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ABSTRACT

Employer Quality and Skilled Workers' Mobility: Evidence from English NHS Hospital Doctors*

We build a unique dataset by linking high-quality administrative data sources and model the mobility choices of tenured English National Health Service (NHS) hospital doctors across hospital organizations according to a random utility choice framework based on hospital quality, pay-for-performance incentives, local residential amenities and travel-to-work commuting distances. We account for the endogeneity of hospital quality through a control function approach. Doctors are willing to move 5.3 extra kilometers in order join a new hospital organization with a one-standard-deviation lower mortality rate, whereas they are willing to trade a standard deviation of the average monetary bonus received for their clinical excellence with the cost of moving 5 extra kilometers from their home. Primary school quality and low crime residential areas are only marginally salient in the choice of new employer. Counterfactual simulation estimates reveal that simultaneous improvements in hospital mortality and performance-related pay awards by one fourth of a standard deviation can lead to decreases in regional hospital doctor vacancy rates by 2% to 11%.

JEL Classification: C25, I11, J24, J45, J62, J63

Keywords: skilled workers, mobility, physicians, hospital, organization quality, incentive pay, vacancies

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1 Introduction

As labor and human capital mobility increase, the competition among organizations to attract skilled, talented workers becomes fiercer. But what attracts workers to a specific organization? According to classical economic models, workers sort into jobs based on a mix of job characteristics and location amenities (Rosen, 1986; Roback, 1982, 1988). However, there remains a paucity of strong, consistent empirical evidence supporting the existence of amenity-wage trade-offs across different labor markets, as isolating workers' trade-offs faces persistent credibility challenges due to the presence of many unobservable factors such as skills (Hwang et al., 1992) or search frictions (Bonhomme and Jolivet, 2009). Thus, identifying workers' preferences for inside and outside job characteristics remains an open empirical question; specifically, evidence on the responsiveness of workers' mobility to the quality of employer organizations is still scant.

In this work, we study whether skilled job movers are responsive to relevant characteristics of prospective employers, such as the quality of the employer organizations, pay-for-performance salary incentives and nearby residential amenities – e.g. primary school quality and crime rates. Our primary research interest is the movers' responsiveness to organization quality and incentive pay, as these are two important levers that employers can act and improve upon in order to attract skilled workers and reduce vacancy rates. To this aim, we build our empirical case study by investigating the mobility choices of hospital physicians for three key reasons. Differently from firms in other industries, hospital organizations can be ranked based on clinical quality measures, such as risk-adjusted mortality, providing us with an *objective* indicator of organizational quality that is presumably known to skilled workers and may contribute to their utility across several dimensions, including but not limited to: reputation, workload burden, career progression, clinical malpractice occupational risks and the related compensating wage differentials. Secondly, hospital doctors are the most skilled professional category in the healthcare sector, and their mobility choices across different hospital providers may matter also for patient outcomes (Stoye, 2022; Moscelli et al., 2024b). Furthermore, the ongoing severe healthcare workforce crisis in Europe makes the churn of doctors across hospital organizations and healthcare systems (and its economic determinants) particularly relevant (Looi, 2024).

Our empirical analysis is based on a sample of hospital tenured doctors employed by the largest public sector employer in the UK, the English National Health Service (NHS). The English NHS provides us with an ideal setting to conduct this study, as it is the *de facto* monopsonist of the hospital physicians' labor market in England:[1] as such, the English labor market for hospital physicians substantially coincides with the entire NHS public hospital sector, where a large pool of skilled and specialized workers (tenured doctors) can choose from a fairly vast set of large firms (almost 140 hospital organizations). English NHS hospital organizations often exhibit large variations in hospital quality and organizational attributes (Public Health England, 2016), which is paramount to identify the effects of interest. Moreover, NHS-employed hospital physicians are subject to a regulated pay regime, which is set at national level and prevents individual worker's wage bargaining; nevertheless, the NHS hospital physicians salary model includes a competitive pay-for-performance salary top-up scheme – an institutional feature that we exploit in our investigation. Finally, focusing on English NHS hospital physicians allows us to build our analysis on a unique dataset that we assembled by linking four high-quality administrative datasets, with detailed information respectively on: hospital doctors' demographic characteristics and employment spells spanning over seven years (from January 2013 to December 2019) and the universe of NHS hospital organizations; in and outside hospital patient mortality, risk-adjusted for health comorbidities; primary school ratings at neighborhood level; criminal offenses at neighborhood level.

We use a revealed preference random utility framework and exploit doctors' transitions across NHS hospital organizations to identify utility parameters and trade-offs. This strategy

[1]English private hospitals provide only planned care treatments and their business model is based on the part-time employment of NHS hospitals' physicians, and over 90% hospital doctors in the private sector are primarily employed as NHS hospital soctors (Wormald, 2022).

allows us to answer several research questions: (i) whether and how much skilled workers are responsive to employer quality and performance-related monetary incentives; (ii) how skilled workers trade off organization quality and performance-related monetary incentives with travel-to-work distances; (iii) what is the skilled workers' marginal rate of substitution between organization quality and performance-related monetary incentives; (iv) whether and to which extent quality of services and performance-related pay can be used as organizational pull factors to attract workers and reduce vacancy rates. These issues are critical in any sector to achieve an effective organization management of the workforce, and even more salient in the context of the healthcare sector, either in the UK or in other developed and developing countries, because high vacancy rates and staff shortages may severely impair quality of care (World Health Organization, 2010; Moscelli et al., 2024b).

We explicitly account for the possibility that hospital organization quality may be endogenous due to unobservable factors, for example due to recursive churn of physicians towards higher quality hospital organizations, by implementing a Petrin and Train (2010) control function approach, in which we instrument the risk-adjusted mortality rate of each hospital organization through the risk-adjusted mortality rates of other hospital organizations in the same NHS administrative region. This strategy exploits the fact that the provision of NHS care is organized at regional level, and so changes in the quality of hospital organizations in the same region are likely driven by institutional factors that are exogenous to doctors' churn towards a given hospital organization, and also unrelated to the idiosyncratic unobservable factors affecting the hospital organization where a doctor chooses to move.

Our results show that organization quality is a relevant pull decisional factor in skilled workers' choice about which organizations to move to: NHS hospital doctors are willing to move to hospitals 5.3 kilometers away from their residence for a one standard deviation reduction in hospital risk-adjusted mortality. Similarly, doctors are willing to travel at least 5 extra kilometers for a one standard deviation increase in pay-for-performance pay. Moreover, doctors may accept a 1.8 percentage point increase in risk-adjusted hospital mortality, which is approximately equal to one standard deviation of the risk-adjusted hospital mortality, for a one standard deviation increase in their pay-for-performance awards. Residential amenities represent a secondary-order pull factor for hospital doctors: access to better primary schools is weakly and negatively associated with the average choice, but it is statistically significant and positive for the younger groups of female doctors (32-39 years old); moreover, doctors dislike hospitals where their peers' housing is located in high-crime areas, although this hospital organization attribute is not statistically significant. Doctors are also less likely to move to hospitals located in rural areas.

Finally, we use our model estimates to perform a counterfactual analysis in which we simulate, separately for each NHS region, how hospital doctor vacancy rates in 2019 would have changed under three alternative scenarios: a 25% decrease in risk-adjusted hospital organization mortality; a 25% increase in pay-for-performance pay; the combination of the former cases. Combining lower mortality rates with a higher clinical performance-related pay can reduce hospital physician vacancy rates by about 2.3-11%, depending on the English region.

This study contributes to the literature in organizational, health and labor economics, by investigating the roles played by workers' preferences for workplace characteristics and local amenities in shaping workers' choice of employer (Mas and Pallais, 2017; Wiswall and Zafar, 2018; Maestas et al., 2023), and the mapping of location choices to local characteristics for skilled workers' mobility (Dal Bó et al., 2013; Diamond, 2016). In relation to the physicians workforce, stated-preference studies have documented how doctors, prominently family doctors, prefer having more autonomy and training opportunities, control over working hours, and have a general distaste for rural regions (Scott et al., 2013; Holte et al., 2015; Pestana et al., 2023). Differently from these studies, we investigate how doctors choose a new employer organization based on their revealed preferences. Furthermore, most of the existing observational evidence on physicians' preferences for workplace and location characteristics focuses on doctors working in primary care and on the choice between urban and rural areas

(Holmes, 2005a; Agarwal, 2015; Falcettoni, 2018; Kulka and McWeeny, 2019; Costa et al., 2023), where large compensation differentials may apply and act as a confounding factor. Our work is also related to a recent set of papers investigating the relationship between financial incentives and the labor supply and geographic mobility of US healthcare professionals (Gottlieb and Zenilman, 2024; Gandhi et al., 2024; Gottlieb et al., 2025). Instead, we study mobility preferences and choices of physicians employed in the hospital care sector of a European country (England) with a healthcare model, different from the US one and internationally widely-adopted, in which hospital doctors' basic salary is largely defined as a deterministic function of doctor seniority, thus not subject to employee-employer bargaining on an individual basis. We add to this literature by investigating the relationship between financial incentives and physician mobility through the incentive pay component available to NHS hospital doctors as a competitive award scheme, and by using our structural model to generate counterfactual predictions of reductions in hospital doctor vacancy rates.

Most importantly, our main contribution departs from the exclusive urban/rural angle and rather assumes an organizational economics perspective: our main objective is to evaluate the relative attractiveness of an employer (i.e., the hospital) based on some of its key attributes – objective quality of services to customers, compensation strategy, amenities of the surrounding residential areas. Specifically, we are among the first to investigate skilled workers' (doctors) preferences over an objective measure of organizational quality like risk-adjusted patient mortality. Our empirical analysis shares some methodological similarities with Costa et al. (2023), who estimate Brazilian primary care doctors' preferences over wages, birthplace or graduation region, health infrastructure and a composite index of location amenities; remarkable differences from their study are that we do not focus on the urban/rural divide and that we model physician choices in order to estimate trade-offs between workplace characteristics and travel-from-home distances.

Lastly, this work relates to a growing literature that investigates how institutional, organizational and policy factors affect the labor supply and turnover of hospital workers (e.g.:

Lee et al. 2019; Friedrich and Hackmann 2021; Chan Jr and Chen 2022; Moscelli et al. 2024c; Kelly et al. 2022a; Moscelli et al. 2023; Propper et al. 2023; Moscelli et al. 2024a, among others); in particular, by focusing on churn across hospital organizations, this paper complements the findings by Moscelli et al. (2024c), who investigate the role of organizational push factors associated with nurses' and senior doctors' retention rates within NHS hospital organizations and NHS attrition rates.

The paper is structured as follows: Section 2 presents background information on the English NHS; Sections 3 describe the datasets and the econometric strategy; Section 4 reports the main results; Section 5 presents findings from robustness checks and additional analyses; Section 6 concludes.

2 Institutional background: hospital doctors in the English NHS

The English National Health Service (NHS) is funded by taxation and provides free-to-use healthcare services to all UK residents.[2] NHS hospital care is provided by legal hospital organizations (HO) called NHS Trusts, comprising groups of hospitals that provide healthcare services to targeted geographic areas. The number of HOs in the English NHS varies over time as the result of opening, closure, merger and acquisition processes between hospital organisations. NHS HOs are coordinated at the regional level within a system that comprises seven administrative regions: East of England, London, Midlands, North East and Yorkshire, North West, South East and South West.

The NHS represents the largest public sector employer in the UK and employs more than 120,000 doctors, about half of whom being trainee doctors. The NHS senior medical workforce is split into three main groups, depending on their training, specialization and

[2]This healthcare system model, often called 'Beveridge healthcare system', is present in countries such as Italy, Spain, Denmark, Sweden, Norway, New Zealand, Finland, Cuba, Greece, Iceland; in 2024, the combined population of these countries and the UK summed up to 216 million people, i.e. about 65% of the US population.

services provided to patients: (i) Specialty and associate specialist (SAS) doctors; (ii) General Practitioners (GPs), also known as 'family doctors' outside the UK; and (iii) senior doctors, called 'hospital consultants'. Hospital consultants account for the majority of the senior medical workforce, represent the most senior role within the doctor hierarchy, and have clinical and administrative responsibilities in managing both SAS and trainee doctors.

NHS doctors' salaries are regulated by national pay scales, with little variations across hospital organisations. On average, the starting salary of an hospital consultant stands at almost £79,000 per year. This centrally-regulated pay scheme does not allow for salary bargaining between individual workers and their employing HOs. NHS HOs can pay a Recruitment and Retention Premium (RRP) in regions struggling with recruitment and retention. However, national terms mandate that RRP must be paid to all employees rather than only for necessary vacancies, and it is therefore rarely implemented for hard-to-fill vacancies (Charlesworth and Lafond, 2017). This setting is ideal to study medical workers' location choices within the public healthcare sector in the presence of low-powered monetary incentives.

NHS doctors are entitled to fixed salary supplements if they work in London, and to variable salary supplements assigned on a competitive basis and depending on their clinical excellence. The Clinical Excellence Awards (CEAs) scheme was launched in 2003 by the UK Department of Health. There are 12 levels of awards, assigned locally up to level 9 (local CEA, LCEA), and nationally from level 10 to 12, with rewards that go from £3,016 (level 1) to £77,320 (level 12, platinum) - level 9 may also be awarded nationally (see Essex et al., 2021). Awards granted before 2018 last until retirement or might be replaced by national awards and are pensionable. Post-2018 awards last only for three years; national CEAs last for five years if eligibility is maintained.

Both renewal or advancement to the next award level are possible: the former occurs after four years for first-time national awards, with subsequent 5-year renewals. If minimum standards are not met, a lower-level renewal may occur; a reversion scheme allows moving to a pensionable local award if scores are low. Awards renewals are quite common: for example, only about 20% of renewal applications in 2017 and 2018 were unsuccessful. The awarding process requires eligible consultants to submit an application for CEA awards, which is then assessed and ranked according to a scoring system that evaluates doctors' clinical excellence based on different domains of the medical profession.[3] While the purpose of these awards is to reward performance and contributions going beyond expectations, the Advisory Committee on Clinical Excellence Awards has encouraged local committees to award at least 0.35 of an award per eligible consultant – changed to at least 0.20 after 2011 (Advisory Committee on Clinical Excellence Awards, 2010). In terms of budget expenditure, in 2011 the scheme cost over £500 million (Bloor and Maynard, 2012).

3 Data and Methods

3.1 Main data sources and hospital organization attributes

We link multiple administrative records and publicly-available datasets to generate the hospital choice sets available for a large sample of NHS moving doctors, for whom we also observe a rich series of demographic and professional characteristics.

Data on doctor employment spells across HOs and over the period from March 2013 to March 2020 come from the Electronic Staff Records (ESR), a monthly payroll registry commissioned by the Department of Health and Social Care (DHSC) and used by 99% of the English NHS hospitals. This database provides us with some of the key information for our analysis: the employer HO for each NHS worker in each month, from which we select the sample of doctors who changed HO in a given financial year; information on doctors' age and gender, as well as their clinical specialty; the residential address of each doctor (up

[3] Consultants' applications for CEA awards encompass five professional domains (service delivery, development, leadership, research and innovation, training), including the doctor's job plan and personal statement. The submission process is online, and assessments follow strict criteria using a four-point scoring system (0, 2, 6, or 10 points) for each domain. Each applicant receives an overall average score for each domain, used to rank applicants on a percentile basis. See Campbell and Abel (2016) for more information regarding the assessment process for these competitive applications.

to the first digit of the inward postcode); information on the monthly monetary amount of Clinical Excellence Awards (CEA) received by hospital doctors. We match ESR doctors' residence outward postcode to the HO postcodes provided by the NHS Organization Data Service (ODS) to compute home-to-HO linear **distances** (in kilometers) between the doctors' residence and each HO in the choice set; travelling distances proxy the opportunity cost of joining a certain HO.

We rely on the universe of English NHS patients' admission records contained in the Hospital Episodes Statistics Admitted Patient Care (HES APC) database to construct **HO mortality** as yearly 30-day mortality rates, risk-adjusted by patient age, gender and month of admission. Patients deaths are captured anywhere, both inside and outside the hospital, through the linkage to the Civil Registration Deaths data provided by the UK Office for National Statistics (ONS). Our HO mortality indicator follows closely the official statistical methodology used by the NHS (NHS Digital, 2023).[4]

We compute the average monetary amount received by a hospital doctor as a **Local clinical excellence awards (LCEA)** (in £1,000) by extrapolating the annual award from the amount paid as of March in each year, and excluding sums that are attributable to the National CEA bands. LCEAs are paid out of, and contingent to, a HO budget; thus, this variable represents a measure of the 'generosity' of a given HO in rewarding the excellence of its physicians' clinical performance.

The Office for Standards in Education, Children's Services and Skills (OFSTED) produces ratings for UK public and private schools upon visiting and assessing them. We use OFSTED inspection outcomes on primary schools starting from October 2011.[5] Inspectors evaluate the following performance areas: (i) effectiveness of leadership and management, (ii) the quality of teaching, learning and assessment, (iii) personal development, behaviour and welfare, (iv) outcomes for pupils. Schools are evaluated under each theme separately, but

[4]In Appendix A we provide a detailed illustration of the procedure, and Appendix Figure A1 shows how our derived metric relates to the NHS official indicator.

[5]The official information on state-funded school inspections conducted by OFSTED is available at: https://www.gov.uk/government/statistical-data-sets/monthly-management-information-ofsteds-school-inspections-outcomes.

they also receive an "overall effectiveness" grade, based on the following ratings: "Outstanding", "Good", "Requires improvement" and "Inadequate" (reported on a 1-4 scale, with 1 for an "Outstanding" rating). We construct our summary primary **school quality rating** at HO-level by averaging the overall effectiveness ratings of the schools in the postcodes where the doctors employed by each HO live. In the empirical analysis, without any bias risk or loss of generality, we reverse the primary school ratings scale, with 1 for "Inadequate" and 4 for "Outstanding", to ease the interpretability of the results.

We use open crime data for the period of interest from the UK Police data archives. The data is aggregated at the Lower-layer Super Output Area (LSOA), a census geography usually comprising between 400 and 1,200 households and a resident population between 1,000 and 3,000 persons. The number of crimes by category is recorded monthly by the Police for each LSOA; three broad categories identify crimes depending on the type of offence: (i) crimes against the person (e.g., violent crimes), (ii) property crimes (e.g., burglaries, thefts), (iii) other crimes (e.g., anti-social behavior, drugs or possession of weapons).[6] We construct a HO-level **high-crime neighborhoods** binary indicator in three steps: we count yearly crimes for the above crime classes (against person, property and other crimes) at the neighborhood LSOA level, based on the neighborhoods of residence of the doctors employed by each HO; for each of the three classes, we then compute neighborhood-level standardized logarithmic differences, defined as the natural logarithm of the neighborhood-level crime-category sum and the natural logarithm of the same crime-category at national-level in the same year; finally, a HO is defined to be located in a high-crime residential area if all the three standardized crime-category variables fall at least one standard deviation above the overall yearly average.

Finally, we classify hospitals as either **rural** or urban organizations, using the official rural-urban classification of lower layer super output areas (LSOAs) by the UK Office for

[6] This categorization of crimes by the UK Police has been mostly consistent since September 2011. The data is available at: https://data.police.uk/data/archive/.

National Statistics (ONS).[7] LSOAs are small geographical areas with an average 1,500 population. The LSOA where the hospital is located is retrieved by matching the hospital postcode, available via the portal of NHS Organization Data Service (ODS),[8] to the LSOA geographies through the related ONS lookup table.[9]

3.2 Empirical strategy

3.2.1 Doctors' utility and choice of hospital organization

Physicians' labor supply extensive margins can be defined as a function of the HO attributes (e.g. clinical quality and pay-for-performance awards), residential amenities (e.g. primary school quality and crime) and distance from the worker's home residence, for all the available HOs in the physician's choice set. We assume that doctor i working in hospital h^o decides to move to hospital h in year t, where $\{h^o, h\} \in H_{it}$, and H_{it} is the set of all acute care HOs in the English NHS in year t. We also assume that doctor i's indirect latent utility, U_i, from choosing to moving from HO h^o to HO h in region r during year t is linear, additive separable and given by

$$U_{ihr,t} = \sum_k x_{hk,t-1}\beta_k + \sum_{m=1}^{3} d^m_{ih,t-1}\gamma_m + tI_r\theta_1 + \epsilon_{ihr,t}. \quad (1)$$

$x_{hk,t-1}$ represents the observed year $t-1$ attributes for hospital h. In the baseline specification, the HO attributes that we include are: the 30-day risk-adjusted HO mortality rate, our measure of organization quality and main variable of interest; the average mone-

[7] The ONS definition of 'urban' domain comprises all physical settlements with a population of 10,000 or more; for details, see https://www.ons.gov.uk/file?uri=/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification/rucoaleafletmay2015tcm77406351.pdf. The assignment of LSOAs to urban or rural categories is based upon the urban/rural category to which the majority of their constituent blocks (i.e., output areas (OAs), the smallest smallest areas for which data are available from the 2001 and 2011 Censuses) is assigned to. The data is available for download at: https://www.data.gov.uk/dataset/967b8527-d026-4e83-b7e9-fced372ed061/rural-urban-classification-2011-of-lsoas-in-ew.

[8] The latest NHS hospital organizations' (Trusts) postcodes are available at https://digital.nhs.uk/services/organisation-data-service/data-search-and-export/csv-downloads/other-nhs-organisations. Historical NHS hospital Trust postcodes are available from the ODS upon request.

[9] The UK postcode-to-LSOAs lookup table is available at: https://geoportal.statistics.gov.uk/datasets/ons::postcode-to-oa-2021-to-lsoa-to-msoa-to-lad-november-2023-best-fit-lookup-in-the-uk/about.

tary LCEA amount received by doctors employed at HO h; the average quality of primary schools and the high-crime neighborhoods binary indicator, both measured in the residential areas around the HO in which other doctors employed at the HO live; the rurality binary indicator. Instead, our institutional setting allows us to exclude baseline wages from the specification of the utility Equation 1, as NHS senior hospital doctor's basic salary in set at national level and it does not depend on the HO h location.

The term $\sum_{m=1}^{3} d_{ih,t}^{m}\gamma_m$ is a third-degree polynomial in distance d between doctor i's residence at time $t-1$ and the headquarter of hospital h. Time-varying regional factors, unobserved by the econometrician and affecting the supply and the organization of hospital services, as well as hospital physician mobility and the residential amenities available around the HOs, are captured by regional linear time trends tI_r. The error term $\epsilon_{ihr,t}$ represents an idiosyncratic preference that physician i has over HO h.

The maximization of the hospital doctors' utility described by Equation (1) defines a set of hospital and residential attributes that are associated with the choice of each HO. The probability of any doctor i to choose a given HO h is then a function of preference parameters $(\boldsymbol{\beta}, \boldsymbol{\gamma})$, observed HO characteristics $\mathbf{x}_{hk,t-1}$ and distance from the current doctor i's residence $d_{ih,t-1}$. Assuming that the error term $\epsilon_{ih,t}$ is i.i.d. extreme value yields the alternative-specific, conditional logit (CL) model (McFadden, 1973), in which the probability that consultant i chooses hospital h can be written as

$$P_{ihr,t} = \frac{\exp(\sum_k x_{kh}\beta_k + \sum_{m=1}^{3} d_{ih,t-1}^{m}\gamma_m + tI_r)}{\sum_{h' \in H_{it}} \exp(\sum_k x_{kh'}\beta_k + \sum_{m=1}^{3} d_{ih',t-1}^{m}\gamma_m + tI_r)}. \tag{2}$$

A few caveats apply, related to modelling our relationships of interest. First, to alleviate concerns of reverse causality bias we model the mobility choice of doctor i in year t as a function of (the vector of) HO attributes observed in the previous year $t-1$, and not in the same year of the job relocation (for similar models on patient choice over treatment hospital, see e.g. Gutacker et al. 2016; Moscelli et al. 2016); this modelling assumption is both realistic and necessary, because any job search takes time and NHS tenured hospital doctors have to give at least a three-month notice to the HO where they work, when they wish to terminate their employment contract.

Second, the adoption of an alternative-specific conditional logit model allows us to effectively difference out the latent effect of the attributes of the 'origin' HO, which may be economically-relevant push factors for doctor's mobility choices. Therefore, β_k represents the marginal utility of the HO attributes of the alternative HOs in the choice set with respect to the 'origin' HO h^o.

Third, since the utility function is unique only up to a linear transformation, the coefficients $\boldsymbol{\beta}_k$ only convey information about the sign of the marginal utility from such attributes. A more informative measure is the ratio between marginal utilities and a cost parameter, unaffected by linear transformations and expressing the trade-offs that individuals face (Revelt and Train, 1998). In our analysis, we use the parameters on the distance polynomial as the implicit cost - by doing so, we can estimate the distance-scaled preferences for attributes of a job at hospital h, informing on how far a doctor would travel in order to work at a higher-quality HO or a HO with better surrounding residential amenities. As such, we compute doctors' willingness-to-move (WTM) for HO attributes as the marginal rate of substitution between HO attributes and distance-to-travel from home to each HO, for a one standard deviation (SD) change in the HO attribute x_k:

$$\text{WTM} = \frac{\partial u_{ih}}{\partial x_{kh}} / \frac{\partial u_{ih}}{\partial d_{ih}} \text{SD}(x_k) = \frac{-\beta_k}{\gamma_1 + 2\bar{d}\gamma_2 + 3\bar{d}^2\gamma_3} \text{SD}(x_k), \tag{3}$$

where $\bar{d}$ is the average distance to doctors' chosen hospitals, and we consider a one SD decrease in HO quality q (i.e. HO mortality), and one SD increases in HO LCEA amounts and HO-areas school quality, respectively for continuous HO attributes quality, incentive pay and school quality.

Similarly, based on the respective marginal utilities parameters, we retrieve also an estimate of the *quality-pay trade-off* (QPTO) between HO LCEA pay-for-performance incentives and HO quality q, given a one standard deviation increase in LCEA pay amounts, as

$$\text{QPTO} = \frac{\partial u_{ih}}{\partial x_{LCEA,h}} / \frac{\partial u_{ih}}{\partial x_{q,h}} \text{SD}(x_{LCEA,h}) = \frac{-\beta_{LCEA}}{\beta_q} \text{SD}(x_{LCEA,h}), \tag{4}$$

where the QPTO estimate measures the decrease in HO quality a hospital doctor is willing to accept for an increase in their LCEA performance pay. Both WTM and QPTO standard errors are estimated using the delta method (Hole, 2007).

Finally, physicians can have heterogeneous preferences with respect to the HO quality and location attributes, or be characterized by unobservable differences in the ability to access and interpret information about HO attributes. For this reason, we also estimate Mixed Logit choice models (McFadden and Train, 2000; Hensher and Greene, 2003; Train, 2009), which allow for both unobserved doctor heterogeneity in tastes over HO attributes and also for unrestricted substitution patterns, thereby relaxing the assumption of independence of irrelevant alternatives (IIA) that characterizes the CL model. This represents the case in which we replace the term β_k with β_{ik} in Equations 1 and 2, and assume $\beta_{ik} = \beta_k + \sigma_k \alpha_i$, where σ_k is the standard deviation of a zero mean normal variable and α_i is an unobserved doctor effect; the case with $\sigma_k = 0$ corresponds to the standard CL model. Unlike the CL model, which has a closed form solution that can be estimated via maximum likelihood, the Mixed Logit model needs to be estimated through maximum simulated likelihood, for which we use 100 Halton draws. For the estimation of the baseline Mixed Logit models, we assume uncorrelated normally distributed random coefficients for HO attributes and fixed coefficients for the home-to-hospital distance.

3.2.2 Controlling for endogenous HO clinical quality

The estimation of doctors' marginal utility with respect to hospital quality may suffer from endogeneity due to omitted variable bias if the estimated association with organizational quality of physicians' employer choice captures both the preferences for hospital quality and other unobserved factors that correlate with hospital quality.[10] Moreover, we might be facing also endogeneity due to reverse causality if hospital quality is inter-temporally affected by doctors' past mobility choices. For example, HOs with lower mortality in year $t-2$ may attract more doctors in year $t-1$, and be characterized by lower patient mortality levels in years $t-1$ and t due to fewer physician vacancies; then, the employer choice of a new set of mover doctors in year t may be affected by the higher quality (lower mortality) realized in year $t-1$ by these hospital organizations. Therefore, the case of a systematic mobility of hospital doctors towards higher quality HOs would result in the attenuation bias of our estimates. If such mobility patterns persist over time, they may bias the estimated marginal utility parameter of hospital quality, despite our use of lagged HO quality variables, $\mathbf{x}_{hk,t-1}$, in the estimation of the choice models stemming from the utility function in Equation 1.

Both omitted variables and reverse causality biases represent deviations from the assumption of weak exogeneity of hospital quality, which is necessary to interpret the estimates of interest as unbiased marginal utilities. To overcome this empirical issue, we apply the control function (CF) approach proposed by Petrin and Train (2010), which has been previously exploited in the doctor location literature by Agarwal (2015) and Costa et al. (2023) to respectively address the endogeneity of wages in the markets for family medicine residents in the US and family doctors in Brazil. The control function correction consists in constructing a variable which proxies for the unobservable factors that correlate with the endogenous variable of interest. In our setting, the inclusion of the control function residuals in the mobility choice model regressions controls for the endogeneity of hospital risk-adjusted mortality and allows us to identify its marginal utility.

We define the instruments for average hospital mortality in hospital h as the leave-out average value of observed attributes of HOs in the same NHS region r as hospital h - i.e., the average of variables $x_{hk,t}$ in equation (1) across all $h \neq h'$ (Berry et al., 1995; Costa et al., 2023). The validity of the leave-one-out instruments is provided by the NHS

[10] The standard independence assumption for consistency is violated in setting where omitted factors are correlated with the included attributes (see, Bass, 1969; Berry, 1994).

institutional framework, as the quality and delivery of the NHS hospital services is organized at regional level.[11] Therefore, variations in the quality of other hospital organizations in the same region can be considered as weakly exogenous (i.e., exogenous conditional to the inclusion of other controls) and due to factors that are not under the control of the specific hospital provider, including the factors contributing to its attractiveness for the current and prospective physician workforce. Moreover, we assume that mortality in hospital h may be determined by unobserved characteristics at the regional level that change throughout time. Thus, we can express the mortality of HO h in year t, q_{hrt}, as a (linear) function of the observed attributes for the remaining HOs in the same NHS region r:

$$q_{hr,t} = \mathbf{x}_{hr,t}^{-q}\lambda_1 + \bar{\mathbf{x}}_{r,t}^{-h}\lambda_2 + tI_r\theta_{2,r} + \nu_{hr,t}, \tag{5}$$

where $\mathbf{x}_{hr,t}^{-q}$ are hospital h attributes (excluding q) and $\bar{\mathbf{x}}_{r,t}^{-h}$ are leave-out average characteristics of hospitals in the same NHS region as hospital h, and tI_r is a region-specific time trend. Given the instruments, $\bar{\mathbf{x}}_{r,t}^{-h}$, we estimate Equation (5) via OLS and retrieve the control function generated regressor $\hat{\nu}_{hr,t}$, which captures the correlation between mortality and unobserved local attributes and modifies the utility function as:

$$u_{ihr,t} = \mathbf{x}_{hr,t-1}\boldsymbol{\beta} + \sum_{m=1}^{3} d_{ih,t-1}^{m}\gamma_m + tI_r\theta_{1,r} + \hat{\nu}_{hr,t-1}\phi + \varepsilon_{ihr,t}. \tag{6}$$

As a two-step estimation procedure, the inclusion of the control function generated regressor can bias maximum likelihood standard errors (Murphy and Topel, 1985), therefore we provide bootstrap-corrected standard errors for the CL estimates with a control function correction.[12]

[11]From the website of NHS England, the supervisory body of NHS hospitals states: "We have seven regions who support local systems to provide more joined up and sustainable care for patients. Our regional teams are responsible for the quality, financial and operational performance of all NHS organisations in their region, drawing on the expertise and support of our corporate teams to improve services for patients and support local transformation.". More information can be found at: https://www.england.nhs.uk/about/regional-area-teams/.

[12]The Mixed Logit standard errors reported are cluster robust to serial correlation at the doctor level. We are unable to provide bootstrap-corrected standard errors when we estimate Mixed Logit models, due to the computational burden of the bootstrap repetitions. The same problem is faced and acknowledged by Costa et al. (2023); given the similar magnitudes of the CL and Mixed Logit estimates without a control function correction, we believe this does not constitute a serious issue with

4 Results

4.1 Descriptive statistics

Our main analysis sample includes all tenured hospital senior doctors (called "consultants" in the NHS) aged 32-60 who changed NHS HO at least once over the period from March 2013 to March 2020.[13] To identify movers in each of these seven financial years, we compare the doctors' HO of employment at the beginning and the end of the same financial year, using ESR records from March of each calendar year. In the definition of a doctor's move, we take into account mergers or acquisitions (M&A) among NHS HOs, which would make doctors erroneously appear as if they changed HO. Hence, we exclude from the movers sample all the doctors who changed employer between HOs that underwent a M&A operation in the same financial year of the move.

To construct the yearly hospital choice set available to each mover, we link doctors to all the open NHS HOs during the financial year of their move, except for the HO where they work in at the beginning of the financial year. Thus, each choice set comprises the HOs that movers could potentially join in the financial year of the move, together with their attributes. The average number of alternatives available to moving doctors is 137, with a minimum of 135 HO alternatives in years 2014/2016 and a maximum of 139 HOs in 2015. The final sample consists of 4,983 doctors, for a total of 5,293 moves. Most HO doctors do not move repeatedly during the analysis period: as shown in Appendix Figure B1, among all the doctors in the movers sample, almost 90% are single-time movers, around 10% move twice, while very few move at least 3 times, with a maximum of 5 moves in 7 years.

Table 1 presents summary statistics about demographic and professional characteristics of HO mover doctors during the period from March 2013 to March 2020, as of year of their first move. Around 40% of movers are female senior doctors, with only 15% being over 50+

our estimates.

[13] In Section 5 we provide a robustness check including the additional category of tenured specialty NHS hospital doctors, also known as "SAS doctors".

years old. In Panel A, we notice that movers are mostly British (66%), and almost 17.5% of them are already recipients of a Clinical Excellence Award (either LCEA or NCEA); 37% and 28% of movers work respectively in General Medicine and Surgery specialties.

Panel B1 of Table 1 displays the distributional summary statistics on HO attribute variables across choice sets: the average yearly HO mortality rate is 2.88%; the average LCEA yearly payment is £4,135; the average primary school quality is 1.92 out of 4 (with 1="Outstanding"); only 3.8% of the hospital organisations included in the choice set is surrounded by residential areas with high criminality levels; finally, 5.3% of hospitals are located in rural areas. Panel B2 of Table 1 reports the pairwise correlations across HO attributes: HOs with high risk-adjusted mortality rates are characterized also by lower LCEA payments (-0.229; $p < 0.01$); HOs in high-crime areas have also lower-quality schools (-0.132; $p < 0.01$). Lastly, Panel B3 of Appendix Table 1 reports the intra-class correlation coefficients (ICC) of each HO attribute at NHS region level, i.e. the proportion of variance attributable to variation between HOs in the same NHS region.[14] The estimated coefficients suggest that the variation in HO mortality rates and LCEA payments is not due to systematic differences between NHS regions, whereas regional NHS clusters explain a considerable share of the variation in primary school quality (30%).

Doctors move to HOs that, on average, are 70 kilometers away from their residential address before the job move, although the median distance to the new HO for the movers is substantially shorter and equal to 44 kilometers (see also Appendix Figure B2a). Doctors generally move to hospitals located within the same NHS administrative region as that of their hospital of origin (see Appendix Table B1). Only 13% of the doctors move to the closest HO, and around 35% of the doctors move to one of the closest five HOs to their residential postcode (Appendix Figure B2b). Appendix Table B2 shows transition patterns across HOs based on the HO attribute distributions. Doctors move to: HOs in the same or

[14]For each attribute x_{hr} in hospital h in NHS region r, we specify the one-way random-effects ANOVA model $x_{hr} = \mu + \eta_r + \zeta_{hr}$, respectively where: hospital $h \in H$, the set of Acute care HOs in the English NHS, and region $r \in R$, the NHS regions, μ is the overall mean, η_r and ζ_{hr} are independent random variables with variance σ^2_η and σ^2_ζ.

lower mortality quartiles; HOs paying higher LCEAs, excluding doctors in the first LCEA quartile; HOs with higher school ratings, especially for doctors moving from HOs located in the top two quartiles of the school rating distribution; HOs located in low crime and prevalently non-rural areas.

4.2 Main regression estimates

Table 2 reports the main estimation results. *Panel A* provides the estimated marginal utilities based on Conditional (columns 1 and 2) and Mixed (columns 3 and 4) logit models, with the specifications in columns 2 and 4 including the control function correction for HO mortality. The estimated workers' preferences for HO attributes are consistent both in sign and magnitude across different models: lower risk-adjusted mortality increases doctors' utility; the same applies to higher LCEA payments. School quality rating and high crime neighborhoods are both negatively signed, although these marginal (dis)utilities are imprecisely estimated. Instead, rural HOs significantly decrease doctors' utility, highlighting a general distaste over employers located in either rural or remote areas (see also Bolduc et al. 1996 and Holmes 2005b).

In models (2) and (4), the association with the first-stage control function residuals, subsumed by the marginal utility coefficient attached to $\hat{\nu}_{hr,t-1}$ from Eq. (5), is positive and marginally significant (p <0.10), consistently with the hypothesis of persistent physicians' transfers to higher-quality HOs.[15] Compared to the models without a control function correction, the magnitude of the estimated marginal utilities of HO mortality increases by about 45%, and the marginal utility of LCEA payments shrinks by almost 7.5%.

The estimate of the coefficient on the control function residuals in the choice models suggests that observed risk-adjusted hospital mortality and unobserved hospital attributes are likely negatively correlated. This result can be explained by the fact that hospitals with "better" unobserved attributes (either job or non-job related) may be more appealing

[15] Appendix Table B3 reports the control function first stage regression estimates for the coefficient vectors (λ_1, λ_2) from Equation (5).

and able to attract more doctors from other hospitals, despite a higher risk-adjusted HO mortality.[16] While in many studies of demand for differentiated products (Berry et al., 1995; Nevo, 2000) the endogeneity problem biases the estimates of wage (or price) elasticities by reversing the sign of the associations of interest, in our setting it appears to work as an attenuation bias, leading to the underestimation of the doctors' disutility for HO mortality. Interestingly, we also find that the CL model estimates are virtually indistinguishable and preferable to the Mixed Logit model estimates, given the lower BIC and the fact that we cannot reject the IIA: for this reason, we take the CL model with control function correction (column 2) as our preferred model hereafter.

In *Panel B* of Table 2, we show that based on our preferred model (column 2) doctors are willing to travel 5.3 extra kilometers for a one SD reduction in the HO mortality differential (around 1.9 percentage points, pp), and about 5 extra kilometers for a one SD increase in LCEA payments, which is worth approximately £1,240 per year (see Table 1). The willingness-to-move (WTM) for accessing better primary schools is negative, but not significant at 5% level. In Panel C we quantify the HO Quality-Pay trade-off: according to our preferred model (column 2), senior doctors are willing to accept a decrease in hospital quality equal to 1.78pp higher HO mortality for a one SD increase in LCEA payments.

4.2.1 Selection on observables with respect to non-movers

By comparing doctors that move across HOs with doctors who rather remain in their HOs (see Appendix Table B4), we notice that movers and non-movers have different demographic and professional profiles. Hence, there may be concerns that our estimates are representative only of NHS physician movers' preferences. To ascertain the severity of this issue and whether this biases our main estimates, we employ a Coarsened Exact Matching (CEM) strategy (Iacus et al., 2012) that matches mover and stayer doctors based on observable characteristics: (i) in each year, we match the movers to the stayers in the same HO and with

[16] See Costa et al. (2023) for a similar instance, but applied to primary physician wages.

the same demographic and professional characteristics; (ii) we retrieve the estimated CEM weights; (iii) we apply the CEM weights to the movers in the discrete choice models, and provide estimates that are representative of the overall population of NHS hospital doctors (i.e. both movers and stayers). The CEM-weighted estimates are reported in Table 3; the table depicts a pattern of results for the marginal utilities of interest similar to the one obtained from the unweighted sample.[17] Moreover, we notice that when using the CEM weights and the CEM-preprocessed sample, the estimates of coefficients of the control function residuals (in columns 2 and 4) are both significant at 5% level, thus confirming the validity of the control function strategy used to control for the reverse causality bias in the estimates of interest for hopsital organization quality.

4.2.2 Mobility preferences by physician's gender, age and medical specialty

In Figure 1 we explore the heterogeneity of NHS senior hospital doctors' WTM with respect to three dimensions – gender, age groups and medical specialties – by estimating separately our preferred CL model with control function correction by movers' subgroups.[18]. Figure 1(a) reports estimated mobility trade-offs based on age-gender demographics.

The WTM point estimate for a 1 SD reduction in HO mortality is generally positive, statistically significant and decreasing in workers'age, respectively around 10km for both male and female doctors up to 39 years old (y.o.) and in the 5km-10km range for male and female doctors in the 40-49 y.o. category. The higher attractiveness of higher quality HOs for younger hospital doctors can be explained by the preference to minimize professional risks in the earlier part of their tenured medical career.

The WTM for a 1 SD increase in HO LCEA payments is positive and statistically significant for male and female doctors; interestingly, the WTM for LCEA payments trends slightly upwards for older female physicians, and downwards for male physicians, which is consistent with female doctors enjoying more freedom from household and child-rearing duties (hence

[17]Post-matching and weighted comparisons with the application of CEM algorithm are reported in Appendix Table B4.
[18]The full set of point estimates are reported in Appendix Table B5 and Appendix Table B6

being less constrained to move across HOs) as they grow older.

The WTM point estimate for a 1 SD increase in primary school ratings is positive for female doctors, at 4.7 extra kilometers for the ones aged below 40 y.o., while it decreases and becomes null for older groups; the same WTM is positive but less significant for male doctors aged below 40 y.o., and significantly negative for other male physicians' age categories, once again highlighting gender differences in both preferences and household constraints. As reported in Panel C of Appendix Table B5, young male doctors appear to be slightly more responsive to monetary incentives than young female doctors, as they are willing to accept higher HO mortality levels for a one SD increase in LCEA payments, despite these quality-pay trade-offs are mostly imprecisely estimated for female physicians.

Figure 1(b) reports the WTM point estimates with respect to HO/location characteristics computed separately for HO physicians working in the largest four medical specialty groups: General Medicine, Surgery, Acute Care Medicine and Pathology. Surgeons are the most averse doctors to mortality, with a 12-km WTM ($p < 0.01$) for a one SD reduction in HO mortality, followed by Pathology doctors with a 5-km WTM for HO mortality reduction. As expected, surgeons have the highest WTM with respect to HO quality, as they are likely the hospital doctors whose professional reputation and career can be more negatively affected by higher HO mortality. The WTM for a one SD increase in LCEA pay is positive and significant across all these different specialties, ranging from 3 to 6km. The WTM for a one SD in primary school quality is generally negative, with the exception of pathologists, but never significant at 5% level.

4.2.3 Mobility preferences using an expanded set of employer attributes

In Table 4 we provide additional results based on the control function augmented CL model and using a broader set of HO attributes.[19] The specification in Column 1 includes HO teaching status, a time-invariant institutional characteristic. HO teaching status is a positive

[19] Appendix Table B8 reports the first stage regressions for the CL choice models including these HO attributes.

pull factor (0.514; $p < 0.01$) to attract physicians, probably because of the reputational gains entailed by an affiliation with a university medical school.

Column 2 specification includes the number of private HO provider sites (ISP; Independent Sector Providers) within a 30 km radius from each NHS HO to the main specification: the marginal utility for ISPs is negative but not significant; the WTM estimates for a one SD decrease in HO mortality are slightly smaller than those reported in Table 2, but with 95% confidence intervals overlapping and including the Table 2 point estimates; instead, the WTM estimates for a one SD increase in HO LCEA payments are slightly larger than those reported in Table 2, but again the 95% confidence intervals overlap with and include the Table 2 point estimates.

Finally, Column 3 specification includes the natural logarithm of house prices to the main specification, in order to account for residential affordability. The resulting WTM estimates for a one SD change in either LCEA pay or HO mortality are very similar to those reported in Table 2. Ceteris paribus, HO doctors show a negative marginal utility in (log) average house prices of the residential area around the hospitals (marginal utility$= -0.329; p < 0.05$), and we estimate a 4.7 km WTM for a one SD reduction in log house prices. As the latter variation represents a very large reduction in the cross-sectional level of *actual* house prices, which is rather unlikely to occur, this result shows that house prices are a relevant yet secondary-level factor in physicians' churn decisions.

4.2.4 Counterfactual analysis: can improvements in hospital organization quality and pay reduce hospital doctor vacancy rates?

We then use the estimates from our preferred model to predict the effects on regional vacancy rates of simulated changes in average regional hospital mortality and bonus LCEA pay. We perform this exercise for each of the seven administrative regions of NHS England - whose geographical distribution is shown in Figure 2. Assuming that shifts in both mortality and bonus pay did not affect doctors' retention between 2012 and 2019, we show how changes in either or both characteristics at the same time may have cumulatively affected regional vacancies (on average) in 2019.

We consider the following three scenarios: (i) a mortality reduction by 25% across all regional HOs each year; (ii) a LCEA pay increase by 25% across all regional HOs each year, (iii) both a mortality reduction by 25% and a LCEA pay increase by 25% across all regional HOs each year. For each NHS region, we predict doctors' HO choices under the above scenarios, and calculate the number of doctors that would have moved to a HO in that specific region.[20] Based on such counterfactual distribution of doctor mobility choices to HOs, we compute how many doctors a given NHS region would have additionally attracted with respect to the actual distribution, thereby retrieving the percentage change in regional vacancies (as of 2019) implied by each scenario.

Table 5 reports the actual 2019 average quarterly vacancy rates and vacancies per region, together with the percentage change in vacancies associated with the simulated counterfactual scenarios. According to the results in Column 3, if all the HOs in a given region had a 25% mortality reduction with respect to the actual values, most regions would have experienced around 0.5-1.3% reduction in HO physician vacancies, with exception of a -4.6% of vacancies in the South West England region. A +25% increase in the average LCEA monetary amount would have resulted in regional HO doctor vacancy rates to decrease between 1.5% and 8.3% depending on the NHS administrative region (Column 4). Finally, a combined effect of lower mortality and higher LCEAs (Column 5) would have produced decreases in regional doctor vacancies ranging from 2.3% (Midlands) to 11% (South West).

[20]See Appendix C for a discussion on the predictive accuracy of our CF-augmented CL model, with a specific assessment of region-level predictions in Appendix Table C1.

5 Robustness checks and additional analyses

5.1 Mixed Logit alternative estimation settings

We test the sensitivity of the baseline Mixed Logit estimates to different model settings, with results reported in Appendix Table 6. Columns 1 and 2 show the estimated Mixed Logit model coefficients obtained with respectively 150 and 200 Halton draws for the unobserved individual random-effects, a larger number of draws than the 100 draws used for the estimation of Table 2 columns 3 and 4 specifications.

Column 3 reports estimates from a Mixed Logit model with Correlated Random Effects (CRE) among HO attribute-specific utility coefficients, which allows for any correlation pattern, including both scale heterogeneity and heterogeneity due to behavioural phenomena.[21] The WTM estimates for HO mortality and LCEA pay from the alternative Mixed Logit models are all very similar, both in magnitude and precision, to the estimates using the baseline Mixed Logit and CL models. The CRE ML model highlights both a larger disutility from higher HO mortality (WTM amounts to almost 6.5km) as well as greater heterogeneity in doctors' preferences over mortality, LCEA payments and school quality than the uncorrelated ML models in Table 2.

5.2 Mobility preferences of outside-London physicians

The geography of English NHS hospital organizations is highly concentrated in the Greater London NHS region, with 28 acute hospital organizations operating in this region – corresponding to about 20% of all English NHS acute HOs. As distances within the Greater London area are considerably shorter than distances in other English regions, a possible con-

[21] Scale heterogeneity is the influence of unobserved factors on an individual's choices, which can differ between them. On one hand, if observed factors are the main drivers of choices and thus unobserved heterogeneity plays a minor role, utility coefficients are large in magnitude. On the other hand, the choices influenced mainly by omitted factors are expected to produce small coefficients. Hence, the scale of the specific utility differs between individuals, and those whose marginal utilities are larger (or smaller) than their corresponding means consequently present correlated coefficients. Behavioural traits may also affect the correlation between utility coefficients: for example, doctors who prefer low-mortality hospitals can also be valuing hospitals with higher local rewards, creating a positive correlation between random mortality and LCEA coefficients.

cern is that the mobility preferences of hospital doctors originally employed in HOs located in the Greater London area differ from those of hospital doctors originally employed in other England regions. To check for this possible source of heterogeneity, in Table 7 we report estimates for CL and Mixed Logit models (both including the control function correction) in which we have excluded from the sample all the movers from and within the Greater London NHS area. As such, the estimates reported in Table 7 represent the preferences and marginal rate of substitution for hospital physicians who are orginally employed in NHS regions other than Greater London, and move to HOs in any NHS region, i.e. either Greater London or outside the Greater London region.

By and large, the estimates of this alternative model confirm the main results: senior hospital doctors prefer lower-mortality and higher-LCEA paying HOs. The WTM point estimates for a one SD reduction in HO mortality are slightly lower in magnitude than those in Table 2, but with substantially overlapping 95% confidence intervals, whereas the WTM point estimates for a one SD increase in HO LCEA payments are greater than those in Table 2; as a result, the quality-pay trade-off between HO quality and LCEA performance-related payments is almost 1 percentage point higher in magnitude compared to the trade-off reported in Table 2, which means that hospital doctors originally employed in outside-London HOs are willing to accept lower HO quality for a one SD increase in LCEA payments.

5.3 Mobility choices including hospital specialty doctors

Table 8 displays the marginal utilities estimated using alternative samples of movers, which include also the subgroup of Specialty and Associate Specialty (SAS) doctors. The SAS doctors' contract generally offers more geographic stability and better work-life balance than that of hospital consultants, for instance by requiring more regular working hours. Moreover, SAS doctors require a shorter training programme to practice and have different clinical duties than hospital consultants. Specifically, SAS doctors primarily focus on the provision of direct patient care and they are less involved in other clinical responsibilities within the hospital.[22] For these reasons, they may present different preferences over the hospital attributes examined in this study.

First, we estimate our baseline specification using a sample of 1232 moving SAS doctors only (Columns 1 and 2). In doing so, we exclude the amount of hospital LCEA payments from the set of attributes, since SAS doctors are not eligible for this type of clinical excellence premia. Instead, in Columns 3 and 4 we use a larger sample which comprises both moving hospital consultants and SAS doctors, in order to estimate a variant of our baseline model in which both the risk-adjusted mortality rate and the amount of LCEA payments have been interacted with indicators for the two different doctor roles.[23] The results indicate that SAS doctors are overall less responsive to the hospital performance than hospital consultants, highlighting how policies aimed at reducing hospital vacancy rates by leveraging over hospital quality indicators should be calibrated to the type of prospective doctors that hospital managers intend to hire.

5.4 Mobility choices by employer of origin's quality and incentive pay

Both the conditional and mixed logit models do not explicitly take into account the characteristics of the origin hospital organization, which may matter for doctors' mobility choices if HO attributes have a large variation range. For instance, hospital physicians moving from a low-quality hospital may be particularly responsive to the quality performance of prospective hospital organisations. To test this hypothesis, columns 1 and 2 of Table 9 provide estimates of an augmented version of our model, in which we interacted the risk-adjusted mortality rate variable with two binary indicators equal to one when the mortality rate of the origin HO was respectively below or above the yearly sample median. The point estimates indicate

[22]Further information on SAS doctors can be retrieved at: https://www.healthcareers.nhs.uk/explore-roles/doctors/career-opportunities-doctors/sas-doctors.

[23]The total amount of movers is not equal to the sum of moving SAS and consultant doctors, as 118 physicians appear in both samples having transitioned over time from a SAS doctor contract to a consultant doctor contract.

that physicians moving from low-mortality hospitals have a slightly higher WTM with respect to HO mortality; however, the 95% confidence intervals largely overlap with the WTM of doctors moving from a high-mortality HOs. Therefore, hospital risk-adjusted mortality represents a generally relevant pull factor for tenured physicians, regardless of the quality level of the organization they are moving from.

We provide a similar exercise in columns 3 and 4 of Table 9, where the the LCEA payments variable has been interacted with two indicators for HOs that respectively were less or more generous with clinical excellence awards than the median HO in the same year. This specification documents a significantly high responsiveness to pay incentives among doctors moving from hospitals with an already high level of LCEA payments: moving from a HO belonging to the upper half of the LCEA payments distribution is associated with a WTM twice as large as compared to the WTM of movers from a HO in the lower half of the LCEA distribution (6.7km as opposed to 3.3km). This finding suggests that doctors used to receive pay incentives based on clinical excellence consider this pay component as a very relevant job amenity, when formulating their moving decisions across hospital organizations, and are keen to preserve their acquired income levels.

5.5 Doctor's mobility based on admission-specific HO mortality

In many sectors of the economy, the quality of the products or services produced by an organization is not unidimensional, and it may depend on the different product lines or categories of products offered to end customers; for example, a car manufacturer may be considered excellent in its 'city cars' product range, and poor in its 'sports car' product range. Within hospital care, a relevant categorization of services is provided by the 'nature' of patient admissions treated by physicians, i.e. *emergency* versus *planned* treatments. According to Appendix Figure B3, within the same NHS HO most senior doctors (over 75% of the total) treat both emergency and planned patients, whereas less than 10% of senior doctors treat exclusively emergency patients, and 11%-14% of senior doctors treat exclusively planned patients. Nevertheless, it is possible that senior doctors' utility is a function which responds heterogeneously to different domains of HO objective quality of services to patients.

To test such hypothesis, we estimate alternative specifications that model doctor's utility to join a HO as a function of both the risk-adjusted HO mortality rates for emergency treatments and the risk-adjusted HO mortality rates for planned treatments, included in the model as separate HO attribute.[24]

Table 10 provides the estimates from the CF-augmented choice models, with control function first stages respectively for HO emergency and HO planned mortality reported in Appendix Table B11. When we consider admission-specific HO quality, differently from the main estimation results, the control function Mixed Logit model is preferable to the control function Conditional Logit model, given that the IIA test is rejected.[25] The specification in column 4 not only confirms the importance of HO quality and performance related pay as factors to attract hospital physicians, but it also retrieves willingness-to-move estimates that are larger than those associated with the baseline model: up to 6.4 kilometers for a 1 SD reduction in emergency HO mortality and up to 13.3 kilometers for a 1 SD reduction in planned HO mortality. According to the same model, we estimate a 3.5 kilometers WTM for a 1 SD increase in LCEA pay; relatedly, the quality-pay trade-offs are shown in Panel C of Table 10: HO physicians are willing to trade a 1 SD increase in LCEA payments with a 2.3% and 0.88% higher HO mortality respectively for emergency and planned admissions.

These results add further nuances to the main policy implications of our study. First, based on the control function Mixed Logit WTM estimates (column 2 in Table 10), if we account for observed heterogeneity in HO quality and unobserved heterogeneity in workers' mobility preferences, HO quality might be a much stronger pull factor to attract hospital physicians than originally estimated, in particular when we assume a single homogeneous measure of HO quality. It follows that HO managers and healthcare policy-makers might

[24]The risk-adjusted HO mortality rates for emergency and planned treatments are constructed from the patient-level HES APC data, by splitting the overall sample in each year according to the initial category of hospital admission. As reported in Appendix Table B10, the HO emergency risk-adjusted patient mortality and HO planned risk-adjusted patient mortality are only moderately correlated, with an average yearly correlation of 0.185 over our study period.

[25]However, no strict superiority can be assessed based on AIC and BIC of the two estimated models.

have more room for reducing hospital physician vacancies by raising the level of HO quality: as shown in Table B12, in some NHS administrative regions a one SD reduction in HO mortality for both emergency and planned admissions would result in larger decreases in HO physician vacancy rates compared to the baseline counterfactual simulation estimates (Table 5).

Moreover, under this scenario the option to incentivize hospital physicians to move to lower quality hospital organizations through the allowance of more generous performance-related LCEA payments becomes marginally more complex: the marginal rate of substitution between LCEA pay and HO mortality remains virtually unchanged with respect to the results in Table 2 if we consider the additional compensation for moving to HOs with higher emergency mortality ($QPTO = 2.3$), but it largely reduces when we consider the additional compensation for moving to HOs with higher planned mortality ($QPTO = 0.88$). Nevertheless, these patterns likely also reflect the fact that HO emergency risk-adjusted mortality drives the distribution and the variation of the overall HO risk-adjusted mortality variable used in the main choice models with a single mortality measure, and so variation is HO risk-adjusted planned treatment mortality is rarer and so more expensive to compensate.

6 Conclusions

Hospital doctors' recruitment and retention have been primary organizational issues on the NHS agenda over the last decade. While the economics literature has so far focused on studying measures to prevent high turnover rates among the medical staff, there has been less attention to understanding how healthcare providers can successfully attract new doctors to join their workforce, especially in developed countries. Our paper fills this gap by considering the role of organizational attributes of potential interest for the medical staff employed in hospitals, using a revealed-preference framework and the universe of mover tenured doctors in English NHS acute care hospital organizations.

We provide new insights about the pull factors that attract skilled-workers to firms within the same sector, with evidence of a utility-maximising behaviour by doctors who change hospital organisation within the NHS hospital care sector. Doctors who leave their current NHS hospital organisation for another public healthcare provider tend to value workplaces characterized by higher quality to customers (i.e. lower risk-adjusted patient mortality) and higher performance-related salary payments. Reputation may play also a role in skilled workers mobility choices, as we find that doctors prefer hospital organizations embedding medical schools. Local amenities, such as primary school quality, have only a secondary relevance in doctors' mobility choices, although they do seem more important for younger doctors, especially female ones. An important caveat in the interpretation of our results is that there may be other relevant factors at play in skilled workers' mobility decisions across alternative employers – such as the financial and psychological costs of mobility choices – which we cannot control for in our data: as shown by Bayer et al. (2016), the omission of such costs would lead to a downward bias in the estimated preference parameters. For such reason, and also taking into account recent evidence showing that workers have myopic beliefs when evaluating their job outside options (Jäger et al., 2024), our estimates can be likely deemed conservative and provide a lower bound for hospital doctors' – and, possibly and more generally, for skilled workers' – mobility preferences with respect to employer organizational quality and performance-related pay.

Our study has three main policy implications, at organizational and managerial level. First, on top of performance-related pay, skilled workers care for organizational quality, defined as the quality of services provided to their end customers; this factor must be taken into account by staff managers who are keen to attract and retain talents within their organization. Second, reducing any existing imbalance in medical staff across NHS hospitals requires not only understanding the relevance of non-monetary retention determinants, as established in the literature that investigates healthcare workforce retention (Kelly et al., 2022b; Moscelli et al., 2024c, 2023), but also the pull factors affecting recruitment. Indeed, the factors that drive job separations and retention decisions within the current workplace may be essentially different, or at least not completely overlapping, from the factors that drive the decision where to move. Third, there is scope for hospital managers to reduce physician vacancy rates by improving hospital attributes that clinical workers value, such as hospital quality and performance-related pay. However, these vacancy rate reductions would be insufficient to fully offset the severe hospital doctor shortages that characterizes most of the healthcare systems in Western countries.

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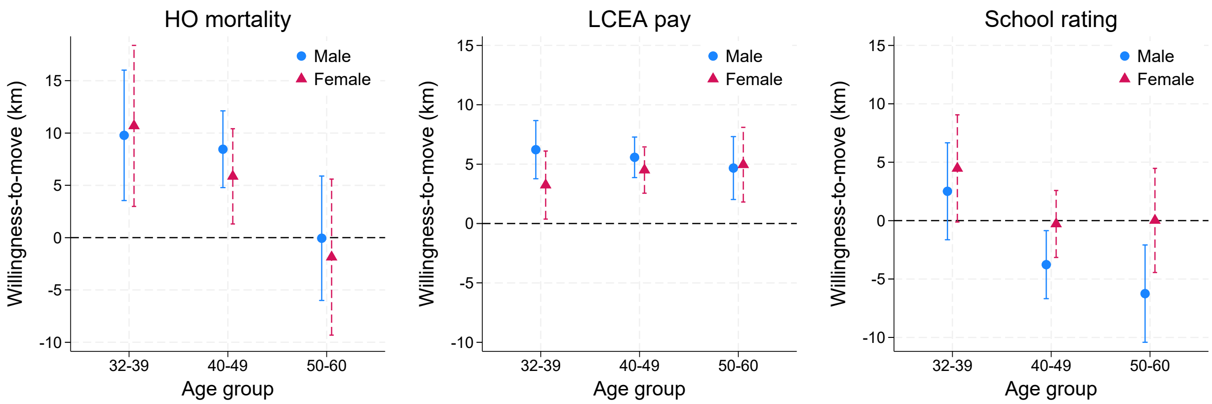
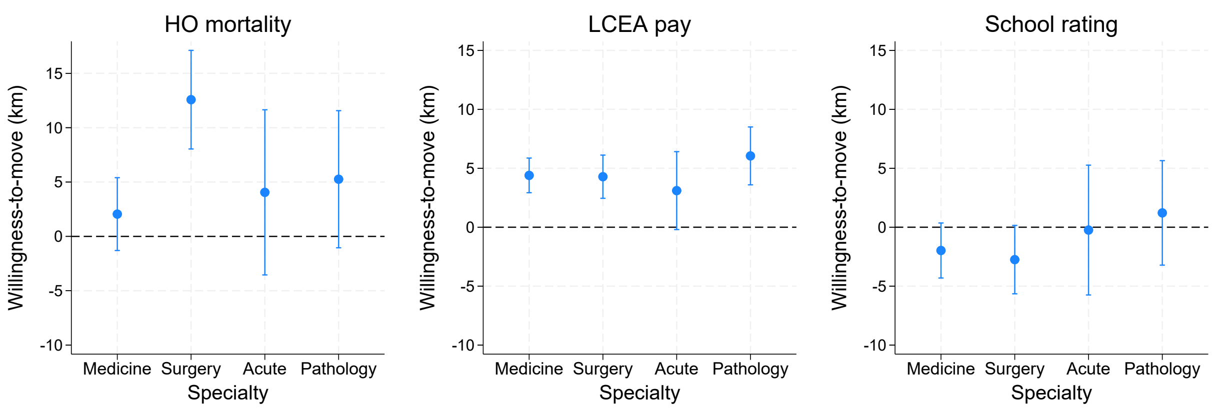
Tables and Figures

Figure 1. Physician willingness-to-move estimates by gender, age groups and medical specialties

(a) WTM estimates by demographic groups

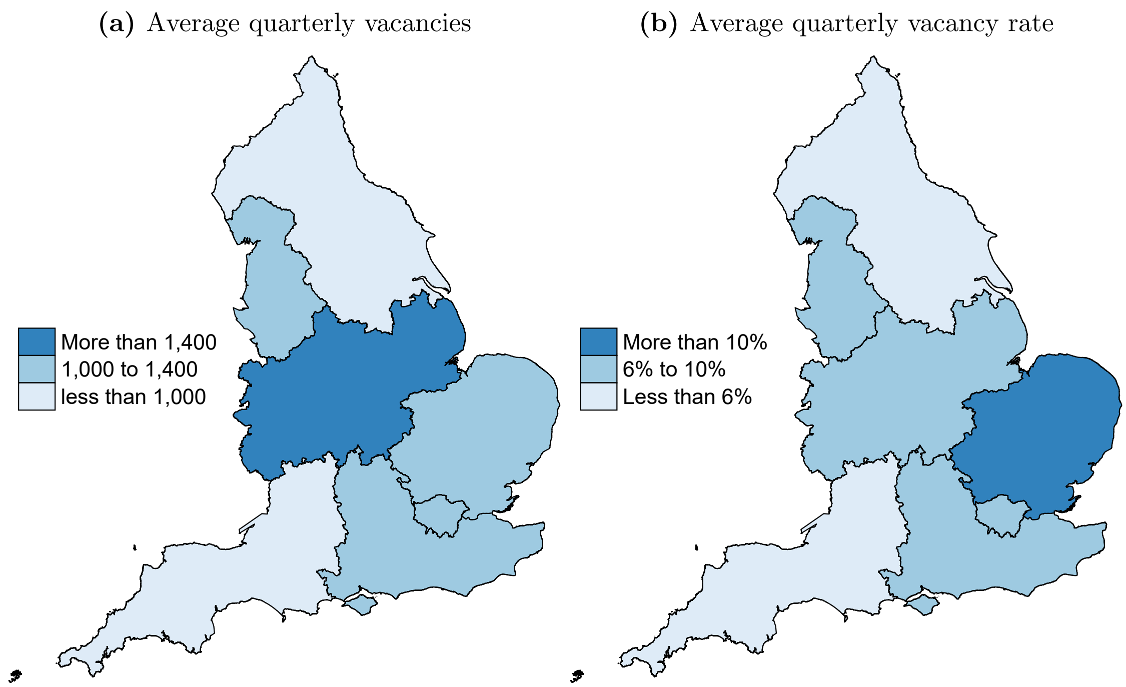


(b) WTM estimates by medical specialties



Notes. Willingness-to-move (WTM) from CF-augmented conditional logit models estimated on sub-samples of doctors, split by demographics and medical specialties (General Medicine, Surgery, Acute Care Medicine, Pathotology). Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. The vertical lines represent 95% confidence intervals for the coefficient estimates. Standard errors are estimated using the delta method (Hole, 2007).

Figure 2. NHS England vacancies 2019



Notes. Medical vacancies FTE (excluding mental health positions) from the NHS England 2023 report. The reported vacancies show the average difference between funded establishment posts and those filled by substantive staff (and associated vacancy rates). Authors' own calculations from NHS England Vacancy Statistics. Original data on vacancies available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-vacancies-survey/april-2015---december-2022-experimental-statistics#.

Table 1. Summary statistics.

	A. Mover Senior hospital Doctors					
	All		Male		Female	
	Mean (1)	SD (2)	Mean (3)	SD (4)	Mean (5)	SD (6)
Female	0.405	0.491				
Age ≤39	0.345	0.475	0.322	0.467	0.379	0.485
Age 40-49	0.506	0.500	0.507	0.500	0.504	0.500
Age ≥50	0.149	0.356	0.171	0.377	0.116	0.321
White	0.479	0.500	0.436	0.496	0.541	0.498
Non-white	0.407	0.491	0.439	0.496	0.360	0.480
British	0.657	0.475	0.655	0.476	0.662	0.473
Non-British	0.290	0.454	0.293	0.455	0.286	0.452
CEA recipient	0.176	0.381	0.200	0.400	0.140	0.347
Surgery	0.282	0.450	0.360	0.480	0.168	0.374
General Medicine	0.373	0.484	0.346	0.476	0.413	0.492
Acute Care Medicine	0.062	0.241	0.069	0.254	0.051	0.219
Pathology	0.096	0.294	0.072	0.259	0.130	0.336
Number of Movers	4,983		2,965		2,018	

	B. Hospital Organizations Attributes ($N = 1050$, HOs×years)				
	HO mortality (mortality %) (1)	Local CEA (£1,000) (2)	Primary school rating$^{(a)}$ (1-4 scale) (3)	High crime (binary) (4)	Rural (binary) (5)
B1. Attribute statistics					
Mean	2.885	4.135	1.921	0.038	0.053
SD	1.871	1.237	0.145	0.192	0.225
10^{th} percentile	2.068	2.779	2.120	0	0
50^{th} percentile	2.724	4.161	1.903	0	0
90^{th} percentile	3.289	5.536	1.755	0	0
B2. Cross-correlations					
Local CEA	-0.229***	1			
Primary school rating$^{(a)}$	-0.088	-0.011	1		
High crime	-0.013	-0.021	-0.132***	1	
Rural	-0.090	-0.001	-0.093	-0.047	1
B3. Random-effects ANOVA					
Intra-class correlations	0.036	0.056	0.301	0.015	0.059

Notes. Panel A: characteristics for senior doctors working in NHS HOs in the period 2013-2019, aged 32-60 y.o. at their first observed move. Panel B: statistics of the main HO attributes used in our empirical analysis; Panel B1: mean, standard deviation and percentiles of the distribution of such attributes; Panel B2: pairwise Pearson correlations among HO attributes; Panel B3: intra-class correlation coefficients at NHS regions level, i.e. the proportion of variance of each HO attribute that is due to variation between NHS regions, obtained through one-way random-effects ANOVA models. Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$ (Bonferroni-adjusted p-values). $^{(a)}$The rating of the primary school quality variable has been inverted and reported from lowest to highest average rating, with 1 for "Inadequate" and 4 for "Outstanding" school ratings, to ease interpretation of results.

Table 2. Physicians' estimated preferences over hospital organization and residential attributes

	(1)	(2)	(3)	(4)
	Cond. Logit	Cond. Logit + CF	Mixed Logit	Mixed Logit + CF
A. *Marginal utilities (coefficients)*				
HO mortality	-0.0621***	-0.0900***	-0.0623***	-0.0901***
	(0.0106)	(0.0205)	(0.0092)	(0.0188)
LCEA payments	0.1401***	0.1297***	0.1392***	0.1289***
	(0.0103)	(0.0119)	(0.0103)	(0.0120)
School quality rating	-0.2877*	-0.2857*	-0.1383	-0.1374
	(0.1652)	(0.1610)	(0.1724)	(0.1724)
High crime neighborhoods	-0.0353	-0.0430	-0.0341	-0.0419
	(0.0714)	(0.0697)	(0.0716)	(0.0720)
Rural	-0.7609***	-0.7860***	-0.7453***	-0.7705***
	(0.0894)	(0.0894)	(0.0900)	(0.0914)
Distance (in 10s km)	-0.5303***	-0.5304***	-0.5350***	-0.5350***
	(0.0239)	(0.0240)	(0.0244)	(0.0244)
Distance^2 (in 100s km)	0.0170***	0.0170***	0.0172***	0.0172***
	(0.0018)	(0.0017)	(0.0018)	(0.0018)
Distance^3 (in 1000s km)	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
1^{st} stage Control Function residuals		0.0379*		0.0375*
		(0.0227)		(0.0222)
σ(HO mortality)			0.0070	0.0086
			(0.0362)	(0.0471)
σ(LCEA payments)			0.0004	0.0004
			(0.0005)	(0.0005)
σ(School quality rating)			-2.0412***	-2.0340***
			(0.4275)	(0.4288)
σ(High crime neighborhoods)			-0.0602	-0.0603
			(0.0554)	(0.0555)
σ(Rural)			-0.0527	-0.0537
			(0.0719)	(0.0721)
B. *Willingness-to-move (km)*				
Extra distance for -1 SD in HO mortality	3.657***	5.301***	3.641***	5.266***
	(0.624)	(1.203)	(0.534)	(1.098)
Extra distance for +1 SD in LCEA pay	5.452***	5.049***	5.377***	4.980***
	(0.419)	(0.475)	(0.419)	(0.480)
Extra distance for +1 SD in school rating	-1.314*	-1.304*	-0.627	-0.623
	(0.754)	(0.734)	(0.782)	(0.782)
C. *Quality-pay trade-off (in risk-adjusted mortality percentage points)*				
Extra HO mortality for +1 SD in LCEA pay	2.790***	1.782***	2.763***	1.770***
	(0.568)	(0.510)	(0.507)	(0.484)
NHS regional time trends	Yes	Yes	Yes	Yes
IIA test: LR χ^2			6.948	6.865
IIA test: p-value			0.225	0.231
AIC	43665	43664	43668	43667
BIC	43827	43838	43889	43900
Movers	4983	4983	4983	4983
N (= movers × alternative HOs in choice set)	831085	831085	831085	831085

Notes. Panel A reports conditional and mixed logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. Coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped in column 2 (500 replications). Panel B and C report the willingness-to-move and quality-pay trade-off from conditional and mixed logit models. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 3. Physicians' estimated preferences based on CEM reweighted sample

	(1)	(2)	(3)	(4)
	Cond. Logit	Cond. Logit + CF	Mixed Logit	Mixed Logit + CF
A. *Marginal utilities (coefficients)*				
HO mortality	-0.0442***	-0.0969***	-0.0690***	-0.1241***
	(0.0155)	(0.0274)	(0.0132)	(0.0256)
LCEA payments	0.1619***	0.1422***	0.1587***	0.1385***
	(0.0134)	(0.0159)	(0.0135)	(0.0160)
School quality rating	-0.3577*	-0.3540	-0.2103	-0.2092
	(0.2174)	(0.2172)	(0.2233)	(0.2233)
High crime neighborhoods	0.0010	-0.0123	0.0066	-0.0071
	(0.0918)	(0.0923)	(0.0920)	(0.0924)
Rural	-0.7661***	-0.8127***	-0.7673***	-0.8163***
	(0.1071)	(0.1088)	(0.1076)	(0.1092)
Distance (in 10s km)	-0.5465***	-0.5466***	-0.5514***	-0.5515***
	(0.0276)	(0.0276)	(0.0283)	(0.0283)
Distance^2	0.0173***	0.0173***	0.0175***	0.0175***
	(0.0020)	(0.0019)	(0.0020)	(0.0020)
Distance^3	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
1^{st} stage Control Function residuals		0.0719**		0.0735**
		(0.0290)		(0.0290)
σ(HO mortality)			-0.0636***	-0.0652***
			(0.0201)	(0.0196)
σ(LCEA payments)			-0.0014	-0.0014
			(0.0012)	(0.0012)
σ(School quality rating)			2.1103***	2.0932***
			(0.4975)	(0.5003)
σ(High crime neighborhoods)			-0.0253	-0.0252
			(0.0469)	(0.0466)
σ(Rural)			-0.0687	-0.0712
			(0.0825)	(0.0836)
B. *Willingness-to-move (km)*				
Extra distance for -1 SD in HO mortality	2.506***	5.495***	3.882***	6.982***
	(0.874)	(1.556)	(0.742)	(1.452)
Extra distance for +1 SD in LCEA pay	6.069***	5.330***	5.907***	5.153***
	(0.526)	(0.610)	(0.529)	(0.611)
Extra distance for +1 SD in school rating	-1.573	-1.557	-0.918	-0.913
	(0.957)	(0.956)	(0.976)	(0.976)
C. *Quality-pay trade-off (in risk-adjusted mortality percentage points)*				
Extra HO mortality for +1 SD in LCEA pay	4.532***	1.815***	2.847***	1.381***
	(1.710)	(0.648)	(0.656)	(0.400)
NHS regional time trends	Yes	Yes	Yes	Yes
Movers	4882	4882	4882	4882
N (= movers × alternative HOs in choice set)	811135	811135	811135	811135

Notes. Panel A reports conditional and mixed logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. Coefficients are marginal utilities. Robust standard errors clustered at the senior doctor level. Panel B and C report the willingness-to-move and quality-pay trade-off from conditional and mixed logit models. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 4. Physicians' estimated preferences with expanded set of attributes.

	(1)	(2)	(3)
	Teaching status	Local private healthcare	Local house prices
A. *Marginal utilities (coefficients)*			
HO mortality	-0.0777***	-0.0768***	-0.0818***
	(0.0194)	(0.0202)	(0.0197)
LCEA payments	0.0569***	0.1345***	0.1321***
	(0.0126)	(0.0119)	(0.0116)
School quality rating	-0.3696**	-0.2016	-0.1550
	(0.1662)	(0.1700)	(0.1666)
High crime neighborhoods	-0.0382	-0.0263	-0.0200
	(0.0698)	(0.0701)	(0.0699)
Rural HO	-0.8420***	-0.7814***	-0.7627***
	(0.0907)	(0.0892)	(0.0898)
Teaching HO	0.5135***		
	(0.0326)		
N. of Private Hospitals (within 30km)		-0.0057	
		(0.0040)	
House prices (log)			-0.3290**
			(0.1281)
1^{st} stage Control Function residuals	0.0130	0.0195	0.0226
	(0.0214)	(0.0226)	(0.0217)
B. *Willingness-to-move (km)*			
Extra distance for -1 SD in HO mortality	4.606***	4.522***	4.822***
	(1.150)	(1.185)	(1.160)
Extra distance for +1 SD in LCEA pay	2.231***	5.236***	5.146***
	(0.495)	(0.476)	(0.464)
Extra distance for +1 SD in school rating	-1.700**	-0.921	-0.708
	(0.762)	(0.775)	(0.761)
Extra distance for -1 SD in house prices (log)			4.743**
			(1.849)
C. *Quality-pay trade-off (in risk-adjusted mortality percentage points)*			
Extra HO mortality for +1 SD in LCEA pay	0.906**	2.166***	1.997***
	(0.368)	(0.689)	(0.587)
NHS regional time trends	Yes	Yes	Yes
AIC	43415	43666	43661
BIC	43601	43852	43847
Movers	4983	4983	4983
N (= movers × alternative HOs in choice set)	831085	831085	831085

Notes. CF-augmented conditional logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. In Panel A coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped (500 replications). Panel B and C report willingness-to-move and quality-pay trade-off. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 5. Effects of simulated regional policies on regional hospital vacancies (FTE).

NHS Region	(1) Vacancy rate (2019)	(2) Vacancies (2019)	Percentage change in year 2019 vacancies (3) HO mortality reduction (-25%)	(4) LCEA pay increase (+25%)	(5) HO mortality reduction (-25%) + LCEA pay increase (+25%)
East of England	0.104	1206	-0.91	-1.49	-3.07
London	0.060	1385	-0.29	-4.77	-5.20
Midlands	0.085	1596	-0.81	-1.57	-2.32
North East and Yorkshire	0.054	929	-1.29	-4.95	-7.86
North West	0.078	1104	-0.54	-2.17	-2.45
South East	0.069	1106	-0.63	-2.26	-3.34
South West	0.036	410	-4.64	-8.30	-10.99

Notes. Counterfactual effects on the distribution of vacancies across NHS England regions of different simulations. We use the CF-augmented conditional logit model. Columns 1 and 2 show the actual distribution of average medical vacancy rates and vacancies FTE (excluding mental health positions) in 2019 as per the NHS England 2023 report. The following columns show the counterfactual effects on the distribution of vacancies if: all region's HOs achieved a 25% mortality reduction since 2012; all region's HOs paid 25% higher LCEA (on average) since 2012; all region's HOs achieved a 25% mortality reduction *and* paid 25% higher LCEA (on average) since 2012.

Table 6. Physicians' estimated preferences from alternative Mixed Logit models.

	(1)	(2)	(3)
	150 Halton draws	200 Halton draws	Correlated Random Effects
A. *Marginal utilities (coefficients)*			
HO mortality	-0.0900***	-0.0897***	-0.1110***
	(0.0196)	(0.0195)	(0.0190)
LCEA payments	0.1289***	0.1289***	0.1268***
	(0.0121)	(0.0120)	(0.0122)
School quality rating	-0.1382	-0.1404	0.0262
	(0.1726)	(0.1726)	(0.1786)
High crime neighborhoods	-0.0438	-0.0405	-0.0698
	(0.0723)	(0.0718)	(0.0947)
Rural	-0.7713***	-0.7694***	-0.8818***
	(0.0921)	(0.0911)	(0.1752)
Distance (in 10s km)	-0.5350***	-0.5349***	-0.5375***
	(0.0244)	(0.0244)	(0.0245)
Distance^2	0.0172***	0.0172***	0.0173***
	(0.0018)	(0.0018)	(0.0018)
Distance^3	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)
CF residuals	0.0375*	0.0375*	0.0409*
	(0.0221)	(0.0222)	(0.0222)
σ(HO mortality)	-0.0073	0.0040	0.0034*
	(0.1723)	(0.0356)	(0.0018)
σ(LCEA payments)	-0.0001	-0.0001	0.0022**
	(0.0003)	(0.0003)	(0.0009)
σ(School quality rating)	2.0229***	2.0106***	7.7143***
	(0.4299)	(0.4355)	(1.7641)
σ(High crime neighborhoods)	-0.0894	0.0133	0.3638
	(0.0562)	(0.0345)	(0.2296)
σ(Rural)	-0.0675	-0.0177	0.5047
	(0.0999)	(0.0659)	(0.4412)
B. *Willingness-to-move (km)*			
Extra distance for -1 SD in HO mortality	5.259***	5.246***	6.463***
	(1.148)	(1.140)	(1.106)
Extra distance for +1 SD in LCEA pay	4.981***	4.984***	4.881***
	(0.481)	(0.480)	(0.485)
Extra distance for +1 SD in school rating	-0.627	-0.637	0.118
	(0.783)	(0.783)	(0.807)
C. *Quality-pay trade-off (in risk-adjusted mortality percentage points)*			
Extra HO mortality for +1 SD in LCEA pay	1.772***	1.777***	1.413***
	(0.500)	(0.499)	(0.340)
NHS regional time trends	Yes	Yes	Yes
AIC	43667	43668	43666
BIC	43900	43900	44015
Movers	4983	4983	4983
N (= movers $\times$ alternative HOs in choice set)	831085	831085	831085

Notes. CF-augmented mixed logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. In Panel A coefficients are marginal utilities. Standard errors are clustered at the doctor level. Panel B and C report willingness-to-move and quality-pay trade-off. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 7. Preference estimates excluding doctors working in London

	(1) Cond. Logit + CF	(2) Mixed Logit + CF
A. *Marginal utilities (coefficients)*		
HO mortality	-0.0720***	-0.0858***
	(0.0232)	(0.0238)
LCEA payments	0.1574***	0.1556***
	(0.0140)	(0.0146)
School quality rating	-0.4390**	-0.3057
	(0.1843)	(0.1936)
High crime neighborhoods	-0.1197	-0.1157
	(0.0869)	(0.0863)
Rural	-0.6637***	-0.6581***
	(0.0929)	(0.0966)
Distance (in 10s km)	-0.5606***	-0.5653***
	(0.0294)	(0.0310)
Distance^2	0.0184***	0.0186***
	(0.0022)	(0.0023)
Distance^3	-0.0002***	-0.0002***
	(0.0000)	(0.0000)
CF 1^{st} stage residuals	0.0300	0.0304
	(0.0259)	(0.0265)
σ(HO mortality)		0.0493
		(0.0309)
σ(LCEA payments)		-0.0011
		(0.0007)
σ(School quality rating)		2.1225***
		(0.4656)
σ(High crime neighborhoods)		-0.0284
		(0.0727)
σ(Rural)		0.0137
		(0.0542)
B. *Willingness-to-move (in km)*		
Extra distance for -1 SD in HO mortality	4.074***	4.815***
	(1.311)	(1.335)
Extra distance for +1 SD in LCEA pay	5.885***	5.774***
	(0.540)	(0.560)
Extra distance for +1 SD in school rating	-1.926**	-1.331
	(0.805)	(0.843)
C. *Quality-pay trade-off (mortality %pt.)*		
Extra HO mortality for +1 SD in LCEA pay	2.703***	2.244***
	(1.022)	(0.757)
NHS regional time trends	Yes	Yes
AIC	31424	31426
BIC	31594	31653
Movers	3750	3750
N (= movers $\times$ alternative HOs in choice set)	614848	614848

Notes. Panel A reports conditional and mixed logit models of choice of hospital for doctors moving in the period 2013-2019. HO attribute variables are lagged by one year. Coefficients are marginal utilities. Standard errors clustered at the doctor level, and bootstrapped (500 replications) for the CL model in column 1. Panel B and C report the willingness-to-move and quality-pay trade-off. Standard errors of trade-off estimates computed using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 8. Physicians' estimated preferences, including Specialty and Associate Specialty (SAS) doctors

	SAS only		Consultants and SAS	
	(1) Cond. Logit + CF	(2) Mixed Logit + CF	(3) Cond. Logit + CF	(4) Mixed Logit + CF
A. Marginal utilities (coefficients)				
HO mortality	-0.0505	-0.0532		
	(0.0336)	(0.0329)		
HO mortality × Consultant			-0.0946***	-0.0952***
			(0.0186)	(0.0177)
HO mortality × SAS			-0.0662***	-0.0663***
			(0.0236)	(0.0232)
LCEA payments × Consultant			0.1339***	0.1332***
			(0.0110)	(0.0117)
LCEA payments × SAS			-0.0662***	-0.0663***
			(0.0236)	(0.0232)
School quality rating	-1.8311***	-1.8276***	-0.6138***	-0.5201***
	(0.3101)	(0.2997)	(0.1445)	(0.1525)
High crime neighborhoods	-0.3302*	-0.3308**	-0.1017	-0.1004
	(0.1689)	(0.1511)	(0.0643)	(0.0648)
Rural	-0.4285***	-1.4460	-0.7287***	-0.7221***
	(0.1615)	(1.5477)	(0.0768)	(0.0802)
Distance (in 10s km)	-0.5670***	-0.5690***	-0.5368***	-0.5396***
	(0.0276)	(0.0282)	(0.0192)	(0.0204)
Distance^2	0.0197***	0.0197***	0.0175***	0.0176***
	(0.0020)	(0.0020)	(0.0014)	(0.0015)
Distance^3	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CF 1^{st} stage residuals	0.0185	0.0206	0.0421**	0.0419**
	(0.0416)	(0.0388)	(0.0197)	(0.0197)
σ(HO mortality)		-0.0007		
		(0.0070)		
σ(HO mortality × Consultant)				0.0129
				(0.0886)
σ(HO mortality × SAS)				-0.0015
				(0.0168)
σ(LCEA payments×Consultant)				0.0001
				(0.0004)
σ(LCEA payments×SAS)				0.0005
				(0.0015)
σ(School quality rating)		-0.0008		1.6016***
		(0.0877)		(0.4459)
σ(High crime neighborhoods)		-0.0194		-0.0356
		(0.0925)		(0.0918)
σ(Rural)		-1.6159		0.1034
		(1.3634)		(0.1197)
B. Willingness-to-move (km)				
Extra distance for -1 SD in HO mortality	2.964	3.109		
	(1.970)	(1.923)		
Extra distance for -1 SD in HO mortality (Consultant)			5.620***	5.631***
			(1.108)	(1.048)
Extra distance for -1 SD in HO mortality (SAS)			3.931***	3.923***
			(1.398)	(1.368)
Extra distance for +1 SD in LCEA pay (Consultant)			5.254***	5.206***
			(0.442)	(0.469)
Extra distance for +1 SD in LCEA pay (SAS)			-2.409***	-2.381***
			(0.789)	(0.795)
Extra distance for +1 SD in school rating	-8.332***	-8.292***	-2.826***	-2.385***
	(1.404)	(1.362)	(0.664)	(0.701)
C. Quality-pay trade-off (mortality %pt.)				
Extra HO mortality for +1 SD in LCEA pay (Consultant)			1.749***	1.730***
			(0.438)	(0.424)
Extra HO mortality for +1 SD in LCEA pay (SAS)			-1.147**	-1.135***
			(0.446)	(0.438)
NHS regional time trends	Yes	Yes	Yes	Yes
AIC	10649	10656	54388	54398
BIC	10792	10840	54590	54683
Movers	1232	1232	6097	6097
N (= movers × alternative HOs in choice set)	199872	199872	1030957	1030957

Notes. Panel A reports conditional and mixed logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. Coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped in column 1 and 3 (500 replications). Panel B and C report mobility and mortality-reward trade-offs from conditional and mixed logit models. Mobility trade-offs are the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 9. Physicians' estimated preferences by origin hospital organization characteristics

	Origin HO mortality		Origin LCEA payments	
	(1)	(2)	(3)	(4)
	Cond. Logit + CF	Mixed Logit + CF	Cond. Logit + CF	Mixed Logit + CF
A. *Marginal utilities (coefficients)*				
HO mortality			-0.0894***	-0.0897***
			(0.0205)	(0.0186)
HO mortality × Low mortality (origin)	-0.0929***	-0.1098***		
	(0.0223)	(0.0218)		
HO mortality × High mortality (origin)	-0.0852***	-0.0863***		
	(0.0228)	(0.0226)		
LCEA payments	0.1298***	0.1275***		
	(0.0119)	(0.0121)		
LCEA payments × Low LCEA pay (origin)			0.0842***	0.0836***
			(0.0151)	(0.0153)
LCEA payments × High LCEA pay (origin)			0.1714***	0.1701***
			(0.0150)	(0.0153)
School quality rating	-0.2859*	-0.1307	-0.2896*	-0.1372
	(0.1610)	(0.1724)	(0.1611)	(0.1725)
High crime neighborhoods	-0.0430	-0.0395	-0.0433	-0.0408
	(0.0697)	(0.0718)	(0.0697)	(0.0718)
Rural	-0.7862***	-0.7774***	-0.7846***	-0.7676***
	(0.0894)	(0.0915)	(0.0894)	(0.0912)
Distance (in 10s km)	-0.5304***	-0.5349***	-0.5306***	-0.5354***
	(0.0240)	(0.0244)	(0.0240)	(0.0244)
Distance^2	0.0170***	0.0172***	0.0170***	0.0172***
	(0.0017)	(0.0018)	(0.0017)	(0.0018)
Distance^3	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
1^{st} stage Control Function residuals	0.0377*	0.0383*	0.0375*	0.0372*
	(0.0227)	(0.0222)	(0.0227)	(0.0221)
σ(HO mortality)				0.0105
				(0.0509)
σ(HO mortality × Low mortality (origin))		0.0561*		
		(0.0293)		
σ(HO mortality × High mortality (origin))		0.0004		
		(0.0006)		
σ(LCEA payments)		0.0002		
		(0.0004)		
σ(LCEA payments × Low LCEA pay (origin))				0.0003
				(0.0006)
σ(LCEA payments × High LCEA pay (origin))				0.0000
				(0.0007)
σ(School quality rating)		-2.0797***		-2.0561***
		(0.4184)		(0.4233)
σ(High crime neighborhoods)		-0.0294		-0.0247
		(0.0559)		(0.0552)
σ(Rural)		-0.0006		0.0019
		(0.1221)		(0.1228)
B. *Willingness-to-move (km)*				
Extra distance for -1 SD in HO mortality			5.264***	5.240***
			1.203	1.087
Extra distance for -1 SD in HO mortality (Low mortality HO)	5.472***	6.417***		
	(1.311)	(1.281)		
Extra distance for -1 SD in HO mortality (High mortality HO)	5.017***	5.048***		
	(1.339)	(1.318)		
Extra distance for +1 SD in LCEA pay	5.051***	4.928***		
	0.475	0.483		
Extra distance for +1 SD in LCEA pay (Low LCEA pay HO)			3.277***	3.231***
			(0.592)	(0.598)
Extra distance for +1 SD in LCEA pay (High LCEA pay HO)			6.668***	6.573***
			(0.600)	(0.610)
Extra distance for +1 SD in school rating	-1.305*	-0.593	-1.322*	-0.622
	(0.734)	(0.782)	(0.734)	(0.782)
C. *Quality-pay trade-off (in risk-adjusted mortality percentage points)*				
Extra HO mortality for +1 SD in LCEA pay (Low mortality HO)	1.727***	1.437***		
	(0.510)	(0.378)		
Extra HO mortality for +1 SD in LCEA pay (High mortality HO)	1.884***	1.827***		
	(0.604)	(0.582)		
Extra HO mortality for +1 SD in LCEA pay (Low LCEA pay HO)			1.165***	1.154***
			(0.397)	(0.383)
Extra HO mortality for +1 SD in LCEA pay (High LCEA pay HO)			2.370***	2.347***
			(0.660)	(0.614)
NHS regional time trends	Yes	Yes	Yes	Yes
IIA test: LR χ^2		9.437		7.559
IIA test: p-value		0.150		0.272
AIC	43666	43668	43653	43658
BIC	43852	43924	43839	43914
Movers	4983	4983	4983	4983
N (= movers × alternative HOs in choice set)	831085	831085	831085	831085

Notes. Panel A reports conditional and mixed logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. Coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped in columns 1 and 3 (500 replications). Panel B and C report the willingness-to-move and quality-pay trade-off from conditional and mixed logit models. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 10. Physicians' estimated preferences, using admission-specific HO mortality

	(1) Cond. Logit + CFs	(2) Mixed Logit + CFs	(3) Cond. Logit + CFs	(4) Mixed Logit + CFs	(5) Cond. Logit + CFs	(6) Mixed Logit + CFs
A. Marginal utilities and heterogeneity (coefficients)						
HO emergency mortality	-0.0271***	-0.0485***	-0.0270***	-0.0485***	-0.0309***	-0.0637***
	(0.0072)	(0.0095)	(0.0073)	(0.0095)	(0.0074)	(0.0094)
HO planned mortality	-0.0292**	-0.1295***	-0.0280**	-0.1282***		
	(0.0129)	(0.0189)	(0.0109)	(0.0175)		
LCEA payments	0.0983***	0.0905***	0.0988***	0.0911***	0.1095***	0.1029***
	(0.0118)	(0.0127)	(0.0113)	(0.0123)	(0.0111)	(0.0120)
School quality rating	-0.0667	0.1449	-0.0669	0.1448	-0.0635	0.1210
	(0.1649)	(0.1771)	(0.1649)	(0.1770)	(0.1658)	(0.1773)
High crime neighborhoods	-0.0873	-0.0932	-0.0860	-0.0917	-0.0749	-0.0720
	(0.0728)	(0.0719)	(0.0726)	(0.0716)	(0.0726)	(0.0716)
Rural	-0.7072***	-0.6912***	-0.7059***	-0.6898***	-0.6844***	-0.6549***
	(0.0873)	(0.0886)	(0.0870)	(0.0883)	(0.0867)	(0.0881)
Distance (in 10s km)	-0.5325***	-0.5415***	-0.5325***	-0.5415***	-0.5299***	-0.5368***
	(0.0235)	(0.0250)	(0.0235)	(0.0250)	(0.0233)	(0.0247)
Distance^2	0.0171***	0.0175***	0.0171***	0.0175***	0.0170***	0.0173***
	(0.0017)	(0.0018)	(0.0017)	(0.0018)	(0.0017)	(0.0018)
Distance^3	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CF residuals (emergency)	0.0175*	0.0161*	0.0174*	0.0160*	0.0199**	0.0189**
	(0.0094)	(0.0091)	(0.0094)	(0.0091)	(0.0094)	(0.0091)
CF residuals (planned)	0.0019	0.0021				
	(0.0109)	(0.0111)				
σ(HO emergency mortality)		-0.0340***		-0.0340***		-0.0425***
		(0.0060)		(0.0060)		(0.0056)
σ(HO planned mortality)		0.0786***		0.0786***		
		(0.0080)		(0.0080)		
σ(LCEA payments)		-0.0005		-0.0005		-0.0001
		(0.0017)		(0.0017)		(0.0011)
σ(School quality rating)		-2.3647***		-2.3655***		2.3427***
		(0.3798)		(0.3796)		(0.3835)
σ(High crime neighborhoods)		-0.0443		-0.0443		-0.0039
		(0.0628)		(0.0629)		(0.0535)
σ(Rural)		0.0760		0.0762		-0.0629
		(0.0830)		(0.0831)		(0.0460)
B. Willingness-to-move (km)						
Extra distance for -1 SD in HO emergency mortality	3.636***	6.432***	3.626***	6.424***	4.168***	8.494***
	(0.965)	(1.263)	(0.969)	(1.263)	(0.982)	(1.246)
Extra distance for -1 SD in HO planned mortality	3.075**	13.460***	2.952***	13.318***		
	(1.355)	(1.945)	(1.144)	(1.794)		
Extra distance for +1 SD in LCEA pay	3.820***	3.471***	3.840***	3.493***	4.268***	3.968***
	(0.468)	(0.497)	(0.449)	(0.481)	(0.441)	(0.471)
Extra distance for +1 SD in school rating	-0.304	0.652	-0.305	0.652	-0.290	0.547
	(0.751)	(0.797)	(0.751)	(0.796)	(0.758)	(0.802)
C. Quality-pay trade-off (mortality %pt.)						
Extra HO emergency mortality for +1 SD in LCEA pay	4.490***	2.306***	4.526***	2.324***	4.377***	1.997***
	(1.240)	(0.537)	(1.253)	(0.532)	(1.085)	(0.368)
Extra HO planned mortality for +1 SD in LCEA pay	4.162**	0.864***	4.359**	0.879***		
	(2.015)	(0.192)	(1.813)	(0.178)		
NHS regional time trends	Yes	Yes	Yes	Yes	Yes	Yes
IIA test: LR χ^2		54.848		54.843		30.158
IIA test: p-value		0.000		0.000		0.000
AIC	43285	43242	43283	43240	43304	43283
BIC	43482	43509	43469	43495	43477	43515
Movers	4972	4972	4972	4972	4972	4972
N	800376	800376	800376	800376	800376	800376

Notes. CF-augmented conditional and mixed logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. In Panel A coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped for conditional logit models (500 replications). Panel B and C report willingness-to-move and quality-pay trade-off. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Appendix A. Risk-adjusted HO mortality indicators

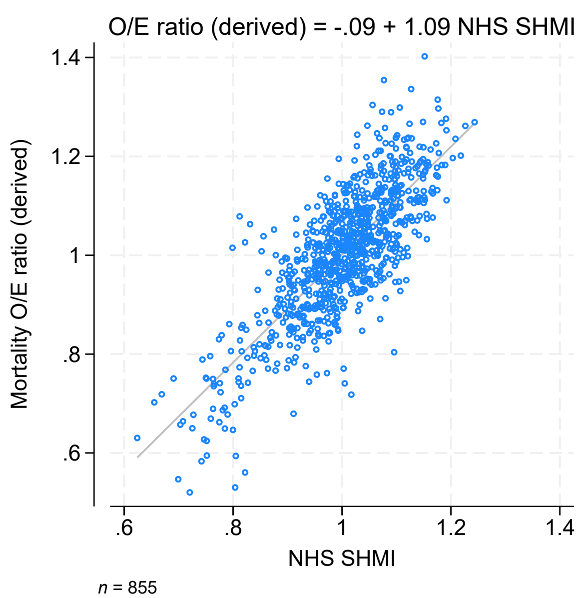
In this section we describe the construction of the mortality index we use in our main models. Our methodology follows closely the ones outlined by the NHS for the estimation of the Standardized Hospital-level Mortality Indicator (SHMI).

The SHMI is the ratio between the actual number of patients who die following hospitalisation at the Trust and the number that would be expected to die on the basis of average England figures, given the characteristics of the patients treated there. It covers all deaths reported of patients who were admitted to non-specialist acute Trusts in England and died either while in hospital or within 30 days of discharge. The expected number of deaths is calculated from statistical models derived to estimate the risk of mortality based on the characteristics of the patients (including the condition the patient is in hospital for, other underlying conditions the patient suffers from, age, gender, method, and month of admission to hospital, and birthweight for perinatal diagnosis groups). The statistical models are derived using a 3-year dataset from Trusts throughout England. Data from the final year of this period are used to calculate the SHMI and accompanying contextual indicators for each individual Trust.

For our index, we first estimate patient-level logit regression models having as outcome an indicator variable for a patient dying within 30 days from hospital admission. These binary models are estimated separately for each year from 2012 to 2018, using the pool of patients admitted by hospitals over an entire calendar year as the corresponding estimation sample. The covariates included in the logit regressions control for a set of demographic, admission and diagnosis characteristics, such as patient's age, gender, month of admission and a comorbidity index, which are all potential mortality determinants. Second, we use the resulting maximum-likelihood logit estimates to predict the monthly number of hospital deaths. Third, we compute the ratio between the number of predicted hospital deaths in a given month and the number of observed deaths in that same month (mortality O/E ratio). This variable represents a summary measure of the quality of care provided by the hospital, given the full case-mix of patients admitted in a given month. Finally, this ratio is rescaled by the average mortality rate across all hospitals in the sample - hence, the resulting variable is measured in percentage point units.

The O/E ratios according to this statistical procedure can classify NHS Trusts: a ratio above 1 means that mortality in that hospital is higher than expected, equal to 1 corresponds to mortality in line with expectations, below 1 corresponds to lower-than-expected mortality. While the NHS warns against using the SHMI as an overall measure of quality of care, they state that a higher than expected number of deaths should be viewed as a negative signal which requires further investigation.

Figure A1. Mortality O/E ratio (derived) vs NHS SHMI (2012-2018)

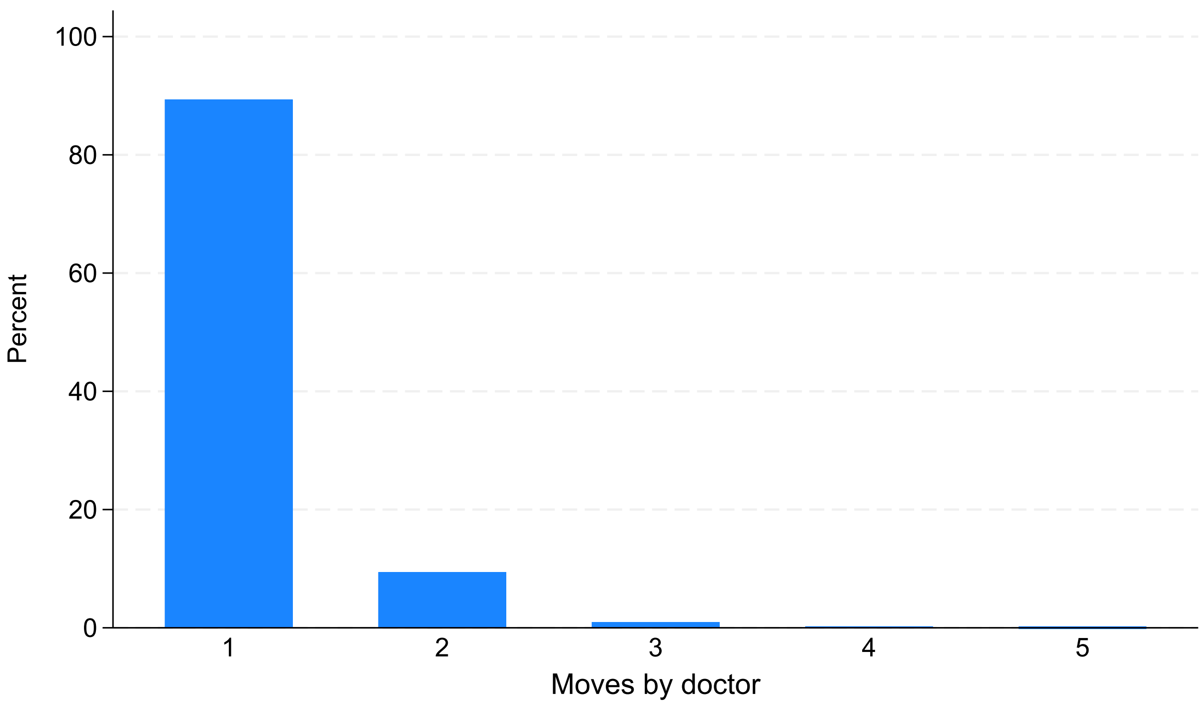


Notes. Authors' own calculations from NHS Hospital Episodes Statistics and NHS Digital.

In Figure A1 we show the correlation between the mortality O/E ratio obtained from our own calculations and the publicly-released NHS SHMI for the years covering the period under analysis. Both ratios, by construction, have an average value around 1; moreover, they range between 0.5 and 1.4. The relationship for the 807 HO-year observations is almost 1-to-1, highlighting how our metric captures almost exactly the NHS SHMI.

Appendix B. Additional descriptive statistics and estimation results

Figure B1. Changes of HO by NHS hospital doctors in the sample, years 2013-2019

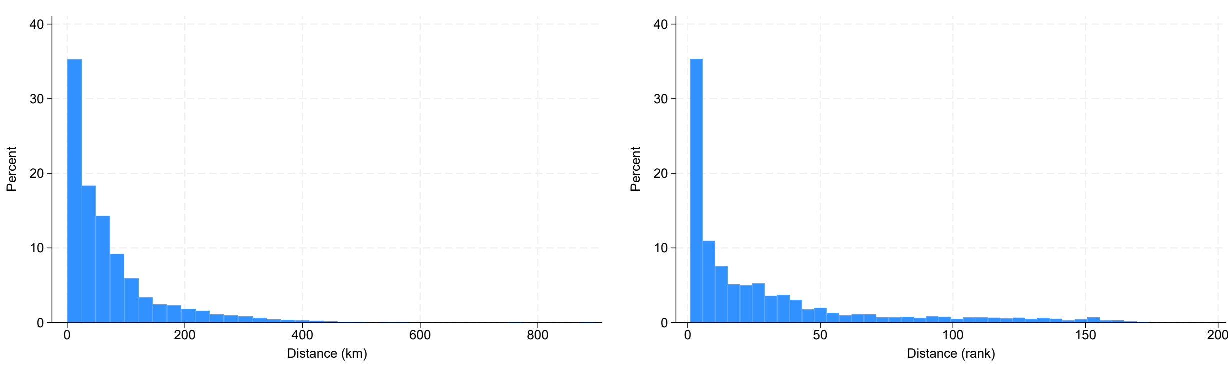


Notes. Authors' own calculations from NHS England Electronic Staff Records.

Figure B2. Histograms of distance from the chosen hospital.

(a) Choice by distance-to-HO radius (km)

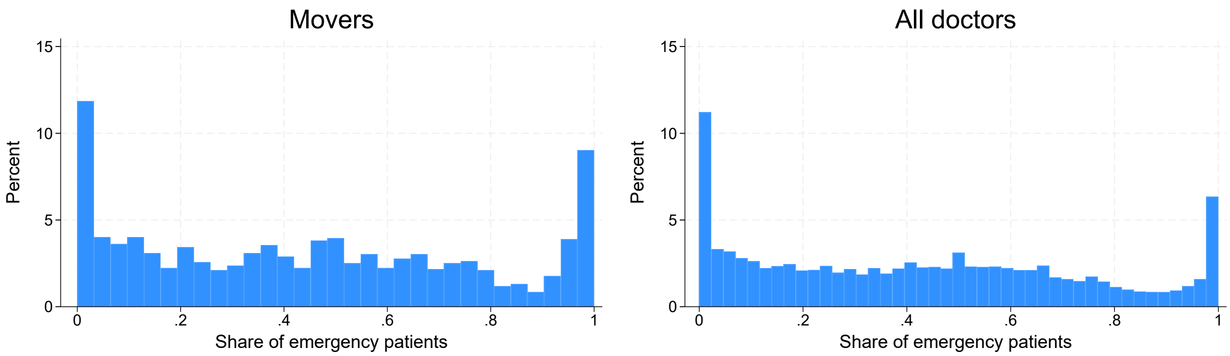
(b) Choice by distance-to-HO rank



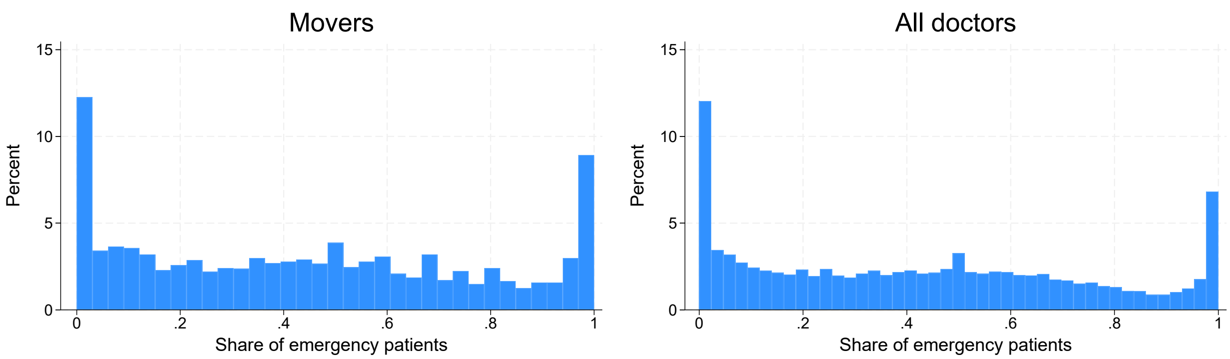
Notes. The figure shows the binned distribution of hospital organizations chosen by NHS hospital doctors with respect to the distance from the postcode residence of the doctor. In panel (a) we report the percentage of doctors moving to hospital organizations at given distances from their home residence. In panel (b) we report the percentage of doctors who moved to their N-th nearest hospital organization; considering the 10 first closest hospital organizations to physicians' residential home location, the values of the cumulative distribution of the observed chosen moves are, respectively: 13.28% (first closest HO), 21.53%, 27.56%, 31.66%, 35.34%, 37.87%, 40.09%, 42.57%, 44.42%, 46.31% (tenth closest HO).

Figure B3. Share of emergency admissions treated by consultants in 2012, 2015 and 2018.

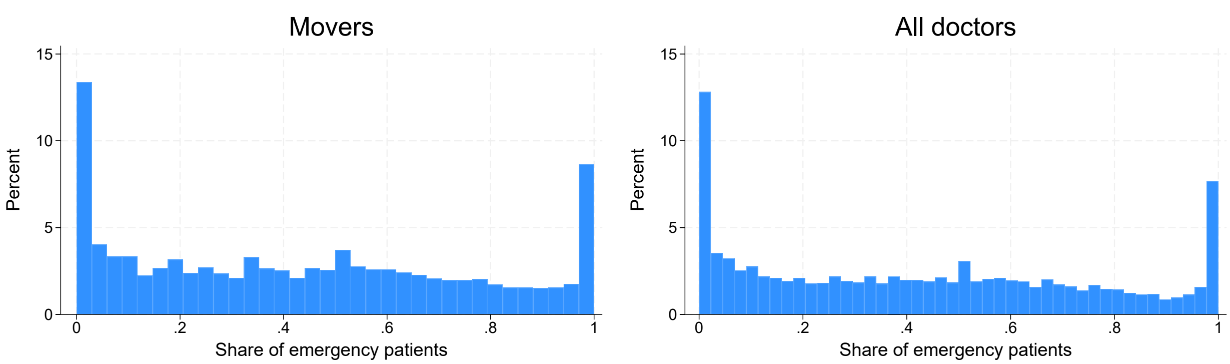
(a) Distribution of HO physician activity by patient admission-type in 2012



(b) Distribution of HO physician activity by patient admission-type in 2015



(c) Distribution of HO physician activity by patient admission-type in 2018



Notes. Distribution of the share of emergency patient admissions over total admissions (i.e. emergency and planned admissions) treated by NHS HO senior doctors in the movers sample and in the whole NHS HO workforce sample in years 2012, 2015 and 2018. The share of emergency patients treated by each senior doctor is obtained by linking the ESR data to the HES APC data on acute patients admitted and treated through the UK General Medical Council (GMC) code identifiers of the senior doctors working in NHS acute HOs.

Table B1. NHS Region choices by hospital region of origin.

NHS region (origin)	NHS region (destination): East of England	London	Midlands	North East and Yorkshire	North West	South East	South West	Total
East of England	222	147	54	23	21	46	23	536
London	159	924	56	45	30	201	42	1457
Midlands	61	70	664	93	73	76	72	1109
North East and York.	28	47	94	469	91	41	21	791
North West	22	29	68	55	476	21	15	686
South East	55	219	56	26	29	257	54	696
South West	13	36	39	17	14	44	150	313
Total	560	1472	1031	728	734	686	377	5588

Notes. The table reports a matrix of flows from and to each NHS Region based on our sample of physicians.

Table B2. Transition matrices of NHS physicians across HOs, by HO attributes

	A. HO mortality				
Quartiles	Destination HO				
Origin HO	1	2	3	4	Total
1 (Lowest mortality)	934	373	338	239	1884
2	392	334	335	227	1288
3	353	364	316	235	1268
4 (Highest mortality)	323	309	279	237	1148
Total	2002	1380	1268	938	
	B. LCEA payments				
Quartiles	Destination HO				
Origin HO	1	2	3	4	Total
1 (Lowest LCEA payments)	229	314	330	275	1148
2	247	363	461	400	1471
3	239	480	500	473	1692
4 (Highest LCEA payments)	161	313	384	419	1277
Total	876	1470	1675	1567	
	C. Primary School rating				
Quartiles	Destination HO				
Origin HO	1	2	3	4	Total
1 (Lowest School rating)	419	371	287	207	1284
2	342	341	305	264	1252
3	239	295	472	448	1454
4 (Highest School rating)	183	235	396	784	1598
Total	1183	1242	1460	1703	
	D. High-crime neighborhoods				
Classification	Destination HO				
Origin HO	No	Yes	Total		
No	5174	186	5360		
Yes	199	29	228		
Total	5373	215			
	E. Rural				
Classification	Destination HO				
Origin HO	No	Yes	Total		
No	5273	145	5418		
Yes	167	3	170		
Total	5440	148			

Notes. The table reports the flows of senior doctors that moved between NHS HOs, based on the HO attributes of interest discretized distribution. For continuous attributes, such as 'HO mortality', 'LCEA payments' and 'School quality rating', we group HOs by quartiles, whereas for the 'High crime neighborhood' and 'Rural' we use the binary classification used in the discrete choice models estimation, i.e. high vs low crime neighborhood and rural vs non-rural HO.

Table B3. Control function first stage

	(1) HO mortality
LCEA payments	-0.132**
	(0.065)
School quality rating	0.195
	(0.482)
High crime neighborhoods	-0.103
	(0.191)
Rural	-1.275**
	(0.626)
HO mortality instrument	-5.288**
	(2.280)
LCEA pay instrument	2.946**
	(1.240)
School rating instrument	6.530***
	(2.185)
High crime instrument	3.402
	(2.118)
Rural instrument	-10.623
	(8.362)
NHS regional time trends	Yes
F-stat test (instruments relevance)	2.996
p-value (F-test)	0.013
Adj. R^2	0.327
# of HOs × financial years	1050

Notes. First stage of our main estimates in the paper. The F-test for the joint significance of the four instruments is reported. Cluster-robust standard errors are in parenthesis. Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B4. Statistics and differences in means, movers vs non-movers HO doctors (2013-2019)

Variable	Full sample (1) Non-movers	(2) Movers	(1)-(2) Pairwise t-test Mean difference	Matched sample (3) Non-movers	(4) Movers	(4)-(3) Pairwise t-test Mean difference
Female	0.344	0.403	-0.059***	0.336	0.336	-0.000
	(0.006)	(0.008)		(0.006)	(0.009)	
Age ≤39	0.134	0.176	-0.042***	0.132	0.132	-0.000
	(0.003)	(0.004)		(0.003)	(0.004)	
Age 40-49	0.484	0.575	-0.092***	0.498	0.498	-0.000
	(0.003)	(0.005)		(0.003)	(0.007)	
Age ≥50	0.382	0.249	0.133***	0.370	0.370	-0.000
	(0.004)	(0.005)		(0.004)	(0.009)	
White	0.609	0.496	0.113***	0.643	0.643	-0.000*
	(0.012)	(0.012)		(0.012)	(0.012)	
Non-white	0.311	0.400	-0.089***	0.300	0.300	-0.000**
	(0.011)	(0.011)		(0.011)	(0.011)	
British	0.732	0.730	0.002	0.777	0.777	-0.000
	(0.014)	(0.008)		(0.011)	(0.011)	
Non-British	0.195	0.234	-0.038***	0.177	0.177	-0.000
	(0.007)	(0.007)		(0.006)	(0.008)	
CEA recipient	0.478	0.276	0.202***	0.474	0.474	-0.000
	(0.007)	(0.007)		(0.007)	(0.010)	
Surgery	0.375	0.274	0.100***	0.389	0.389	-0.000
	(0.006)	(0.007)		(0.006)	(0.010)	
General Medicine	0.337	0.380	-0.043***	0.356	0.356	-0.000
	(0.004)	(0.008)		(0.005)	(0.009)	
Acute Care Medicine	0.049	0.059	-0.010**	0.045	0.045	-0.000
	(0.002)	(0.003)		(0.002)	(0.003)	
Pathology	0.054	0.104	-0.050***	0.052	0.052	-0.000
	(0.002)	(0.005)		(0.002)	(0.003)	
Number of observations	216634	24929	241563	195689	24378	220067
Number of clusters (HOs)	162	161	162	162	161	162

Notes. Doctor characteristics are provided for all doctors working in NHS HOs in the period 2013-2019, aged 32-60 y.o., for each year of employment in a NHS hospital. In columns 3 and 4 CEM weights have been applied (Iacus et al., 2012). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B5. Preferences estimates across demographic profiles.

	Male			Female		
	(1) $\leq$ 39yo	(2) 40-49yo	(3) $\geq$ 50yo	(4) $\leq$ 39yo	(5) 40-49yo	(6) $\geq$ 50yo
A. Marginal utilities (coefficients)						
HO mortality	-0.1570***	-0.1363***	0.0009	-0.1881***	-0.1088**	0.0352
	(0.0508)	(0.0302)	(0.0498)	(0.0682)	(0.0430)	(0.0718)
LCEA payments	0.1510***	0.1360***	0.1160***	0.0863**	0.1265***	0.1420***
	(0.0290)	(0.0206)	(0.0332)	(0.0385)	(0.0276)	(0.0451)
School quality rating	0.5200	-0.7837**	-1.3222***	1.0150*	-0.0685	0.0044
	(0.4377)	(0.3074)	(0.4505)	(0.5256)	(0.3499)	(0.5554)
High crime neighborhoods	-0.1954	-0.1040	-0.1049	0.2477	0.0527	-0.0257
	(0.2123)	(0.1318)	(0.1831)	(0.2005)	(0.1658)	(0.2894)
Rural	-0.5905***	-0.9351***	-0.5274**	-1.2786***	-0.7771***	-0.7606**
	(0.2234)	(0.1698)	(0.2110)	(0.3745)	(0.1975)	(0.3351)
Distance (in 10s km)	-0.4515***	-0.5188***	-0.5037***	-0.5722***	-0.6346***	-0.6187***
	(0.0758)	(0.0331)	(0.0243)	(0.0430)	(0.0292)	(0.0356)
Distance^2	0.0117**	0.0175***	0.0156***	0.0198***	0.0236***	0.0212***
	(0.0056)	(0.0025)	(0.0014)	(0.0030)	(0.0023)	(0.0022)
Distance^3	-0.0001	-0.0002***	-0.0002***	-0.0002***	-0.0003***	-0.0002***
	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)
CF residuals	0.1500***	0.0326	0.0138	-0.0018	0.0412	-0.0475
	(0.0561)	(0.0352)	(0.0573)	(0.0817)	(0.0520)	(0.0867)
B. Willingness-to-move (km)						
Extra distance for -1 SD in HO mortality	9.780***	8.451***	-0.055	10.681***	5.860**	-1.859
	(3.180)	(1.872)	(3.034)	(3.926)	(2.322)	(3.805)
Extra distance for +1 SD in LCEA pay	6.220***	5.576***	4.671***	3.240**	4.503***	4.956***
	(1.249)	(0.871)	(1.351)	(1.462)	(0.994)	(1.604)
Extra distance for +1 SD in school rating	2.513	-3.769**	-6.249***	4.469*	-0.286	0.018
	(2.117)	(1.485)	(2.125)	(2.341)	(1.462)	(2.274)
C. Quality-pay trade-off (in risk-adjusted mortality percentage points)						
Extra HO mortality for +1 SD in LCEA pay	1.190**	1.234***	-159.018	0.567	1.438*	-4.988
	(0.532)	(0.405)	(8748.495)	(0.418)	(0.792)	(9.406)
NHS regional time trends	Yes	Yes	Yes	Yes	Yes	Yes
Movers	750	1792	792	639	1188	427
N (= movers $\times$ alternative HOs in choice set)	112051	266551	117544	95163	176588	63188

Notes. CF-augmented conditional logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. In Panel A coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped (500 replications). Panel B and C report willingness-to-move and quality-pay trade-off. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B6. Physicians' estimated preferences, by medical specialty groups

	(1) General Medicine	(2) Surgery	(3) Acute Care Medicine	(4) Pathology
A. *Marginal utilities (coefficients)*				
HO mortality	-0.0365	-0.1935***	-0.0733	-0.1010
	(0.0305)	(0.0351)	(0.0705)	(0.0616)
LCEA payments	0.1184***	0.0997***	0.0850*	0.1758***
	(0.0197)	(0.0213)	(0.0456)	(0.0360)
School quality rating	-0.4535*	-0.5455*	-0.0564	0.3010
	(0.2730)	(0.2933)	(0.6560)	(0.5605)
High crime neighborhoods	-0.0308	0.0205	-0.5124	-0.3301
	(0.1196)	(0.1289)	(0.3357)	(0.2944)
Rural	-0.7507***	-0.7085***	-0.6039*	-0.8291**
	(0.1501)	(0.1518)	(0.3601)	(0.3234)
Distance (in 10s km)	-0.6025***	-0.4584***	-0.5421***	-0.6442***
	(0.0208)	(0.0348)	(0.0478)	(0.0331)
Distance^2	0.0220***	0.0134***	0.0162***	0.0233***
	(0.0015)	(0.0023)	(0.0032)	(0.0024)
Distance^3	-0.0003***	-0.0001***	-0.0002***	-0.0003***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)
CF residuals	0.0106	0.0849**	-0.0148	0.0202
	(0.0340)	(0.0398)	(0.0942)	(0.0743)
B. *Willingness-to-move (km)*				
Extra distance for -1 SD in HO mortality	2.050	12.575***	4.050	5.258
	(1.709)	(2.314)	(3.876)	(3.218)
Extra distance for +1 SD in LCEA pay	4.396***	4.284***	3.104*	6.049***
	(0.750)	(0.935)	(1.686)	(1.253)
Extra distance for +1 SD in school rating	-1.975*	-2.749*	-0.242	1.215
	(1.191)	(1.480)	(2.809)	(2.261)
C. *Quality-pay trade-off (in risk-adjusted mortality percentage points)*				
Extra HO mortality for +1 SD in LCEA pay	4.012	0.637***	1.434	2.152
	(3.724)	(0.224)	(1.929)	(1.626)
NHS regional time trends	Yes	Yes	Yes	Yes
Movers	2057	1591	354	547
N (= movers × alternative HOs in choice set)	305803	236828	52701	81310

Notes. CF-augmented conditional logit models of choice of hospital for doctors moving in the period 2013-2019. Attribute metrics are lagged by one year. In Panel A coefficients are marginal utilities. Standard errors clustered at the doctor level are bootstrapped (500 replications). Panel B and C report willingness-to-move and quality-pay trade-off. Willingness-to-move is the ratio of the coefficient on the attribute variable to the marginal utility of distance evaluated at the average distance to the chosen HO. Standard errors of trade-off estimates are retrieved using the delta method (Hole, 2007). Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B7. Summary statistics of HO additional attributes

	(1) Teaching HO (binary)	(2) N. of ISPs (within 30km)	(3) House prices (log)	(4) House prices (in £)
Mean	0.221	9.585	12.07	194181
SD	0.415	7.693	0.458	95104
10^{th} percentile	0	2	11.55	103299
50^{th} percentile	0	7	11.97	158585
90^{th} percentile	1	23	12.76	346596

Notes. Mean, standard deviation and percentiles of the distribution of additional HO attributes.

Table B8. Control function first stage - expanded set of HO attributes

	(1) HO mortality	(2) HO mortality	(3) HO mortality
LCEA payments	-0.133*	-0.133**	-0.111
	(0.068)	(0.066)	(0.070)
School quality rating	0.321	0.608	0.630
	(0.497)	(0.500)	(0.426)
High crime neighborhoods	0.066	0.020	0.004
	(0.189)	(0.173)	(0.177)
Rural HO	-1.334**	-1.260**	-1.297**
	(0.622)	(0.631)	(0.652)
Teaching HO	1.483***		
	(0.529)		
N. of ISPs (30km)		-0.045***	
		(0.016)	
House prices (log)			-0.632
			(0.507)
HO mortality instrument	-5.642**	-5.572**	-5.463**
	(2.315)	(2.322)	(2.326)
LCEA payments instrument	3.084**	2.792**	3.342**
	(1.290)	(1.160)	(1.352)
School rating instrument	8.190***	6.329***	3.690**
	(2.651)	(2.171)	(1.544)
High crime instrument	7.430**	3.963*	3.212
	(3.248)	(2.271)	(2.105)
Rural HO instr.	-12.368	-9.876	-11.907
	(8.966)	(8.422)	(8.687)
Teaching HO instrument	28.141***		
	(10.263)		
N. of ISPs instrument		-0.299**	
		(0.124)	
House prices instrument			9.502***
			(2.814)
NHS regional time trends	Yes	Yes	Yes
F-stat test (instruments relevance)	2.378	2.279	3.386
p-value (F-test)	0.031	0.039	0.004
Adj. R^2	0.348	0.345	0.345
# of HOs × financial years	1050	1050	1050

Notes. First stage for control function approach with expanded set of attributes. The F-test for the joint significance of the instruments is reported. Cluster-robust standard errors are in parenthesis. Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B9. Correlated Random Effects Mixed Logit model Variance-Covariance matrix estimates

	β(LCEA payments)	β(School quality rating)	β(High crime neighborhoods)	β(Rural)
β(HO mortality)	0.0027***	-0.1592***	-0.0320*	-0.0294*
	(0.0010)	(0.0486)	(0.0193)	(0.0167)
β(LCEA payments)		-0.0322***	-0.1304***	1.6375***
		(0.0123)	(0.0357)	(0.5672)
β(School quality rating)			-0.0277*	1.7371*
			(0.0102)	(0.8990)
β(High crime neighborhoods)				0.4070
				(0.2589)

Notes. Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B10. Pairwise correlations between elective and planned HO risk-adjusted mortality measures

Year	Pairwise correlations coefficient
2012	0.2217***
2013	0.3029***
2014	0.0619
2015	0.0480
2016	0.2634***
2017	0.4397***
2018	0.2790***
Overall: 2012-2018	0.1846***

Notes. Pairwise correlation between risk-adjusted emergency and planned HO mortality measures, for all NHS acute HOs in the sample.

Table B11. Control function first stage - case-specific mortality

	(1) HO emergency mortality	(2) HO planned mortality
LCEA payments	0.291	-0.146**
	(0.329)	(0.059)
School quality rating	-0.701	0.015
	(0.626)	(0.573)
High crime neighborhoods	-0.148	-0.270
	(0.241)	(0.249)
Rural HO	0.792	1.059
	(1.136)	(1.221)
HO mortality instrument	-7.643**	-6.834*
	(3.839)	(3.626)
LCEA payments instrument	3.412**	2.899*
	(1.429)	(1.592)
School rating instrument	3.460*	-1.594
	(2.075)	(1.993)
High crime instrument	8.824*	3.777*
	(5.296)	(1.973)
Rural HO instr.	16.997	27.454
	(16.789)	(22.762)
NHS regional time trends	Yes	Yes
F-stat IV test	2.654	1.080
p-value (F-test)	0.025	0.373
Adj. R2	0.332	0.419
N	1035	1021

Notes. First stage for control function approach with expanded set of attributes. The F-test for the joint significance of the instruments is reported. Robust standard errors are in parenthesis. Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table B12. Effects of simulated regional policies on regional hospital vacancies (FTE) - emergency and planned mortality

			Percentage change in vacancies (2019)		
NHS Region	(1) Vacancy rate (2019)	(2) Vacancies (2019)	(3) HO emergency & planned mortality reduction (-25%)	(4) LCEA pay increase (+25%)	(5) HO mortality reduction (-25%) + LCEA pay increase (+25%)
A. *Values based on Mixed Logit choice model (column 4 of Table 10) including emergency & planned HO mortality*					
East of England	0.104	1206	-1.08	-1.66	-2.40
London	0.060	1385	-0.36	-1.59	-1.95
Midlands	0.085	1596	-0.75	-1.19	-1.63
North East and Yorkshire	0.054	929	-2.48	-3.02	-3.98
North West	0.078	1104	-2.36	-3.71	-4.71
South East	0.069	1106	-1.63	-1.90	-2.71
South West	0.036	410	-3.17	-6.35	-10.74
B. *Values based on Mixed Logit choice model (column 6 of Table 10) including only emergency HO mortality*					
East of England	0.104	1206	-1.58	-2.07	-2.57
London	0.060	1385	-0.94	-2.53	-3.68
Midlands	0.085	1596	-0.44	-0.88	-1.69
North East and Yorkshire	0.054	929	-2.80	-3.66	-4.85
North West	0.078	1104	-1.54	-3.62	-4.53
South East	0.069	1106	-1.18	-1.54	-2.71
South West	0.036	410	-4.40	-6.84	-10.74

Notes. The table reports the counterfactual simulation on the distribution of vacancy rate changes across NHS England regions, based on the CF-augmented Mixed Logit choice models shown in Table 10 (Panel A. is based on column 4 of Table 10; panel B. is based on column 6 of Table 10). Columns 1 and 2 show the actual distribution of average medical vacancy rates and vacancies FTE (excluding mental health positions) in 2019 as per the NHS England 2023 report, available at: `https://digital.nhs.uk/data-and-information/publications/statistical/nhs-vacancies-survey/april-2015---december-2022-experimental-statistics#.`. The following columns show the counterfactual changes in the distribution of HO physician vacancy rates if: all region's HOs achieved a 25% mortality reduction in either emergency and planned admissions or only emergency admissions since 2012; all region's HOs paid 25% higher LCEA (on average) since 2012; all region's HOs achieved a 25% mortality reduction *and* paid 25% higher LCEA (on average) since 2012.

Appendix C. Model fit

We assess the model accuracy in prediction by calculating the number of times (and relative share) it predicts the exact hospital chosen by the doctor in the sample - i.e., it attaches the highest probability of match to the actually observed choice. We show the actual frequencies, the number of and share of correct predictions of the CF-augmented conditional logit model at the hospital as well as regional level in Table C1. We define the predicted NHS region as the correct one if the model associates the highest chance of match to any hospital in the same NHS region as the actually observed choice.

The predicted frequencies by hospital and NHS region of the model is reported trough columns 2 to 3. A noticeable patterns concerns London HOs, which are the least-correctly predicted, with London being the second-to-last in accuracy among the regions. However, the model predicts the exact match between doctor and hospital in over 18% of the cases, with regional accuracy rising to almost 59%.[26] Compared to the similar setting in Costa et al. (2023), our model predicts with extremely similar accuracy at the regional level (57.7% vs 58.3%).

Table C1. Model fit - Conditional Logit + CF

NHS Region	Actual frequency (1)	Correctly predicted HO (2)	Correctly predicted Region (3)	% Correctly predicted HO (2/1)	% Correctly predicted Region (3/1)
East of England	517	108	301	19.3%	53.8%
London	1452	76	652	5.2%	44.3%
Midlands	967	219	751	21.2%	72.8%
North East and Yorkshire	712	189	540	26.0%	74.2%
North West	595	75	529	10.2%	72.1%
South East	673	114	295	16.6%	43.0%
South West	377	115	195	30.5%	51.7%
Total	5293	896	3263	18.4%	58.8%

Notes. Model fit using the estimated parameters from the CF-augmented conditional logit model. Column 1 shows the distribution of physicians as observed in the data. Columns 2 and 3 have the frequency of physician choices that were correctly predicted by the model at the hospital and at the regional level. The last two columns report the ratios between column 2 and 1, and between column 3 and 1.

[26] If the hospital-doctor matching occurred following a random allocation, the model would predict correctly only 0.729% (= 1/137) of the HO physician moves, instead of the 18.4% shown in Column 4.