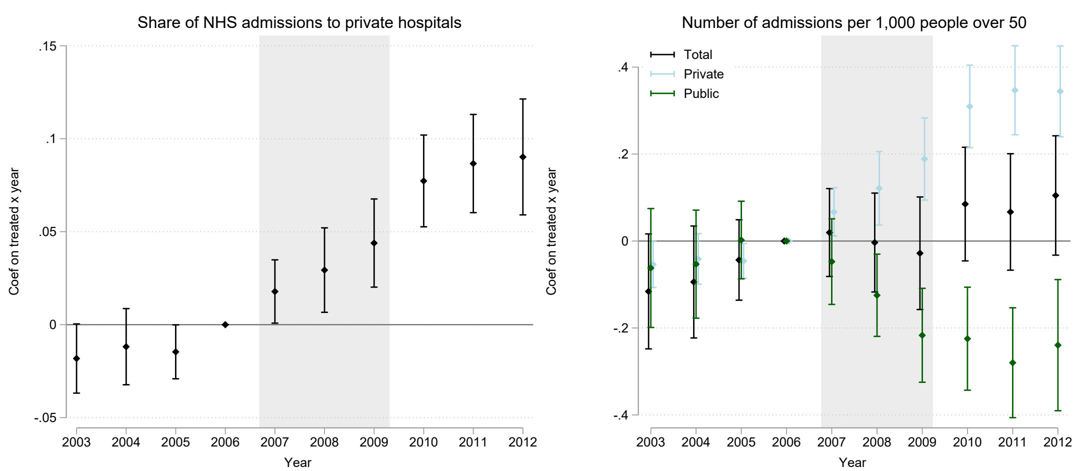
[18]Note that post_t is omitted because the model contains a full set of year × month fixed effects

[19]This is analogous to the Wald-DID estimator discussed by de Chaisemartin and D'HaultfŒuille (2017). However in most 'fuzzy DID' setups the 'treatment' is measured at the individual level where as in my setting I define treatment at the market level.

entry and year dummies. Total NHS-funded admissions are shown in black, private admissions in blue and public admissions in green. Private entry into a market increases total number of admissions per 1,000 people over 50 by 0.12 and decreases admissions to public hospitals by 0.20 per 1,000. Almost two thirds (63%) of the effect of entry is reallocation to private entrants ('business stealing') and one third of the effect is an increase in aggregate admissions ('market expansion'). The overall effect of the reform was to increase number of elective admissions per 1,000 people over 50 by 5.4% or approximately 42,000 per year by 2011.

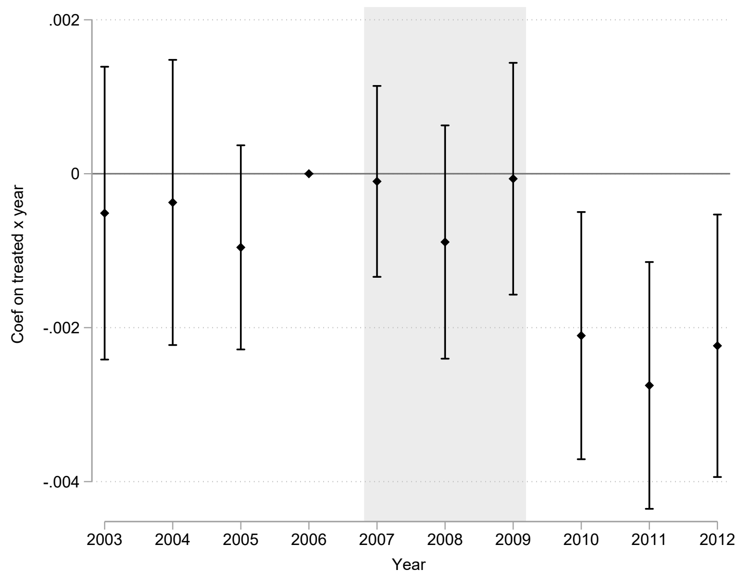
Figure 7 shows the effect of entry on risk-adjusted emergency readmission within 30 days of discharge from the initial hospital spell. Results from the pooled version of this regression are shown in table 3. Private entry into a market decreases emergency readmission rate by 0.2 percentage points. The overall effect of the reform is to decrease emergency readmission rate by 0.3 percentage points or 12% relative to the post-reform average of 2.6%. This is equivalent to averting approximately 2,500 readmissions per year by 2011. Figure 8 shows the effect of entry on log wait times and the fraction of patients waiting less than the target in place at the time they were admitted. The left panel shows that entry into a market reduces log wait times by 0.16 log points. I estimate the overall effect of the reform From figure 4, which plots raw log waits, we can see that entry markets have higher waits before the reform and there is evidence of pre-reform convergence in wait times as government targets get increasingly tight. For this reason, I run a version replacing log wait with a dummy equal to 1 if a patient waited less time that the target in place when they were treated. Entry results in a 2 percentage point increase in the probability of waiting less than the target, a small increase relative to the post reform mean of 79%.

Figure 6: Event study: Effect of private entry on number of NHS orthopaedic admissions and share treated at private hospitals



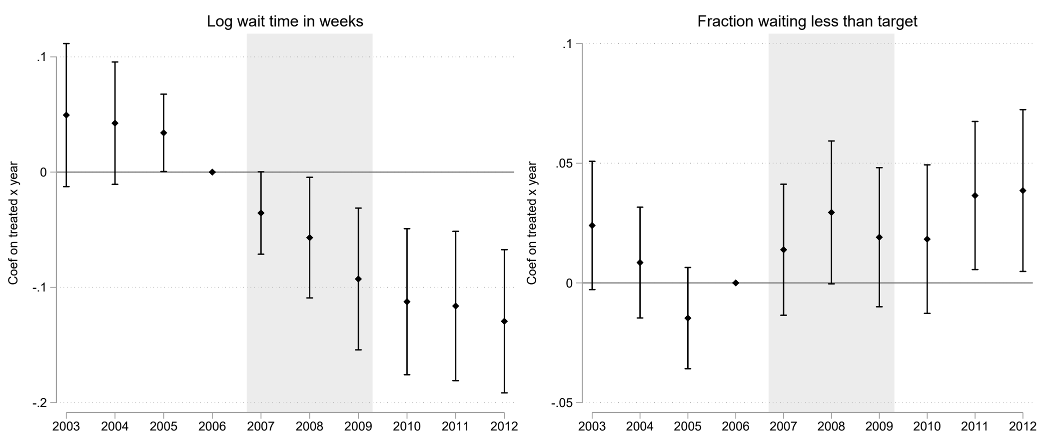
Notes: Figures shows coefficient on private entry × year dummies from estimating equation 6. All regression specifications include market fixed effects and year-by-month fixed effects. Observations are weighted by population over 60. Standard errors are clustered at the market level.

Figure 7: Event study: Effect of private entry on emergency readmission rate



Figures shows coefficient on private entry $\times$ year dummies from estimating equation 7. All regression specifications include market fixed effects, year and month-of-year fixed effects, procedure fixed effects and the following patient characteristics: age-category, sex, non-white, Charlson comorbidity index, a vector of comorbidity dummies, and dummy for decile of deprivation of census area. Standard errors are clustered at the market level.

Figure 8: Event study: Effect of private entry on wait times



Figures shows coefficient on private entry $\times$ year dummies from estimating equation 7. All regression specifications include market fixed effects, year and month-of-year fixed effects, procedure fixed effects and the following patient characteristics: age-category, sex, non-white, Charlson comorbidity index, a vector of comorbidity dummies, and dummy for decile of deprivation of census area. Standard errors are clustered at the market level.

Table 3: Pooled difference-in-differences estimates

	Admissions per 1,000			**Patient outcomes**		
	Total	Public	Private	Emerg readmit	Log wait	Wait less than target
Post × Entry	0.122	-0.199	0.351	-0.0020	-0.1628	0.0215
	(0.068)	(0.066)	(0.047)	(0.0007)	(0.0338)	(0.0132)
Mean outcome pre	2.668	2.623	0.046	0.029	2.525	0.820
Mean outcome post	3.574	3.015	0.559	0.026	1.940	0.791

Notes: Number of patients is 4,398,131. Number of market-months is 18,776. Number of markets is 190. The table shows coefficient on entry × post from equation 8. Columns 1-3 are estimated at the market-month level and include market fixed effects and year × month fixed effects. Columns 4-6 are estimated using individual patient data and include market fixed effects, year × month fixed effects, procedure fixed effects and the following patient characteristics: age-bands, sex, non-white, Charlson comorbidity index, comorbidity dummies and a dummy for whether the patient lives in the 10% of most deprived neighborhoods. Standard errors are clustered at the market level.

Table 4: The effect of private entry on case-mix

	Pred. emerg readmit	Pred. log wait	Age	White	Charlson index	Most deprived decile
Post × Entry	0.0005	-0.0066	0.160	0.0047	-0.0044	-0.0013
	(0.0002)	(0.0025)	(0.110)	(0.0026)	(0.0057)	(0.0011)
Mean outcome pre	0.026	2.177	52.594	0.945	0.169	0.080
Mean outcome post	0.029	2.149	54.525	0.938	0.291	0.076

Number of patients is 4,398,131. Number of markets is 190. Table shows coefficient on entry × post from equation 8, excluding patient covariates X All regression specifications include market fixed effects and year and month fixed effects. In column (1), the predicted readmission rate is generated using a linear probability model with the following set of patient covariates: age-bands, sex, non-white, Charlson comorbidity index, comorbidity dummies and a dummy for whether the patient lives in the 10% of most deprived neighborhoods. Standard errors are clustered at the market level.

Table 5: The effect of private entry on emergency (non-contested) orthopaedic admissions

	Admissions per 1,000	Emerg readmit	Mortality
Post $\times$ Entry	-0.007	-0.0026	0.0007
	(0.023)	(0.0012)	(0.0006)
Mean outcome pre	1.136	0.070	0.024
Mean outcome post	1.128	0.083	0.023

Table shows coefficient on entry $\times$ post from equation 8 estimated using unplanned orthopaedic admissions. All specifications include market fixed effects, year $\times$ month fixed effects, procedure fixed effects and the following patient characteristics: age-bands, sex, non-white, Charlson comorbidity index, comorbidity dummies and a dummy for whether the patient lives in the 10% of most deprived neighborhoods. Standard errors are clustered at the market level.

A key threat to the identification of a causal effect of entry on patient outcomes is the possibility that the policy may have induced changes to the case-mix that are not fully controlled for in regression specification 8. Figure 4 shows estimates of the pooled difference-in-differences model with various patient characteristics on the left hand side. Column (1) shows the change in predicted emergency readmission in entry versus non-entry areas after the reform. Emergency readmission rate is predicted using a linear probability model containing all the patient covariates from the baseline model. There is a non-significant 0.05 percentage point *increase* in predicted emergency readmission in treatment areas. The sign is the opposite of what we would expect if casemix change was driving the observed reduction in emergency readmission rates seen in the raw data in 4 and the event study in 7. Column (2) shows the change in predicted log wait in entry versus non entry areas. The coefficient is negative but not significantly different from zero, and two orders of magnitude smaller than the baseline estimate. Columns (3)-(6) show changes in some of the components of predicted readmission. The strongest predictor of emergency readmission is age, and there is a small increase in average age in entry areas. On the other hand, there is also a small but non-significant reduction in patient comorbidities, measured using the Charlson index.

Table 5 estimates the effect of private entry on emergency orthopaedic admissions. All emergency admissions are treated in public hospitals so they are subject to fewer concerns about selection. I find that entry does not change volume of emergency admissions per 1,000 people over 50, implying that the volume change observed for elective procedures is not driven by increasing need in entry areas. Private entry into an hospital market reduces readmission rate for emergency orthopaedic patients by 0.3 percentage points or 4% relative to the post-reform mean. In other words, I observe a quality spillover from entry to emergency patients at affected public hospitals. I do not see any effect on mortality for these patients.

6.2 Estimating direct and indirect effects of the reform

In this section I decompose the effects of entry into the direct effect of reallocating patients to private hospitals and the indirect effect of entry on public hospitals. I estimate equation 9, instrumenting for observed private entry with four quartiles of differential distance interacted with a post dummy. Table 6 shows the results of this analysis. The first column shows the OLS estimates from regressing emergency readmission on treatment at a private hospital

Table 6: Decomposition of reallocation and public hospital exposure effects

	Emergency readmission		Log wait	
	OLS	IV	OLS	IV
Private	-0.0088	-0.0027	-0.6955	-0.9747
	(0.0003)	(0.0068)	(0.0073)	(0.1085)
Pub exp × Post	-0.0153	-0.0193	-1.0149	-0.8513
	(0.0028)	(0.0053)	(0.0523)	(0.0830)
F-statistic from first stage		93.483		72.815
Mean outcome post	0.0263	0.0263	1.940	1.940
$\beta_{\text{priv}}\overline{priv} + \beta_s\overline{S}$	-0.0041	-0.0037	-0.291	-0.311
% of effect due to pub exp	63	88	59	47

Number of patients is 4,135,583. Table shows coefficients on private treatment and public hospital exposure from equation 9. The F-statistic reported is the Kleibergen-Paap rk Wald statistic. All specifications include market fixed effects, year × month fixed effects, procedure fixed effects and the following patient characteristics: age-bands, sex, non-white, Charlson comorbidity index, comorbidity dummies and a dummy for whether the patient lives in the 10% of most deprived neighborhoods. Standard errors are clustered at the census area level

and public hospital exposure to entry. The OLS estimate implies that treatment at a private hospital lowers readmission rate by 0.9 percentage points. However, this does not account for selection of healthier patients into private hospitals. When I instrument for private treatment in the IV-DD framework, the effect of being treated at a private hospital shrinks and is not significantly different from zero. This implies that the quality of public and private hospitals is not significantly different among the set of compliers. I estimate that the effects of entry on public incumbents account for almost 90% of the estimated readmission effect. Unsurprisingly private hospitals have significantly lower waits than public hospitals, and reallocation to private hospitals accounts for half of the observed wait time effect.

6.3 Mechanisms and heterogeneity

Table 7 shows the effects of entry by pre-reform capacity and competitiveness of the market. The *lowcomp* dummy is equal to 1 if pre-reform HHI is greater than 5,000. The *lowcap* dummy is equal to 1 if the composite index of pre-reform capacity (including acute beds, critical care beds, operating theatres and intensive care) is below median. The coefficient on *entry* × *post* × *lowcomp* is the differential effect of entry on low-competition markets. Similarly, the coefficient on *entry* × *post* × *lowcap* is the differential effect of entry on low-capacity markets.

For emergency readmission, the coefficient estimates are noisy. However, the point estimates indicate that the effect of entry on emergency readmission is larger for markets with low capacity and low competitiveness at baseline. This can be seen more clearly in figure 9, which plots the effect of entry for (i) high competition, high capacity markets (β_1), (ii) low-competition, high capacity markets ($\beta_1 + \beta_2$), (iii) high competition, low capacity markets ($\beta_1 + \beta_3$) and (iv) low competition, low capacity markets ($\beta_1 + \beta_2 + \beta_3$). The effect of entry on emergency readmission is only significantly different from zero for hospital markets that have both low competitiveness and low capacity at baseline. The effect of entry on wait times is much larger for markets with below median capacity. In contrast, the effect of entry on waits is not significantly different in markets with low competitiveness at baseline. The two separate 'competition' and 'capacity' channels identified in the conceptual framework appear to influence the effect of private entry on emergency readmission and wait times.

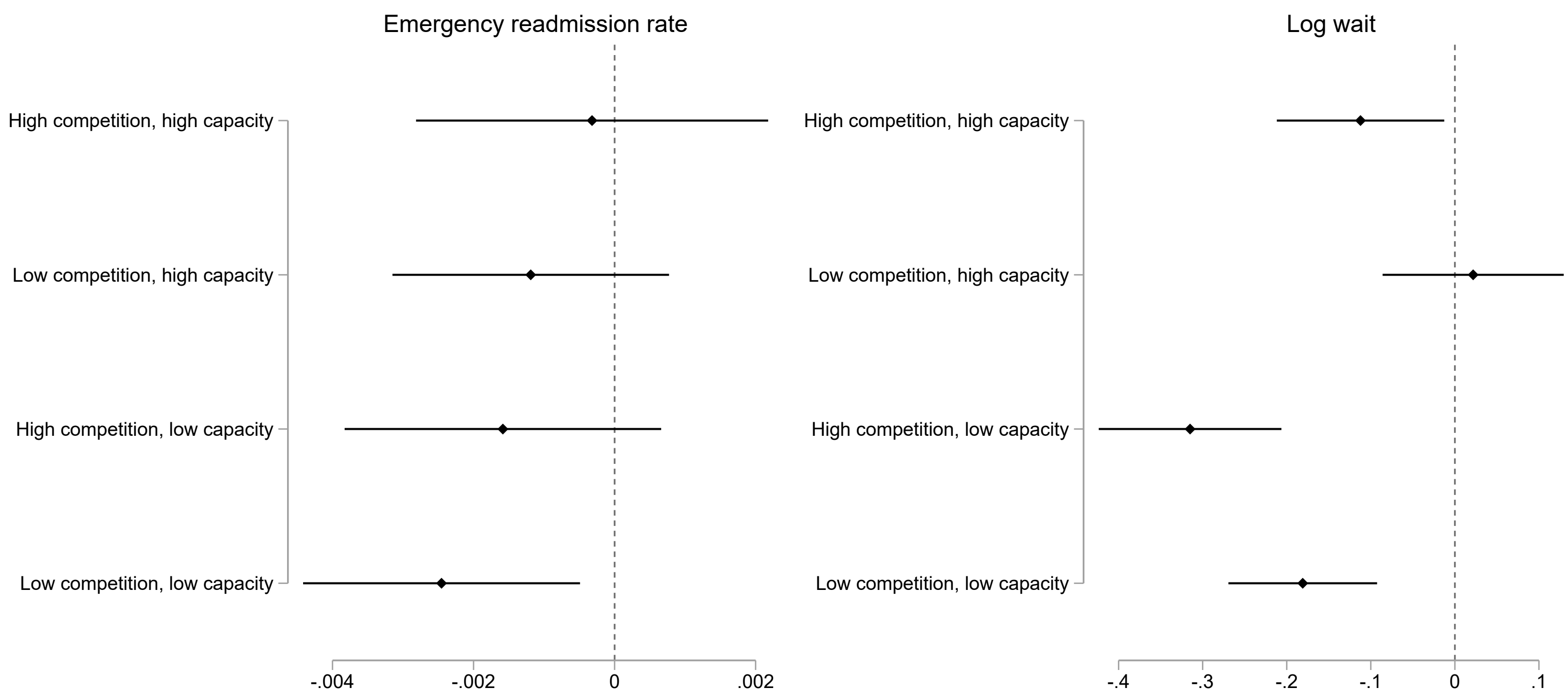
Table 7: Heterogeneity by competition and capacity

	Emergency readmission				Log wait			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Entry × post	-0.00200	-0.000779	-0.00101	-0.000319	-0.163	-0.191	-0.0468	-0.112
	(0.000677)	(0.00113)	(0.000820)	(0.00127)	(0.0338)	(0.0548)	(0.0423)	(0.0508)
Entry × post × lowcomp		-0.00129		-0.000870		0.0840		0.134
		(0.00146)		(0.00144)		(0.0709)		(0.0661)
post × lowcomp		-0.000925		-0.000721		-0.123		-0.117
		(0.00103)		(0.00102)		(0.0434)		(0.0423)
Entry × post × lowcap			-0.00150	-0.00126			-0.199	-0.203
			(0.000872)	(0.000831)			(0.0461)	(0.0478)
post × lowcap			-0.00147	-0.00123			-0.0469	-0.0422
			(0.000671)	(0.000657)			(0.0329)	(0.0333)
Observations	4398131	4398131	4398131	4398131	4138086	4138086	4138086	4138086

Standard errors in parentheses

Number of patients is 4,398,131. Number of markets is 190. The table shows coefficients from equation 10. All specifications include market fixed effects, year × month fixed effects, procedure fixed effects and the following patient characteristics: age-bands, sex, non-white, Charlson comorbidity index, comorbidity dummies and a dummy for whether the patient lives in the 10% of most deprived neighborhoods. Standard errors are clustered at the market level.

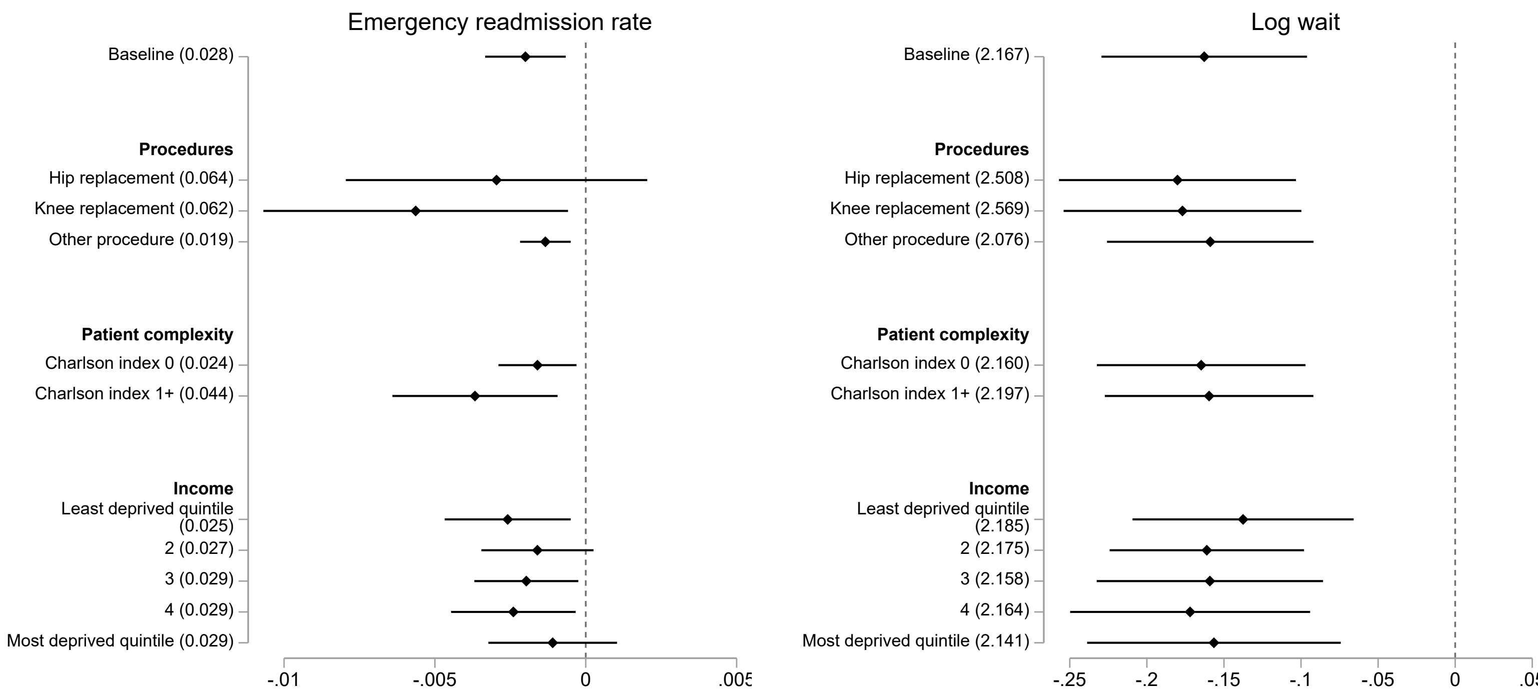
Figure 9: Effect of private entry by market competitiveness and capacity



The figure shows linear combinations of coefficients from regression 10. The full set of coefficients is included in table 7. 'High competitiveness, high capacity' is β_1, 'Low competitiveness, high capacity' is $\beta_1 + \beta_2$,'High competitiveness, low capacity' is $\beta_1 + \beta_3$ and 'Low competitiveness, low capacity' is $\beta_1 + \beta_2 + \beta_3$

Figure 10 shows the effect of entry for different subgroups of patients. The top panel plots the coefficient on entry interacted with the post dummy for patients undergoing each of the two most common procedures, hip and knee replacement, and other procedures. The confidence intervals for individual procedures are large, but the point estimates indicate that the percentage point reductions in emergency readmission resulting from entry are larger for patients with higher baseline rates of emergency readmission. Converted to relative risk adjustments, none of these coefficients is significantly different from the pooled relative risk reduction of 8%. The second panel shows coefficients for patients split by Charlson comorbidity index and the third panel shows coefficients for patients split by census area income quintile. Again these estimates are noisy, but indicate there is little. Lower income households are less likely to live in a market that has private entry (table 2) but there is no evidence that the causal effect of entry is smaller for these households.

Figure 10: Effect of private entry by subgroups of patients



Figures shows coefficient on private entry × year dummies from estimating equation 7. All regression specifications include market fixed effects, year and month-of-year fixed effects, procedure fixed effects and the following patient characteristics: age-category, sex, non-white, Charlson comorbidity index, a vector of comorbidity dummies, and dummy for decile of deprivation of census area. Standard errors are clustered at the market level.

7 Discussion and conclusions

In this paper I study the effects of private entry into public hospital markets, in the context of a large reform in the English NHS that shifted a fifth of orthopaedic patients into private hospitals. I show that private entry increased volume of admissions and decreased wait times and risk-adjusted readmission. Almost the entire readmission effect and more than half of the wait time effect are attributable to improvements at public incumbents. The positive effects were concentrated in areas with low preexisting public sector capacity, suggesting that relaxation of supply constraints played a key role in the observed improvements.

This work raises several questions and directions for further research. First, how does expanding private provision compare with a policy that expands capacity in the public sector? On the one hand, contracting with existing private hospitals means the government does not need to undergo additional capital expenditure. In addition, variable cost of private provision may be lower at the margin because private hospitals retain 'spare' capacity to ensure private-paying patients get quick access to care. On the other hand, expanding the capacity of existing public hospitals could avoid some of the pitfalls of private entry, including the ambiguous effect of competition and cream-skimming of lower cost patients, both explored in this paper. In an industry with free entry and high fixed costs, there is also the risk of excessive entry, which may benefit patients but reduce overall social surplus (Mankiw and Whinston 1986). This could be exacerbated if policy-makers weight the surplus accruing to public hospitals more than profits received by private providers, for example if public hospitals use this surplus to subsidize training of health care workers or other socially valuable activities.

Additionally, expanding provision through the private sector can only take place in areas where private hospitals choose to enter. Private hospitals tend to be located in higher income areas where the private-pay market is larger. Extra public capacity could be targeted more precisely at areas with high need and unmet demand for care. Public capacity is also more fungible than private provision; since public hospitals treat emergency patients, additional public beds can more readily be used for emergency patients or patients from other specialties in the event of demand shocks. The optimal policy may involve some private provision in combination with public expansion in areas poorly served by private hospitals. In fact, during the period I study expansion of existing hospitals also took place, including construction of onsite publicly-run surgery centres, and there is little evidence on the overall effectiveness of this expansion.

My findings also shed some light on the economics of 'hybrid' public-private systems of provision, also common in education and criminal justice. One component of this is understanding differences between quality and efficiency of public and private providers, and the second is understanding how they interact in a hybrid system. Private hospitals are observably different from public hospitals on several dimensions: they treat only elective patients, focus on a limited number of specialties and do not have critical care facilities. They have lower wait times and often offer amenities such as private rooms. Choosing not to invest in critical care is doubly beneficial: it reduces their fixed costs and differentially attracts less complex patients, reducing variable cost.

Economic theory predicts that where contracting is incomplete, private providers will skimp on dimensions of quality that are hard to observe (Hart, Shleifer and Vishny 1997). In contrast to this prediction, in my setting I find private hospitals appear to offer care of comparable clinical quality to public hospitals. There are several potential explanations for this. The existence of public incumbents may limit the ability of private hospitals to skimp since patients always have the option of being treated at the public hospital (Besley and Malcomson 2018). Most private hospitals also treat paying patients so must offer clinical quality high enough that patients are willing to pay for care. Third, the vast majority of publicly-funded private sector procedures are performed by doctors who also work in public hospitals, limiting variation in clinical quality between sectors.[20] Finally, for the set of low-risk patients treated at both public private hospitals there may be limited scope for skimping. Readmission rates may also be a poor measure of quality for this group of patients. In equilibrium private hospitals have lower wait times than public hospitals, implying that the the patient who is just indifferent between attending public and private facilities perceives the public hospital to be preferable on other dimensions of quality.

The conceptual framework and empirical findings in this paper help to reconcile some of the previous mixed results on competition in health care. For example, Cooper, Gibbons and Skellern (2018), Gaynor, Moreno-Serra and Propper (2013) and Gaynor, Propper and Seiler (2016) all find that introducing competition between public hospitals in England reduced mortality for heart surgery and some emergency conditions. In contrast, Moscelli, Gravelle and Siciliani (2021) finds that public-public competition increased readmission rate for hip and knee replacements. The competitive effect is more likely to be negative when a hospital faces high costs of treating marginal patients, for example when it has to run evening and weekend surgery lists to clear its wait list. Also, competition between incumbent providers is likely to increase demand for high quality providers as well as increasing quality elasticity of demand. If they are capacity-constrained and marginal cost is high, this demand shock may move them up the marginal cost curve, eroding quality (a reversal of the 'capacity effect' I outline). The results are broadly in line with previous findings on private entry in the NHS; like Kelly and Stoye (2020) I find that entry reduces wait times, although unlike them I find effects on readmission rates[21]. Like Cooper, Gibbons and Skellern (2018), I observe an increase in patient severity at hospitals exposed to private entry.

This analysis has important caveats. First, while the policy change I study is substantial, the overall share of government spending going to private hospitals is still relatively small. As spending on private providers increases further, it may be increasingly difficult for public hospitals to cover their fixed costs and make new quality-improving fixed cost investments and this could erode quality in the longer run. There are other potential medium-run implications of private entry that are hard to study in the short window around the policy reform. Increased demand for labour at private hospitals may bid up wages, eroding the monopsony

[20]The NHS has a fixed pay scale for doctors, meaning the distribution of earnings in the public sector is low variance. The marginal cost to private hospitals of hiring relatively more experienced NHS doctors is low, and doctors operating in private hospitals have an average of 2.5 more years of experience than their counterparts who only work in public hospitals.

[21]This may be because they focus exclusively on hip replacement. My point estimate for hip replacements is not significantly different from zero (table 7).

power of public hospitals. In the even longer run, increasing use of private providers and the quality changes that result may have implications for public support for funding the NHS. As the UK works to clear huge backlogs of patients whose treatment was delayed by the COVID-19 pandemic, private provision is likely to become even more extensive – and controversial – in the coming years.

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A Additional details of theory model

A.1 Effect of price, casemix and demand on pre-reform quality

Recalling that $h'' < 0$, $C' > 0$ and $C'' \geq 0$, pre-reform choice of quality α_{pre} is decreasing in average severity and demand and constant in price:

$$\frac{d\alpha_{pre}}{dp} = 0$$
$$\frac{d\alpha_{pre}}{d\bar{\theta}} = \frac{C'(\alpha_{pre}\bar{\theta}N) + \alpha_{pre}\bar{\theta}NC''(\alpha_{pre}\bar{\theta}N)}{h'' - \bar{\theta}^2 NC''(\alpha_{pre}\bar{\theta}N)} < 0$$
$$\frac{d\alpha_{pre}}{dN} = \frac{\bar{\theta}^2\alpha_{pre}C''(\alpha_{pre}\bar{\theta}N)}{h'' - \bar{\theta}^2 NC''(\alpha_{pre}\bar{\theta}N)} \leq 0$$

A.2 Effect of entry on quality when budget constraint binds

If h is large enough then the hospital increases quality up to the point at which the budget constraint binds:

$$pN = C(\alpha\bar{\theta}N)$$

Quality is increasing in price and decreasing in severity and demand:

$$\frac{d\widetilde{\alpha}}{dp} = \frac{1}{\bar{\theta}C'(\widetilde{\alpha}\bar{\theta}N)} > 0$$
$$\frac{d\widetilde{\alpha}}{d\bar{\theta}} = -\frac{\widetilde{\alpha}}{\bar{\theta}} < 0$$
$$\frac{d\widetilde{\alpha}}{dN} = \frac{p - \widetilde{\alpha}\bar{\theta}C'(\widetilde{\alpha}\bar{\theta}N)}{N\bar{\theta}C'(\widetilde{\alpha}\bar{\theta}N)} \leq 0$$

The last inequality holds because the net surplus on the marginal patient $p - \widetilde{\alpha}\bar{\theta}C'$ must be weakly negative, otherwise the budget constraint would be slack and the hospital would be able to increase quality.

B Data construction

Construction of admissions level data: The Hospital Episode Statistics data set is at the 'episode' level, where each episode is a period of care in hospital under one senior physician (equivalent to an attending physician in the US). Most patients only have one episode per admission, but where there are multiple episodes with the same admission date, I include only the first episode to avoid double-counting. If variables needed for the analysis are missing from the first episode, specifically date of discharge, I fill in data from subsequent episodes. Admissions are categorized as planned if a patient was admitted off the waiting list or if the patient was given a treatment date at the time the decision to admit was made, determined mainly on the grounds of resource availability. I define an 'index' admission as one occurring at least 30 days after a previous orthopaedic admission. To avoid double-counting readmissions, I keep only the index admissions i.e. if someone is admitted then admitted again within 30 days this counts as a readmission, and the second admission is dropped from the analysis. However, if a person is admitted and then admitted again *after* 30 days, the first admission does not count as being associated with a readmission. The second admission is kept as a separate admission.

Mapping admissions to locations: I map the site code for each admission to its post code using NHS Digital ODS data. If no site code is given or the site code is invalid, I map the site to a post code using the 'procode' field. I code any site code beginning with '5' or 'R' as public and any site codes beginning with '8' or 'N' as private. Where there are multiple site codes per post-code, I consider this to be a single hospital site. Sometimes operations taking place at private hospitals are coded 'R'; this happens when a public hospital directly contracts out procedures. To ensure that procedures in private hospitals are coded correctly, I manually checked all instances in which one or more public and private sites share the same post-code. Hospitals frequently change code over this period, for example because they are transferred to another NHS trust or because NHS trusts merge. I harmonize the site code

Market definition: To construct the hospital markets, I identified public hospital sites conducting 100 or more hip/knee replacements in 2006. I use hip/knee replacements as the basis of the restriction to ensure that markets are defined around hospitals conducting the full range of common elective orthopaedic procedures. There are some examples where this definition excludes large hospitals: for example, in 2006 most of the hip and knee replacements in Birmingham were conducted at Birmingham Treatment Centre at Birmingham City Hospital, meaning most other large hospitals in Birmingham do not have their own markets.

Construction of variables: Emergency readmission is defined as an admission to any hospital within 30 days after discharge from the index hospital spell that is unplanned occurring either through the emergency department or due to a request for immediate admission by a General Practitioner or other doctor). The variables included as controls in the patient outcome regression are defined as follows:

- Age bands: 0-19, 20-34, 35-49, 50-59, 60-64, 65-69, 70-74, 75-79, 80-84 and 85+
- A dummy for whether the patient is female
- A dummy for whether the patient is white. Race/ethnicity are poorly populated for the early years of the sample so a dummy for race/ethnicity 'unknown' is also included
- A vector of patient comorbidities, defined using all the diagnosis fields: congestive heart failure, cardiac arrhythmia, valvular disease, pulmonary circulation disorders, peripheral vascular disease, hypertension, diabetes, diabetes with complications, hypothyroidism, renal disease, liver disease, HIV/AIDS, cancer, metastatic solid tumor, rhematoid arthritis, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, blood loss anemia, deficiency anemia, alchohol/drug abuse, psychoses, depression
- Charlson index. This is constructed using the *charlson* command using the first ten diagnoses fields.

- Procedure dummies. To code these I take the first 3-digit OPCS code of the episode. I code any procedure with fewer than 5,000 admissions in 2011 as 'other'
- Deprivation dummy indicating whether patient's census area (LSOA) is in the decile of most deprived neighbourhoods. Deprivation is defined using the income component of the 'index of multiple deprivation'.

C Supplemental tables and figures

Table 8: Percent of government spending in private hospitals for most common procedures in 2012

	Gov exp (m GBP)	Gov-funded admissions	% exp in private hosps
Knee replacement	478	76,253	19.9
Hip replacement	436	71,667	18.9
Rotator cuff repair / subacromial decompression	164	38,101	21.3
Knee arthroscopy	156	74,647	28.7
Fracture reduction/fixation	87	41,085	2.5
Joint aspiration or injection	62	61,838	17.0
Joint resurfacing	46	8,025	24.6
Carpal tunnel release	44	42,575	18.9
Joint replacement (exc. hip/knee)	13	2,575	9.4
Other	754	395,633	15.0

Table includes all NHS-funded planned orthopaedic admissions in England. Admissions are grouped by OPCS code of the primary procedure. Knee and hip replacement categories include primary procedures and revisions